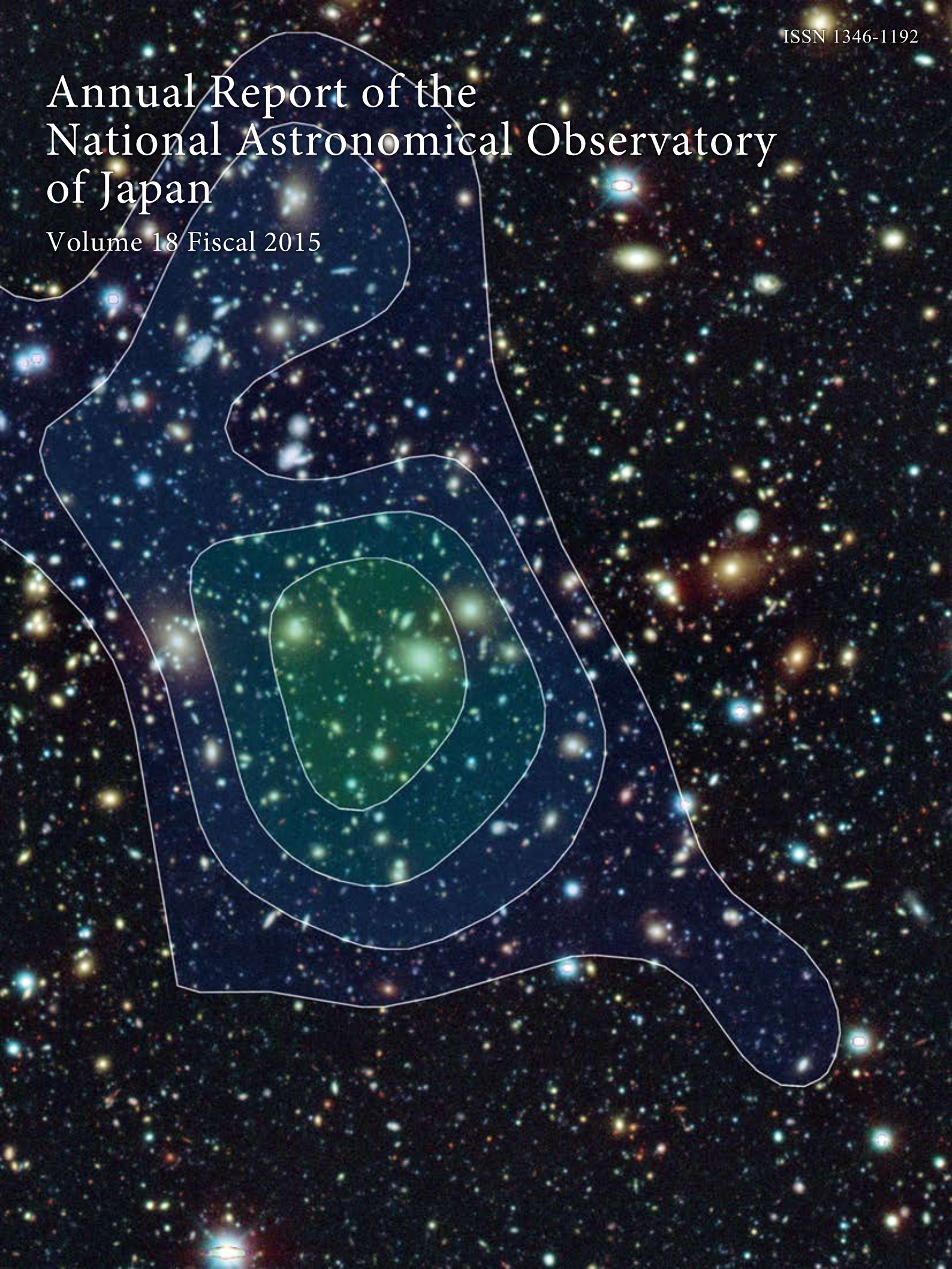
ISSN 1346-1192

Annual Report of the National Astronomical Observatory of Japan

Volume 18 Fiscal 2015



Cover Caption

Dark matter distribution (contour lines) determined by weak lensing analysis in a part (14 arc minute by 9.5 arc minute) of an image taken with Subaru Telescope's Hyper Suprime-Cam.
Credit: NAOJ/HSC Project

Postscript

Editor Publications Committee
HANAOKA, Yoichiro
UEDA, Akitoshi
OE, Masafumi
SÔMA, Mitsuru
NISHIKAWA, Jun
HIROTA, Tomoya
YOSHIDA, Haruo

Publisher National Institutes of Natural Sciences
National Astronomical Observatory of Japan
2-21-1 Osawa, Mitaka-shi, Tokyo 181-8588, Japan
TEL: +81-422-34-3600
FAX: +81-422-34-3960
http://www.nao.ac.jp/

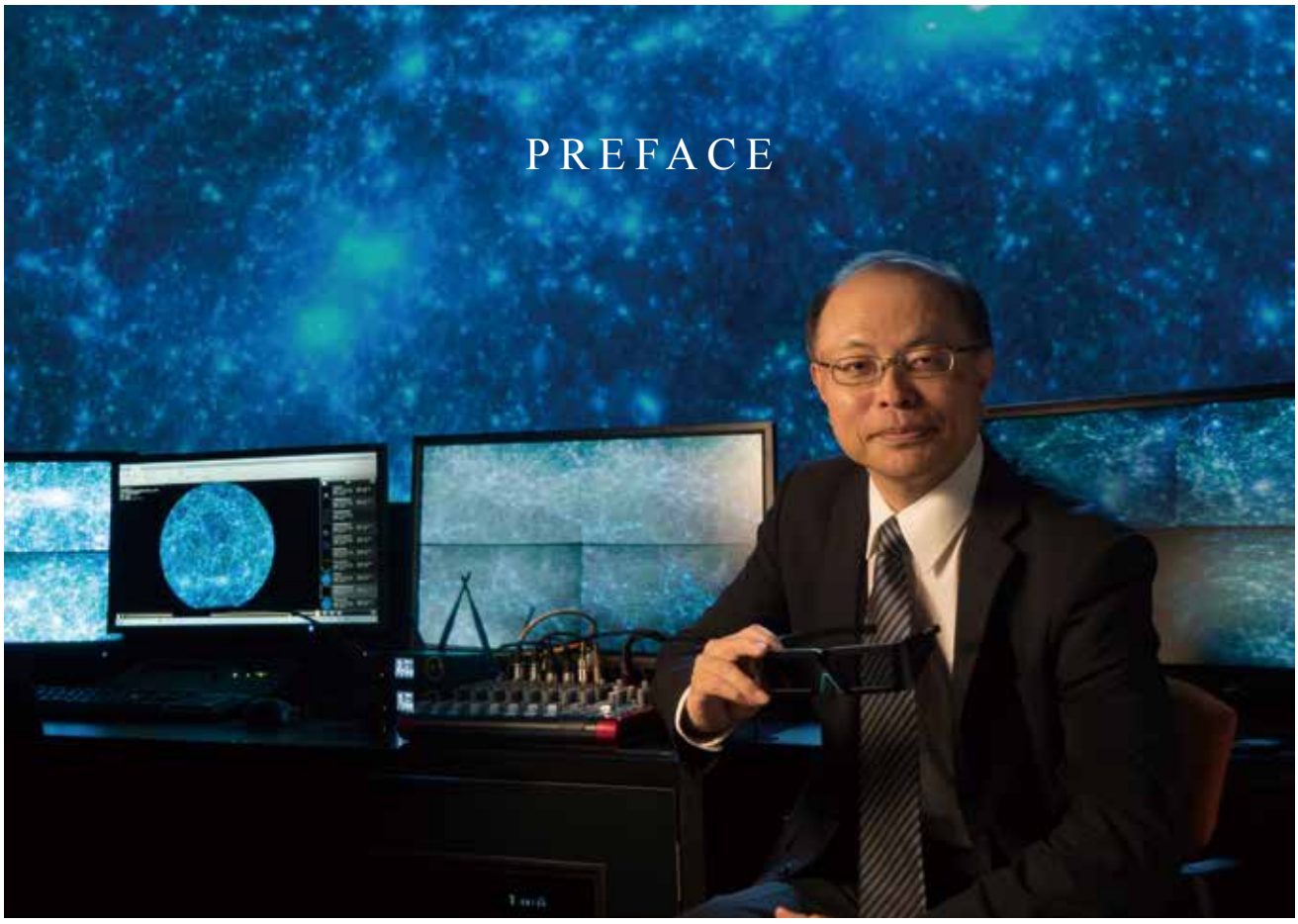
Printer **Kyodo Telecom System Information Co., Ltd.**
4-34-17 Nakahara, Mitaka-shi, Tokyo 181-0005, Japan
TEX: +81-422-46-2525
FAX: +81-422-46-2528

Annual Report of the National Astronomical Observatory of Japan

Volume 18, Fiscal 2015

T A B L E O F C O N T E N T S

PREFACE



Masahiko HAYASHI
Director General of NAOJ

It is my pleasure to present the Annual Report of the National Astronomical Observatory of Japan.

In 2015, the new 4D2U system, with an updated control computer network and projectors, was opened to the public. The overall brightness increased and the colors become more vivid. During simulations of the large-scale structure of the Universe or of Saturn's Ring you actually accept the illusion that you are really floating in space. So that as many people as possible can experience this feeling, which words cannot adequately convey, the seating of the Dome Theater has been doubled and the number of days offering public screenings has also been increased.

In February of 2016, it was announced that LIGO had directly detected gravitational waves. Currently in Japan, the Large-scale Cryogenic Gravitational Wave Telescope KAGRA is being constructed in Kamioka, led by the University of Tokyo Institute for Cosmic Ray Research (ICRR) together with the National Astronomical Observatory of Japan (NAOJ) and the High Energy Accelerator Research Organization (KEK). Attempts in Japan to directly detect gravitational waves began in the 1970's with the creation of a resonant-mass detector by Dr. Hiromasa Hirakawa at the University of Tokyo. Laser interferometer type detectors started at NAOJ from the 1980's; and in the 1990's TAMA300 with 300 m arm-lengths was completed and succeeded in continuous operation. At NAOJ, making the best use of experiences like these, the Advanced Technology Center has been developing key components for KAGRA such as the end mirror vibration isolation systems, utilizing 14 m high multistage pendulums, and the main interferometer, which creates laser light interference patters with orthogonal 3 km arms. With KAGRA added to the LIGO and VIRGO gravitational wave detector network, the locations of gravitational wave sources will be able to be determined with a precision of a couple of degrees. We are looking forward to that day.

ALMA continues to show its true capabilities through long baseline observations which became possible with ALMA Cycle 3 observations starting from October 2015. Multiple-

ring structures, like the protoplanetary disk of HL Tauri observed year before last, have been found surrounding other young stars. From variations in the submillimeter spectrum emitted by dust at different locations within the disk, the spatial distribution of the dust sizes continues to be clarified. It has reached a point where we can do research into the essence of planetary system formation by observing where in the disk dust particles are growing and planetesimals are forming, etc.

It is worth noting that thanks to ALMA's extremely high sensitivity, it is now possible to detect the far-infrared fine-structure lines of carbon and oxygen from galaxies in the distant Universe. These emission lines are good indicators of star formation activity. But because they are in the far infrared, they can't be observed from the ground, so previously they had only been observed by using flying instruments. But when the redshift exceeds 3 (i.e. the distance exceeds 12 billion light-years) the observed wavelengths of these emission lines shift to submillimeter waves, making them visible to ALMA. This is an excellent observational method to understand the details of star formation in the early Universe and the history of element production. Recently, the redshifted 88 μm wavelength emission line of ionized oxygen has been detected coming from a galaxy more than 13.1 billion light-years away discovered by the Subaru Telescope.

At the Subaru Telescope, the strategic program using the ultra-wide-field prime-focus camera (Hyper Suprime-Cam) is proceeding smoothly. This camera's survey speed (= limiting magnitude x field of view area) is more than 10 times that of previous surveys. Equipped with this camera, the Subaru Telescope will without a doubt be on the world's leading edge of observations until the U.S.A.'s Large Synoptic Survey Telescope starts operation in the mid-2020's. Observations by this camera will elucidate the distribution of dark matter across wide regions (and a wide range of distances) in the Universe. Hopefully we will be able to pursue the evolution of the large-scale structure of the Universe and get closer to understanding the true nature of dark matter and dark energy.

In addition there is KaVA (KVN and VERA Array), the joint research observation project utilizing both the Japanese and the South Korean VLBI networks which started in Fiscal Year 2014. Combining the strengths of VERA, which obtains high resolution, and KVN, which can detect spatially extended elements with high sensitivity, it ascertained that jets from active galactic nuclei (black holes) are accelerated to nearly the speed of light at their bases.

Regarding TMT, the next-generation extremely large optical-infrared telescope scheduled to be constructed in Hawai`i, the Maunakea Conservation District Use Permit was invalidated by the Hawai`i Supreme Court in December of 2015. This was extremely disappointing, especially since the construction of TMT near the summit of Maunakea is now supported by about 70 % of the people in the State of Hawai`i. The reason given for invalidating the permit was that there was a problem in the procedure used by the State of Hawai`i to grant the Conservation District Use Permit. The actual construction of TMT near the top of Maunakea has not been condemned. At NAOJ, together with the TMT International Observatory, we have reapplied for a Conservation District Use Permit for the summit area of Maunakea while working even harder than before to obtain the understanding of the local people.

From the experience with the Subaru Telescope, the resistance in the Japanese astronomy community to building telescopes overseas disappeared. For ALMA it was a natural assumption that the telescopes would be arrayed overseas; the construction and operation also proceeded as an international project. For NAOJ, that was a new challenge. Fortunately, with the incorporation of NAOJ in 2004 the personnel system for academic faculty was reconsidered and the project system was established, changing the organizational structure to give it the flexibility needed for large international projects. It also became possible to have people with exceptional, specialized skills participate in large international projects as contract employees. Moreover by representing Japan in this kind of large international project, NAOJ's duty as an inter-university research institute became better defined; this role has become making great contributions to strengthening research throughout all of Japan in the field of astronomy. Based on considerations like these, from here forward we would like to continue efforts towards realizing large-scale international collaboration projects.

Masahiko HAYASHI
Director General of NAOJ

I Scientific Highlights

(April 2015 – March 2016)

Rapidly Rising Transients from Subaru/HSC Transient Survey

TANAKA, Masaomi (NAOJ)
TOMINAGA, Nozomu (Konan University)
MOROKUMA, Tomoki, YASUDA, Naoki (University of Tokyo)
FURUSAWA, Hisanori, MORIYA, Takashi (NAOJ)
BAKLANOV, Petr V., BLINNIKOV, Sergei I. (ITEP, Russia)
and HSC Transient Collaboration

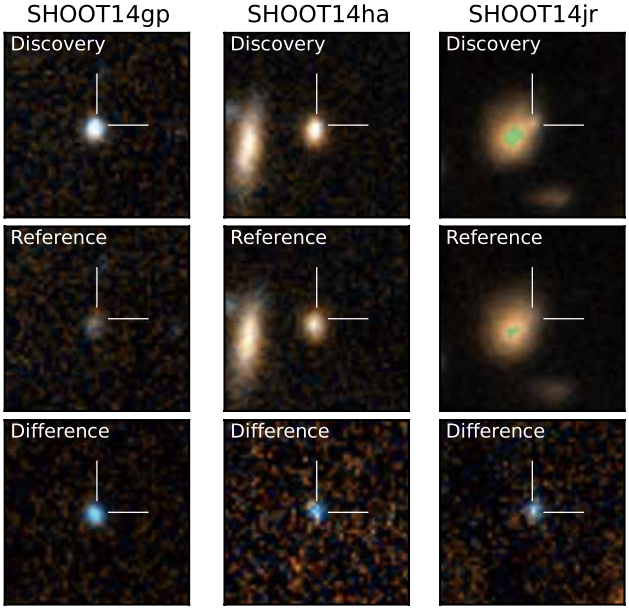


Figure 1: Images of rapidly rising transients (*g*- and *r*- band two-color composite images, 8″ × 8″ size). Three objects out of the five samples are shown. From top to bottom, each panel shows the discovery images, references images and difference images.

The transient sky has been intensively explored by various surveys in the last decade. One of the important discovery spaces for transient surveys is phenomena with a short timescale less than ~ 1 day. There are, in fact, several theoretical expectations for short-timescale transients, such as supernova (SN) shock breakout (~ 1 hr) and the subsequent cooling emission (a few days). In addition to these, there might also be unknown kind of transients with a short duration since our knowledge on the short-timescale transients is still limited.

To explore the short-timescale transient sky, we have performed a high-cadence transient survey with the Subaru telescope and Hyper Suprime-Cam (HSC). We discovered five transients at $z = 0.384-0.821$ (Figure 1) showing the rising rate faster than 1 mag per 1 day in the restframe near-ultraviolet wavelengths. The absolute magnitudes of the five objects range from −16 to −19 mag in the restframe near-ultraviolet wavelengths, and they all show blue colors, $g - r < -0.2$ mag. The rising

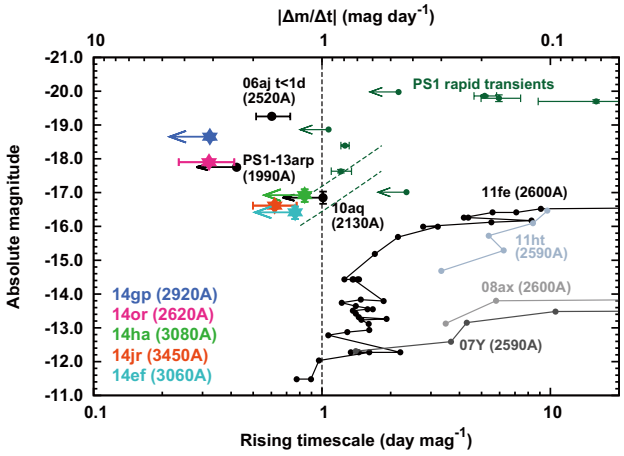


Figure 2: Summary of absolute magnitudes and rising timescale of transients.

rate and brightness of our samples are the most similar to those of the very early phase (< a few days after the explosion) of core-collapse SNe, such as SN 2010aq and PS1-13arp detected by *GALEX* at the very early phases (Figure 2). A conservative estimates suggest that the event rate of rapidly rising transients is higher than ~ 9 % of core-collapse SN rates.

We find that the light curves of the three faint objects agree with the cooling envelope emission from the explosion of red supergiants. The other two luminous objects are, however, brighter and faster than the cooling envelope emission. We interpret these two objects to be the shock breakout from dense wind with the mass loss rate of ~ $10^{-3}\,M_{\odot}\,\mathrm{yr}^{-1}$, as also proposed for PS1-13arp. This mass loss rate is higher than that typically observed for red supergiants. The event rate of these luminous objects is higher than ~ 1 % of core-collapse supernova rate, and thus, our study implies that more than ~ 1 % of massive stars can experience an intensive mass loss at a few years before the explosion.

Reference

[1] Tanaka, M., et al.: 2016, *ApJ*, **819**, 5.

Large-Scale Energy Conversion Mechanism of Collisionless Magnetic Reconnection

FUJIMOTO, Keizo
(NAOJ)

TAKAMOTO, Makoto
(University of Tokyo)

Magnetic reconnection is a natural energy converter which allows explosive energy release of the magnetic field energy into plasma kinetic energy. The reconnection processes inherently involve multi-scale process. The reconnecting of the field lines takes place predominantly in a small region called the diffusion region formed around the x-line, while the fast plasma jets resulting from reconnection extend to a distance far beyond the ion kinetic scales from the x-line. The large-scale energy conversion associated with reconnection is expected to have a significant impact on a variety of global scale phenomena in space such as geo-magnetospheric substorms and solar flares. However, the multi-scale nature of reconnection makes it difficult to model the large-scale behaviour and, therefore, to evaluate the actual impact on such the global systems.

Large-scale dynamics of magnetic reconnection has been investigated in the magnetohydrodynamics (MHD) framework. A fast reconnection can be achieved through plasma acceleration at a pair of slow mode shocks extending from the x-line [1]. Although the so-called Petschek model was based on an approximated solution of the MHD equations, the model has been widely believed to exist in real space because the self-consistent MHD simulations successfully reproduced the model. Satellite observations in the Earth's magnetotail have also shown the evidences of slow shock-like structures in association with magnetic reconnection. On the other hand, a number of particle-in-cell (PIC) simulations have revealed that both the ions and electrons are accelerated through the Speiser-type motions in the vicinity of the x-line. The distinct scales of the Speiser orbit of the ions and electrons result in an ion-electron decoupling motion generating the Hall current system . The associated Hall magnetic field has been often observed in the Earth's magnetosphere and laboratory experiments.

The question arising here is how the kinetic process around the x-line connects to an MHD-scale dynamics of reconnection far downstream of the x-line. In order to investigate the large-scale evolution of collisionless reconnection, we have developed a new electromagnetic PIC model with adaptive mesh refinement (AMR-PIC model) [2], which facilitates large-scale kinetic simulations of multi-scale processes. The system size in the current simulation is $L_x \times L_z = 655\,\lambda_i \times 328\,\lambda_i$ with λ_i the ion inertia length. The highest resolution is 32,768 × 16,384 and the maximum number of particles is ~ 10^{10} for each species. The simulation employs an open boundary condition both in the x and z directions.

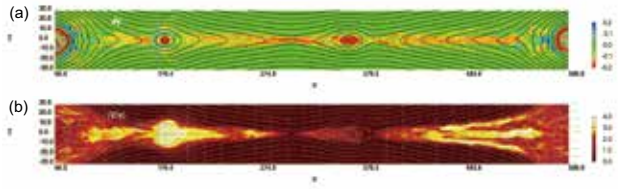


Figure 1: 2D snapshots at t = 140 of (a) the out-of-plane current density J_y and (b) the ion flow speed $|V_{ix}|$ with the magnetic field lines in solid curves. The green arrows in (b) represent the ion flow vectors.

Figures 1a and 1b show the out-of-plane current density and the ion outflow speed, respectively, after a long-time evolution of collisionless reconnection. The width (in z) of the exhaust reaches $\approx 30\,\lambda_i$ that is much larger than the ion gyro-radius in the lobe region. One can see that the current sheet is elongated significantly in the downstream direction far beyond the ion kinetic scales, in contrast with the Petschek model. The elongated current sheet reminds us of a slow reconnection in the MHD framework. However, we found that the diffusion region is localized around the x-line, so that the reconnection process is more similar to the Petschek model in this sense.

One of the important characteristics of the Petschek model is energy conversion at slow mode shocks. We consider the Rankine-Hugoniot (RH) conditions based on the ideal MHD equations across the exhaust boundary far downstream of the x-line. It is found that the RH conditions are almost satisfied at the exhaust boundary, even though the distribution functions of the ions and electrons are far from the Maxwellian. This is because the RH conditions provide only a series of conservation laws along the plasma flow. In other words, these conditions do not always guarantee the existence of shocks in the kinetic systems. In fact, we found that the energy conversion hardly occurs at the boundaries, implying that they are not slow mode shocks. Instead, the ions are accelerated mostly in the current sheet due to the Speiser motions even in the region far downstream of the x-line. Therefore, the current simulation suggests that collisionless reconnection differs from classical MHD reconnection models even in large scale beyond the ion kinetic scales and kinetic treatments is necessary to describe reconnection in collisionless plasmas [3].

References

[1] Petschek, H. E.: 1964, *NASA Spec. Publ.*, **SP-50**, 425.
[2] Fujimoto, K.: 2011, *J. Comput. Phys.*, **230**, 8508.
[3] Fujimoto, K., Takamoto, M.: 2016, *Phys. Plasmas*, **23**, 012903.

High-resolution ALMA Observations of SDP.81. II. Molecular Clump Properties of a Lensed Submillimeter Galaxy at $z = 3.042$

HATSUKADE, Bunyo (NAOJ)
TAMURA, Yoichi (University of Tokyo)
IONO, Daisuke, MATSUDA, Yuichi, HAYASHI, Masao (NAOJ)
OGURI, Masamune (University of Tokyo)

Deep and wide-field submillimeter surveys have uncovered dust-obscured star-forming galaxies at high redshift (referred to as submillimeter galaxies; SMGs). SMGs have intense star-forming activity with star-formation rates (SFRs) of a few 100–1000 $M_\odot$ yr^{-1}, which could be triggered by gas-rich galaxy mergers. SMGs and local ultra-luminous infrared galaxies are known to be on the same relation on the molecular gas mass–far infrared (FIR) luminosity plane (M_{H_2}–L_{FIR}) or molecular gas surface density–SFR surface density plane (Σ_{H_2}–Σ_{SFR}), so-called 'burst sequence' high above that of 'normal' star-forming galaxies at local and $z \sim$ 1–3 universe. In order to investigate the star-forming properties of SMGs, spatially resolved observations of molecular gas are essential. However, only a handful of studies exists due to the limited spatial resolution and sensitivity of existing instruments.

We studied spatially-resolved properties of molecular gas and dust in a gravitationally-lensed SMG H-ATLAS J090311.6+003906 (SDP.81) at $z = 3.042$ revealed by the Atacama Large Millimeter/submillimeter Array (ALMA) [1]. We identified 14 molecular clumps in the CO(5–4) line data. The surface density of molecular gas and star-formation rate of the clumps are more than three orders of magnitude higher than those found in local spiral galaxies (Figure 1). The clumps are placed in the 'burst' sequence in the Σ_{H_2}–Σ_{SFR} plane, suggesting that $z \sim 3$ molecular clumps follow the star-formation law derived for local starburst galaxies. With our gravitational lens model [2], the positions in the source plane are derived for the molecular clumps, dust clumps, and stellar components identified in the *Hubble Space Telescope* image. The molecular and dust clumps are confined within a ~2 kpc region, while the spatial extent of the stellar components is as large as ~6 kpc and offset toward the west. The molecular clumps have a systematic velocity gradient in the north-south direction, which may indicate a rotating gas disk. One possible scenario is that the components of molecular gas, dust, and stars are distributed in a several-kpc scale rotating disk, and the stellar emission is heavily obscured by dust in the central star-forming region. Alternatively, SDP.81 can be explained by a merging system, where dusty starbursts occur in the region where the two galaxies collide, surrounded by tidal features traced in the stellar components.

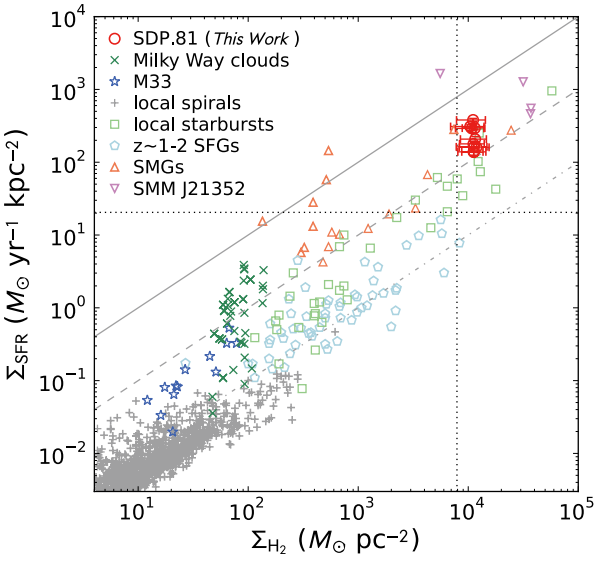


Figure 1: Molecular gas surface density–SFR surface density plot [1]. The molecular clumps of SDP.81 are plotted as red circles. The vertical and horizontal dotted line represents the 2σ detection limit on the surface density of molecular gas and SFR, respectively, for a clump with a source size comparable to the beamsize. For comparison we also plot data points taken from literature: Milky Way clouds, giant H II regions in M33, local disk galaxies, local starbursts, $z \sim$ 1–2 star-forming galaxies, SMGs, and a spatially-resolved lensed SMG SMM J21352. The solid, dashed, and dot-dashed lines represent the gas depletion time scale of 10 Myr, 100 Myr, and 1 Gyr, respectively. If the filling factor is less than unity, the data points of SDP.81 shift to the upper-right direction.

References

[1] Hatsukade, B., Tamura, Y., Iono, D., et al.: 2015, *PASJ*, **67**, 93.
[2] Tamura, Y., Oguri, M., Iono, D., et al.: 2015, *PASJ*, **67**, 72.

Optical–Infrared Properties of Faint 1.3 mm Sources Detected with ALMA

HATSUKADE, Bunyo (NAOJ)
OHTA, Kouji (Kyoto University)
YABE, Kiyoto (Kavli IPMU)
SEKO, Akifumi (Kyoto University)
MAKIYA, Ryu (Kavli IPMU)
AKIYAMA, Masayuki (Tohoku University)

Since the fraction of dust-obscured star formation to the total star formation increases with redshift, observations at infrared (IR) to millimeter/submillimeter (mm/submm) wavelengths are essential to understand the cosmic star formation history and the galaxy evolution. Deep and wide-field surveys uncovered a new population of mm/submm–bright galaxies at high redshifts (SMGs). SMGs are highly obscured by dust, and the resulting thermal dust emission dominates the bolometric luminosity. The energy source of mm/submm emission is primarily from intense star formation activity, with star-formation rates (SFRs) of 10^2–$10^3\,M_\odot\,\mathrm{yr}^{-1}$. The heavy dust obscuration in SMGs makes it difficult to understand their optical/near-infrared (NIR) properties. In addition, the coarse angular resolution of single dish telescopes (> 15″) prevents from identifying optical/NIR counterparts. The advent of ALMA has changed this situation thanks to its high sensitivity and high angular resolution.

We studied optical-IR properties of faint 1.3~mm sources ($S_{1.3\,\mathrm{mm}}$ = 0.2–1.0 mJy) detected with ALMA in the Subaru/*XMM-Newton* Deep Survey (SXDS) field [1]. We conducted ALMA band 6 observations toward 20 star-forming galaxies at $z \sim 1.4$ [2,3]. The targets were extracted from a stellar mass limit ($> 10^{9.5}\,M_\odot$) sample whose redshifts and Hα SFR were obtained by NIR spectroscopy. We detected 8 sources at SN ≥ 4.0, of which three sources are the original targets of ALMA observations and five sources are serendipitously-detected sources. We searched for optical/IR counterparts of the 8 ALMA-detected sources in a *K*-band source catalog. Four ALMA sources have *K*-band counterpart candidates within a 0.4″ radius. Comparison between ALMA-detected and undetected *K*-band sources in the same observing fields shows that ALMA-detected sources tend to be brighter, more massive, and more actively forming stars. While many of the ALMA-identified SMGs in previous studies lie above the sequence of star-forming galaxies (main sequence) in stellar mass–SFR plane, our ALMA sources are located in the sequence (Figure 1), suggesting that the ALMA-detected faint sources are more like 'normal' star-forming galaxies rather than 'classical' SMGs.

We found a region where multiple ALMA sources and *K*-band sources reside in a narrow photometric redshift range ($z \sim 1.3$–1.6) within a radius of 5″ (42 kpc if we assume $z = 1.45$). This is possibly a pre-merging system and we may be witnessing the early phase of formation of a massive elliptical galaxy (Figure 2).

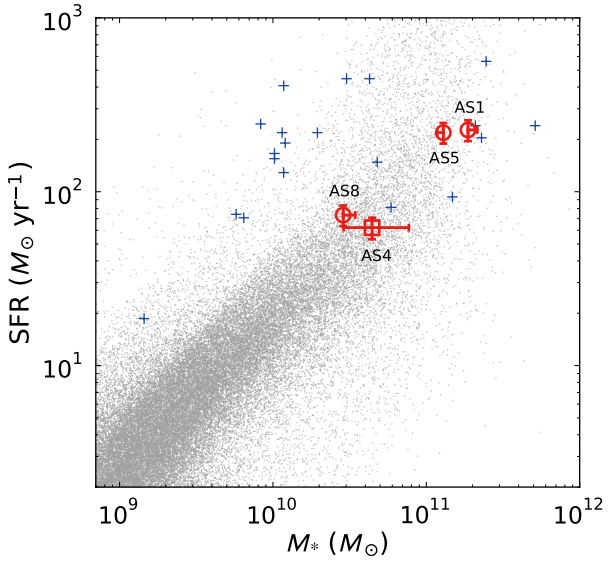


Figure 1: Comparison of stellar mass and SFR for the ALMA sources identified with the original targets (circles), the ALMA serendipitous source (square), ALMA-identified SMGs in previous studies (crosses), and the *K*-band sources (dots).

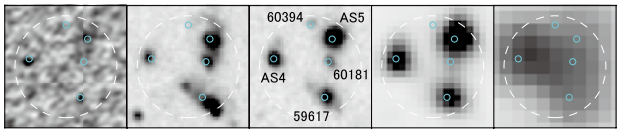


Figure 2: Multi-wavelength images around the multiple ALMA sources (ALMA 1.3 mm, *B*, K_s, 3.6 μm, and 24 μm). The dashed circle shows a region within a radius of 5″.

References

[1] Hatsukade, B., Ohta, K., Yabe, K., et al.: 2015, *ApJ*, **810**, 91.
[2] Hatsukade, B., et al.: 2013, *ApJ*, **769**, L27.
[3] Seko, A., Ohta, K., Yabe, K., et al.: 2016, *ApJ*, **819**, 82.

Carbon, Oxygen, and Sodium Abundances of Red Giant Stars

TAKEDA, Yoichi (NAOJ)
SATO, Bun'ei (Tokyo Institute of Technology)
OMIYA, Masashi, HARAKAWA, Hiroki (NAOJ)

"Are the surface C, O, ad Na abundances of red giants (suffering from evolution-induced dredge-up of nuclear-processed materials) consistent with the prediction from the canonical theory of envelope mixing?" In order to answer this question while adequately taking into account the chemical evolution effect (i.e., initial abundance at the time of star formation should be taken as the reference to detect the purely evolution-induced abundance change), we compared the abundances of C, O, and Na for 239 evolved red giants with those of 160 unevolved dwarfs at the same metallicity, where the abundancees were derived by non-LTE analysis of C I 5052/5380, O I 7771–5, and Na I 6160 lines based on the spectra obtained with 188 cm reflector+HIDES spectrograph at Okayama Astrophysical Observatory.

The resulting [X/Fe] vs. [Fe/H] diagrams (X = C, O, and Na) plotted for giants and dwarfs are shown in Figure 1, where the mean $\langle$[X/Fe]$\rangle$ at each metallicity group (0.1 dex bin within $-0.4 \leq$ [Fe/H] $\leq +0.2$) along with the distribution of $\langle$[X/Fe]$\rangle_{\rm giants} - \langle$[X/Fe]$\rangle_{\rm dwarfs}$ are also presented. We can state from this figure that the abundance changes (compared to the initial values when stars were formed) in the red-giant phase caused by evolution-induced envelope mixing area moderate decrease of C by ~ 0.2 dex, only a slight decrease of O by < ~ 0.1 dex, and a marginal increase of Na by ~ 0.1–0.2 dex.

By comparing these results with the theoretical preductions from recent stellar evolution calculations published by [1], we can draw the following consequences:

— Regarding oxygen, our observational result (only a slight deficiency by < ~ 0.1 dex) satisfactorily matches the theoretical expectation that the surface O abundances are hardly altered (the predicted decrease is < ~ 0.05 dex at most). This means that the current theory for the mixing in the envelope of evolved stars is quite sufficient to account for the observed oxygen abundances of red giants, without any necessity to invoke a non-canonical deep mixing causing a significant dredge-up of ON-cycle product.

— Similarly, the observed mild enrichment of Na and deficiency of C are reasonably consistent with theoretical simulations (e.g., for typical case of 2.5 $M_{\odot}$ star of solar-metallicity around $T_{\rm eff}$ ~ 4800–5000 K), which predict an underabundance of C by ~ 0.2–0.3 dex and an overabundance of Na by ~ 0.2–0.3 dex. Though the observed extents of anomaly (~ 0.2 dex deficiency for C and ~ 0.1–0.2 dex enrichment for Na) appear somewhat smaller than the theoretical predictions, we may state that theory and observation are reasonably consistent with each other.

Consequently, the abundance characteristics of C (mildly deficient), O (barely changed or only slightly deficient), and Na (mildly enriched) observed in red giants are reasonably explained by the recent theoretical simulations. This consistency indicates that a substantial or intrinsic modification of the theory (such as an inclusion of special non-canonical deep mixing) is not necessary.

See [2] for more details of this study.

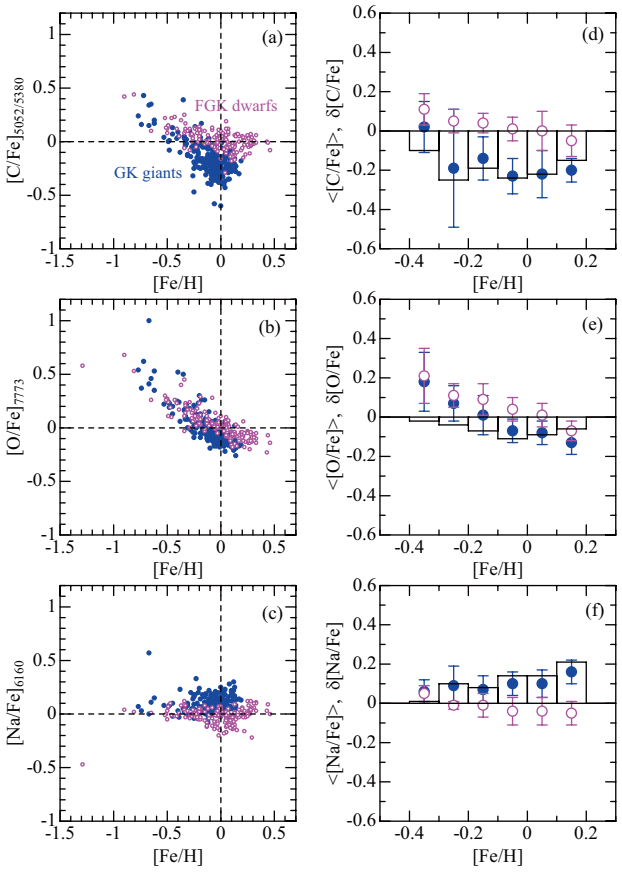


Figure 1: Left: comparison of [X/Fe] vs. [Fe/H] relations (X = C or O or Na) for 239 red giants (filled symbols) with those of 160 FGK dwarfs (open symbols). Right: mean $\langle$[X/Fe]$\rangle$ at each metallicity group where error bars denote the standard deviations, while bar graphs represent the mean abundance differences between giants and dwarfs defined as $\langle$[X/Fe]$\rangle_{\rm giants} - \langle$[X/Fe]$\rangle_{\rm dwarfs}$.

References

[1] Lagarde, N., et al.: 2012, *A&A*, **543**, A108.
[2] Takeda, Y., et al.: 2015, *PASJ*, **67**, 24.

High-sensitivity 3 mm VLBI Observations of M87: Imaging the Jet Base Near the Supermassive Black Hole

HADA, Kazuhiro[1], KINO, Motoki[2], DOI, Akihiro[1], NAGAI, Hiroshi[1], HONMA, Mareki[1]
AKIYAMA, Kazunori[1], TAZAKI, Fumie[1], LICO, Rocco[4], GIROLETTI, Marcello[4]
GIOVANNINI, Gabriele[4], ORIENTI, Monica[4], HAGIWARA, Yoshiaki[5]

1: NAOJ, 2: KASI, 3: ISAS/JAXA, 4: INAF-IRA, 5: Toyo University

Understanding the formation, collimation and propagation of relativistic jets in active galactic nuclei (AGN) is a longstanding concern in high-energy astrophysics. Recent theoretical progress based on general relativistic magneto-hydrodynamical simulations has begun to reveal the detailed physics of jet formation regions within 10–100 Schwarzschild radii (R_S) from the central black hole. It is therefore important to present detailed observations that can directly image the relevant scales.

The radio galaxy M87 at the center of the Virgo cluster shows one of the nearest (16.7 Mpc) AGN jets. Due to the proximity and the large mass of the central black hole, the jet formation region has been imaged on a scale of 100 R_S with cm-VLBI. More recently, an extremely compact structure below 6 R_S has been resolved with the global mm-VLBI array project at 1.3 mm (Event Horizon Telescope; EHT). However, the EHT is still technically challenging to synthesize interferometric images due to the severe atmospheric disturbance and the limited number of available stations. Consequently, there still remains a large gap in our current understanding of this jet between the cm-VLBI and the EHT. In this context, an important bridge to connect this gap is observational study at a wavelength of 3 mm.

In 2014 February we conducted high-sensitivity 3 mm VLBA observations of M87 in concert with the Green Bank Telescope (GBT) [1]. The results are shown in Figure 1. Thanks to the large collecting area of the GBT, we obtained images of the M87 jet at a unprecedented quality, where the image dynamic range improved by a factor of greater than 10 from previous VLBA-only images. We found a complicated evolution of the jet forming between 10 and 100 R_S from the black hole.

Moreover, we detected significant polarized emission from the jet base near the black hole, where a highly polarized (up to 20 %) feature was seen, suggesting the presence of a well-ordered magnetic field at this scale. This may be in agreement with the magnetically-driven jet scenario. A further increase in the array sensitivity is necessary. The upcoming incorporation of the phased-ALMA to the existing mm/submm VLBI network will allow us to image the jet launching structure and associated magnetic-field structure in much more detail.

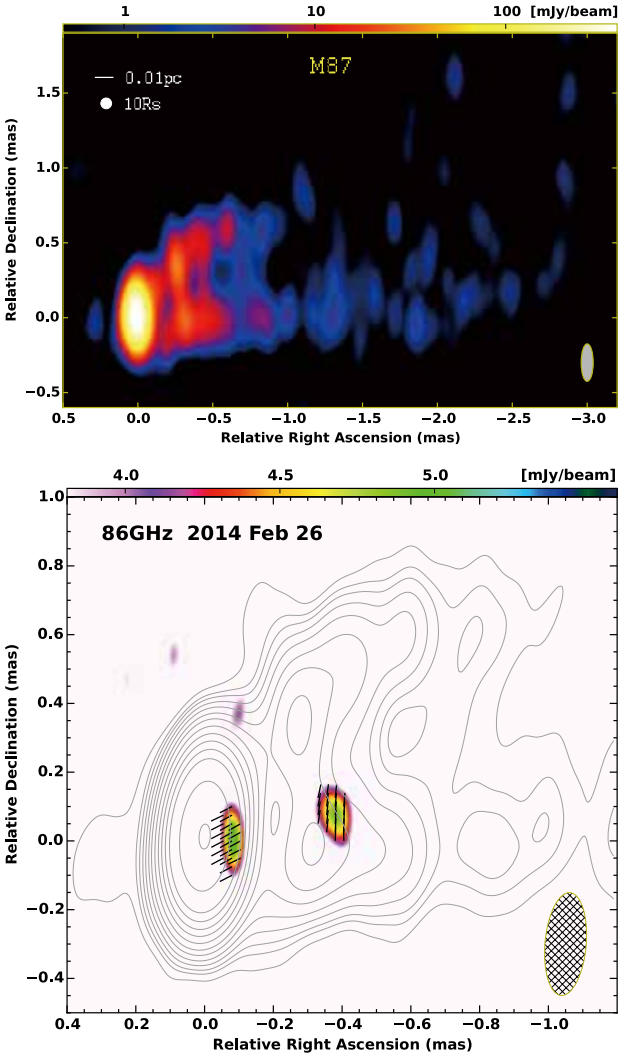


Figure 1: VLBA+GBT 3 mm images of the M87 jet [1]. The top panel shows the observed total intensity image, while the bottom panel (colored) indicates the observed polarization emission (the contours describe the total intensity). At the bottom-right corner of each panel the beam size is shown by the filled ellipse.

Reference

[1] Hada, K., et al.: 2016, *ApJ*, **817**, 131.

High Dispersion Spectroscopy of Solar-type Superflare Stars

NOTSU, Yuta (Kyoto University)
HONDA, Satoshi (University of Hyogo)
MAEHARA, Hiroyuki (NAOJ)
NOTSU, Shota (Kyoto University)
SHIBAYAMA, Takuya (Nagoya University)
NOGAMI, Daisaku, SHIBATA, Kazunari (Kyoto University)

Flares are energetic explosions on the surface of the stars, and are thought to occur by intense releases of magnetic energy stored around starspots. Superflares are flares $10\sim10^6$ times more energetic ($\sim10^{33-38}$ erg) than the largest solar flares ($\sim10^{32}$ erg). Recently, we analyzed the data of the Kepler spacecraft, and discovered 1547 superflares on 279 solar-type (G-type main sequence) stars [1,2]. This discovery was very important since it enabled us to conduct statistical analysis of superflares for the first time, but more detailed observations were needed to investigate detailed properties of superflare stars.

Based on the initial discovery, we carried out high-dispersion spectroscopic observations on 50 solar-type superflare stars with Subaru/HDS [3,4].

1. More than half of the observed 50 stars show no evidence of binarity. We confirmed the characteristics of the target stars (e.g., temperature, surface gravity) as similar to those of the Sun.

2. On the basis of the Kepler data, superflare stars show somewhat regular, periodic changes in their brightnesses (Figure 1). The typical periods range from one day to a few tens of days. Such variations are explained by the rotation of the star with its large starspots [5]. If this is true, the timescales of the brightness variations should correspond to the stars' rotation speeds. Spectroscopic observations allow us to estimate the rotation velocity from the broadening of absorption lines, and we confirm that a velocity derived from spectroscopic data matches the brightness variation timescale as the star rotates. In addition, the measured rotation velocity of some target superflare stars is as slow as that of the Sun.

3. Based on solar observations, it is known that, the intensity of the Ca II line is a good indicator of starspot coverage. We investigated this line, and found that there is a correlation between the amplitude of the brightness variation of the Kepler data and the intensity of Ca II 8542Å line (Figure 2). We then confirmed that superflare stars have large starspots compared with sunspots.

These results confirm that stars similar to the Sun can have superflares if they have large starspots. In the future, in addition to the continuing spectroscopic observations with Subaru Telescope, we will conduct observations with the Kyoto University's Okayama 3.8m telescope, which is now under construction. This will allow them to investigate more detailed properties and changes in long-term activity of superflare stars.

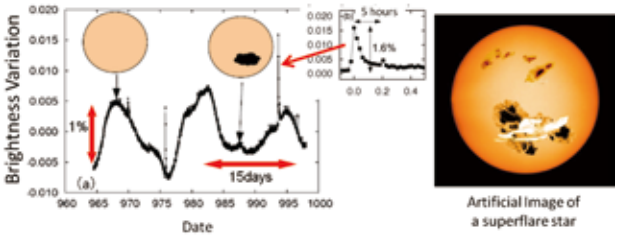


Figure 1: The brightness variation of solar-type superflare stars (from Kepler data). In addition to the sudden brightenings caused by flares, quasi-periodic brightness variations with periods of about 15 days are seen. Right: An artificial image of a superflare star seen with visible light. This figure shows a large superflare (shown in white) occurring in the large starspot area.

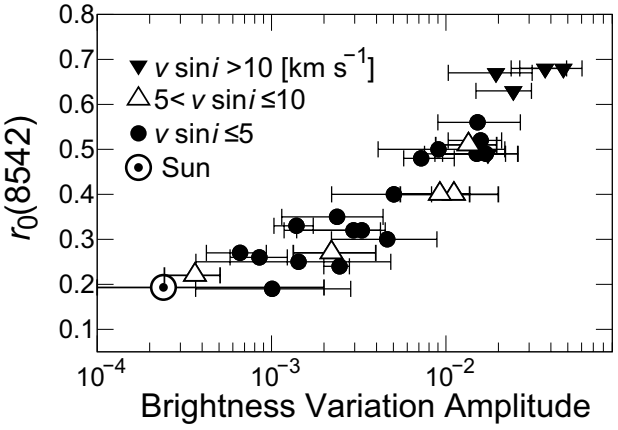


Figure 2: The quantity r_0(8542) (the residual core flux normalized by the continuum level at the line cores of the Ca II 8542Å) as a function of the amplitude of stellar brightness variation estimated from Kepler data.

References

[1] Maehara, H., et al.: 2012, *Nature*, **485**, 478.
[2] Shibayama, T., et al.: 2013, *ApJS*, **209**, 5.
[3] Notsu, Y., et al.: 2015, *PASJ*, **67**, 32.
[4] Notsu, Y., et al.: 2015, *PASJ*, **67**, 33.
[5] Notsu, Y., et al.: 2013, *ApJ*, **771**, 127.

Predicting Dust Extinction Properties of Galaxies from Hα/UV Ratio

KOYAMA, Yusei[1], KODAMA. Tadayuki[1], HAYASHI, Masao[1], SHIMAKAWA, Rhythm[2], YAMAMURA, Issei[3]
EGUSA, Fumi[1], OI, Nagisa[3], TANAKA, Ichi[1], TADAKI, Ken-ichi[4], TAKITA, Satoshi[3], MAKIUTI, Sin'itiro[3]

1: NAOJ, 2: GUAS, 3: JAXA, 4: MPE

Star formation rate (SFR) is one of the most fundamental parameters which characterize the nature of galaxies. The Hα line (6563Å) is widely used as a good indicator of SFRs and is well calibrated in the local universe. With recent advents of sensitive near-infrared facilities, it is becoming easier to observe Hα line of high-z galaxies. However, to reliably measure SFRs, it is important to derive their extinction levels. Ideally, we want to use Hα/Hβ (4861Å) ratio (i.e. Balmer decrement) to measure the dust extinction, but it is usually impossible to detect faint Hβ line from individual high-z galaxies.

In this work, we use SDSS (DR7) spectroscopic catalog, in combination with GALEX FUV all-sky survey data, to establish empirical calibration to predict Hα extinction ($A_{\mathrm{H}\alpha}$) from the observed Hα/UV luminosity ratio [1]. As shown in Fig. 1, we find that there is a positive correlation between $L_{\mathrm{H}\alpha}/L_{\mathrm{UV}}$ ratio and $A_{\mathrm{H}\alpha}$, but at the same time there is a large scatter around the correlation. We find that this scatter is related to various galaxy properties——e.g. stellar mass. We find that more massive galaxies tend to have higher $A_{\mathrm{H}\alpha}$ at a fixed $L_{\mathrm{H}\alpha}/L_{\mathrm{UV}}$ ratio (the color coding of Fig. 1 indicates average stellar mass of galaxies measured at each pixel). By quantifying this trend, we demonstrate that we are able to predict dust extinction levels of individual galaxies by combining Hα, UV, and stellar mass information.

Furthermore, by combining the AKARI FIR all-sky survey data, we compare the $A_{\mathrm{H}\alpha}$ and $L_{\mathrm{IR}}/L_{\mathrm{UV}}$ ratio (Fig. 2). $L_{\mathrm{IR}}/L_{\mathrm{UV}}$ represents the dust extinction for *stellar continuum light*, whilst $A_{\mathrm{H}\alpha}$ indicates extinction toward *nebular lines*. As demonstrated in Fig. 2, we show that more massive galaxies tend to show higher extinction levels toward nebular regions at fixed $L_{\mathrm{IR}}/L_{\mathrm{UV}}$ ratio. The difference between the extinction toward nebular and stellar continuum lights is often interpreted as a consequence of different star/dust geometry within the galaxies. Our results therefore suggest that internal dust geometry of galaxies could depend on stellar mass of galaxies, and this can be (at least a part of) the physical explanations of the trend that we reported in Fig. 1.

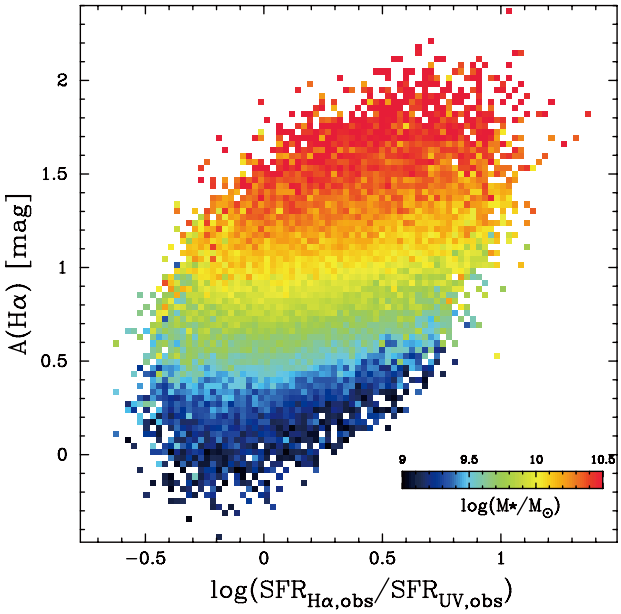


Figure 1: Hα dust extinction derived from Hα/Hβ as a function of Hα/UV ratio. The color coding indicates the average stellar mass of galaxies in each pixel. More massive galaxies tend to be more heavily obscured by dust at fixed Hα/UV.

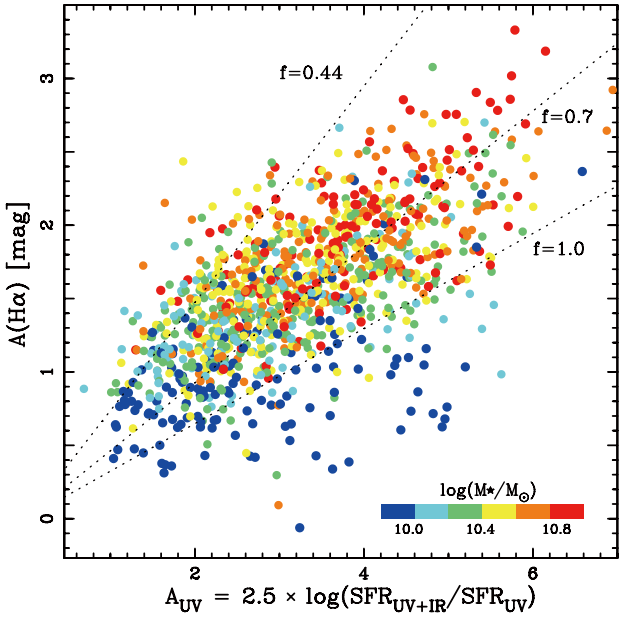


Figure 2: Hα extinction as a function of IR/UV ratio. The color of the data points indicate their stellar mass. $A_{\mathrm{H}\alpha}$ shows extinction for *nebular emission lines*, whilst IR/UV ratio reflects extinction for *stellar continuum light*. More massive galaxies tend to have higher extinction for nebular lines.

Reference

[1] Koyama, Y., et al.: 2015, *MNRAS*, **453**, 879.

Enrichment of *r*-process Elements in Dwarf Spheroidal Galaxies in Chemo-dynamical Evolution Model

HIRAI, Yutaka (University of Tokyo/NAOJ)
ISHIMARU, Yuhri (International Christian University)
SAITOH, Takayuki R. (Tokyo Institute of Technology)
FUJII, Michiko S. (University of Tokyo)
HIDAKA, Jun (Meisei University/NAOJ)
KAJINO, Toshitaka (NAOJ/University of Tokyo)

The rapid neutron capture process (*r*-process) is one of the main processes to synthesize elements heavier than iron. Recent astronomical high-dispersion observations have shown that there are large star-to-star scatters in extremely metal-poor stars of the Milky Way halo. Nevertheless, astrophysical sites of *r*-process have not yet been identified. Nucleosynthesis calculations suggest that binary neutron star mergers are the promising astrophysical site of *r*-process. In contrast, previous galactic chemical evolution studies pointed out that it is difficult to reproduce the observed *r*-process abundance in extremely metal-poor stars by neutron star mergers due to their long merger time and low occurrence rate [1]. However, most previous studies did not consider the galaxy formation process. Extremely metal-poor stars would have formed before the Milky Way halo gains large mass. It is thus required to calculate chemical evolution with models of the Milky Way progenitor haloes.

In this study, we performed a series of hydrodynamical simulations of galaxies assuming that neutron star mergers are the major astrophysical site of *r*-process [2]. The simulations were performed using *N*-body/hydrodynamic code, ASURA [3]. In ASURA, we calculate gas cooling, thermal feedback from supernovae, chemical evolution as well as *N*-body/hydrodynamic calculations. We assume neutron star mergers with a merger time of 100 Myr occur with 0.5 % of the rate of supernovae. We adopt the isolated dwarf galaxy model with its halo mass of $7\times10^8\,M_\odot$ in order to perform high-resolution simulations.

Figure 1 shows [Eu/Fe] as a function of [Fe/H] predicted by this simulation. According to Figure 1, the dispersion of [Eu/Fe] appears at [Fe/H] ~ −3. This feature is consistent with observations of extremely metal-poor stars. This means that it is possible to explain the observed *r*-process abundance in extremely metal-poor stars by neutron star mergers with merger times of ~100 Myr. We find that the metallicity is constant over ~300 Myr from the onset of star formation due to low star formation rate suppressed by supernova feedback in dwarf galaxies. We confirm that merger times shorter than 500 Myr do not significantly affect the distribution of *r*-process elements. We moreover find that metal mixing in star-forming region avoids producing extremely *r*-process rich stars, which are inconsistent with the observation, due to the low rate of neutron star mergers. The *r*-process elements observed in the Milky-Way halo might originate in accreted dwarf galaxies. This study supports that neutron star mergers are the promising site of *r*-process elements on the point of chemo-dynamical evolution of galaxies.

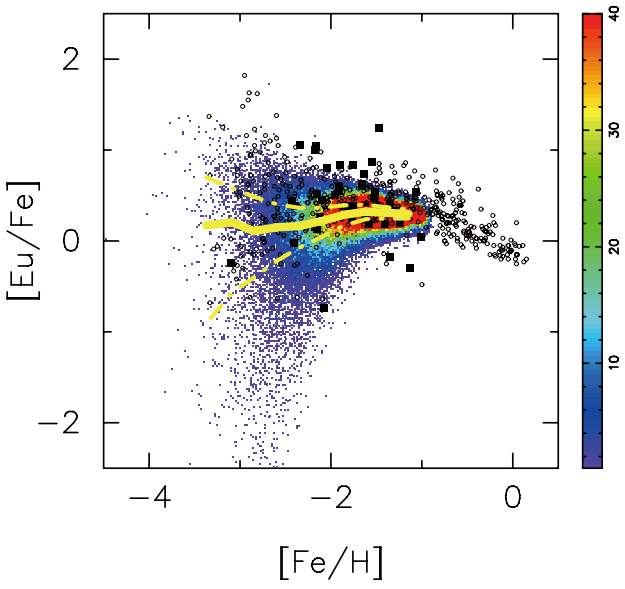


Figure 1: [Eu/Fe] as a function of [Fe/H] [2]. Color contour is the number of stars produced in this model. Yellow curve and dash-dotted curve are the median, first, and third quartiles of model prediction, respectively. Circles and squares are the observed values of stars in the Galactic halo and the Local Group dwarf galaxies, respectively. The observational data are taken from SAGA database [4].

References

[1] Argast, D., Samland, M., Thielemann, F.-K., Qian, Y.-Z.: 2004, *A&A*, **416**, 997.
[2] Hirai, Y., Ishimaru, Y., Saitoh, T. R., Fujii, M. S., Hidaka, J., Kajino, T.: 2015, *ApJ*, **814**, 41.
[3] Saitoh, T. R., Daisaka, H., Kokubo, E., et al.: 2008, *PASJ*, **60**, 667.
[4] Suda, T., Katsuta, Y., Yamada, S., et al.: 2008, *PASJ*, **60**, 1159.

Physical Conditions of Supernova Ejecta as Viewed from the Sizes of Presolar Al_2O_3 Grains

NOZAWA, Takaya, WAKITA, Shigeru (NAOJ)
HASEGAWA, Yasuhiro (NASA JPL)
KOZASA, Takashi (Hokkaido University)

Presolar grains are tiny solid particles identified in meteorites thanks to their anomalous isotopic composition, and are invaluable fossils that allow us to directly observe the detailed chemical compositions and sizes of stellar dust. Among the presolar grains that are considered to have originated in core-collapse supernovae (SNe), Al_2O_3 grains are of great importance because Al_2O_3 is known to be one of the major components of SN condensates [1,2]. In particular, the measured sizes of presolar Al_2O_3 grains are 0.5–1.5 μm in diameter [3,4], which are much larger than those (< 0.05 μm) predicted from theoretical calculations of dust formation in SNe [e.g., 5].

With the aim of clarifying the formation condition of such large Al_2O_3 grains, we investigate the condensation of Al_2O_3 grains for wide ranges of density and cooling rate of the gas [6]. The calculations are performed by applying the formulation of non-steady-state dust formation [7]. The formula enables us to estimate the size distribution of newly formed grains and the condensation efficiency defined as the fraction of Al atoms that are locked up in Al_2O_3 grains.

We first show that the average radius $a_{\rm ave,\infty}$ and condensation efficiency $f_{\rm con,\infty}$ of newly formed Al_2O_3 grains are nicely described by a non-dimensional quantity $\Lambda_{\rm on}$, defined as the ratio of the timescale on which the supersaturation ratio increases to the collision timescale of Al atoms at dust formation. Figure 1 shows that the formation of Al_2O_3 grains can be realized at $\Lambda_{\rm on} \geq 1$, and $f_{\rm con,\infty} = 1$ at $\Lambda_{\rm on} \geq 20$. Since $\Lambda_{\rm on}$ is approximately proportional to the product of gas density and cooling timescale, the average radius is larger for a higher gas density and/or a slower gas cooling.

Then we find that, in order to produce Al_2O_3 grains with radii larger than 0.25 μm as measured in meteorites, $\Lambda_{\rm on}$ should be higher than 3×10^4. Such a high $\Lambda_{\rm on}$ could be achieved by adopting more than one order of magnitude higher gas density than that presented by the one-dimensional SN model. This indicates that presolar Al_2O_3 grains might be formed in dense gas clumps within the SN ejecta. Our analysis strongly suggests that the measured sizes of presolar grains can be a powerful tool for constraining the physical conditions and structure of the SN ejecta.

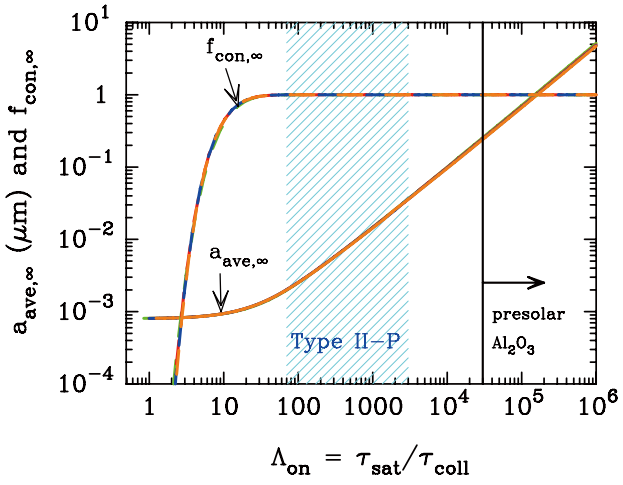


Figure 1: Average radius ($a_{\rm ave,\infty}$) and condensation efficiency ($f_{\rm con,\infty}$) of newly formed Al_2O_3 grains as a function of $\Lambda_{\rm on}$, which is defined as the ratio of the supersaturation timescale ($\tau_{\rm sat}$) to the collision timescale of Al atoms ($\tau_{\rm coll}$) at dust formation. The results for four different cooling rates ($T(t) \propto t^{-3(\gamma-1)}$where γ = 1.1, 1.3, 1.5, and 1.7) are shown in different colors but they are plotted as almost the same curve. The hached region draws the expected range of $\Lambda_{\rm on}$ for the formation of Al_2O_3 grains in the Al-rich region, referring to the one-dimensional model of a Type II-P SN [8]. The solid vertical line indicates the minimum value of $\Lambda_{\rm on}$ necessary for explaining the radii larger than 0.25 μm as measured for presolar Al_2O_3 grains.

References

[1] Douvion, T., Lagage, P. O., Pantin, E.: 2002, *A&A*, **369**, 589.
[2] Rho, J., et al.: 2008, *ApJ*, **673**, 271.
[3] Choi, B.-G., Huss, G. R., Wasserburg, G. J.: 1998, *Science*, **282**, 1284.
[4] Nittler, L. R., Alexander, C. M. O'D., Wang, J., Gao, X.: 1998, *Nature*, **393**, 222.
[5] Nozawa, T., et al.: 2003, *ApJ*, **598**, 785.
[6] Nozawa, T., Wakita, S., Hasegawa, Y., Kozasa, T.: 2015, *ApJ*, **811**, L39.
[7] Nozawa, T., Kozasa, T.: 2013, *ApJ*, **776**, 24.
[8] Kozasa, T., et al.: 2009, *ASP Conf. Ser.*, **414**, Cosmic Dust: Near and Far, ed. Th. Henning, E. Gr¨un, & J. Steinacker (San Francisco, CA: ASP), 43.

The Sloan Digital Sky Survey Reverberation Mapping Project: Post-Starburst Signatures in Quasar Host Galaxies at $z < 1$

MATSUOKA, Yoshiki[1], STRAUSS, Michael A.[2], SHEN, Yue[3/4], BRANDT, William N.[5], GREENE, Jenny E.[2]
HO, Luis C.[3], SCHNEIDER, Donald P.[5], SUN, Mouyuan[5/6], TRUMP, Jonathan R.[5]

1: NAOJ, 2: Princeton University, 3: Peking University, 4: Carnegie Observatories, 5: The Pennsylvania State University, 6: Xiamen University

Quasar host galaxies are key for understanding the relation between galaxies and the supermassive black holes (SMBHs) at their centers. We present a study of 191 broad-line quasars and their host galaxies at $z < 1$, using high signal-to-noise ratio (SNR) spectra produced by the Sloan Digital Sky Survey Reverberation Mapping project [1]. Clear detection of stellar absorption lines allows a reliable decomposition of the observed spectra into nuclear and host components, using spectral models of quasar and stellar radiations as well as emission lines from the interstellar medium. We estimate age, mass M_*, and velocity dispersion σ_* of the host stars, the star formation rate (SFR), quasar luminosity, and SMBH mass $M_\bullet$, for each object. The quasars are preferentially hosted by massive galaxies with $M_* \sim 10^{11}\,M_\odot$ characterized by stellar ages around a billion years, which coincides with the transition phase of normal galaxies from the blue cloud to the red sequence (Figure 1). The host galaxies have relatively low SFRs and fall below the main sequence of star-forming galaxies at similar redshifts. These facts suggest that the hosts have experienced an episode of major star formation sometime in the past billion years, which was subsequently quenched or suppressed. The derived $M_\bullet - \sigma_*$ and $M_\bullet - M_*$ relations agree with our past measurements and are consistent with no evolution from the local Universe. The present analysis demonstrates that reliable measurements of stellar properties of quasar host galaxies are possible with high-SNR fiber spectra, which will be acquired in large numbers with future powerful instruments such as the Subaru Prime Focus Spectrograph.

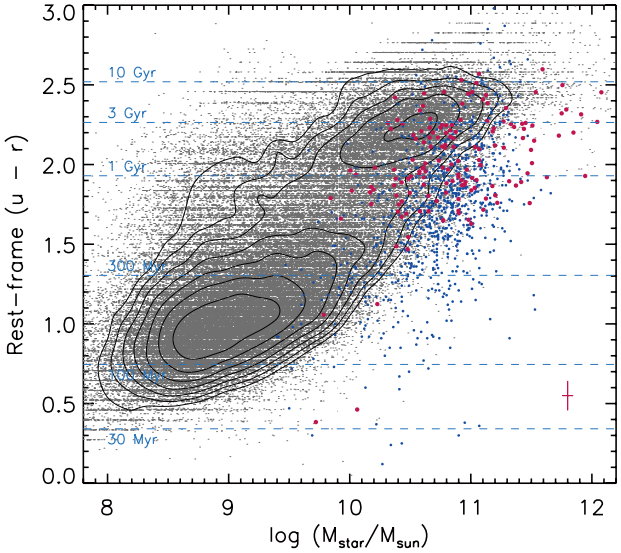


Figure 1: Rest-frame ($u - r$) colors and stellar masses of the quasar host galaxies in this work (red dots) and in [2] (blue dots). The typical error for the present sample is shown by the error bar at the bottom right corner. The small gray dots and contours, drawn at logarithmically stepped levels of number density, represent non-AGN galaxies at $0.5 < z < 1.0$ taken from the COSMOS/UltraVISTA K-band selected catalog. The dots are given small random offsets to improve visibility. The dashed lines mark the SSP colors with $t_* = 0.03$, 0.1, 0.3, 1, 3, and 10 Gyr, as labelled. The quasar hosts are preferentially hosted by massive galaxies distributed from the massive tip of the blue cloud to the red sequence. Their mean stellar age ($t_* \sim 1$ Gyr) corresponds to the gap of the bimodal distribution of inactive galaxies, where blue star-forming galaxies may be rapidly transitioning to the red sequence.

References

[1] Matsuoka, Y., Strauss, M. A., Shen, Y., et al.: 2015, *ApJ*, **811**, 91.

[2] Matsuoka, Y., Strauss, M. A., Price, T. N., III, DiDonato, M. S.: 2014, *ApJ*, **780**, 162.

The Ages, Metallicities, and Element Abundance Ratios of Massive Quenched Galaxies at $z \simeq 1.6$

ONODERA, Masato, CAROLLO, C. Marcella, TACCHELLA, Sandro
(ETH Zurich)

RENZINI, Alvio, MANCINI, Chiara
(INAF–Osservatorio Astronomico di Padova)

CAPPELLARI, Michele
(INAF–Osservatorio Astronomico di Padova)

ARIMOTO, Nobuo
(NAOJ/Graduate University for Advanced Studies)

YAMADA, Yoshihiko
(NAOJ)

DADDI, Emanuele
(CEA Saclay)

GOBAT, Raphaël
(Korea Institute for Advanced Study)

STRAZZULLO, Veronica
(Ludwig-Maximilians University)

We studied the ages, metallicities ([Z/H]), and α-element abundance ratios ([α/Fe]) of stellar populations in quenched and passively evolving galaxies by using MOIRCS on Subaru Telescope [1]. The sample galaxies were selected in the COSMOS field and their spectroscopic redshifts range in $1.25 < z < 2.09$ with a mean of 1.6. Since these galaxies are extremely faint, it is difficult to study stellar population properties spectroscopically for individual objects. Therefore, we carried out our analysis by stacking 24 spectra to obtain an adequate S/N ratio, resulting in a stacked spectrum with an equivalent integration time of 200 hours.

We measured a set of Lick indices [2, 3] and compared them with the prediction from stellar population synthesis models [4] to obtain the stellar population parameters of $z \simeq 1.6$ passively evolving galaxies. The resulting stellar population parameters are $\log_{10}$ age/Gyr = $0.04^{+0.10}_{-0.08}$, [Z/H] = $0.24^{+0.20}_{-0.14}$, and [α/Fe] = $0.31^{+0.12}_{-0.12}$. In particular, this is the first time that stellar [α/Fe] is measured at $z > 1$.

Comparing the stellar population parameters above with low redshift counterparts of our sample at $0 < z < 1$, all of them show excellent agreement with passive evolution of the stellar populations, and we found the formation redshift of them as $z_f \simeq 2.3$. This supports a scenario that these passively evolving galaxies have formed by $z \simeq 2.3$ and evolved passively since then. The [α/Fe] ratio indicates a short formation timescale, at most 1 Gyr.

We then investigated star-forming precursors of the passively evolving galaxies we studied. Since the age of the sample is well constrained to be $\simeq 1$ Gyr, progenitors must be star-forming galaxies at $z \simeq 2.3$. Indeed, star-forming galaxies at $z \simeq 2.3$ with similar stellar masses show star formation rates of a few hundred solar masses per year, which agrees well with that expected from the stellar population parameters we derived above. If these star-forming galaxies form stars at this rate, they will grow in mass with which no corresponding counterpart exists in the local Universe. Therefore, they must soon be quenched due to some physical mechanisms and follow passive evolution to present.

References

[1] Onodera, M., et al.: 2015, *ApJ*, **808**, 161O.
[2] Worthey, G., Ottaviani, D. L.: 1997, *ApJS*, **111**, 377.
[3] Trager, S. C., et al.: 1998, *ApJS*, **116**, 1.
[4] Thomas, D., et al.: 2011, *MNRAS*, **412**, 2183.
[5] Jrgensen, I., Chiboucas, K.: 2013, *AJ*, **145**, 77.
[6] Spolaor, M., et al.: 2010, *MNRAS*, **408**, 272.

Polarization Structure of Magnetically Supported Molecular Filaments

TOMISAKA, Kohji
(NAOJ)

Observations of thermal dust emissions with Herschel satellite have revealed that molecular clouds consist of many filaments [1]. That is, the molecular filaments are the building blocks of interstellar clouds. On the other hand, near IR interstellar polarization indicates the filaments are extending in the perpendicular direction to the interstellar magnetic field [2].

Equilibrium solutions of isothermal clouds, in which the gravity is balanced with the Lorentz force, thermal pressure and the external pressure, are obtained with a self-consistent field method [3]. Figure 1 shows two typical such solutions, where the left one has a low density-contrast between the center and the surface $\rho_c/\rho_s = 10$ while the right one has a higher contrast $\rho_c/\rho_s = 300$. Here, we studied polarization structures of the thermal dust emissions expected for the magnetized filaments [4].

The polarization of the thermal dust emissions comes from dusts which are aligned to the interstellar magnetic field. Expected polarization pattern is calculated for the equilibrium filaments observed from the line of sight specified with two angles θ and φ (see Fig. 2 left). We showed the models with $(\theta, \varphi)=(80°, 90°)$ in Figure 2. The middle panel corresponds to a low-density filament of Fig. 1 (left). Low polarization degree comes from the configuration in which the line of sight is nearly parallel to the large-scale B-field. On the other hand, a high-density filament with $\rho_c/\rho_s = 300$ (right) shows a polarization pattern as if B-field were perpendicular to the filament. This may explain the fact that the perpendicular configuration is so commonly observed.

References

[1] Men'shchikov, A., Andre, Ph., Didelon, P., et al.: 2010, *A&A*, **518**, L103.
[2] Sugitani, K., Nakamura, F., Watanabe, M., et al.: 2011, *ApJ*, **734**, 63.
[3] Tomisaka, K.: 2014, *ApJ*, **785**, 24.
[4] Tomisaka, K.: 2015, *ApJ*, **807**, 47.

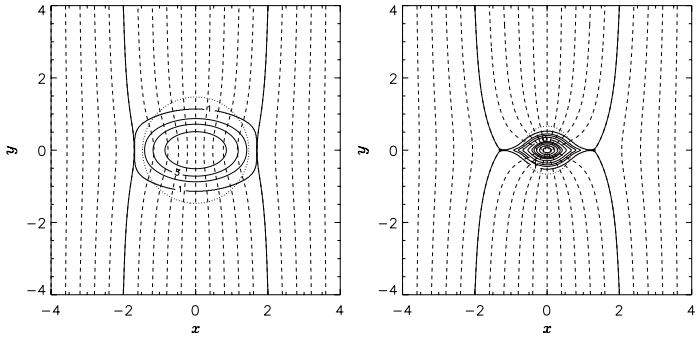


Figure 1: Isothermal filaments threaded by lateral magnetic fields, which were obtained under the assumption of mechanical equilibrium using a self-consistent field method [3]. These two models have the identical magnetic flux, isothermal sound speed and external pressure but different central density (left: $\rho_c = 10\,\rho_s$; right: $\rho_c = 300\,\rho_s$).

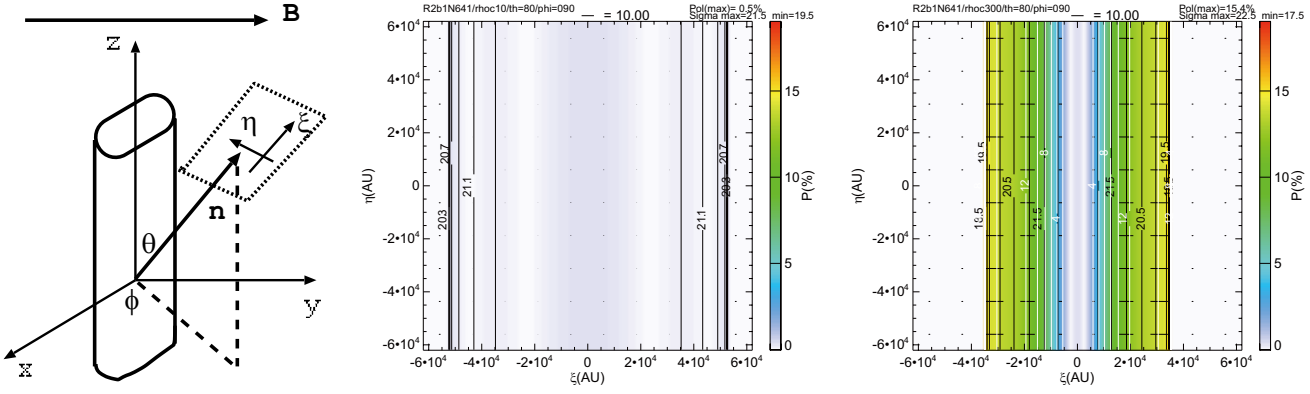


Figure 2: Left: relation between the filament and the observing line-of-sight. Expected polarization patterns of the low-density filament (middle), and the high-density filament (right). The polarization degree and its direction (electromagnetic wave B-vector) are shown by false-color and short bars, respectively.

Wide-field Infrared Polarimetry of the Ophiuchi Cloud Core

KWON, J. (University of Tokyo/JSPS)
TAMURA, M. (University of Tokyo/NAOJ)
HOUGH, J. H. (University of Hertfordshire)
NAKAJIMA, Y. (Hitotsubashi University)
NISHIYAMA, S. (Miyagi University of Education)
KUSAKABE, N. (NAOJ)
NAGATA, T. (Kyoto University)
KANDORI, R. (NAOJ)

We have conducted wide and deep near-infrared imaging polarimetry of the ρ Ophiuchi cloud complex [1]. Aperture polarimetry in the JHK_S band was conducted for 2136 sources in all three bands, of which 322 sources have significant polarizations in all the JHK_S bands and have been used for a discussion of the core magnetic fields in the ρ Ophiuchi cloud complex. There is a positive correlation between degrees of polarization and $H - K_S$ color up to $H - K_S \approx 3.5$. The magnetic field structures in the core region are revealed up to at least $A_V \approx 47$ mag and are unambiguously defined in each sub-region (core) of Oph-A, Oph-B, Oph-C, Oph-E, Oph-F, and Oph-AC. Their directions, degrees of polarization, and polarization efficiencies differ but their changes are gradual. Therefore, the magnetic fields seem to be connected from core to core, rather than as a simple overlap of the different cloud core components. Comparing our results with the large-scale field structures obtained from previous optical polarimetric studies [2], we suggest that the magnetic field structures in the core were distorted by the cluster formation in this region, which may have been induced by shock compression due to wind/radiation from the Scorpius–Centaurus association.

References

[1] Kwon, J., et al.: 2015, *ApJS*, **220**, 17.
[2] Vrba, J., et al.: 1976, *AJ*, **81**, 958.

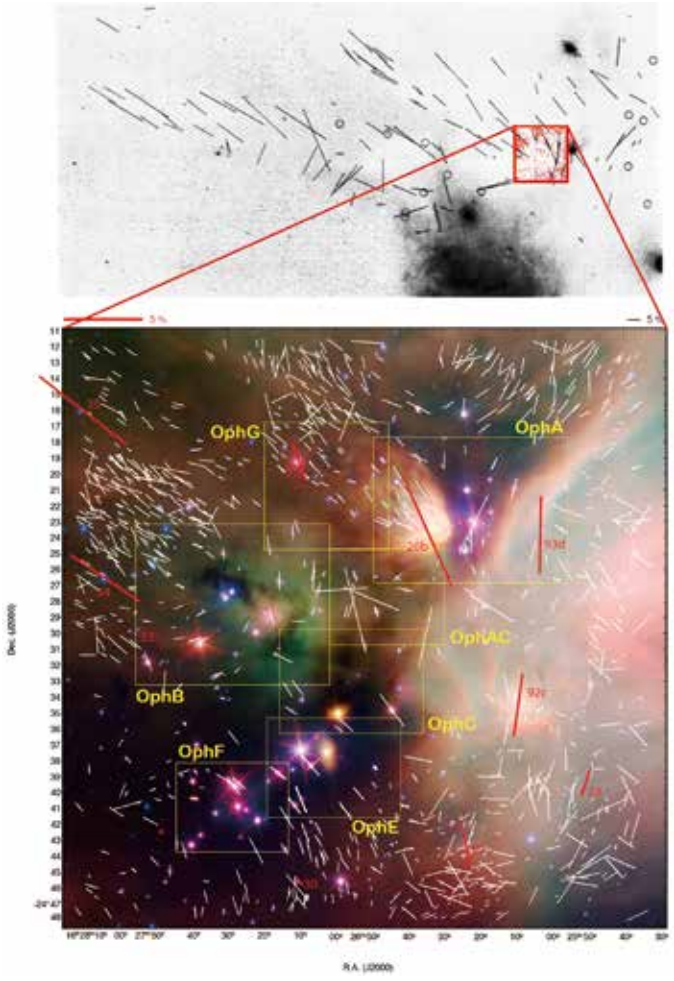


Figure 1: Comparison between infrared and optical polarimetry [1].

Early Cosmic Merger of Multiple Black Holes

TAGAWA, Hiromichi (University of Tokyo)
UMEMURA, Masayuki (University of Tsukuba)
GOUDA, Naoteru (University of Tokyo/NAOJ)
YANO, Taihei (NAOJ)
YAMAI, Yuki (Mitsubishi Space Software co., Ltd.)

At redshifts higher than six quasars are found that possess SMBHs with the mass higher than $10^9\,M_\odot$ [1]. The formation history of these SMBHs is among the most significant unsolved issues in astrophysics. For SMBHs to grow from such first star remnants through mass accretion at $z > 6$, a super-Eddington accretion rate is requisite. However, the continuous accretion is unlikely to be sustained due to feedbacks, and thus the average mass accretion rates should be lower than the Eddington rate [2]. Another possible pathway of SMBH formation is the merger of BHs. If the merger of multiple black holes precedes the growth via gas accretion, the merged BH can be a seed of a supermassive black hole.

Recent radiation hydrodynamic simulations on the formation of first stars show that several or more stars form in a primordial gas cloud with the density of around $10^7\,\mathrm{cm}^{-3}$ and the extension of 1000 AU, where the gas fraction is 99 % [3]. In this circumstance, BH remnants of first stars are most likely subject to the dynamical friction by abundant gas. The gas dynamical friction has been considered as a mechanism that prompts the BH merger. Hitherto, the merger processes by the gas dynamical friction have been investigated in the case of two massive BHs (e.g. Escala 2004, Escala 2005). In our study, we explore the merger of multiple BHs, supposing a first-generation object of $\sim 10^5$–$10^6\,M_\odot$ or a gas-rich primordial galaxy of $\sim 10^8$–$10^9\,M_\odot$.

The simulations incorporate such general relativistic effects as the pericentre shift and gravitational wave emission.

As a result, we find that multiple BHs are able to merge into one BH within 100 Myr in a wide range of parameters. In the case of $M_{\rm BH} = 30\,M_\odot$, if multiple BHs are embedded in the gas density with $n_{\rm gas} = 5\times10^6$ to $10^8\,\mathrm{cm}^{-3}$, then all the BHs can merge together over six orders of BH density as $\rho_{\rm BH} = 72-7.2\times10^7\,M_\odot\,\mathrm{pc}^{-3}$. The merger mechanism is revealed to be categorized into three types: gas drag-driven merger (type A), three body-driven merger (type C), and interplay-driven merger (type B). We find the relation between the merger mechanism and the ratio of the gas mass within the initial BH orbit ($M_{\rm gas}$) to the total BH mass ($\sum M_{\rm BH}$). Type A merger occurs if $M_{\rm gas} \gtrsim 10^5 \sum M_{\rm BH}$, type B if $M_{\rm gas} \lesssim 10^5 \sum M_{\rm BH}$, and type C if $M_{\rm gas} \ll 10^5 \sum M_{\rm BH}$. Supposing the gas and BH density based on the recent numerical simulations on first stars, all the BH remnants from first stars are likely to merge into one BH through the type B or C mechanism.

The present results imply that the BH merger may contribute significantly to the formation of supermassive BHs at high redshift epochs [4].

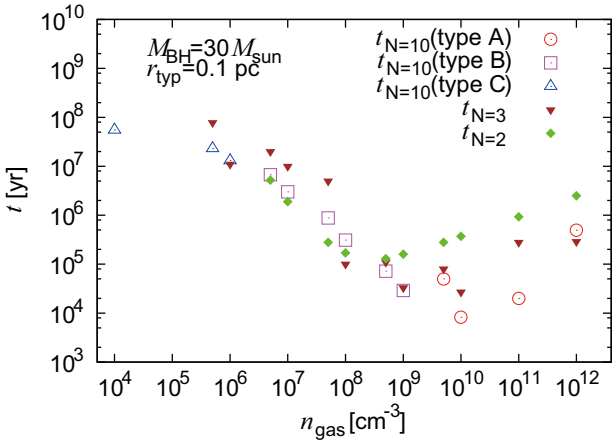


Figure 1: Merger time in ten-BH systems ($t_{N=10}$) as a function of gas number density $n_{\rm gas}$. Red, pink, and blue open symbols represent the results of the type A, B, and C mergers, respectively. Green- and brown-filled symbols are the results of two-BH ($t_{N=2}$) and three-BH ($t_{N=3}$) systems, respectively.

References

[1] Fan, X.: 2001, *AJ*, **122**, 2833.
[2] Milosavljevic, M., Couch, S. M., Bromm, V.: 2009, *ApJ*, **696**, 146.
[3] Susa, H., Hasegawa, K., Tominaga, N.: 2014, *ApJ*, **792**, 32.
[4] Tagawa, H., et al.: 2015, *MNRAS*, **451**, 2174.

Planetary System Formation in Protoplanetary Disk around HL Tauri

AKIYAMA, Eiji[1], HASEGAWA, Yasuhiro[1/2/3], HAYASHI, Masahiko[1/4], and IGUCHI, Satoru[1/4]

1: NAOJ, 2: NASA JPL, 3: Caltech, 4: The Graduate University for Advanced Studies

Since the outstanding pictures of HL Tau protoplanetary disk are unveiled, it has been demanded to investigate how much we can constrain the disk structure and physical properties. We re-processed the ALMA long-baseline science verification data taken toward HL Tauri [1] and improved the image quality by modifying data flagging and contriving ways to make deconvolution as shown in Figure 1. Assuming the observed gaps are opened up by currently forming, unseen bodies, we estimate the mass of such hypothetical bodies at the first 4 gaps from the central star based on following two approaches; the Hill radius analysis and a more elaborated approach developed from the angular momentum transfer analysis in gas disks. For the former, the measured gap widths are used for estimating the mass of the bodies, while for the latter, the measured gap depths are utilized [2]. As a result, their masses are comparable to or less than the mass of Jovian planets. By evaluating Toomre's gravitational instability (GI) condition and cooling effect, we find that the GI might be a possible mechanism and can occur in the region beyond $r \sim 52$ AU, where both of the conditions are simultaneously met as shown by the shaded area in Figure 2.

Since the disk might be gravitationally unstable only in the outer region of the disk, inward planetary migration would be needed to construct the current architecture of the observed disk. We estimate the gap-opening mass (M_{gap}) to show what type of migration can take place in the HL Tau system, and can be expressed as

$$M_{gap} \simeq 2.7 M_{\oplus} \times \left(\frac{r}{1\ \mathrm{AU}}\right)^{3/2} \left(\frac{M_*}{1 M_{\odot}}\right)^{-1/2} \left(\frac{T}{100\mathrm{K}}\right)^{3/2}. \quad (1)$$

As a result of comparing planet masses with M_{gap}, planets are sufficiently massive to open up a gap in their gas disk via disk-planet interactions, and hence the planets will undergo type II migration. Combining GIs with inward migration, we conjecture that all of the observed gaps may be a consequence of bodies that might have originally formed at the outer part of the disk, and have subsequently migrated to the current locations. While ALMA's unprecedented high spatial resolution observations can revolutionize our picture of planet formation, more dedicated observational and theoretical studies are needed to fully understand the HL Tauri images.

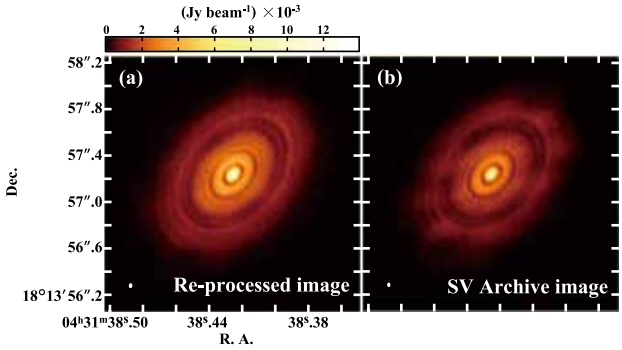


Figure 1: Comparison of the 0.87 mm continuum dust emission of HL Tau between our re-processed image (a) and the archive data (b).

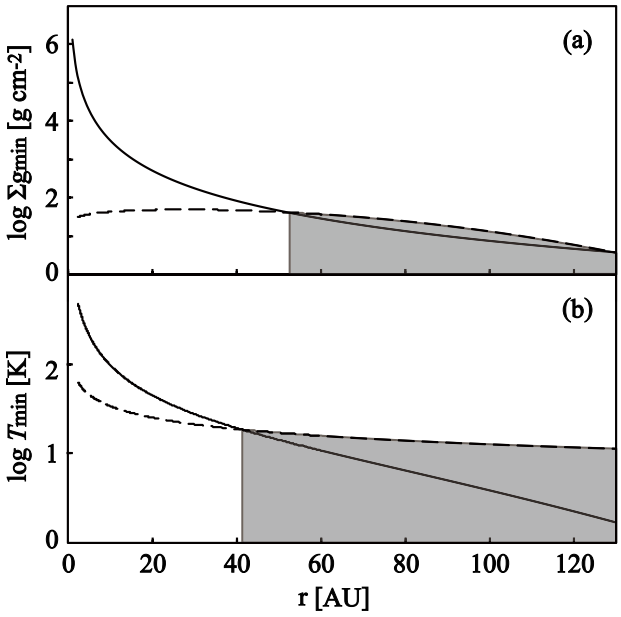


Figure 2: Panel (a) represents the surface density distribution of Kwon et al. (2011) model (solid curve) [3] and the minimum surface density of gas (Σ_{gmin}) that is required to trigger GIs (dashed curve). Panel (b) shows the radial temperature distribution given by power low function (solid curve) and the minimum disk temperature (T_{min}) that satisfies the cooling condition of the GI (dashed curve). The shaded area in both panels represents the region where the GI can be invoked.

References

[1] ALMA Partnership, Brogan, C. L., Perez, L. M., et al.: 2015, *ApJ*, **808**, L3.

[2] Kanagawa, K. D., Muto, T., Tanaka, H., et al.: 2015, *ApJ*, **806**, L15.

[3] Kwon, W., Looney, L. W., Mundy, L. G.: 2011, *ApJ*, **741**, 3.

Constraints on the Birth of the Universe and Origin of Cosmic Dark Flow

MATHEWS, Grant J. (University of Notre Dame/NAOJ)
GANGOPADHYAY, Mayukh R., GARNAVICH, P., ROSE, B. (University of Notre Dame)
ICHIKI, Kiyotomo (Nagoya University)
KAJINO, Toshitaka (NAOJ/University of Tokyo)

This paper [1] reviewed several constraints on new physics in the early universe including resonant particle creation [2] and Supersymmetry motivated inflation in the M-theory landscape leading to a cosmic dark flow. Such dark flow is the result of quantum entanglement with a neighboring universe that persists during inflation [1]. This residual curvature would appear as a bulk motion of the universe with respect the the CMB frame corrected for motion with respect to the cosmic dipole moment.

We summarized [1] recent constraints on the dark (or bulk) flow velocity based upon a new analysis of the deviations from Hubble flow in the SNIa redshift-distance relation. We made two analyses: one identifying the three dimensional Cartesian velocity components; the other analyzing the cosine dependence on the sky of the deviation from Hubble flow. Fits were for $z < 0.05$ and $z > 0.05$ using both the Union2.1 [3] and SDSS-II [4,5] supernova surveys. We also studied [1] simulated data in which a bulk flow was imposed to determine whether the difficulty in detecting a bulk flow at high redshift is due to uncertainty in the redshift-distance relation, confusion with peculiar velocities, or the absence of a bulk flow. We found [1] a bulk flow velocity of $270 \pm 30\,\mathrm{km\,s^{-1}}$ in the direction $(l, b) = (295 \pm 30, 10 \pm 5)°$ in the Cartesian analysis, while the cosine analysis gave $325 \pm 50\,\mathrm{km\,s^{-1}}$ in the direction $(l, b) = (276 \pm 15, 37 \pm 3)°$, consistent with previous analyses. In the redshift bin $z > 0.05$, however, we found [1] only marginal evidence for a bulk flow velocity. We also found that the SDSS-II supernova data set has insufficient sky coverage to provide a meaningful result.

Galaxies in which a SN Ia has occurred provide, perhaps, the best alternative ([1] and refs therein) because their distances are better determined. However there are fewer data available. There has been a wide variety in the attempts to find a bulk flow in SN Ia data sets. Our study [1] differed from that of the previous analyses in several key aspects. We made an independent analysis based upon two different approaches and two separate data sets. We utilized a MCMC fit to the three Cartesian components of bulk flow velocity rather than the velocity magnitude in galactic coordinates. This approach had better stability near the Galactic pole. We then also analyzed the same data by searching for a deviation from Hubble flow with a $\cos\theta$ angular dependance on the sky. These studies established the robustness of these two complementary techniques for identifying the magnitude and direction of the bulk flow and confirmed previous detections of a bulk flow out to at least $z = 0.05$.

Having established the viability of the methods adopted, we then applied them for the first time to the large sample of (~ 1000) galactic redshifts and SN Ia distances from the *SDSS*-II survey [4,5]. However, we found that the analysis of the *SDSS*-II data was severely limited by the paucity of data in the direction of the cosmic dipole moment. We establish [1] that there is a detectable bulk flow at low redshifts, but at best a marginal detection for high redshifts.

From simulated data sets, we deduced [1] that the current uncertainty at high redshifts arises mostly from the current error in the distance modulus. We estimated [1] that with a sample like the Union2.1 data set, a detection would require both significant sky coverage of SNIa out to z = 0.3 and a distance modulus error reduction from 0.2 to ≤0.02 mag. However, a greatly expanded data set of 3×10^4 events might detect a bulk flow even with a typical distance modulus error of 0.2 mag as may be achievable with the next generation of large surveys like LSST.

References

[1] Mathews, G. J., et al.: 2015, *Int. J. Mod. Phys. A*, **30**, 1545022.
[2] Mathews, G. J., et al.: 2015, *Phys. Rev. D*, **92**, 123519.
[3] Suzuki, N., et al.: 2012, *ApJ*, **746**, 85.
[4] Sako, M., et al.: 2007, *AJ*, **135**, 348.
[5] Frieman, J. A., et al.: 2008, *AJ*, **135**, 338.
[6] Planck Collaboration, *Planck XVI*: 2014, *A&A*, **566**, A54.

Possible Evidence for Planck-scale Resonant Particle Production during Inflation from the CMB Power Spectrum

MATHEWS, Grant J. (University of Notre Dame/NAOJ)
GANGOPADHYAY, Mayukh (University of Notre Dame)
ICHIKI, Kiyotomo (Nagoya University)
KAJINO, Toshitaka (NAOJ/University of Tokyo)

The *Planck* Satellite has provided the highest resolution yet available in the determination of the power spectrum of the cosmic microwave background (CMB) [1]. Analysis of this power spectrum provides powerful constraints on the physics of the very early universe [1].

The primordial power spectrum is believed to derive from quantum fluctuations generated during the inflationary epoch. In this paper [2] we analyzed a peculiar feature visible in the observed power spectrum near multipoles ℓ = 10–30. This is an interesting region in the CMB power spectrum because it corresponds to angular scales that are not yet in causal contact, so that the observed power spectrum is close to the true primordial power spectrum.

An illustration of the *Planck* observed power spectrum in this region is shown in Figure 1. Although the error bars are large, there is a noticeable systematic deviation in the range ℓ = 10–30 below the best fit based upon the standard ΛCDM cosmology with a power-law primordial power spectrum. This same features is visible in the CMB power spectrum from the Wilkinson Microwave Anisotropy Probe (*WMAP*) [3], and hence, are likely a true feature in the CMB power spectrum.

The line drawn on Figure 1 shows a fit to the the ℓ = 10–30 dip in the *Planck* CMB power spectrum based upon a model for the creation of N nearly degenerate trans-Planckian massive fermions during inflation. The best fit to the CMB power spectrum implies an optimum feature at $k_* = 0.0011 \pm 0.0004\, h\,\mathrm{Mpc}^{-1}$ (wave number at the resonant frequency) and an amplitude of $A \approx 1.7 \pm 1.5$. For monomial inflation potentials consistent with the *Planck* tensor-to-scalar ratio, this feature corresponds to the resonant creation of nearly degenerate particles with $m \sim 8$–$11\, m_{\rm pl}/\lambda^{3/2}$ and a Yukawa coupling constant λ between the fermion species and the inflaton field of $\lambda \approx (1.0 \pm 0.5)N^{-2/5}$ for N degenerate fermion species.

If the present analysis is correct, this may be one of the first hints at observational evidence of new particle physics at the Planck scale. Indeed, one expects a plethora of particles at the Planck scale, particularly in the context of string theory. Perhaps, the presently observed CMB power spectrum contains the first suggestion that a subset of such particles may have coupled to the inflaton field leaving a relic signature of their existence in the CMB primordial power spectrum.

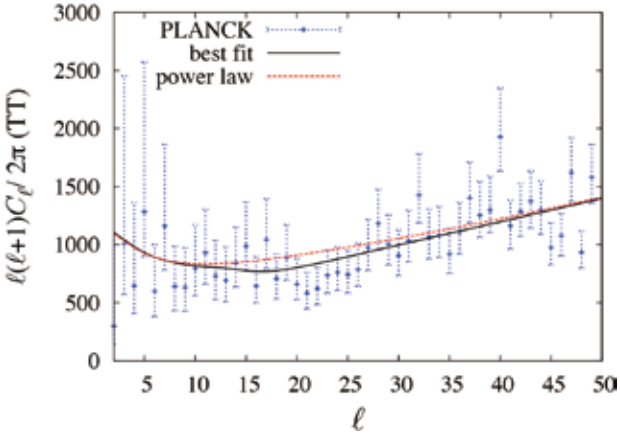


Figure 1: (Color online) CMB power spectrum in the range of ℓ = 3–50 Points with error bars are from the *Planck* Data Release [1]. The dashed line shows the best standard ΛCDM fit to the *Planck* CMB power spectrum based upon a power-law primordial power spectrum. The solid line shows the best fit for a model with resonant particle creation during inflation.

References

[1] Planck Collaboration, Planck XX: 2016, *A&A*, **594**, A20.
[2] Mathews, G. J., et al.: 2015, *Phys. Rev. D*, **92**, 123519.
[3] Hinshaw, G., et al. (WMAP Collaboration): 2013. *ApJS*, **208**, 19.

Constraints on Pre-inflation Fluctuations in a Nearly Flat Open ΛCDM Cosmology

MATHEWS, Grant J.
(University of Notre Dame/NAOJ)

SUH, InSaeng
(University of Notre Dame)

LAN, Nguyen Q.
(Hanoi National University of Education)

KAJINO, Toshitaka
(NAOJ/University of Tokyo)

There is now a general consensus that we live in a nearly flat universe. The best fit of the combined CMB + HiL + BAO fit by the Planck collaboration [1] obtained a closure content of the universe to be $\Omega_0 = 1.005^{+0.0062}_{-0.0065}$ implying a curvature content of $\Omega_k \equiv 1 - \Omega_0 = -0.0005^{+0.0065}_{-0.0062}$. This is indeed very close to exact flatness. Nevertheless, in this paper [2] we considered the possibility that the present universe is slightly open, i.e. $\Omega_0 \geq 0.994$ at the 95 % confidence level. In this case any fluctuations that existed before inflation might now be visible on the horizon. In our paper [2], we determined what constraints can be placed on inhomogeneities in the pre-inflation universe based upon current cosmological observations. Such pre-inflation isocurvature fluctuations would appear as a distortion in the cosmic microwave background dipole moment and can be characterized as a cosmic *dark flow* velocity $v_{\rm DF}$.

We developed a simple analytical model in which the pre-inflation universe contained a plane-wave sinusoidal inhomogeneity as an isocurvature fluctuation. $\phi(t, z) = \phi_i + \delta\phi_i \sin\frac{2\pi}{\lambda_i}(a_i z - t)$. The wavelength of the fluctuation can then be parameterized by: $\lambda_i = lH_i^{-1}$, The pre-inflation universe is then characterized by: 1) the scale l of the fluctuation in the inflaton field; 2) the initial closure parameter of the universe Ω_i; and 3) the fraction of the energy density of the universe in the inflaton field f as the universe enters the inflationary epoch.

Figure 1 from [2] summarizes values for Ω_i and l that satisfy the constraint $f < 1$ based upon the upper limit $v_{\rm DF} = 254\,{\rm km\,s^{-1}}$ from the *Planck* analysis of the KSZ effect, and the constraint that the quadrupole and higher moments not exceed the value from the observed CMB power spectrum. The upper region shows that only values of l near unity can satisfy this constraint while the the upper limit to the initial closure parameter is $\Omega_i < 0.4$ ($\Omega_{k,i} > 0.6$) as $f \rightarrow 1$. Indeed, from these constraints alone we find that the pre inflation fluctuation in the power spectrum must reside at least ~80 times the current Hubble scale. Such fluctuations are also constrained by the near flatness of the current universe. Indeed, all together we find that the wavelength of the pre-inflation fluctuation must be of order the Hubble scale as inflation begins. Also, if there is a pre-inflation component to the current cosmic dipole moment, then the initial pre-inflation closure parameter could have been as large as $\Omega_i < 0.4$ ($\Omega_{k,i} > 0.6$).

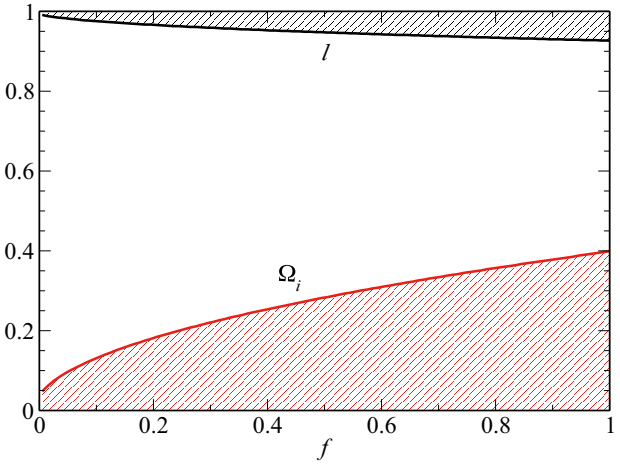


Figure 1: Constraints on the pre-inflation parameters as a function of the fraction f of the initial pre-inflation energy density in the inflaton field for a present dark flow velocity of $254\,{\rm km\,s^{-1}}$ from the upper limit to the *Planck* analysis [3]. Lower shaded region shows allowed values for the initial closure parameter Ω_i. Upper shaded region shows the allowed values of the wavelength parameter l.

References

[1] Planck Collaboration, *Planck XVI*: 2014, *A&A*, **566**, A54.
[2] Mathews, G. J., et al.: 2015, *Phys. Rev. D*, **92**, 123514.
[3] Planck Collaboration, *Planck XIII*: 2014, *A&A*, **561**, A97.

Universality of the Supernova r-Process and Radioactive Nuclei [1]

LORUSSO, Giuseppe (NPL/RIKEN)
NISHIMURA, Shunji (RIKEN)
SHIBAGAKI, Shota, KAJINO, Toshitaka (NAOJ/University of Tokyo)
for international EURICA collaboration

The discovery of how chemical elements are made in stars is one of the humanity's greatest achievement but several important questions are still unanswered. One of them surely concerns the rapid neutron capture (r) process, a key to the creation of the elements from Iron to Uranium (Z=26–92). The astrophysical site and exact mechanism of the r process have not yet been identified with certainty, a problem requiring astrophysics, astronomy, particle and nuclear physics to work together.

We have produced and studied exotic nuclei with neutron number $N \approx 82$ that have filled or nearly filled neutron shells configuration. These nuclei lie in the pathway of r process nucleosynthesis predicted for some of the most promising r process sites such as neutrino-driven wind in core-collapse supernovae. The enhanced stability of these nuclei is reflected in the large abundance of Xe and Te in the solar system. The experiment aimed at half-life measurements, was carried out at the Radioactive Ion Beam Factory (RIBF, RIKEN) where exotic nuclei were produced by fission of a Uranium beam induced by collision with a Be target. Fission fragments were unambiguously identified (see Fig. 1) and their following decay studied with the WAS3ABi silicon stopper and the EURICA germanium array.

The study evidences the persistence of shell structure and robust half-life systematics that underpin our current understanding of exotic neutron-rich nuclei. The new measurements also have a direct impact in r process models that achieve \emph{hot} conditions, i.e., strong $(n, \gamma) \Leftrightarrow (\gamma, n)$ equilibrium (see Fig. 2). In this case we find that the new data alleviate the long standing model underproduction of isotopes just below and above the mass $A \approx 130$ peak, and greatly improve the description of rare-earth elements. The latter is a prerequisite for understanding why the abundance of such elements matches coherently solar system and metal-poor stars (r process universality), and what is the full elemental range of such universal feature.

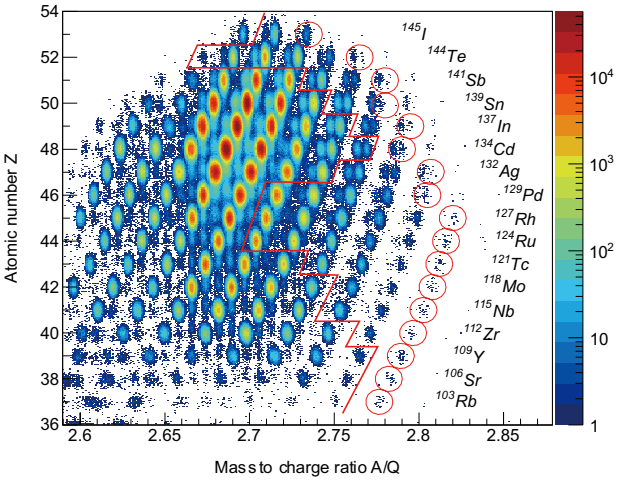


Figure 1: Particle Identification Plot. Nuclei on the right side of the red line were studied for the first time [1].

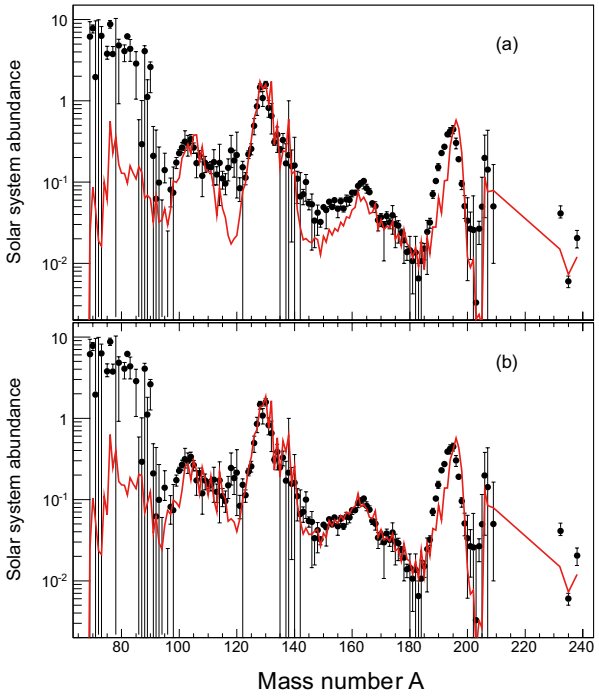


Figure 2: Comparison between the r process solar system abundance pattern and the abundances calculated (a) without and (b) with our new half-lives [1].

Reference

[1] Lorusso, G., et al.: 2015, *Phys. Rev. Lett.*, **114**, 192501.

R-process Nucleosynthesis in the MHD+neutrino-heated Collapsar Jet

NAKAMURA, Ko (Waseda University)
KAJINO, Toshitaka, SATO, Susumu, HARIKAE, Seiji (NAOJ/University of Tokyo)
MATEHWS, Grant J. (University of Notre Dame)

Nucleosynthesis by a process of rapid neutron-capture (the r-process) accounts for about a half of the abundance of nuclei heavier than iron. Two possible astrophysical sites of r-process production, supernovae and neutronstar mergers, have been discussed by many researchers. In the case of supernovae, neutrino-driven wind from a central proto-neutronstar was XXX. Recent state-of-the-art numerical simulations, however, do not produce high-entropy and neutron-rich conditions necessary for r-process. For neutronstar merger models, the low rate and the long time delay of binary mergers are incompatible with the history of Galactic chemical evolution deduced from observations of r-process elements in metal-poor stars.

In this article [1], we consider long-duration gamma-ray bursts (LGRBs) as another astrophysical site for the r-process. The collapsar model [2] is a favored model for the formation of observed LGRBs. In the collapsar model, the central core of a rotating massive star collapses to a black hole and forms an accretion disk around the black hole. Harikae et al. [3] simulated LGRB evolution based on the collapsar scenario and found that a relativistic jet along the polar axis can be launched, mainly powered by heating from the pair annihilation of thermally generated neutrinos emanating from this accretion disk. In order to follow the evolution of mass elements in the jet, we have employed 20,000 tracer particles moving with the material. We have followed the time evolution of temperature, density, and electron fraction (Y_e) for the tracer particles and calculated nucleosynthesis by means of a large nuclear network involving about 5,000 nuclei.

Of the 20,000 tracer particles, 1289 of them were determined to be participating in the jet. About a half of them have high electron fraction ($Y_e > 0.4$) and r-process is unlikely. On the other hand, some particles show very neutron-rich composition ($Y_e \sim 0.1$). They also present a wide variety of entropy per baryon in unit of the Boltzmann constant (S/k_B) from ~ 10 to more than 1,000.

Figure 1 shows the final isotopic abundance distribution for all 1289 particles emitted in the jet. Here, we can see that this collapsar simulation produces elements up to the mass number $A = 195$ r-process peak. We found that particles with very high entropy per baryon ($S/k_B \sim 1{,}000$) can produce heavy elements up to the third r-process abundance peak and even beyond to the actinides. On the other hand, particles with relatively low entropy per baryon ($S/k_B \sim 100$) only produce light elements up to the 2nd r-process peak as is evident in Figure 1. The elemental abundances with $140 < A < 180$ is referred to the *universality* region and approximately reproduced by our calculations.

Our results, however, includes some problems such as the r-process peaks appearing at slightly higher mass numbers. Further investigation is necessary to evaluate the role of LGRBs in r-process nucleosynthesis.

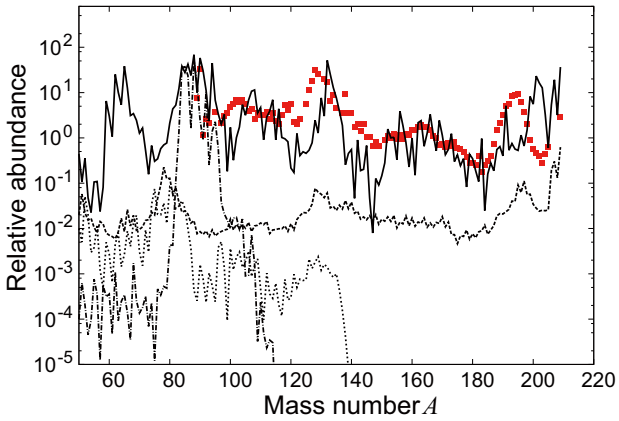


Figure 1: Calculated r-process abundance pattern (solid line) in long-duration gamma-ray bursts, compared with solar-system r-process abundances (red). Yields are normalized to ^{153}Eu. Dotted, dashed and dot-dashed lines display respectively the abundance yields for the typical flows of high ($S/k_B = 1000$), intermediate (100) and low (25) initial entropy/baryons.

References

[1] Nakamura, K., et al.: 2015, *A&A*, **582**, A34.
[2] Woosley, S. E.: 1993, *ApJ*, **405**, 273.
[3] Harikae, S., Takiwaki, T., Kotake, K.: 2009, *ApJ*, **704**, 354.

The 658 GHz Vibrationally Excited H_2O Maser in Orion Source I

HIROTA, Tomoya, HONMA, Mareki (NAOJ/SOKENDAI)
KIM, Mi-Kyoung (KASI)

We carried out an observational study of the 658 GHz vibrationally excited H_2O maser line ($v_2 = 1$, $1_{1,0}$–$1_{0,1}$, $E_l = 2329$ K) toward a massive protostar candidate Source I in the Orion KL region using the Atacama Large Millimeter/Submillimeter Array (ALMA) in cycle 0 [1]. The observation was carrid out at ALMA band 9 with the longest baseline length of 385 m, which achieved the spatial resolution of 0.28″×0.25″.

The 658 GHz H_2O line is found to be emitted from a compact structure with the size of ~100 AU (Figure 1). The source structure is elongated along the northeast-southwest direction parallel to the low-velocity (18 km s^{-1}) molecular outflow (Figure 1). The most remarkable feature is a velocity gradient along the northwest-southeast direction, which is perpendicular to the outflow axis and the source elongation suggesting a rotating structure. A spectral profile shows an asymmetric structure with the brighter red-shifted component as seen in other H_2O lines [2] and SiO masers [3] (Figure 2). The observed flux density and the compact structure suggest a high brightness temperature of >2×10^4 K, which is consistent with a strong maser emission.

These basic properties suggest that the 658 GHz H_2O line is most likely emitted from the base of the northeast-southwest low-velocity (18 km s^{-1}) molecular outflow ejected from a rotating disk around Source I. Our results demonstrate that the vibrationally excited H_2O line at 658 GHz could be a unique tracer of hot molecular gas close to the central protostar as proposed for another submillimeter H_2O line at 321 GHz [2] and the 43 GHz SiO masers [3].

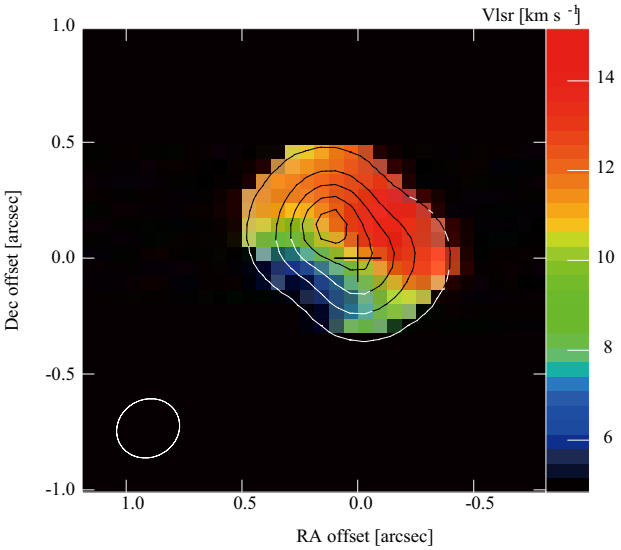


Figure 1: Moment 0 (contour) and 1 (color) maps of the 658 GHz H_2O line emission. The contour levels are 10 %, 30 %, 50 %, 70 %, and 90 % of the peak intensity of 3923 Jy beam^{-1} km s^{-1}. A black cross corresponds to the position of Source I determined by the continuum emission. A synthesized beam size is shown at the bottom-left corner. Position offset is measured with respect to the continuum peak.

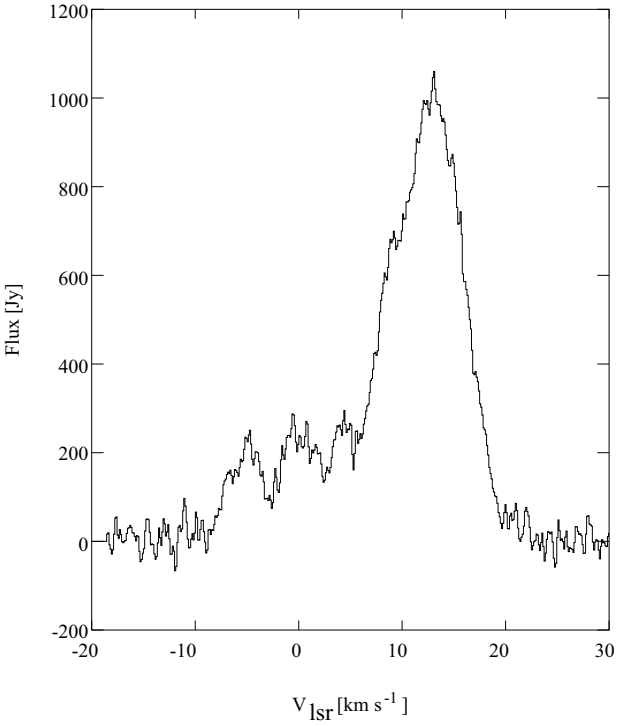


Figure 2: Spectrum of the 658 GHz H_2O line.

References

[1] Hirota, T., Kim, M. K., Honma, M.: 2016, *ApJ*, **817**, 168.
[2] Hirota, T., et al.: 2014, *ApJ*, **782**, L28.
[3] Kim, M. K., et al.: 2008, *PASJ*, **60**, 991.

Astrometry of Galactic Star-Forming Region IRAS 20126+4104 with VERA

NAGAYAMA, Takumi, KOBAYASHI, Hideyuki, CHIBUEZE, James
SATO, Katsuhisa, UENO, Yuji, SHIZUGAMI, Makoto
(NAOJ)

OMODAKA, Toshihiro, HANDA, Toshihiro, BURNS, A. Ross
(Kagoshima University)

We report astrometric observation results of IRAS 20126+4104 with the VLBI Exploration of Radio Astrometry (VERA). The parallax was obtained to be 0.750±0.092 mas, corresponding to a distance of $1.33^{+0.19}_{-0.15}$ kpc. We found IRAS 20126+4104 has a large peculiar motion of approximately 16±4 km s^{-1} which is originated with the expanding motions of the Cygnus superbubble. These results are published in Nagayama et al. (2015) [1].

IRAS 20126+4104 is associated with the Cygnus superbubble which is expected to be located near the Sun, and is extended over large angular size. Since the numerous sources at different distances from 0.4 to 4 kpc located along the line of sight direction of this superbubble [2], the measurement of the distance and proper motion by VLBI astrometry is important for studying the structures of this superbubble.

We made VERA observations of 22.235080 GHz H_2O masers in IRAS 20126+4104 during 2010–2011. IRAS 20126+4104 and a position reference source J2007+4029 were observed with VERA dual-beam system. The position of IRAS20126+4104 was measured using the phase-referencing method.

Figure 1 shows the measured parallax motion. We can find a sinusoidal motion a period of 1 year caused by a parallax. The parallax of IRAS 20126+4104 was measured to be 0.750±0.092 mas, corresponding a distance of $1.33^{+0.19}_{-0.15}$ kpc. This is consistent with the parallax measured with VLBA [3].

The peculiar motion of IRAS 20126+4104 is estimated to be $(\Delta v_l, \Delta v_b, \Delta v_r)$ = (−3±4, 15±4, −11±4) km s^{-1} from the observed proper motion of $(\mu_\alpha \cos\delta, \mu_\delta)$ = (−4.15±0.51, −4.07±0.51) mas yr^{-1} and LSR velocity of $v_{\rm LSR}$ = −3.5±4 km s^{-1}. This peculiar motion of IRAS 20126+4104 appears to be associated with the expansion of Cygnus superbubble. The interpolated position of IRAS 20126+4104 ~3.6 Myr ago, which is the expansion time-scale of the Cygnus superbubble, is consistent with the center of OB type-stars's expanding motion observed with Hipparcos [4].

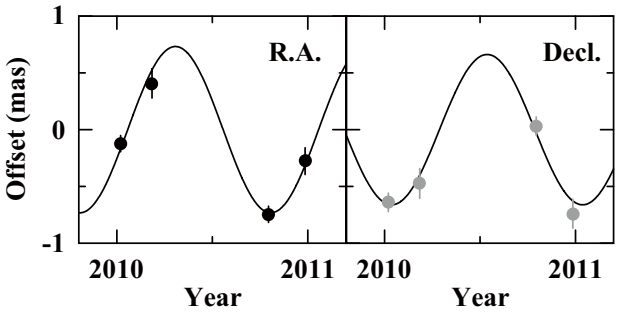


Figure 1: Paralllax of IRAS 20126+4104.

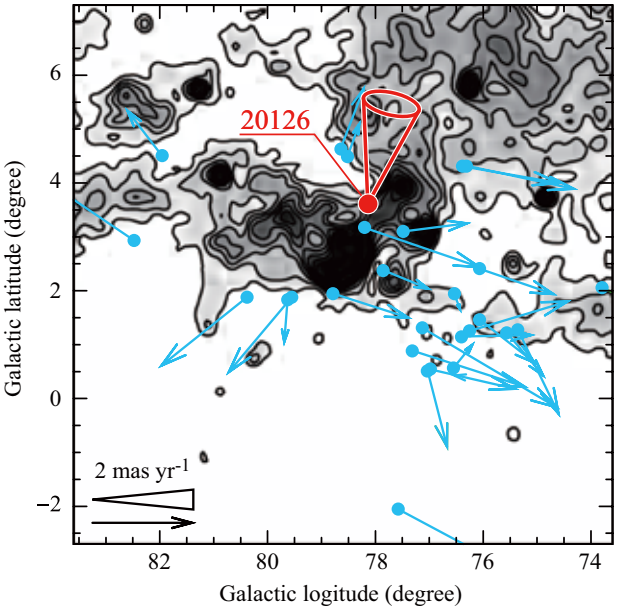


Figure 2: The peculiar motion of IRAS 20126+4104 (red cone). The bule arrows show the peculiar motions of OB type stars measured by Hipparcos [4]. The background contour shows the ROSAT 1/4 kev map of the Cygnus supserbubble [2].

References

[1] Nagayama, T., et al.: 2015, *PASJ*, **67**, 66.
[2] Uyanker, B., et al.: 2001, *A&A*, **371**, 675.
[3] Moscadelli, L., et al.: 2011, *A&A*, **526**, A66.
[4] Comeron, F., Torra, J., Gomez, A. E.: 1998, *A&A*, **330**, 975.

Monitoring Observations of the Jupiter-Family Comet 17P/Holmes during its 2014 Perihelion Passage

KWON, Yuna G.[1], ISHIGURO, Masateru[1], HANAYAMA, Hidekazu[2], KURODA, Daisuke[2], HONDA, Satoshi[3]
TAKAHASHI, Jun[3], KIM, Yoonyoung[1], LEE, Myung Gyoon[1], CHOI, Young-Jun[4], KIM, Myung-Jin[4]
VAUBAILLON, Jeremie J.[5], MIYAJI, Takeshi[2], YANAGISAWA, Kenshi[2], YOSHIDA, Michitoshi[6], OHTA, Kouji[7]
KAWAI, Nobuyuki[8], FUKUSHIMA, Hideo[2], WATANABE, Jun-Ichi[2]

1: Seoul National University, 2: NAOJ, 3: University of Hyogo, 4: Korea Astronomy and Space Science Institute, 5: Observatoire de Paris, 6: Hiroshima University, 7: Kyoto University, 8: Tokyo Institute of Technology

17P/Holmes is known as an object that underwent a historic outburst in October, 2007. Subsequent observation revealed that the refractory surface layer (so-called dust mantle) was blown off by the outburst and the nucleus remained active around its aphelion passage in 2010, showing lingering dust tail even beyond 5 AU [1]. In this study, we performed a monitoring observation of 17P/Holmes during its 2014 perihelion passage that is the first time after the outburst, using the 105 cm Murikabushi telescope at the Ishigakijima Astronomical observatory, the 50 cm telescope at the Okayama Astrophysical Observatory (OAO), the 188 cm telescope at OAO, the 2 m Nayuta telescope at the Nishi-Harima Astronomical Observatory (University of Hyogo), the 1.8 m telescope at the Bohyunsan Optical Astronomy Observatory (Korea Astronomy and Space Science Institute), and the 50 cm telescope at the Siding Spring Observatory (operated by iTelescope). We investigated the dust production and the fractional active area using these data [2].

Figure 1 shows selected R_C-band images just after its 2014 perihelion passage. The active dust emission seen after the outburst could not be confirmed, although the circumnuclear coma and the feeble tail were confirmed. Figure 2 shows the active area fraction estimated from the observation as a function of the heliocentric distance (upper horizontal axis) or the true anomaly (lower horizontal axis). Although the fraction was 20–40 % just after the 2007 outburst, it was significantly decreased to 0.1–0.3 % during its 2014 perihelion passage. We presumed from these results that the fresh nucleus would be covered with the newly formed dust mantle to be inactive in only several years. The dust layer of ~10 cm would be piled up to the nucleus from the estimation of the ejected dust amount. This suggests that icy volatile materials in the comet can be maintained with the dust piled up only ~10 cm.

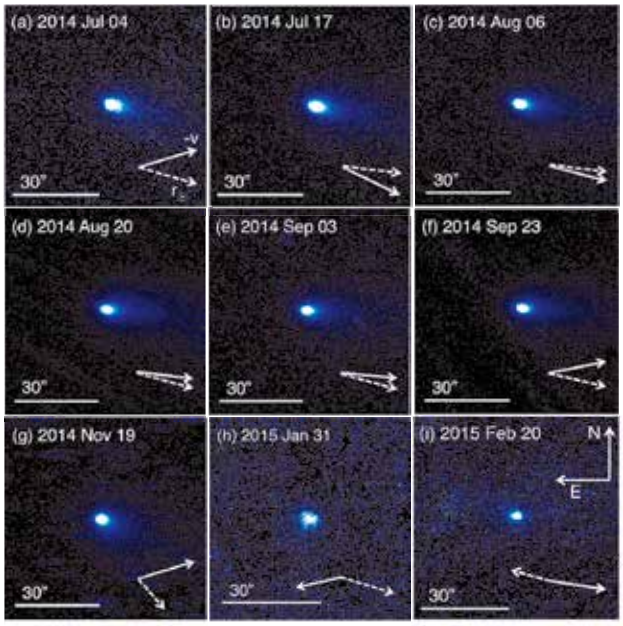


Figure 1: Comet 17P/Holmes immediately after its 2014 perihelion passage.

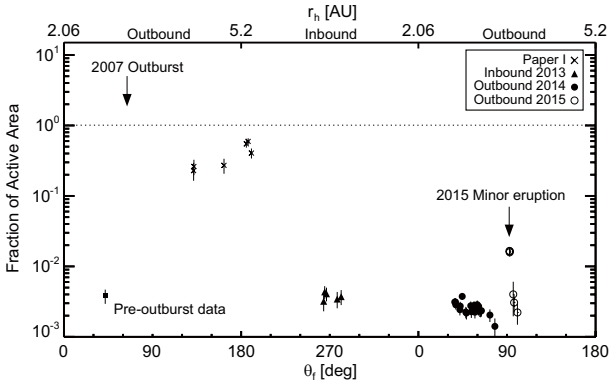


Figure 2: Time evolution of the active area fraction over the cometary surface.

References

[1] Ishiguro, M., et al.: 2013, *ApJ*, **778**, 19.
[2] Kwon, Y., et al.: 2016, *ApJ*, **818**, 67.

Pion Production from Proton Synchrotron Radiation under Strong Magnetic Fields in Relativistic Quantum Approach [1]

MARUYAMA, Tomoyuki (Nihon University)
KAJINO, Toshitaka (NAOJ/University of Tokyo)
CHEOUN, Myung-Ki, KWON, Yongshin, RYU, Chung-Yeol (Soongsil University)
MATHEWS, Grant J. (University of Notre Dame)

It is widely accepted that soft gamma repeaters (SGRs) and anomalous X-ray pulsars (AXPs) correspond to magnetars [2]. In the magnetars a proton is expected to be accelerated in a strong magnetic field and to emit photons through the synchrotron radiation. The meson-nucleon couplings are about 100 times larger than the photon-nucleon coupling, and the meson production process is expected to exceed photon synchrotron emission in the high energy regime.

However, the synchrotron radiation has been studied only in the semi-classical framework [3] and it has not treated discretized Landau levels and the anomalous magnetic moment (AMM) of protons. In this work [1], then, we study the pion production from proton synchrotron radiation in the relativistic quantum approach.

We assume a uniform magnetic field along the z-direction, $\boldsymbol{B} = (0, 0, B)$, and take the electro-magnetic vector potential A^μ to be $A = (0, 0, xB, 0)$ at the position $\boldsymbol{r} \equiv (x, y, z)$. The relativistic proton wave function $\tilde{\psi}$ is obtained from the following Dirac equation:

$$\left[(i\partial\!\!\!/ - eA\!\!\!/) - m_N - \frac{e\kappa_p}{2m_N}\sigma_{\mu\nu}F^{\mu\nu}\right]\tilde{\psi}(x) = 0, \qquad (1)$$

where $F^{\mu\nu} \equiv \partial^\mu A_\nu - \partial^\nu A^\mu$, m_N is the proton mass, and κ_p is the proton AMM. By solving Eq. (1), we then obtain the energy eigenvalues as

$$e(n, p_z, s) = \sqrt{p_z^2 + (\sqrt{eB(2n+1-s)+m_N^2} - \frac{se\kappa_p B}{m_N})^2}, \qquad (2)$$

where n is the Landau level number, $s = \pm 1$ is the spin index, and p_z is z-component of the proton momentum.

In Fig. 1 we show the initial and final spin-dependence of the proton differential pionic decay widths with (a) and without (b) the AMM with a proton kinetic energy of 1 GeV, emitted pion energy of 300 MeV and a strength of the magnetic field to be 5×10^{18} G. These widths are averaged over the initial Landau levels $0 \le n_{max} - n_i \le 9$.

When $\kappa_p = 0$, the contributions from the spin-flip transition, $s_i = -sf$, are about 100 times larger than those of the spin non-flip, $s_i = sf$. The spin-flip contributions become much larger than those from the spin non-flip reaction.

When the AMM is included, only the contribution from $s_i = -sf = 1$ is about 10,000 times larger than those of the other channels. When $s_i = -sf = 1$, the effects of the AMM and spin-flip are synchronized, and they increase very largely, while the two effects cancel when $s_i = -sf = 1$.

Thus, we have found that the proton AMM largely contributes to the pion production. We can clarify this effect by solving the Dirac equation in a strong magnetic field in a fully relativistic and quantum mechanical way. Furthermore, we found that the AMM effect becomes larger as the magnetic field decreases when the initial energy is fixed while the AMM effects diminish as the proton energy increases when the magnetic field is fixed. When $B \sim 10^{15}$ G, the proton is expected to be $e_p \sim 1$ TeV, and the maximum Landau level number becomes about 10^{11}, but one expects the AMM effect to remain because of the above results.

As for future studies, we must consider a method to treat huge numbers of the Landau levels for the magnetic field of $B \sim 10^{15}$ G. We should have to derive a new formulation including effects of the AMM from the exact formulation given in this paper.

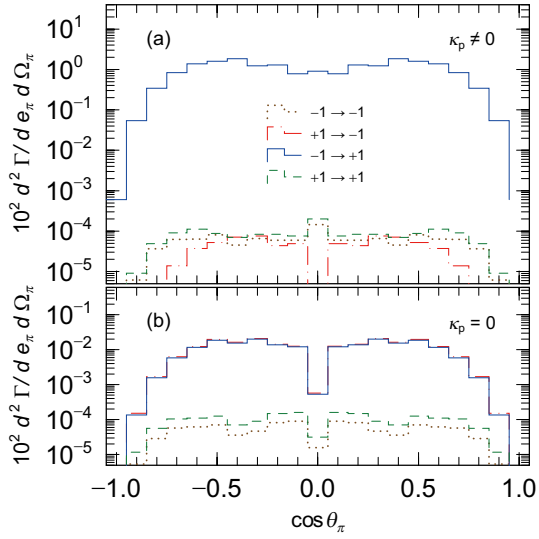


Figure 1: The differential pionic decay widths of protons with (a) and without (b) the AMM included. The widths are averaged over initial Landau numbers, $0 < n_{max} - n_i < 9$. The solid, dot-dashed, dashed, and dotted lines represents the results when $s_i = -s_f = -1$, $s_i = -s_f = 1$, $s_i = s_f = 1$, and $s_i = s_f = -1$, respectively, where $s_{i(f)}$ indicates the initial (final) spin of the proton.

References

[1] Maruyama, T., et al.: 2015, *Phys. Rev. D*, **91**, 123007.
[2] Mereghetti, S.: 2008, *Annu. Rev. Astron. Astrophys.*, **15**, 225.
[3] Tokushita, A., Kajino, T.: 1999, *ApJ.* **525**, L117.

Near-infrared imaging Polarimetry of LkCa 15: A possible Warped Inner Disk [1]

OH, Daehyeon[1/2], HASHIMOTO, Jun[3/2], TAKATO, Naruhisa[1], TAMURA, Motohide[3/4/2], and SEEDS team

1: SOKENDAI, 2: NAOJ, 3: Astrobiology Center, 4: The University of Tokyo

The protoplanetary disks around young stars are considered as the main birthplace of giant gas planets. Numerous pectral energy distribution (SED) analyses on disk-host stars have suggested the presence of cavities in several disks, such as gaps and central holes. These structures are believed as a sign of transition from optically thick dust disk to optically thin debris disk, and these disks in the intermediate phase have been called transitional disks (with central hole) and pre-transitional disks (with gap). Currently, the most convincible mechanism to form cavities in the disks is gravitational interaction with planets in the disks. However, there is no clear observational evidence to explain the formation of these disk structures.

LkCa 15 is a solar-like T-Tauri star located in the Taurus-Auriga region ~140 pc away from us. Previous studies using SED and optical wavelengths imaging revealed that the disk of LkCa 15 is a pre-transitional disk with large gap and optically thick inner disk [1,2]. The pre-transitional disk of LkCa 15 could have a evidence of disk-planet interaction, and we conducted high-contrast and high-resolution near-infrared polarimetric differential imaging observation with HiCIAO and AO188 on LkCa 15 disk, as a part of SEEDS (Strategic Explorations of Exoplanets and Disks with Subaru).

From the resultant image, the wide gap structure (width $\lesssim$ 27 au) and the inner disk were resolved and clear enough to be quantitatively analysed (Fig. 1,2). It shows that the inner disk has misaligned position angle of $13° \pm 4°$ with respect to that of the outer disk. This suggests that the inner disk is possibly warped. Warped disks were observed from several objects (e.g., AB Aurigae [5] and β Pictoris [6]), however, this is the first clear observational evidence of warped disk around young T-Tauri star. From the comprehensive discussion including previous studies on disk-planet interactions [7,8] and LkCa 15 optical imaging [2], the large gap and the warped inner disk of LkCa 15 both are indicative of a multiple planetary system with a mass of $\lesssim 1\,M_{\rm Jup}$ in LkCa 15 system.

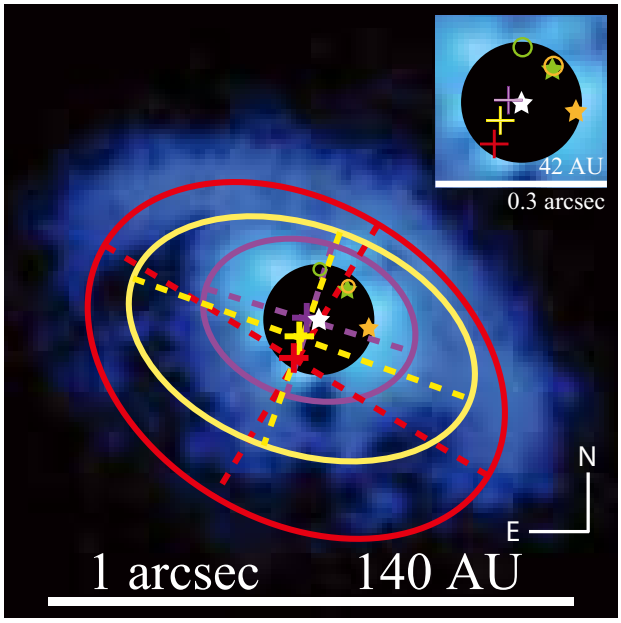


Figure 1: Elliptical fitting results of the inner disk (*purple*), the gap (*yellow*), and the outer disk (*red*). *White star* indicates the location of LkCa 15. *Green and orange stars* indicate where the planet candidates LkCa 15 b and c were detected in 2014, respectively [3]. *Empty green and orange circles* indicate the locations of two infrared sources seen in 2009-2010 [4], which are assumed as LkCa 15 b and c, respectively.

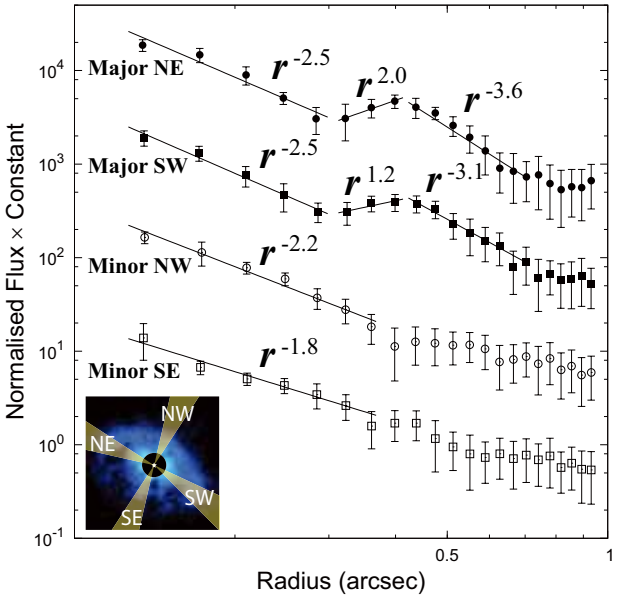


Figure 2: Radial surface brightness profiles with 1σ error bars at major and minor axes.

References

[1] Oh, D., et al.: 2016, *PASJ*, **68**, L3.
[2] Thalmann, C., et al.: 2015, *ApJ*, **808**, L41.
[3] Sallum, S., et al.: 2015, *Nature*, **527**, 342.
[4] Kraus, A. L., Ireland, M. J.: 2012, *ApJ*, **745**, 5.
[5] Hashimoto, J., et al.: 2011, *ApJ*, **729**, L17.
[6] Mouillet, D., et al.: 1997, *MNRAS*, **292**, 896.
[7] de JuanOvelar, M., et al.: 2013, *A&A*, **560**, A111.

Pitch Angle of Self-Gravity Wakes in Dense Planetary Ring

MICHIKOSHI, Shugo
(University of Tsukuba)

KOKUBO, Eiichiro
(NAOJ)

In Saturn's ring, gravitational forces between particles tend to form gravitationally bound clumps, while differential rotation tears them apart. Due to these competing processes, spatial structures called self-gravity wakes appear (Salo 1992). The self-gravity wakes are non-axisymmetric structures on sub-kilometer scales. The A and B rings exhibit a remarkable asymmetric brightness variation (Camichel 1958). Salo et al. (2004) found that this asymmetric brightness variation was explained by self-gravity wakes. Thus, the existence of self-gravity wakes was indirectly supported by the observations.

The physical mechanism of the self-gravity wakes has not been understood completely. It was suggested that the swing amplification mechanism may be applicable (Toomre 1981, Salo 1995). The pitch angle of the spiral arms formed by the swing amplification was obtained (Michikoshi and Kokubo 2014). From this estimation, the pitch angle of the self-gravity wakes should be about 10°, which does not depend on the Saturnicentric distance. However, the observational studies indicate that the pitch angle increases with the Saturnicentric distance (Hedman et al. 2007). Therefore, to understood this discrepancy, we investigated the pitch angle of the self-gravity wakes by *N*-body simulations (Michikoshi et al. 2015).

We performed the local shearing box simulations. The inelastic collisions among particles were considered. The self-gravity was calculated by GRAPE-DR in NAOJ. The typical self-gravity wakes are shown in Figure 1. The self-gravity wakes are trailing structures. We calculated the pitch angle from the autocorrelation function. We confirmed that the pitch angle increases with the Saturnicentric distance (Figure 2).

To understand this trend, we considered the simple model of the self-gravity wakes. Comparing the timescales of self-gravity and the shear, we obtained the estimate of the pitch angle

$$\tan\theta \propto a^{3/2}, \qquad (1)$$

where a is the Saturnicentric distance. This estimate agrees well with the numerical simulations. Our results suggest that the pitch angle is determined by the strength of the self-gravity relative to the shear.

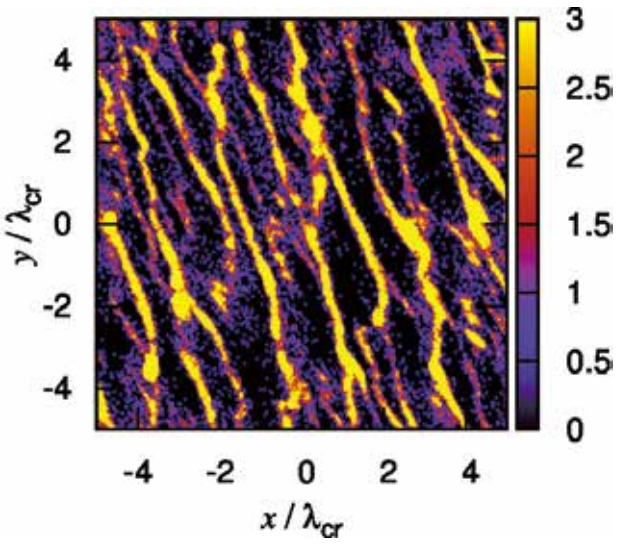


Figure 1: Surface density normalized by the averaged surface density. The clear self-gravity wakes are observed.

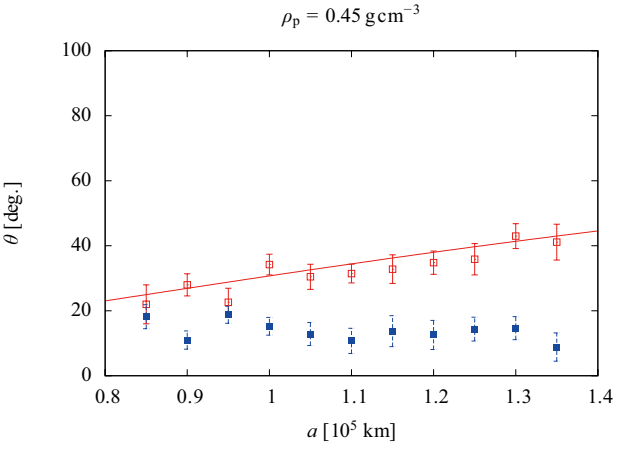


Figure 2: The pitch angle against the Saturnicentric distance. The red open and blue filled squares denote the pitch angle in the high and low density regions, respectively.

References

[1] Salo, H.: 1992, *Nature*, **359**, 619.
[2] Camichel, H.: 1958, *A&A*, **21**, 231.
[3] Salo, H., Karjalainen, R., French, R. G.: 2004, *Icarus*, **170**, 70.
[4] Toomre, A.: 1981, Structure and Evolution of Normal Galaxies (Cambridge: Cambridge Univ. Press).
[5] Michikoshi, S., Kokubo, E.: 2014, *ApJ*, **787**, 174.
[6] Hedman, M. M., et al.: 2007, *AJ*, **133**, 2624.
[7] Michikoshi, S., et al.: , ApJ, 812, 151.

Explosions and Jet Ejections in a Developing Sunspot Light Bridge

TORIUMI, Shin, KATSUKAWA, Yukio, CHEUNG, Mark C. M.
(NAOJ, LMSAL)

Light bridges (LBs), the elongated structures dividing sunspot umbra, are known to produce repeated explosions and jet ejections, and thus have been a target of observational studies [1]. One importance of the LBs is that they separate the existing spots and eventually lead to their collapse [2]. Although the LBs are known to appear also in developing active regions (ARs), there were few such observational studies.

In this study, aiming at the cause of activity in the developing sunspot LBs, we analyzed observation data of NOAA AR 11974 (Fig. 1: top).

From the photospheric vector magnetogram taken by Hinode/SOT, it was revealed that the elongated LB harbors weak, horizontal magnetic fields inside and is sandwiched between strong, vertical fields of the surrounding pores (pre-mature sunspots). Observational data of the IRIS satellite, which simultaneously targeted the same region, show that smaller-scale explosions and jet ejections occur repeatedly in the chromosphere above the LB. Especially, the UV spectra indicate that the repeated explosions are caused by magnetic reconnection, the plasma process that releases magnetic energy. From these results, we obtained a physical picture that the explosions and jets in the LBs are caused by repeated reconnection between the horizontal fields of LBs and vertical fields of ambient pores.

However, there remained outstanding questions such as why LBs appear in the developing ARs, what the 3D magnetic and velocity structures of the LBs are, and why reconnection occurs repeatedly above the LBs. In order to answer to those questions, we then carried out a radiative magnetohydrodynamic (MHD) simulation including convection that reproduces the spot formation [4], and analyzed the simulation result (Fig. 1: bottom).

We found that, in the subsurface layer, when the vertical fields of two pores approach each other to create a single sunspot, they trap a plasma that contains weak, horizontal magnetic fields. Since there exists a thermal convection inside the trapped plasma, the horizontal fields are transported upward repeatedly with a certain time scale and create a LB in the surface layer. Therefore, we can conclude that the observed explosions and jets in the chromosphere above the LB are caused by repeated reconnection between the magnetic flux transported from the interior and the flux of surrounding pores [5].

The above results indicate that the repetitive reconnection observed in the Sun may be driven by magneto-convective evolution in the interior. Similar explosions and jets are reported in sunspot umbrae and penumbrae, which suggests that these features may be a common phenomena of convection in strong background fields.

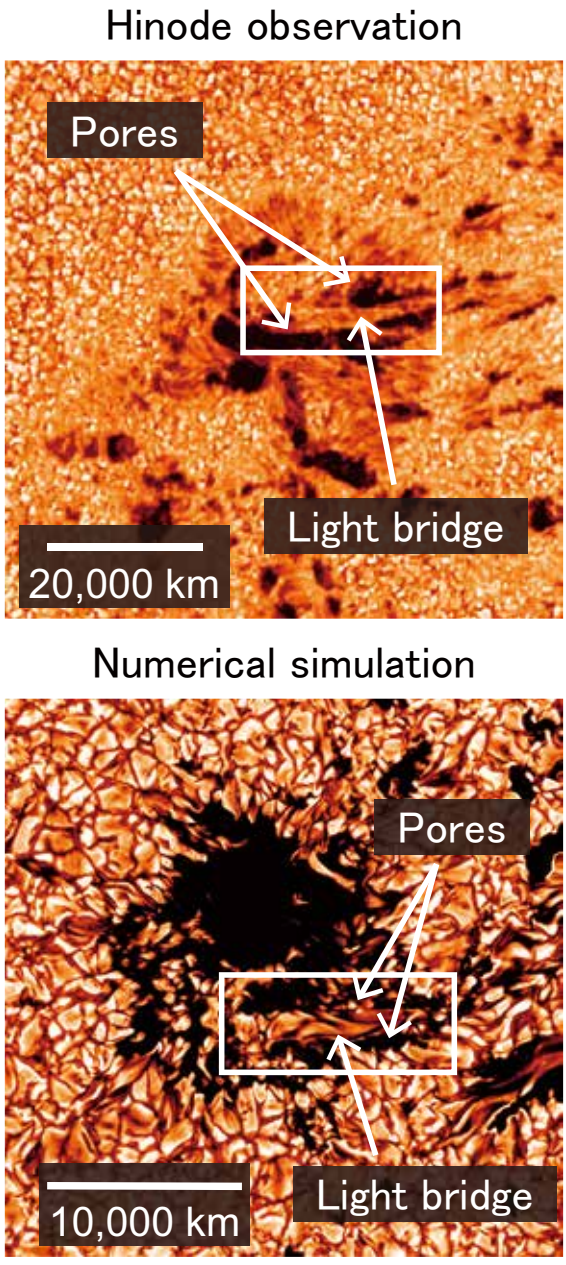


Figure 1: (Top) Hinode observation of NOAA AR 11974. (Bottom) MHD simulation of sunspot formation.

References

[1] Shimizu, T., et al.: 2009, *ApJ*, **696**, L66.
[2] Katsukawa, Y., et al.: 2007, *PASJ*, **59**, S577.
[3] Toriumi, S., et al.: 2015, *ApJ*, **811**, 137.
[4] Cheung, M.C.M, et al.: 2010, *ApJ*, **720**, 233.
[5] Toriumi, S., et al.: 2015, *ApJ*, **811**, 138.

Initializing Relativistic Velocity Distribution Functions in Plasma Simulations

ZENITANI, Seiji
(NAOJ)

Particle-in-cell (PIC) simulations and Monte-Carlo simulations are important research tools in modern astrophysics. In these numerical simulations, particle velocities are usually initialized by random variables with certain algorithms. For example, the Box–Muller algorithm [1] is popularly used to generate a Maxwell–Boltzmann distribution. It is summarized in Table 1 and described in many textbooks. One can also incorporate the bulk velocity, by considering an offset to the particle velocities.

Since relativistic plasma processes have been growing in importance in high-energy astrophysics, there is a strong demand for algorithms to deal with relativistic velocity distribution functions of plasmas. However, algorithms to generate relativistic velocity distributions are not well established. Here, "relativistic velocity distributions" contain both relativistically-hot distributions and/or relativistically-moving distributions.

Our recent article [2] summarize the state-of-art algorithms to deal with both of them. Going back to the original article by Russian mathematician Sobol [3], we review standard algorithms [4] to generate a relativistic Maxwellian (Jüttner–Synge distribution) at a rest frame. We further propose two rejection methods to deal with the spatial part of the Lorentz transformation of arbitrary distribution functions, which has never been discussed in previous literature. These results are summarized in Table 2. We note that our algorithms are drastically simpler than similar attempts in recent years.

We hope that these algorithms are useful in relativistic kinetic simulations in high-energy astrophysics.

Table 1: Box–Muller algorithm.

generate X_1, X_2, X_3, X_4, uniform on $(0, 1]$
$v_x \leftarrow \sqrt{-2 \ln X_1} \sin(2\pi X_2) + V_0$
$v_y \leftarrow \sqrt{-2 \ln X_1} \cos(2\pi X_2)$
$v_z \leftarrow \sqrt{-2 \ln X_3} \sin(2\pi X_4)$
return v_x, v_y, v_z

Table 2: Sobol algorithm with the flipping method.

repeat
  generate X_1, X_2, X_3, X_4, uniform on $(0, 1]$
  $u \leftarrow -T \ln X_1 X_2 X_3$
  $\eta \leftarrow -T \ln X_1 X_2 X_3 X_4$
until $\eta^2 - u^2 > 1$.
generate X_5, X_6, X_7, uniform on $[0, 1]$
$u_x \leftarrow u\ (2X_5 - 1)$
$u_y \leftarrow 2u\sqrt{X_5(1 - X_5)} \cos(2\pi X_6)$
$u_z \leftarrow 2u\sqrt{X_5(1 - X_5)} \sin(2\pi X_6)$
if $(-\beta v_x > X_7)$, $u_x \leftarrow -u_x$
$u_x \leftarrow \Gamma(u_x + \beta\sqrt{1 + u^2})$
return u_x, u_y, u_z

References

[1] Box, G. E. P., Muller, M. E.: 1958, *Annals of Mathematical Statistics*, **29**, 610.
[2] Zenitani, S.: 2015, *Phys. Plasmas*, **22**, 042114.
[3] Sobol, I. M.: 1976, in Monte Carlo Methods in Computational Mathematics and Mathematical Physics, p.24 [in Russian].
[4] Pozdnyakov, L. A., Sobol, I. M., Sunyaev, R. A.: 1983, *Astrophys. Space Phys. Rev.*, **2**, 189 (Translation).

Physical Conditions of the Interstellar Medium in Star-forming Galaxies at $z \sim 1.5$

HAYASHI, Masao[1], KASHIKAWA, Nobunari[1], LY, Chun[2], SHIMASAKU, Kazuhiro[3], MOTOHARA, Kentaro[3]
GOTO, Ryosuke[3], NAITO, Yoshiaki[3], MALKAN, A. Matthew[4], NAGAO, Tohru[5]

1: NAOJ, 2: NASA, 3: University of Tokyo, 4: UCLA, 5: Ehime University

We perform Subaru/FMOS near-infrared spectroscopy of 118 star-forming galaxies at $z \sim 1.5$ in the Subaru Deep Field which are selected as [O II]λ3727 emitters from Subaru/Suprime-Cam narrow-band imaging. Hα emission line is detected in 115 galaxies, [O III]λ5007 emission line in 45 galaxies, and Hβ, [N II]λ6584, and [S II] $\lambda\lambda$6716,6731 in 13, 16, and 6 galaxies, respectively. Since we already detect [O II] emission line by narrow-band imaging, the 6 strong nebular emission lines are available in the individual and composite rest-frame optical spectra to investigate physical conditions of the interstellar medium in star-forming galaxies at $z \sim 1.5$.

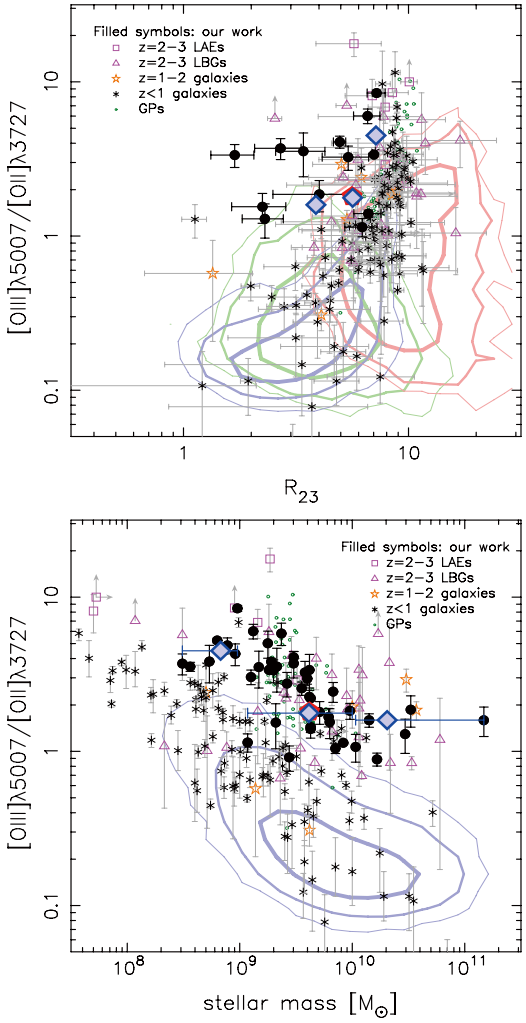


Figure 1: The line ratio of [O III]/[O II], which is sensitive to ionization parameter, as a function of R_{23} ([O II] λ3727+[O III]$\lambda\lambda$4959,5007)/Hβ) (upper) and stellar mass (lower). The black circles show the ratio of the individual galaxies, while red pentagon and blue diamonds show the average ratios derived from the stacked spectra. Different populations up to $z \sim 3$ are also shown; Lyα emitters (LAEs) at $z = 2$–3 (open squares: [2,3,4,5]), Lyman break galaxies (LBGs) at $z = 2$–3 (open triangles: [6,7,8,9,10,11]), star-forming galaxies at $z = 1$–2 (open stars: [4,12,13]), star-forming galaxies at $z < 1$ (asterisks: [14,15,16,17,18]), and green pea galaxies (GPs) (open circles:[19]). The contours show the distribution of star-forming galaxies (blue), composite objects (green), and AGNs (red) in the local Universe, respectively.

Figure 1 shows that typical star-forming galaxies at $z \sim 1.5$ have strong [O III] emission lines and that the [O III]/[O II] ratios are larger than normal star-forming galaxies in the local Universe. These results suggest that star-forming galaxies at $z \sim 1.5$ have a higher ionization parameter than the local galaxies. There is a dependence of the [O III]/[O II] ratios on stellar mass in the sense that less massive galaxies have larger [O III]/[O II] ratios. Since we also reveal that the electron density is consistent with local galaxies, we argue that the high ionization of galaxies at high redshifts is due to a harder radiation field by a young stellar population and/or an increase in the number of ionizing photons from each massive star.

In this study, we also find a tight correlation between Hα and [O II] and that the line ratios of Hα/[O II] are consistent with those of local galaxies. Thus, [O II] is useful to estimate star formation rate of galaxies even at $z \sim 1.5$. See [1] for more details of the results and discussions.

References

[1] Hayashi, M., et al.: 2015, *PASJ*, **67**, 80.
[2] Fosbury, R. A. E., et al.: 2003, *ApJ*, **596**, 797.
[3] Erb, D. K., et al.: 2010, *ApJ*, **719**, 1168.
[4] Christensen, L., et al.: 2012, *MNRAS*, **427**, 1953.
[5] Nakajima, K., et al.: 2013, *ApJ*, **769**, 3.
[6] Pettini, M., et al.: 2001, *ApJ*, **554**, 981.
[7] Maiolino, R., et al.: 2008, *A&A*, **488**, 463.
[8] Mannucci, F., et al.: 2009, *MNRAS*, **398**, 1915.
[9] Richard, J., et al.: 2011, *MNRAS*, **413**, 643.
[10] Wuyts, E., et al.: 2012, *ApJ*, **755**, 73.
[11] Belli, S., et al.: 2013, *ApJ*, **772**, 141.
[12] Queyrel, J., et al.: 2009, *A&A*, **506**, 681.
[13] Rigby, J. R., et al.: 2011, *ApJ*, **732**, 59.
[14] Savaglio, S., et al.: 2005, *ApJ*, **635**, 260.
[15] Maier, C., et al.: 2005, *ApJ*, **634**, 849.
[16] Henry, A., et al.: 2013, *ApJ*, **776**, L27.
[17] Ly, C., et al.: 2014, *ApJ*, **780**, 122.
[18] Ly, C., et al.: 2015, *ApJ*, **805**, 45.
[19] Cardamone, C., et al.: 2009, *MNRAS*, **399**, 1191.

All-sky Simulations of Gravitational Lensing

SHIRASAKI, Masato
(NAOJ)

Gravitational lensing is one of the most promising tools to probe matter density distribution in the Universe. The foreground gravitational field causes small image distortion of distant galaxies. The small distortion contains, collectively, rich cosmological information about the matter distribution. We can reconstruct the foreground mass distribution from observed image of distant galaxies with statistical analysis. Ongoing and upcoming imaging surveys such as Hyper Suprime-Cam (HSC) survey in the near future, will provide the largest dark matter map we have never seen before. Therefore, it is important and timely to investigate the cosmological information content of the reconstructed mass map.

In order to realize the realistic situation in galaxy imaging surveys, we perform gravitational lensing simulations on curved full sky as shown in Figure 1. We then utilize these simulations to create two hundreds of mock weak lensing catalogs with the proposed sky coverage in ongoing HSC survey. These mock catalogs enable us to study the statistical property of reconstructed mass map from gravitational lensing observables.

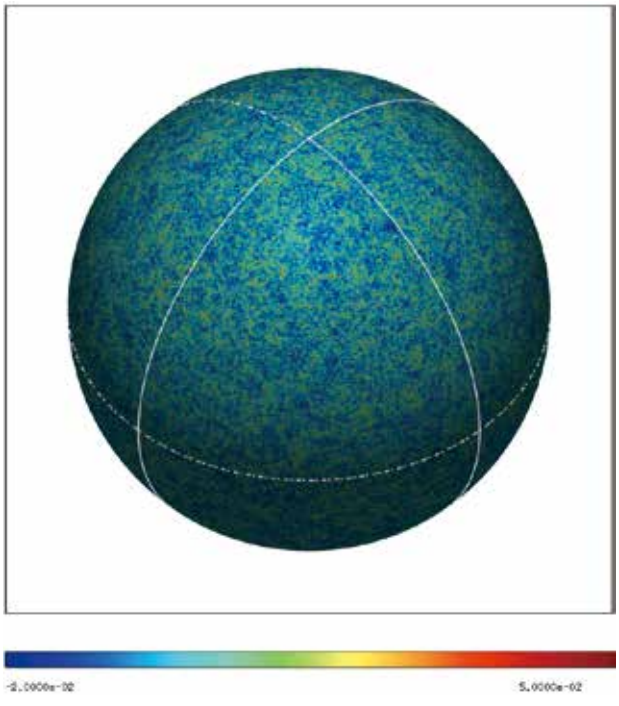


Figure 1: One of our simulated gravitational lensing maps. The red regions represent high surface mass density regions, while the blue regions correspond to under-dens regions in the Universe.

In Ref [1], we explore a variety of statistics of clusters selected with cosmic shear measurement by utilizing both analytic models and large numerical simulations. Weak lensing selection of clusters does not rely on conventional assumptions such as the relation between luminosity and mass and/or hydrostatic equilibrium, allowing us to construct *clean* cluster sample. We first develop a halo model to predict the abundance and the clustering of weak lensing selected clusters. Observational effects such as galaxy shape noise are included in our model.

We show that our theoretical model agrees well with the ensemble average of statistics and their covariances calculated directly from the mock catalogues. With a typical selection threshold, ignoring shape noise correction causes overestimation of the clustering of weak lensing selected clusters with a level of about 10 %, and shape noise correction boosts the cluster abundance by a factor of a few.

Furthermore, we extend our theoretical framework to model the statistical properties of clusters in variants of cosmological models as well as in the standard ΛCDM model in Ref [2]. We use a large set of realistic mock weak lensing catalogs as well as analytic models to make a forecast for constraining two competing cosmological models, the *w*CDM model and modified gravity model, with our lensing statistics. We show that weak lensing selected clusters are excellent probes of cosmology when combined with cosmic shear power spectrum even in the presence of galaxy shape noise and masked regions. With the information from weak lensing selected clusters, the precision of cosmological parameter estimates can be improved by a factor of ~1.6 and ~8 for the *w*CDM model and modified gravity model, respectively. The HSC survey with sky coverage of 1250 degrees squared can constrain the equation of state of dark energy w_0 with a level of $\Delta w_0 \sim 0.1$. It can also constrain the additional scalar degree of freedom in the $f(R)$ gravity model with a level of $|f_{R0}| \sim 5 \times 10^{-6}$, when constraints from cosmic microwave background measurements are incorporated.

References

[1] Shirasaki, M., Hamana, T., Yoshida, N.: 2015, *MNRAS*, **453**, 3043-3067.
[2] Shirasaki, M., Hamana, T., Yoshida, N.: 2016, *PASJ*, **68**, 414.

A Numerical Scheme for Special Relativistic Radiation Magnetohydrodynamics Based on Solving Time-dependent Radiative Transfer Equation

OHSUGA, Ken
(Graduate University for Advanced Studies/NAOJ)

TAKAHASHI, Hiroyuki R.
(NAOJ)

Radiation transport (including the interaction between the matter and the radiation) and magnetic fields play important roles in a number of astrophysical phenomena. Although some of approximate methods (Flux-limited diffusion approximation [1], M1-closure method [2], and the Eddington approximation) are employed in order to numerically solve the radiation fields, the accurate radiation fields are not always obtained by such methods. Recently, a new algorithm were proposed for the radiation magnetohydrodynamics (RMHD), in which the time-dependent radiation transfer equation is solved and the radiation energy density, flux, and stress tensor are calculated by angular quadrature of the specific intensity [3]. However, their numerical code is accurate to $\mathcal{O}(v/c)$, and total energy as well as momentum of the radiation magnetofluids is not necessarily conserved. We develop a numerical scheme for solving the equations of fully special relativistic RMHD, in which the conservation of total mass, momentum, and energy of the radiation magnetofluids is guaranteed.

We propose a new method for RMHD, in which we solve the fully special relativistic RMHD equations [4]. By solving the time-dependent radiation transfer equation, the energy density, the flux, stress tensor for the radiation, are computed by angular integrating of the specific intensity. Ad hoc closure relation as used in FLD approximation, M-1 closure method, and the Eddington approximation is not required. The advection terms are explicitly solved, and the source terms, which describe the gas-radiation interaction, are implicitly integrated. In Figure 1, we show the results of the relativistic shock tube problem, the gas density (ρ), the gas pressure (p_g), the four velocity (u^z), the radiation energy density ($E_{\rm rad}$), the radiation flux ($F^z_{\rm rad}$), zz-component of the Eddington tensor ($\tilde{D}^{zz}_{\rm rad}$). The red lines indicate our results, and the results by the Eddington approximation and M1-closure method are plotted by blue and orange lines. The dotted lines in the panels of $E_{\rm rad}$, $F^z_{\rm rad}$, and $\tilde{D}^{zz}_{\rm rad}$ represent the reference solutions. We find that our results nicely agree with the reference solutions. Our code shows reasonable results in some numerical tests for propagating radiation and radiation hydrodynamics.

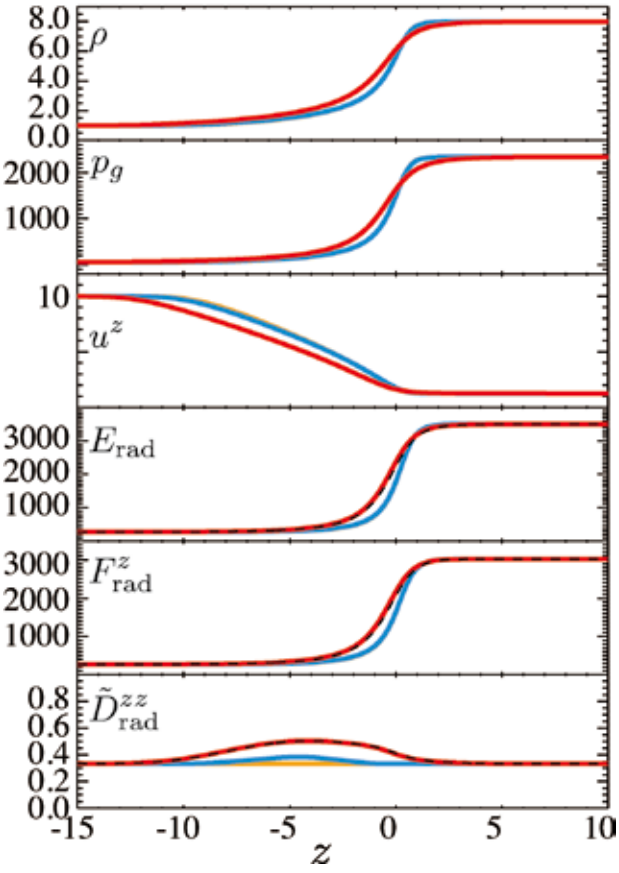


Figure 1: One-dimensional plots of the density, gas pressure, four velocity, radiation energy density, radiation flux, and zz-component of the Eddington tensor for the non-relativistic strong shock.

References

[1] Levermore, C. D., Pomraning, G. C.: 1981, *ApJ*, **248**, 321.
[2] Gonzalez, M., Audit, E., Huynh, P.: 2007, *A&A*, **464**, 429.
[3] Jiang, Y.-F., Stone, J. M., Davis, S. W.: 2014, *ApJS*, **213**, 7.
[4] Ohsuga, K., Takahashi, H. R.: 2016, *ApJ*, **818**, 162.

Discovery of About 1000 Ultra Diffuse Galaxies in the Coma Cluster: Opening the Low Surface Brightness Universe with Archival Data

KODA, Jin
(NAOJ/Joint ALMA Observatory/Stony Brook University)

YAGI, Masafumi, YAMANOI, Hitomi, KOMIYAMA, Yutaka
(NAOJ)

Forty-seven low surface brightness (LSB) galaxies were recently discovered in the direction of the Coma cluster [1]. If they really reside in the cluster, these galaxies, namely ultra-diffuse galaxies (UDGs), have only ~1/1000 of the Milky Way (MW)'s stellar mass ($\sim 10^{7-8}\,M_\odot$), but being as large as the MW in size with the effective radius of $r_e \gtrsim 1.5$ kpc. Such diffuse and puffy stellar structures are subject to tidal disruption in the cluster's gravitational potential [1,2]. If they are long-lived, these stellar systems must be protected by a large amount of dark matter halo, suggesting them to be potential "dark galaxies". Therefore, UDGs in clusters provide an important clue to studies of galaxy formation and evolution, galactic dark matter, and galaxy clusters.

We analyzed archival data from the Subaru Prime Focus Camera (Suprime-Cam) and discovered 854 UDGs in the Coma cluster, ~ 20 times more than previously reported [3]. Many of them (332) are Milky Way-sized with very large effective radii of r_e >1.5 kpc. About 2/3 of the Coma cluster field (4.1 degree^2) was observed by Suprime-Cam in the past, having deep *R* band images with partial *B*, *i*, and Hα band coverage.

This significant leap in sample size enhanced our knowledge of this important galaxy population. Our discovery suggests about 1,000 UDGs in the Coma cluster after accounting for the whole cluster size compared to the smaller Subaru field. The Subaru UDGs show a distribution concentrated clearly around the cluster center, strongly suggesting that the great majority are (likely longtime) cluster members. They are a passively evolving population, lying along the red sequence in the color-magnitude diagram with no signature of Hα emission. Star formation was, therefore, quenched in the past. They have exponential light profiles, effective radii $r_e \sim 800$ pc – 5 kpc, effective surface brightnesses $\mu_e(R) = 25$–28 mag arcsec^{-2}, and stellar masses $\sim 1 \times 10^7\,M_\odot - 5 \times 10^8\,M_\odot$. There is also a population of nucleated UDGs. Some MW-sized UDGs appear closer to the cluster center than previously reported; their survival in the strong tidal field, despite their large sizes and longevities, indicates a large dark matter fraction protecting the diffuse stellar component. The indicated baryon fraction < 1 % is less than the cosmic average, and thus the gas must have been removed (from the possibly massive dark halo). The UDG population is elevated in the Coma cluster compared to the field, indicating that the gas removal mechanism is related primarily to the cluster environment.

Beyond the importance of UDGs, this study clearly demonstrated the treasury value of archival data, and unveiled the new discovery space of the low surface brightness universe using the Subaru telescope and its large format cameras.

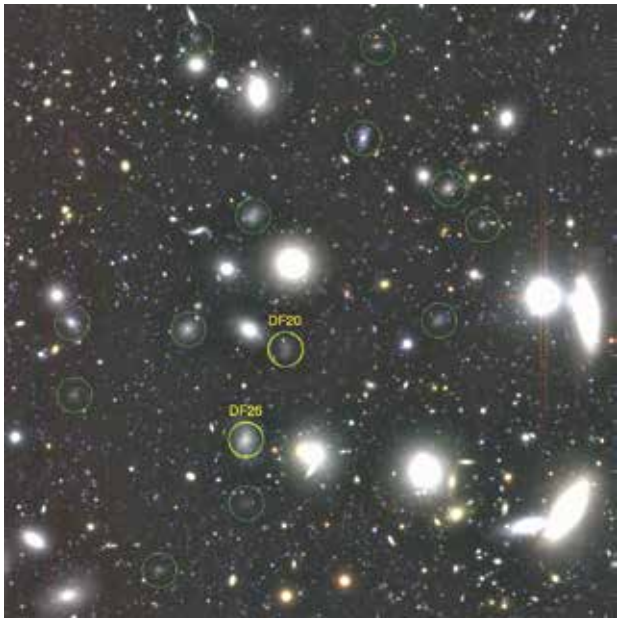


Figure 1: Subaru *BRi* color image of the ~6′ × 6′ region (~ 170 × 170 kpc^2 region at d = 97.7 Mpc) out of the 4.1 degree^2 Subaru coverage. The van Dokkum's Dragonfly UDGs and Subaru UDGs are marked respectively with yellow and green circles with a diameter of 20″ (~ 9.5 kpc).

References

[1] van Dokkum, P. G., Abraham, R., Merritt, A., et al.: 2015, *ApJ*, **798**, L45.
[2] Penny, S. J., Conselice, C. J., de Rijcke, S., Held, E. V.: 2009, *MNRAS*, **393**, 1054.
[3] Koda, J., Yagi, M., Yamanoi, H., Komiyama, Y.: 2015, *ApJ*, **807**, L2.

Discovery of an Inner Disk Component around HD 141569 A

KONISHI, Mihoko[1]*, GRADY, Carol A.[2/3], SCHNEIDER, Glenn[4], SHIBAI, Hiroshi[5], MCELWAIN, Michael W.[3]
NESVOLD, Erika R.[6], KUCHNER, Marc J.[3], CARSON, Joseph[7], DEBES, John. H.[8], GASPAR, Andras[4]
HENNING, Thomas K.[9], HINES, Dean C.[8], HINZ, Philip M.[4], JANG-CONDELL, Hannah[10]
MORO-MARTÍN, Amaya[8], PERRIN, Marshall[8], RODIGAS, Timothy J.[6], SERABYN, Eugene[11]
SILVERSTONE, Murray D.[2], STARK, Christopher C.[8], TAMURA, Motohide[12/1/13], WEINBERGER, Alycia J.[6]
WISNIEWSKI, John. P.[14]

1: NAOJ, 2: Eureka Scientific, 3: Goddard Space Flight Center, 4: The University of Arizona, 5: Osaka University, 6: Carnegie Institution of Washington, 7: College of Charleston, 8: Space Telescope Science Institute, 9: Max Planck Institute for Astronomy, 10: University of Wyoming, 11: Jet Propulsion Laboratory, 12: Astorobiology Center, 13: University of Tokyo, 14: University of Oklahoma

Planets are considered to form in protoplanetary disks during star formation process. Protoplanetary disks and planets interact with each other. Thus, detail understanding of disk structures is important in order to elucidate star and planet evolution. Disks have been imaged recently, and it has become clear that they have complex structures.

This work [1] is focused on a disk around HD 141569 A (spectral type: B9.5, age: 5 Myr). This is a young debris disk, containing various complex structures that have been imaged in the optical and near-infrared (e.g., [2,3,4]). The disk has a double-ring structure (inner and outer ring) with spiral structures, and a cavity inside the inner ring (< 175 AU). In addition, emission from dust and CO gas has been detected inside the inner ring using mid-infrared (e.g., [5]) and CO emission lines (e.g., [6]). We obtained disk images in the optical, using Space Telescope Imaging Spectrograph (STIS) aboard on Hubble Space Telescope (HST) as a part of general observer program (GO 13786). The scattered light from an inner disk component within the known inner ring was firstly detected, after adopting suitable analysis in that the scattered light from the disk and star light were divided. The inner disk component extends from 0.″4 (46 AU) to 1.″0 (120 AU) in deprojected stellocentric distance, with no gaps or a cavity. A spiral was detected at 130 AU. A pericenter offset of 6 AU may exist towards the north. An unseen planet would trigger such spiral and gap structures between the inner disk component and the inner ring. However, our data indicate that there is no point source heavier than 9 M_J in the gap. On the other hand, the mass of the planet that could create such gap is < 1 M_J, as estimated by the dynamical model [7]. Thus, we cannot reject the possibility that an unseen planet creates the gap.

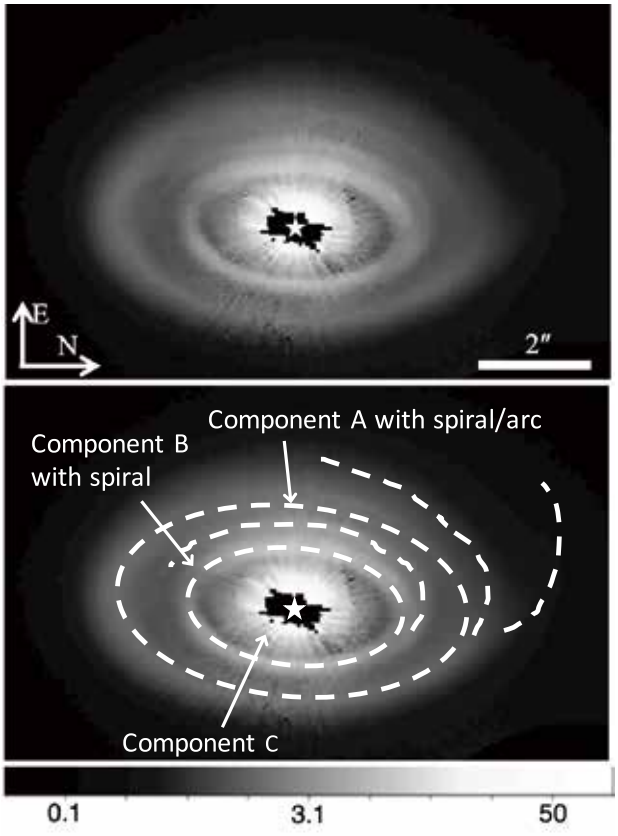


Figure 1: HD 141569 A disk image (see [1]). Nomenclature is annotated on the lower panel that is the same image as the upper panel. Star mark indicates the HD 141569 A position. Component C is the inner disk component that we discovered.

* Affiliation was Osaka University when the paper was published.

References

[1] Konishi, M., et al.: 2016, *ApJ*, **818**, L23.
[2] Weinberger, A. J., et al.: 1999, *ApJ*, **525**, L53.
[3] Mouillet, D., et al.: 2001, *A&A*, **372**, L61.
[4] Clampin, M., et al.: 2003, *AJ*, **126**, 385
[5] Fisher, R. S., et al.: 2000, *ApJ*, **532**, L141.
[6] Goto, M., et al.: 2006, *ApJ*, **652**, 758.
[7] Nesvold, E. R., Kuchner, M. J.: 2015, *ApJ*, **798**, 83.

FastSound: The Subaru FMOS Galaxy Redshift Survey

TONEGAWA, Motonari[1], TOTANI, Tomonori[1], OKADA, Hiroyuki[1], AKIYAMA, Masayuki[2], DALTON, Gavin[3]
GLAZEBROOK, Karl[4], IWAMURO, Fumihide[5], MAIHARA, Toshinori[5], OHTA, Koji[5], SHIMIZU, Ikkoh[1]
TAKATO, Naruhisa[6], TAMURA, Naoyuki[7], YABE, Kiyoto[6], BUNKER, Andrew J.[3/7], COUPON, Jean[8]
FERREIRA, Pedro G.[3], FRENK, Carlos S.[9], GOTO, Tomotsugu[10], HIKAGE, Chiaki[11], ISHIKAWA, Takashi[5]
MATSUBARA, Takahiko[11], MORE, Surhud[7], OKUMURA, Teppei[7], PERCIVAL, Will J.[12]
SPITLER, Lee R.[13/14], SZAPUDI, Istvan[15]

1: University of Tokyo, 2: Tohoku University, 3: University of Oxford,4: Swinburne University of Technology, 5: Kyoto University, 6: NAOJ, 7: Kavli IPMU, 8: University of Geneva, 9: University of Durham, 10: National Tsing Hua University, 11: Nagoya University, 12: Portsmouth University, 13: Australian Astronomical Observatory, 14: Macquarie University, 15: University of Hawaii

Recent precision cosmological observations have revealed that our Universe is in the phase of an accelerated expansion currently. However, this unexpected acceleration is still a mystery, with possible two descriptions: an exotic form of energy with negative pressure (dark energy) and breakdown of general relativity on cosmological scales (modified gravity). FastSound project is a redshift survey with FMOS on Subaru telescope, probing a distant Universe beyond redshift one for the first time. The primary goal is to detect an anisotropy in the 3-D distribution of galaxies brought by redshift space distortion (RSD), measure the growth rate of the large-scale structure $f\sigma_8$, and test gravity theories by comparing $f\sigma_8$ with theoretical predictions.

The observation was carried out over 35 nights from April 2012 to July 2014, taking spectra of ~47,000 galaxies over 20 deg^2. Target selection was based on optical 5 bands ($u^*g'r'i'z'$) of CFHTLS Wide 1–4. The image data was processed using the standard reduction pipeline of FMOS [1], followed by automated emission line detection by a dedicated software algorithm [3], resulting in ~4,000 emission line detections. Table 1 shows the number of emission lines and estimated contamination rate for several *S/N* thresholds, and Figure 1 is the galaxy distribution on the celestial sphere.

Table 1: Number of emission lines and estimated contamination rate for several *S/N* thresholds.

	Line Number	Contamination
$S/N \geq 5.0$	3,080	2.3 %
$S/N \geq 4.5$	3,769	4.5 %
$S/N \geq 4.0$	4,797	9.2 %
$S/N \geq 3.5$	6,805	22.2 %

RSD was detected with 4σ confidence level from a clustering analysis with this data [2], giving the linear growth rate of the large-scale structure ($f\sigma_8 = 0.482^{+0.116}_{-0.116}$ at $z = 1.4$), which is consistent with the prediction of ΛCDM model. Fundamental metallicity relation of FastSound galaxies was also examined using detected Hα and [NII] lines [5].

Redshift catalog has been created from these data [4] and become public (http://www.kusastro.kyoto-u.ac.jp/Fastsound/index.html) and accessible to anyone.

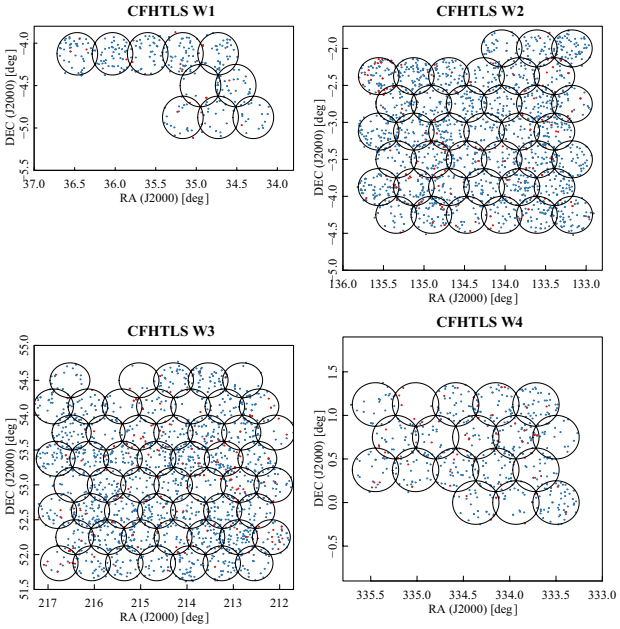


Figure 1: The 2-D distribution of FastSound galaxies. Blue dots are galaxies whose emission lines are detected in normal spectrum, while red dots are those for which the line detection algorithm find signals in inverted (−1 multiplied) spectrum. The latter gives an estimation of false detection rate.

References

[1] Iwamuro, F., et al.: 2012, *PASJ*, **64**, 59.
[2] Okumura, T., et al.: 2016, *PASJ*, **68**, 38.
[3] Tonegawa, M., et al.: 2015, *PASJ*, **67**, 31.
[4] Tonegawa, M., et al.: 2015, *PASJ*, **67**, 81.
[5] Yabe, K., et al.: 2015, *PASJ*, **67**, 102.

Internal Structure of the Moon Inferred from Apollo Seismic Data and Latest Selenodetic Data

MATSUMOTO, Koji, YAMADA, Ryuhei, KIKUCHI, Fuyuhiko, HANADA, Hideo
(NAOJ)

KAMATA, Shunichi
(Hokkaido University)

ISHIHARA, Yoshiaki, IWATA, Takahiro
(ISAS/JAXA)

SASAKI, Sho
(Osaka University)

The knowledge of the internal structure of the Moon is a key to understand the origin and the evolution of our nearest celestial body. The Apollo seismic data have been successfully used to infer its internal structure. However, the network consisted of only a few near-side observation points, and the deepest source is located at roughly 1200 km depth (~540 km radius). Thus, the models of the lunar interior deeper than 1200 km are different by authors (e.g., [1,2]), leaving the structure near the center uncertain. On the other hand, information on density and viscoelastic profiles can be obtained by measuring moments of inertia and tidal response of the Moon through observation of lunar rotation and gravity variations. Recently, Gravity Recovery and Interior Laboratory (GRAIL) mission has accurately observed slight tidal change in gravity, and estimates of quality factor have also been updated [3]. It is also shown by numerical calculations that frequency dependence of the quality factor can be explained by existence of ultra low-viscosity zone at the base of the lower mantle [4]. This study explores eight-layer lunar internal structure models with such a deep-seated low-viscosity zone which are consistent with both the data sets of the latest selenodetic data and Apollo seismic data [5].

Fig. 1 shows vertical profiles inferred by Markov chain Monte Carlo algorithm. Estimated value of mean crustal thickness is 44 ± 10 km, that of fluid outer core radius is 335^{+60}_{-115} km, that of solid inner core with assumed density of 8000 kg/m^3 is < 260 km, those of P- and S-wave velocities in the low-velocity zone above the core-mantle boundary are $V_P = 7.1 \pm 1.0$ km/s and $V_S = 2.9 \pm 0.5$ km/s, and that of the viscosity of the same zone is about 3×10^{16} Pa s, respectively. The top of the low-velocity and low-viscosity zone is located at about 570 km from the center and this zone is considered to extend into the deep moonquake region. Although previous study suggests that the thickness and density of the low-velocity zone are 150 km and 3400 kg/m^3 [1], respectively, those values inferred by this study are > 170 km and 3450 – 3650 kg/m^3, respectively. This density at the the pressure near the core-mantle boundary of about 4.5 GPa is consistent with that of titanium-rich basalt measured by high-pressure and high-temperature experiments [6]. Such a Ti-rich composition deep in the mantle supports a lunar evolution model involving lunar mantle overturn in which the Ti-rich material, that was formed in the upper mantle at the final stage of magma ocean solidification, sank down to the deep interior due to gravitational instability.

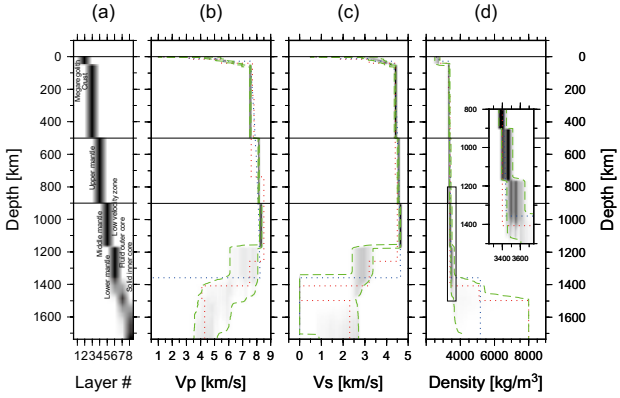


Figure 1: Vertical profiles of (a) modeled layer, (b) P wave velocity, (c) S wave velocity, and (d) density. A darker black color indicates a higher probability of occurrence. Green broken lines indicate the 2-sigma uncertainty of our results. Models by [1] and [2] are indicated as red and blue dotted lines, respectively.

References

[1] Weber, R. C., et al.: 2011, *Science*, **331**, 309-312.
[2] Garcia, R. F., et al.: 2011, *Phys. Earth Planet. Inter.*, **188**, 96-113.
[3] Williams, J. G., Boggs, D. H.: 2015, *J. Geophys. Res.*, **120**, 689-724.
[4] Harada, Y., et al.: 2014, *Nat. Geosci.*, **7**, 569-572.
[5] Matsumoto, K., et al.: 2015, *Geophys. Res. Lett.*, **42**, 7351-7358.
[6] Sakamaki, T., et al.: 2010, *Earth Planet. Sci. Lett.*, **299**, 293-297.

Radiation Drag Effects in Black Hole Outflows from Super-critical Accretion Disks via Special Relativistic Radiation Magnetohydrodynamics Simulations

TAKAHASHI, Hiroyuki R., OHSUGA, Ken
(NAOJ)

A black hole accretion disk system is one of the most energetic phenomena in the universe. A mass accretion onto the black holes results in efficient gravitational energy release. According to the mass accretion rate, three accretion modes, i.e., standard disk model, radiatively inefficient accretion flow model, and slim disk model have been proposed. Whereas these three models are established by one-dimensional approach, multi-dimensional effects are also very important because jets and outflows are observed in black hole accretion disk system. Also the relativistic effects should be taken into account since the jet velocity is close to the light speed. For the case of high accretion rate (slim disk), a radiation is an important ingredient for understanding disk and jet structures. The radiation pressure dominates the gas pressure, so that the most of energy is transported in the form of radiation. Such a large amount of radiation energy would form the radiatively driven jets or outflows. Thus, the relativistic radiation magnetohydrodynamic (RRMHD) simulations are required to study the radiatively-driven high-velocity outflows. In this paper, we performed RRMHD simulation to study the mechanisms of outflow acceleration and determine the outflow speed [1].

Figure 1 shows overall structure of the accretion disks. At this time ($t = 10$ s), the accretion rate onto the black hole is $\dot{M} \simeq 1000\, \dot{M}_{\rm Edd}$. Here $\dot{M}_{\rm Edd}$ is the Eddington accretion rate $\dot{M}_{\rm Edd} \equiv 4\pi GM_{\rm BH}/c\kappa_{\rm es} = 1.4 \times 10^{18}\, (M_{\rm BH}/10\, M_\odot)$ g s^{-1}, where G is the gravitational constant, c is the light speed, $M_{\rm BH} = 10\, M_\odot$ is the black hole mass, and $\kappa_{\rm es}$ is the opacity for electron scattering. Thus the super-critical accretion is stably realized. Besides the accretion flow, a fast relativistic outflow is observed just above the accretion disks (arrows in the right panel). The direction of velocity vector almost coincides with the radiation flux vector (arrows in the left panel), indicating that the relativistic flow is accelerated by the radiation force. The gas is accelerated at the small altitudes, and its velocity finally saturates at the outer region ($z \gtrsim 100\, r_{\rm S}$, where $r_{\rm S}$ is the Schwarzschild radius). The terminal outflow velocity is about $0.3-0.4\, c$, which nicely agrees with the jets speed ($0.26\, c$) observed in SS433. Considering the outflow acceleration, a balance between two forces determines the terminal velocity. First one is the radiation flux force, which pushes the gas away from the accretion disks. Then the gas is accelerated upward. The accelerated gas is subjected to the radiation drag force, which prevents the outflow from further acceleration. By comparing these two forces, the outflow velocity is estimated at $0.3–0.4\, c$. We observed that these results are justified in the range of $10^2 \lesssim \dot{M}/\dot{M}_{\rm Edd} \lesssim 10^4$.

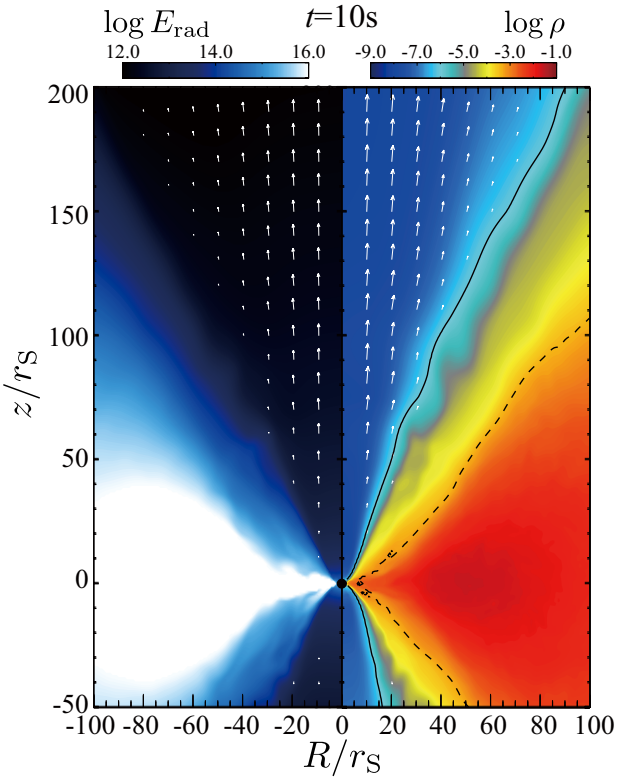


Figure 1: Overall structure of the super critical accretion disks. Left and right colors show the radiation energy density and gas density. The arrows show the radiation flux (left) and the velocity (right). Solid and dashed curves denotes where the total and effective optical depths become unity.

Reference

[1] Takahashi, H. R., Ohsuga, K.: 2015, *PASJ*, **67**, 60.

Near-infrared Imaging Observations of Circumstellar Disk around HD 169142 with Subaru/HiCIAO

MOMOSE, Munetake[1], MORITA, Ayaka[1], FUKAGAWA, Misato[2], MUTO, Takayuki[3], TAKEUCHI, Taku[4], HASHIMOTO, Jun[2/5]
HONDA, Mitsuhiko[6], KUDO, Tomoyuki[2], OKAMOTO, Yoshiko K.[1], KANAGAWA, Kazuhiro D.[7], TANAKA, Hidekazu[8]
GRADY, Carol A.[9/10/11], SITKO, Michael L.[12/13], AKIYAMA, Eiji[2], CURRIE, Thayne[2], FOLLETTE, Katherine B.[14]
MAYAMA, Satoshi[15], KUSAKABE, Nobuhiko[2/5], ABE, Lyu[16], BRANDNER, Wolfgang[17], BRANDT, Timothy D.[18]
CARSON, Joseph C.[19], EGNER, Sebastian[2], FELDT, Markus[17], GOTO, Miwa[20], GUYON, Olivier[2], HAYAHO, Yutaka[2]
HAYASHI, Masahiko[2], HAYASHI, Saeko S.[2], HENNING, Thomas[17], HODAPP, Klaus W.[21], ISHII, Miki[2], IYE, Masanori[2]
JANSON, Markus[24], KANDORI, Ryo[2], KNAPP, Gillian R.[23], KUZUHARA, Masayuki[4], KWON, Jungmi[24], MATSUO, Taro[25]
McELWAIN, Michael W.[9], MIYAMA, Shoken[26], MORINO, Jun-Ichi[2], MORO-MARTIN, Amaya[23/27], NISHIMURA, Tetsuo[2]
PYO, Tae-Soo[2], SERABYN, Eugene[28], SUENAGA, Takuya[2/15], SUTO, Hiroshi[2], SUZUKI, Ryuji[2], TAKAHASHI, Yasuhiro H.[2/24]
TAKAMI, Michihiro[29], TAKATO, Naruhisa[2], TERADA, Hiroshi[2], THALMANN, Christian[30], TOMONO, Daigo[2]
TURNER, Edwin L.[23/24], WATANABE, Makoto[31], WISNIEWSKI, John[32], YAMADA, Toru[33], TAKAMI, Hideki[2]
USUDA, Tomonori[2], TAMURA, Motohide[2/5/24]

1: Ibaraki University, 2: NAOJ, 3: Kogakuin University, 4: Tokyo Tech., 4: ABC, 6: Kurume University, 7: Szczecin University, 8: Tohoku Univsersity, 9: Goddard Space Flight Center, 10: Eureka Scientific, 11: Goddard Center for Astrobiology, 12: Space Science Institute, 13: University of Cincinnati, 14: University of Arizona, 15: Sokendai, 16: Universitè de Nice-Sophia Antipolis, 17: Max Planck Institute for Astronomy, 18: Institute for Advanced Study, Princeton, 19: College of Charleston, 20: Universitäts-Sternwarte München, 21: University of Hawaii, 22: Stockholm University, 23: Princeton University, 24: University of Tokyo, 25: Osaka University, 26: Hiroshima University, 27: CAB-CSIC/INTA, 28: Jet Propulsion Laboratory, 29: Institute of Astronomy and Astrophysics, Academia Sinica, 30: University of Amsterdam, 31: Hokkaido University, 32: University of Oklahoma, 33: ISAS/JAXA

HD 169142 is a Herbig Ae star (A8 Ve) located at a distance of 145 pc from the Sun [1]. Interferometric observations at millimeter and submillimeter wavelengths revealed a circumstellar disk around HD 169142, with the radius of 1.4″ (≈ 200 au) and with its inclination angle of 13° [2,3]. Near-infrared imaging with the HST coronagraph also detected scattered light with similar size [1]. The amount of excess emission at mid-infrared wavelengths is small, suggesting that the outer disk is truncated at ~ 0.15″ (~ 20 au) from the star [4,5]. We carried out polarization differential imaging (PDI) of the disk scattered light in H-band with Subaru/HiCIAO.

Figure 1 shows the obtained polarized intensity (PI) image. The emission scattered by dust particles at the disk surface in $0.2'' \leq r \leq 1.2''$, or $29 \leq r \leq 174$ au, is successfully detected. The azimuthally-averaged radial profile of the PI, shown in Figure 2, manifests a double power-law distribution, in which the PIs in r = 29–52 au and r = 81.2–145 au respectively show r^{-3}-dependence. These two power-law regions are connected smoothly with a transition zone, exhibiting an apparent gap in r = 40–70 au.

The observed radial profile of the PI is reproduced by a minimally flaring disk with an irregular surface density distribution or with an irregular temperature distribution or with the combination of both. The depletion factor of surface density in the inner power-law region ($r <$ 50 au) is derived to be ≥ 0.16 from a simple model calculation. The obtained PI image also shows small scale asymmetries in the outer power-law region. Possible origins for these asymmetries include corrugation of the scattering surface in the outer region, and shadowing effect by a puffed up structure in the inner power-law region.

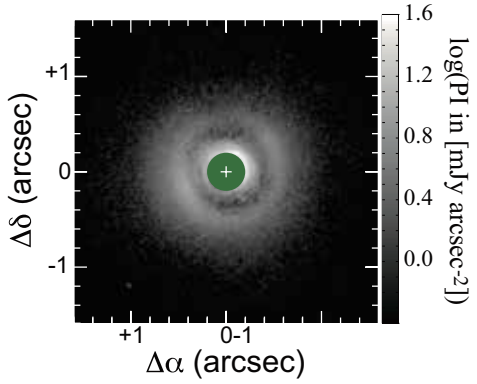


Figure 1: PI image with HiCIAO. Green circle and white cross indicate the masked region and stellar position, respectively.

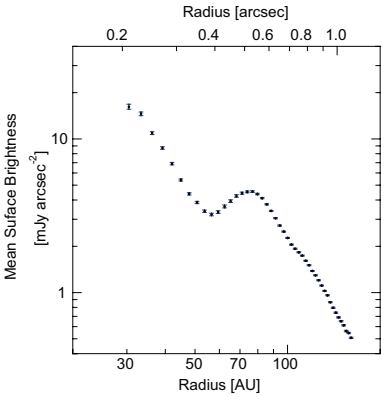


Figure 2: Azimuthally-averaged radial profile of PI surface brightness.

References

[1] Grady, C. A., et al.: 2007, *ApJ*, **665**, 1391.
[2] Raman, A., et al.: 2006, *ApJ*, **131**, 2290.
[3] Panic, O., et al.: 2008, *A&A*, **491**, 219.
[4] Meuus, G., et al.: 2010, *A&A*, **518**, L124.
[5] Honda, M., et al.: 2012, *ApJ*, **752**, 143.
[6] Momose, M., et al.: 2015, *PASJ*, **67**, 83.

Nuclear Fission and Solution of *r*-Process Underproduction Problem

SHIBAGAKI, Shota, KAJINO, Toshitaka
(University of Tokyo/NAOJ)

MATHEWS, Grant J.
(University of Notre Dame/NAOJ)

CHIBA, Satoshi
(Tokyo Institute of Technology)

NISHIMURA, Shunji
(RIKEN Nishina Center/NAOJ)

LORUSSO, Giuseppe
(National Physical Laboratory/RIKEN Nishina Center/University of Surrey)

The origin of heavy elements like gold and uranium, called *r*-process elements, is one of the important mystery in astrophysics. There are several candidates for *r*-process sources such as the neutrino-driven wind (NDW) of core-collapse supernovae (CCSNe), magnetohydrodynamic jets (MHDJs) from CCSNe and binary neutron-star mergers (NSMs), but the major r-process source has not been identified yet.

Although the formation process of the characteristic *r*-process abundance peaks around mass numbers 130 and 195 is understood well, the elemental abundances just above and below those peaks are frequently underproduced by more than an order of magnitude in the literature. This underproduction has been interpreted as the result of the strong shell closure. It is known that the resulting elemental abundances matches well to the solar-system *r*-process abundances if the shell effects is quenched enough. However, there is no experimental evidence of the shell quenching, and some alternative solutions of the underproduction problem are desirable.

We proposed a scenario that contribution of NSMs solves the underproduction problem. In such neutron-rich environments, like NSMs, that neutron-rich fissile nuclei are synthesized, the resulting *r*-process elemental abundances are sensitive to the applied fission model. We performed numerical simulations of *r*-process nucleosynthesis for dynamical ejecta from the NSM model [1,2,3] with a realistic fission model. We used an extended version of the nuclear reaction network described in [4], where some nuclear reactions based on the KTUY nuclear mass model and a new fission fragment distributions model [5] are newly adopted.

The red line in Figure 1 [6] shows the result of the nucleosynthesis simulation for the NSM model in comparison with the solar-system *r*-process abundances [7] represented in the black dots. The flat abundance pattern between A = 100 and 160, which has not been found in the literature, is due to the new fission model adopted, which predicts that a wide mass range of fission products is formed. The results of the nucleosynthesis simulations for the NDW model and the MHDJ model taken from [8,9] are also plotted in Figure 1. Those three models shows the completely different elemental abundance patterns. The total abundance curve from all models is shown as the black line. We found that the elements produced in the NDW and NSM model supplement the underproduced elements of the MHDJ model, and the resulting total elemental abundance pattern is very close to the solar-system *r*-process abundances.

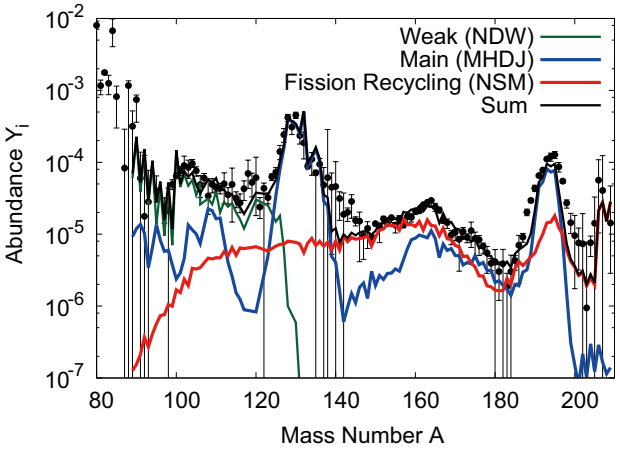


Figure 1: Solar-system isotopic *r*-process abundance pattern. Observation (black dots) vs. theoretical calculation which consists of the *r*-process in magnetohydrodynamic jet supernova model (blue), neutrino-driven wind model (green), binary neutron-star merger model (red) and total sum (black).

References

[1] Terasawa, M., et al.: 2001, *ApJ*, **562**, 470.
[2] Chiba, S., et al.: 2008, *AIP Conf. Proc.*, **1016**, 162.
[3] Korobkin, O., et al.: 2012, *MNRAS*, **426**, 1940.
[4] Piran, T., et al.: 2013, *MNRAS*, **430**, 2121.
[5] Rosswog, S., et al.; 2013, *MNRAS*, **430**, 2585.
[6] Shibagaki, S., et al.: 2016, *ApJ*, **816**, 79.
[7] Goriely, S.: 1999, *A&A*, **342**, 881.
[8] Wanajo, S.: 2013, *ApJ*, **770**, L22.
[9] Nishimura, N., et al.: 2012, *Phys. Rev. C*, **85**, 048801.

Black Hole Mass Measurement in Nearby Galaxy Using Molecular Gas Dynamics

ONISHI, Kyoko, IGUCHI, Satoru
(SOKENDAI/NAOJ)

SHETH, Kartik
(National Aeronautics and Space Administration)

KOHNO, Kotaro
(The University of Tokyo)

Abstract— A new method is carried out to measure SuperMassive Black Hole (SMBH) mass in the center of nearby galaxy NGC 1097, by using dense molecular gas dynamics traced with HCN(J=1–0). The dynamics is observed with Atacama Large Millimeter/submillimeter Array (ALMA). This work demonstrates the capability of radio interferometers to measure SMBH mass, which helps to better understand the evolution of black holes and hence their host galaxies. The original paper is published by Astrophysical Journal in June 2015 [1]. Here we quote the published paper and our related works.

Introduction— Observations and studies particularly in the last two decades have shown that every stellar spheroids harbor SuperMassive Black Holes (SMBHs; larger than $10^6\,M_\odot$ where $M_\odot$ is the mass of the sun) in their centers [2]. Meanwhile, developed observing facilities allowed us to measure the SMBH mass in some of the nearby galaxies by using different dynamical methods. The measured SMBH mass ($M_{\rm BH}$) are empirically known to be tightly correlated to host galaxy bulge properties such as central velocity dispersion of stars (known as $M_{\rm BH} - \sigma$ relation, [2,3,4,5]). These correlations, together with recent numerical simulations, suggest that galaxy and black hole evolves by influencing each other. SMBH mass is thus considered to be the key parameter to better understand the growth of galaxy and SMBH. SMBH mass measuring method using molecular gas dynamics, observed with radio interferometers, enables one to measure more SMBH mass in this Atacama Large Millimeter/submillimeter Array (ALMA) era. Reference [1] and [6] started this method with newly developed radio interferometers. With a larger sample realized with this new method, correlations such as $M_{\rm BH} - \sigma$ relation are expected to be better constrained, and eventually makes the co-evolutionary process of galaxy and black hole to be better understood.

Data— NGC 1097 is a nearby Type-1 Seyfert galaxy at a distance of 14.5 Mpc [7] (~70 pc arcsecond^{-1}). The nucleus is located at *RA* (J2000.0) = $02^{\rm h}46^{\rm m}18^{\rm s}.96$, *DEC* (J2000.0) = −30°16′28″.9 [8]. The SMBH mass in NGC 1097 is estimated to be $(1.2 \pm 0.2) \times 10^8\,M_\odot$ by using the empirical $M_{\rm BH} - \sigma$ relation from [3] with an observed $\sigma = 196 \pm 5\,{\rm km\,s^{-1}}$ [9].

SMBH mass measurement— We measure the SMBH mass in NGC 1097 by using molecular gas dynamics observed with ALMA. The method is described in reference [1], while we give a short summary here. A Position-Velocity Diagram (PVD) is cut along the galaxy major axis (P.A = 130°) from the observed data to compare with the model velocity field, calculated by MGE_circular_velocity method [10] and Kinematic Molecular Simulation (KinMS) [6]. The model considers a mass-to-light ratio (M/L) and SMBH mass as free parameters. We run a grid simulation to obtain $M_{\rm BH} = 1.40^{+0.27}_{-0.32} \times 10^8\,M_\odot$, M/L = $5.14^{+0.03}_{-0.04}$ with a reduced chi-square $\chi^2_{\rm red} = 1.09$ realized by the best fit (see Figure).

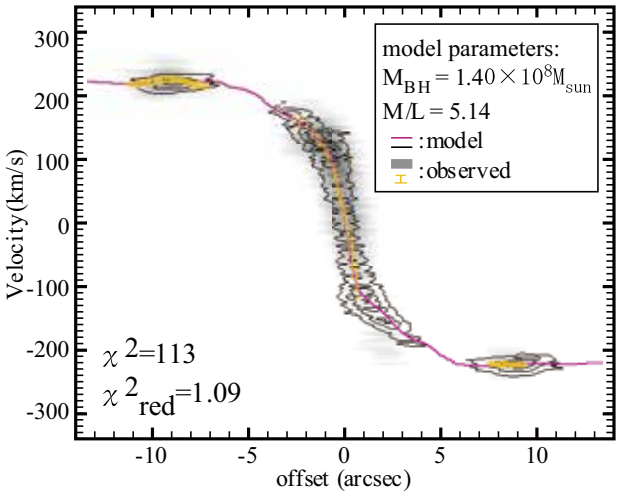


Figure 1: Comparison of the observed PVD and the model (grey scale filled contours and yellow points) and the model (black contours and purple lines). Model parameters are set to be $M_{\rm BH} = 1.40 \times 10^8\,M_\odot$, M/L = 5.14. The reduced chi-square is $\chi^2_{\rm red} = 1.09$ with the degree of freedom of 104.

References

[1]Onishi, K., et al.: 2015, *ApJ*, **806**, 39.
[2]Kormendy, J., Ho, L. C.: 2013, *Ann. Rev. Astron. Astrophys.*, **51**, 511.
[3] McConnell, N. J., Ma, C.-P.: 2013, *ApJ*, **764**, 184.
[4] Ferrarese, L., Merritt, D.: 2000, *ApJ*, **539**, L9.
[5] Gltekin, K., et al.: 2009, *ApJ*, **698**, 198.
[6] Davis, T. A., et al.: 2013, *Nature*, **494**, 328.
[7] Tully, R. B.: 1988, *Nearby Galaxies Catalog* (Cambridge: Cambridge University Press).
[8] Hummel, E., et al.: 1987, *A&AS*, **70**, 517.
[9] Lewis, K. T., Eracleous, M.: 2006, *ApJ*, **642**, 711.
[10] Cappellari, M., et al.: 2002, *ApJ*, **578**, 787.

Effect of Stellar Encounters on Comet Cloud Formation

HIGUCHI, Arika
(Tokyo Institute of Technology)

KOKUBO, Eiichiro
(NAOJ)

The Oort Cloud is a spherical comet reservoir surrounding the Solar system [1]. Observations and statistical studies estimate that it consists of more than 10^{12} comets and is on the order of 10^4–10^5 AU in size (e.g., [2]). Now it is generally accepted that the comets are residual planetesimals from planet formation and are originally inside the planetary region. In the standard scenario of the Oort cloud formation, passing stars randomize and eject planetesimals from the Solar system by giving velocity kicks. The perturbations from passing stars, due to their random-walk nature, may play an important role in the production of the nearly isotropic inclination distribution of planetesimals Many authors have examined this effect, however, their main interest is in the production of long-period comets from the spherical Oort cloud (e.g., [3]).

In the present paper we investigate the effect of stellar encounters on the evolution of a planetesimal disk, from the point of view of Oort Cloud formation. We calculate the evolution of a planetesimal disk into a spherical Oort cloud due to the perturbation from passing stars for 10 Gyr. We use the classical impulse approximation to calculate the perturbation from the passing stars. The stellar encounters are assumed to occur with random directions and follow the distribution $\mathrm{d}n_s/\mathrm{d}b \propto b$, where n_s and $\mathbf{b}$ are a number of stellar encounters and the position vectors to the star from the Sun, respectively. The time interval to the next stellar encounter is given according to a Poisson distribution [3].

The number of planetesimals decreases while the distributions of the orbital elements approach the isotropic distribution. We fit the decay curve empirically using the standard exponential decay curve and the stretched exponential decay defined by the Kohlrausch formula [6]. Let P_{bound} denotes the survival rate of planetesimals in the Solar system. The empirical fit for P_{bound} for the standard exponential decay is

$$P_{\mathrm{bound}}^{\mathrm{fit}} = \exp\left(-\frac{t}{t_e^{\mathrm{fit}}}\right), \tag{1}$$

$$t_e^{\mathrm{fit}} \simeq 5.6\left(\frac{a_0}{2\times10^4\ \mathrm{AU}}\right)^{-1.4}\left(\frac{m_*}{0.5M_\odot}\frac{20\ \mathrm{kms}^{-1}}{v_*}\right)^{-1.7}\left(\frac{f_{\mathrm{enc}}}{10\ \mathrm{Myr}^{-1}}\right)^{-1}\mathrm{Gyr}, \tag{2}$$

where a_0 is the initial semimajor axes of the planetesimals, m_* and v_* are the stellar mass and velocity, respectively, and f_{enc} is the encounter frequency per 1 Myr within 1 pc from the Sun.

We also show the radial variations of the e-folding times to the Oort cloud. We show that if the initial planetesimal disk has the semimajor axes distribution $\mathrm{d}n/\mathrm{d}a \propto a^{-2}$, which is produced by planetary scattering [7]. the e-folding time for planetesimals in the Oort cloud is ~10 Gyr at any heliocentric distance r (Fig. 1). This uniform e-folding time over the Oort cloud means that the supply of comets from the inner Oort cloud to the outer Oort cloud is sufficiently effective to keep the comet distribution as $\mathrm{d}n/\mathrm{d}r \propto r^{-2}$. We also show that the final distribution of the semimajor axes in the Oort cloud is approximately proportional to a^{-2} for any initial distribution [8].

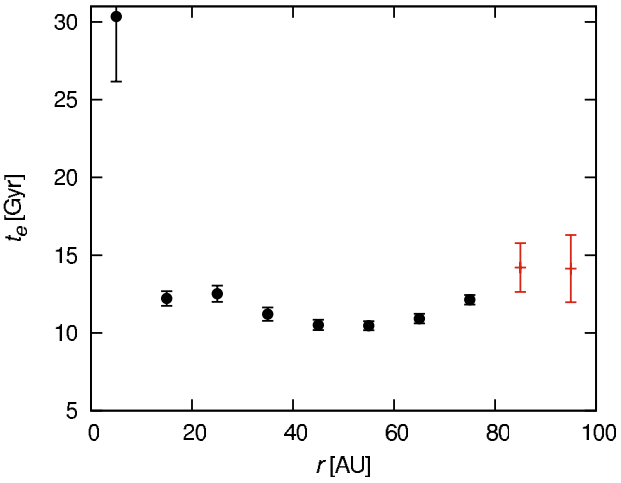


Figure 1: Standard e-folding time against r.

References

[1] Oort, J. H.: 1950, *Bull. Astron. Inst. Netherlands*, **11**, 91.
[2] Dones, L., et al.: 2004, In Comet II.
[3] Heisler, J., Tremaine, S., Alcock, C.: 1987, *ICARUS*, **70**, 269.
[4] Dobrovolskis, A. R., Alvarellos, J. L., Lissauer, J. J.: 2007 *ICARUS*, **188**, 481.
[5] Higuchi, A., Kokubo, E., Mukai, T.: 2006, *AJ*, **131**, 1119.
[6] Higuchi, A., Kokubo, E.: 2015, *AJ*, **150**, 17.

Developments of Millimeter-wave MKID Camera

SEKIMOTO, Y., DOMINJON, A., KARATSU, K., NOGUCHI, T., MATSUO, H., SHAN, W. L., KIUCHI, H.
(NAOJ)

SEKINE, M., SEKIGUCHI, S., SHU, S.
(University of Tokyo/NAOJ)

NITTA, T., YAMADA, Y., HISAMATSU, S.
(University of Tsukuba)

NARUSE, M.
(Saitama University)

MKID (Microwave Kinetic Inductance Detector) group of Advanced Technology Center is developing superconductive camera in millimeter and terahertz wavelengths for Antarctica terahertz telescope/Nobeyama 45m telescope which observes distant galaxies with wide field-of-view and for LiteBIRD which detects CMB B-mode polarization in collaboration with University of Tsukuba, Saitama University, ISAS/JAXA, KEK, and Riken. Five papers related to millimeter/submillimeter MKID instruments were published in 2015 fiscal year.

1. Nb/Cu bilayer MKID

MKID is a Cooper pair breaking detector, in which superconducting resonators sense variations of the surface impedance caused by quasi-particles, which are generated by higher frequency photons than the gap frequency. A gap frequency is proportional to the critical temperature (T_c) of a superconductor film. For aluminum, T_c = 1.1 K corresponds to the gap frequency of 90 GHz. If the gap frequency (or T_c) can be adjusted, it makes easier to use MKID for millimeter and submillimeter observations.

Dominjon et al. [1] have developed Nb/Cu bilayer MKID. The T_c of the bilayer can be *settled* by the thickness of Nb and Cu. Fig. 1 shows the evoluation of T_c as a function of the Nb layer thickness.

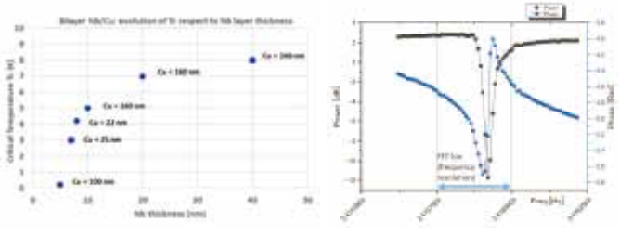


Figure 1: (Left) Evoluation of the critical temperature T_c of the Nb/Cu bilayer respect to the Nb layer thickness [1]. (Right) A resonance of MKID taken by a frequency sweeping FFT readout system [2].

2. Frequency sweeping readout

MKID is capable of frequency multiplexing with high Q superconducting resonators. To utilize this advantage, we are developing multi-channel FFT readout system. A frequency sweeping readout with synchronizing the FFT interval has been proposed and demonstrated [2]. This enables us to read multi-channel MKIDs with a large dynamic range (Fig. 1).

3. Dual polarization MKID camera

A combination of Si lens array and double slot antenna connected to MKID has been developed (eg. Nitta et al., 2014). This paper demonstrates single-layer dual polarization capability of the lens and double slot antenna with MKID (Fig. 2), which improves the sensitivity of millimeter observations [3].

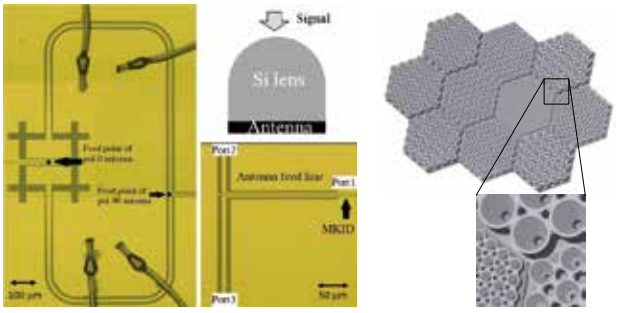


Figure 2: (Left) A picture of the dual polarization antenna coupled to an MKID. (Right) Corrugated-horn coupled OMT-MKID focal plane of LiteBIRD.

4. LiteBIRD focal plane design

Observations of B-mode polarization of cosmic microwave background radiation (CMB) sense the inflation theory (K. Sato, 1981), which explains the hot big-bang. This paper shows a focal plane design with corrugated horn coupled OMT-MKID of LiteBIRD (Fig. 2), which observes CMB B-mode polarization from the gravitational wave.

5. Radiation tolerance of MKID

Radiation tolerance of Al-MKID has been investigated. NEP of MKD has been measured at the level of 2×10^{-18} W/$\sqrt{\text{Hz}}$ before and after the total dose of 10 k rad, which corresponds 5 years absorption at the Lagrange point [5].

References

[1] Dominjon, A., et al.: 2016, *IEEE Trans. Appl. Supercond.*, **26**, online available.
[2] Kiuchi, H., et al.: 2016, *IEEE Trans. Terahertz Sci. Technol.*, **5**, 456.
[3] Naruse, M., et al.: 2015, *Int. J. Infrared Millimeter THz*, **37**, 128.
[4] Sekimoto, Y., et al.: 2015, ESA antenna workshop.
[5] Karatsu, K., et al.: 2016, JLTP online available.

The Mass-metallicity Relation and the Fundamental Metallicity Relation at $z \sim 1.4$ Revealed with the Subaru FMOS Galaxy Redshift Survey (FastSound)

YABE, Kiyoto (Kavli IPMU) OHTA, Kouji (Kyoto University) AKIYAMA, Masayuki (Tohoku University) BUNKER, Andrew, DALTON, Gavin (Oxford University)
ELLIS, Richard (Caltech) GLAZEBROOK, Karl (Swinburne University of Technology) GOTO, Tomotsugu (National Tsing Hua University)
IMANISHI, Masatoshi, TAKATO, Naruhisa (Subaru Telescope) IWAMURO, Fumihide (Kyoto University) TAMURA, Naoyuki (Kavli IPMU)
OKADA, Hiroyuki, SHIMIZU, Ikkoh, TONEGAWA, Motonari & TOTANI, Tomonori (University of Tokyo)

The gas-phase metallicity (hereafter, metallicity) is one of the key parameters required for understanding galaxy formation and evolution. Although enormous efforts on studying the correlation between the stellar mass and metallicity (hereafter mass-metallicity relation) and the dependence of star-formation rate (SFR) on the mass-metallicity relation (hereafter fundamental metallicity relation) have been made, those at $z>1$ still remain unclear because the sample size is still limited. FastSound is a galaxy redshift survey of galaxies at $z = 1.2$–1.5 with Fiber Multi-Object Spectrograph (FMOS) on the Subaru Telescope. Although the main goal of the project is the detection of the redshift space distortion (RSD) to test the general theory of relativity by measuring the growth rate of large-scale structure and to constrain modified gravity models for the origin of the accelerated expansion of the universe [1], the large sample of galaxies is very useful for the study of galaxies at this redshift.

Here, we present the results from the near-infrared sample of FastSound consisting of ~4,000 galaxies at $z \sim 1.4$ with significant Hα detection [2]. We measure the metallicity from the [N II]λ6583/Hα emission line ratio of the composite spectra in various stellar mass and SFR bins. The resulting mass-metallicity relation is generally in agreement with previous results obtained in a similar redshift range to that of our sample. Although no clear dependence of the mass-metallicity relation with SFR is found, our result at $z \sim 1.4$ roughly agrees with the fundamental metallicity relation at $z \sim 0.1$ with fiber aperture corrected SFR [3,4].

We detect significant [S II]$\lambda\lambda$6716,6731 emission lines from the composite spectra. The electron density estimated from the [S II]$\lambda\lambda$6716,6731 line ratio ranges from 10 – 500 cm^{-3}, which generally agrees with that of local galaxies. The distribution of our sample on [N II] λ6583/Hα vs. [S II]$\lambda\lambda$6716,6731/Hα is different from that found locally. From the obtained N2S2 index, we estimate the nitrogen-to-oxygen abundance ratio (N/O), and find that the N/O in galaxies at $z \sim 1.4$ is significantly higher than the local values at a fixed metallicity and stellar mass (Figure 1). The metallicity at $z \sim 1.4$ recalculated with this N/O enhancement taken into account decreases by 0.1 – 0.2 dex and the resulting metallicity is lower than the local fundamental metallicity relation.

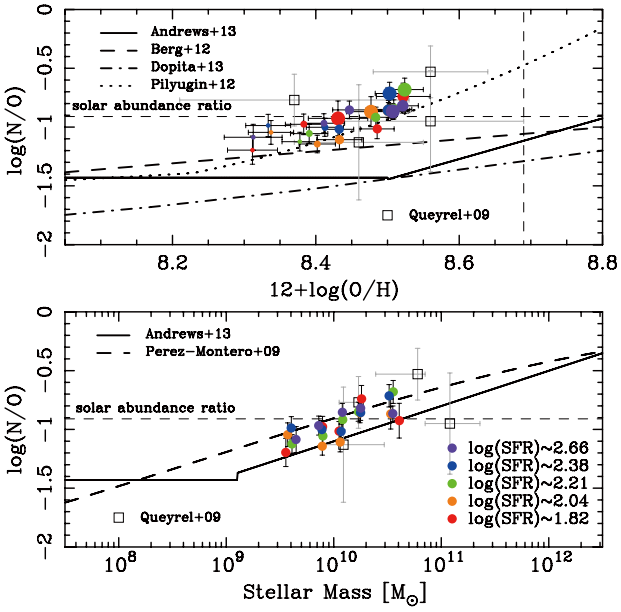


Figure 1: The N/O against the metallicity (top panel) and the stellar mass (bottom panel). The color of symbols of our sample represents SFR. Solid, dashed, dotted and dashed curves show the location of local galaxies at $z < 0.3$. The vertical and horizontal dashed line indicate the solar abundance and the solar abundance ratio, respectively.

References

[1] Tonegawa, M., et al.: 2015, *PASJ*, **67**, 81.
[2] Yabe, K., et al.: 2015, *PASJ*, **67**, 102.
[3] Andrews, B. H., Martini, P.: 2013, *ApJ*, **765**, 140.
[4] Zahid, H. J., et al.: 2014, *ApJ*, **792**, 75.

A Strong Interaction between The Ejecta of SN IIb 2013df and The CSM

MAEDA, Keiichi[1/2], HATTORI, Takashi[3], MILISAVLJEVIC, Dan[4], FOLATELLI, Gaston[2/5], DROUT, Maria R.[4]
KUNCARAYAKTI, Hanin[6], MARGUTTI, Raffaella[4], KAMBLE, Atish[4], SODERBERG, Alicia[4]
TANAKA, Masaomi[3], KAWABATA, Miho[7], KAWABATA, Koji[7], YAMANAKA, Masayuki[1/8], Nomoto, Ken'ichi[2]
KIM, Ji Hoon[3], SIMON, Joshua D.[9], PHILLIPS, Mark M.[9], PARRENT, Jerod[4], NAKAOKA, Tatsuya[7]
MORIYA, Takashi[10], SUZUKI, Akihiro[1], TAKAKI, Katsutoshi[7], ISHIGAKI, Miho[2], SAKON, Itsuki[2]
TAJITSU, Akihito[3], IYE, Masanori[3]

1: Kyoto University, 2: The University of Tokyo, 3: NAOJ, 4: Harvard-Smithsonian Center for Astrophysics, 5: Instituto de Astrofísica de La Plata, 6: Universidad de Chile, 7: Hiroshima University, 8: Konan University, 9: Carnegie Observatories, 10: University of Bonn

Type IIp supernovae are believed to be an explosion of a red supergiant, while type Ib/c supernovae (SNe Ib/c) are an outcome of an explosion of a star which has lost most of the hydrogen envelope before the explosion. They should represent different evolutionary paths, and thus a unified understanding of these phenomena is key to clarifying the unresolved nature of massive stellar evolution in the final centuries. SNe IIb retain a small but non-negligible amount of the hydrogen envelope at the time of the explosion, about the Solar mass or less, and thus they represent a link between SNe IIp and Ib/c. Their progenitors have diverse properties from a blue supergiant to a red supergiant, which are difficult to understand in the standard stellar evolution theory [1,2].

We have performed follow-up observations of SN IIb 2013df [3]. Especially surprising was a spectral feature at ~600 days after the explosion, obtained through the Subaru/FOCAS. At ~200 days, SN 2013df showed a spectrum similar to other SNe, characterized by forbidden lines of heavy elements. However, at ~600 days the spectrum showed a dramatic change, showing a strong Hα emission (Fig. 1). This transition is interpreted as follows: early on the SN was powered by radioactive decays of ^{56}Co, while later on the interaction between the expanding SN ejecta and circumstellar materials (CSM) became a dominant energy source. Such a transition has never been seen previously except for SN IIb 1993J.

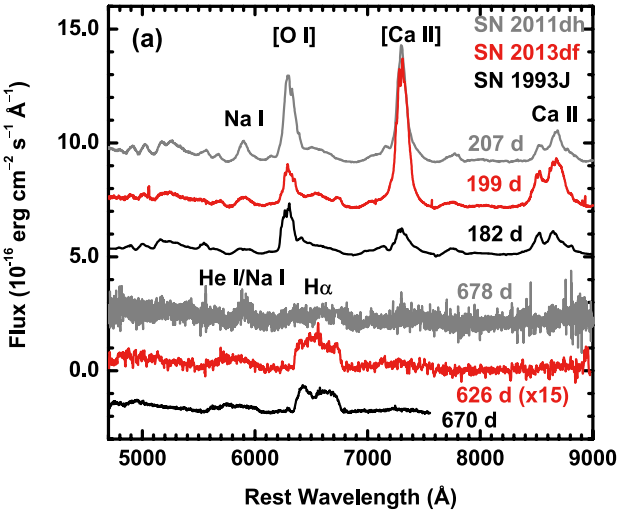


Figure 1: Late time spectra of SN 2013df as compared to those of SNe IIb 1993J and 2011dh at similar epochs [3].

This observational finding indicates that at least a fraction of SNe IIb have a large amount of CSM, namely they experience a huge mass loss in the last ~1000 years. On the other hand, for other SNe IIb the ejecta-CSM interaction have never been observed (Fig. 1) [4]. We have discovered that there is a relation between the mass loss rate and the radius of the progenitor (Fig. 2). A more extended progenitor is associated with a larger mass loss rate just before the explosion. It seems that SNe IIb from a more extended progenitor are the explosions during a strong binary interaction phase, while those from a less extended progenitor have a delay between the binary interaction and the explosion. A confirmation of the idea will require further studies, but in any case our discovery places a new and strong constraint on the unresolved nature of the final evolution of massive stars.

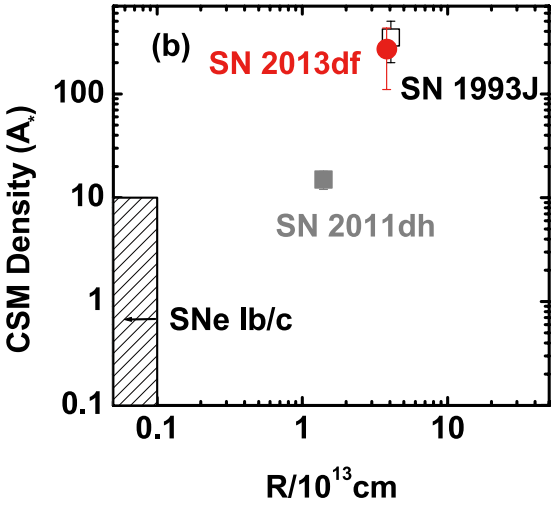


Figure 2: A relation between the progenitor radius and the CSM density (i.e., the mass loss rate) [3].

References

[1] Van Dyk, S. D., et al.: 2014, *AJ*, **147**, 37.
[2] Folatelli, G., et al.: 2015, *ApJ*, **811**, 147.
[3] Maeda, K., et al.: 2015, *ApJ*, **807**, 35.
[4] Maeda, K., et al.: 2014, *ApJ*, **785**, 95.

Deep Impact on Close-in Super-Earths: Atmospheric Escape and Material Mixing

HORI, Yasunori (NAOJ/Astrobiology Center)
LIU, Shangfei (Rice University/LANL)
LIN, Douglas N. C. (University of California, Santa Cruz)
ASPHAUG, Eric (Arizona State University)

A violent collision between two objects is thought to occur repeatedly at the advanced stage of planet formation. In the Solar System, a giant impact is believed to be closely-related to a moon-forming event and the origin of highly-tilting Uranus. Recently, the *Kepler* telescope has revealed that close-in super-Earths, namely 1–10 Earth-mass planets orbiting within 0.1 AU, are common and abundant in the Milky Way. They are likely to have experienced giant impacts as well while migrating inward their host stars via disk-planet interactions. A mass-radius relation for transiting super-Earths suggests that some of them are rocky planets with no atmosphere, whereas super-Earths with thick atmospheres of < 10 wt % exist. Such a diversity of their bulk compositions should reflect formation processes, one of which could be a giant impact.

We performed three-dimensional hydrodynamic simulations of a giant impact between a super-Earth and an Earth-sized planet using Cray XC30 at NAOJ and examined an impact-driven atmospheric loss and a thermal state and material mixing inside a target planet after the impact [1]. Figure 1 shows that snapshots of two giant impact simulations: (top) a low-velocity head-on collision (v_{esc}) on 4.3 $M_\oplus$ and (bottom) a high-velocity one ($3v_{esc}$) on 10 $M_\oplus$. We assumed that each target has a rocky/iron core surrounded by a H/He atmosphere of 7.5 wt % and the projectile is a naked rocky/iron core.

In a high-velocity case, the atmosphere heated by a propagating shock wave expands beyond the Hill radius of a target, and then escapes from it rapidly. A hot and well-mixed interior triggers vigorous convection. On the other hand, a low-velocity collision allows a target to retain a large fraction of its original atmosphere and produce a non-uniform distribution of chemical compositions inside itself, which leads to an inefficient heat transport (e.g. double-diffusive convection). Collisional histories of super-Earths can strongly affect thermal evolution as post-formation processes. Also, giant impact would be one of key factors that cause the diversity of bulk compositions as seen in the mass-radius relation of transiting super-Earths.

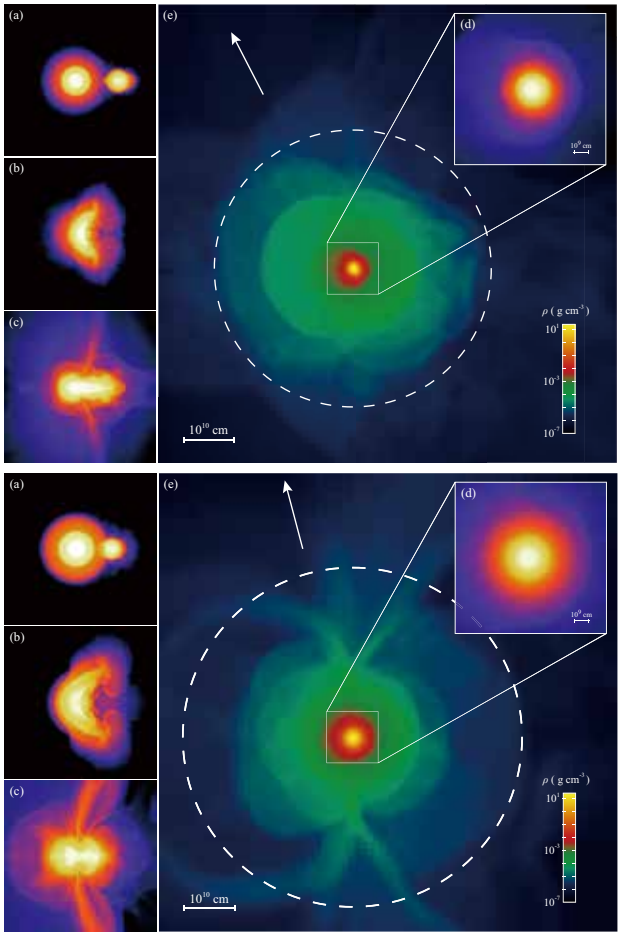


Figure 1: Snapshots of two giant impact simulations on a close-in super-Earth orbiting at 0.1 AU around 1 $M_\oplus$. (Top) a low-velocity collision : the density distribution across slices in the planets' orbital plane (a) before the impact, (b) immediately after, (c) at 1.56 hours, and (d) at 18 hours after the impact. (Bottom) a high-velocity collision : panels (a)–(d) are snapshots taken at the start of the impact, at 15 minutes, at 1.5 hr and at 21.5 hr after the impact, respectively. The dashed circle overplotted on the planet indicates its Hill sphere. The parent star is in the direction of the white arrow.

Reference

[1] Liu, S. -F., Hori, Y., Lin, D. N. C., Asphaug, E.: 2015, *ApJ*, **812**, 164.

M81 Galactic Archaeology with Subaru/Hyper Suprime-Cam

OKAMOTO, Sakurako
(Shanghai Astronocmial Observatory)

ARIMOTO, Nobuo, YAMADA, Yoshihiko
(NAOJ)

FERGUSON, Annette M. N., BERNARD, Edouard J.
(University of Edinburgh)

IRWIN, Mike J.
(University of Cambridge)

UTSUMI, Yousuke
(Hiroshima University)

The currently favored cosmological models are based on the idea of hierarchical structure formation: the structures in the universe such as galaxies develop from small "overdensities" to become large-scale objects [1]. The Milky Way and M81 grew over time via the agglomeration of numerous smaller building blocks, some of which may have survived later mergers to become present-day dwarf satellite galaxies [2]. Over the last decade, a number of new satellite galaxies, stellar streams, and over-densities around the Milky Way and the M31 have been discovered in the large photometric surveys [3]. However, the outskirts of two large spirals are the only places that have been surveyed to sufficiently faint depths to enable detailed tests of hierarchical galaxy assembly process across wide scales.

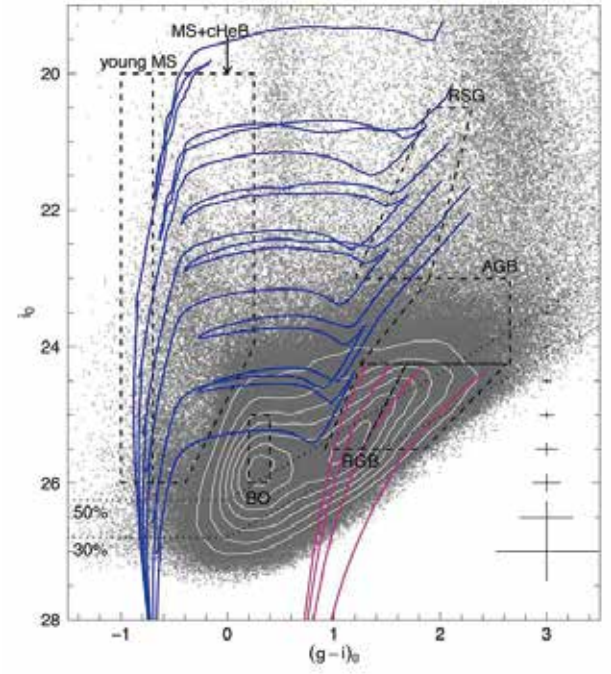


Figure 1: Dereddened CMD of stellar objects. The dashed boxes delineate the selection criteria for different stellar populations and are used to construct the maps of young and old stellar contents presented in Fig. 2.

We are conducting a state-of-the-art wide-field mapping survey of the M81 Group with Hyper Suprime-Cam (HSC) on Subaru. Figure 1 shows the resulting color-magnitude diagram (CMD) of roughly 550,000 dereddend point sources found in the 4 deg^2 area around M81 [4]. Theoretical isochrones are overlaid to aid in understanding the range of stellar populations. The left panel of Figure 2 shows the spatial distribution of stars in young MS and MS+cHeB boxes of Figure 1. Overall distribution of young stars agrees extremely well with those of the HI blobs. Bright stars are mainly located in the inner disk of M81, while most of young stars in the outlying associations are fainter than $i_0 \sim 24$ and have similar luminosity distributions each other, suggesting that star formation in these tidal features was synchronized and may have stopped about 30 Myr ago. The right panel of Figure 2 shows the spatial distribution of RGB stars. A tidal stream between M81 and M82 can clearly be seen, and the outer regions of M82 and NGC 3077 exhibit an S-shaped morphology. The NGC 3077 halo is extended far beyond the R_{25} (r = 2.7′). Numerical modeling suggests the encounters between NGC 3077, M81, and M82 took place ~200–300 Myr ago, which may not leave enough time to restore equilibrium in the NGC 3077 halo. The dwarf galaxies such as IKN and BK5N cannot be seen in the maps of young stars, but appear as overdensities of old populations, implying they have not formed as a result of the recent interaction.

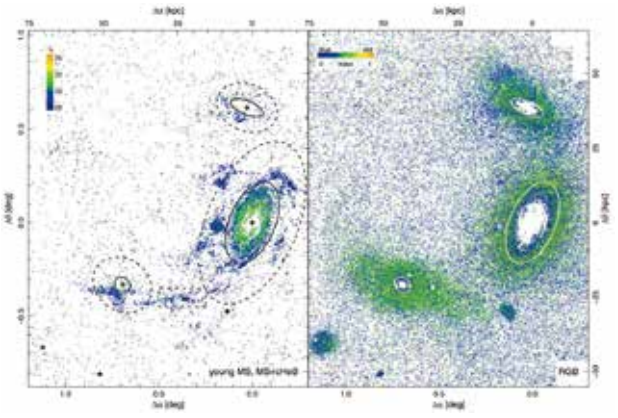


Figure 2: *Left*: The spatial distribution of MS and cHeB stars that are color coded according to the luminosity with transparency. *Right*: The spatial distribution of RGB stars. The color of each point represents the $(g-i)_0$ color of star with transparency. The solid lines are R_{25} radii of galaxies.

References

[1] White, S., Frenk, C.: 1991, *ApJ*, **379**, 52.
[2] Mihos, J., et al.: 2005, *ApJ*, **631**, L41.
[3] Willman, B., et al.: 2005, *ApJ*, **626**, 85.
[4] Okamoto, S., et al.: 2015, *ApJ*, **809**, L1.

A New Multi-Energy Neutrino Radiation-Hydrodynamics Code in Full General Relativity and Its Application to Gravitational Collapse of Massive Stars

KURODA, Takami
(University of Basel)

TAKIWAKI, Tomoya, KOTAKE, Kei
(NAOJ)

Gravitational collapse of massive stars initiate supernovae that are one of the most bright objects in the universe. The mechanism of core-collapse supernovae is not clarified yet though the steady progress of supernova simulations. We explain two reasons. (i) Supernovae are not reproduced in a simple numerical setup. (ii) The ultimate simulations that employ all required physical ingredient, have not been performed although we sometimes observe explosions in the simulations under a relatively realistic situations.

An huge energy of 10^{53} ergs is released when an iron core of a massive star collapses and become a neutron star. A portion of the energy is used to push a shock wave that are generated at that time and propagates from the center to the outer region. The shock experience strong cooling via the process of photo-dissociation of iron, that is inverse process of the nuclear fusion. An important lesson of one dimensional (1D) spherically symmetric simulations is that the shock stalls at 150 km due to the cooling process [1].

Recently two dimensional (2D) or three dimensional (3D) simulations are performed thanks to the development of super-computers [2]. In this setup, we can employ effect of convection: some matters go upward while the others go downward. We observe shock revivals in the setup since the convection promotes neutrino heating process. While the neutrino takes the thermal energy away in the vicinity of the neutron stars, that gives thermal energy to the matter in outer region. The convection efficiently conveys the thermal energy given by the neutrino heating to the vicinity of the shock where the energy is required to revive the shock. The convection relaxes the condition of the neutrino luminosity required to the shock revival by 30–50 %.

The next problem arises. How reliable are such multi-dimensional simulations? Unfortunately the results of the simulation strongly depends on their input physics. Different groups show different results even if they use same progenitor models. To solve the problem, we should construct ultimate models which employ all physical knowledge we have. For the purpose, we developed a new code that solve multi-group neutrino transport under fully general relativistic framework [3].

In Fig. 1, we compare our new methods with the previous work. We evaluate the methods with 4 axises. Left top is dimensionality of hydrodynamics and right top is schemes employed to solve the radiation-hydrodynamics. Right bottom is sophistication level of micro-physics i.e. the number of neutrino reactions considered in the simulation. Left bottom is treatment of the gravity. Our new code (red) [3] takes high score in the diagram compared to the previous works [1,2]. We can obtain most reliable results with the new code.

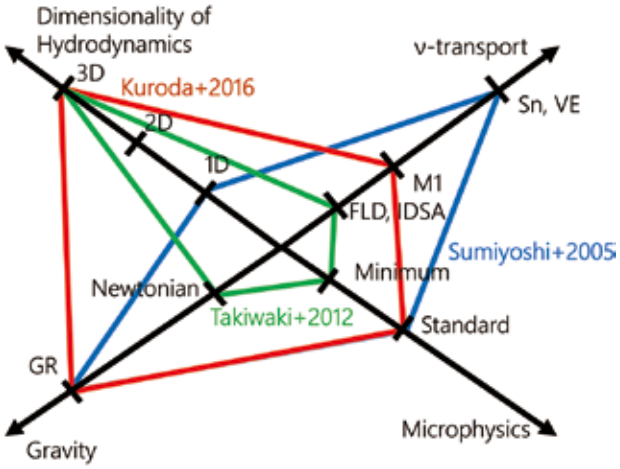


Figure 1: Comparison of the method used in supernova simulations.

References

[1] Sumiyoshi, K., Yamada, S., Suzuki, H., et al.: 2005, *ApJ*, **629**, 922.
[2] Takiwaki, T., Kotake, K., Suwa, Y.: 2012, *ApJ*, **749**, 98.
[3] Kuroda, T., Takiwaki, T., Kotake, K.: 2016, *ApJS*, **222**, 20.

Multi-wavelength Observations of the Black Widow Pulsar 2FGL J2339.6–0532 with OISTER and Suzaku

YATSU, Y. (Tokyo Institute of Technology)
KATAOKA, J., TAKAHASHI, Y. (Waseda University)
TACHIBANA, Y., KAWAI, N. (Tokyo Institute of Technology)
SHIBATA, S. (Yamagata University)
PIKE, S. (Brown University)
YOSHII, T., ARIMOTO, M., SAITO, Y. (Tokyo Institute of Technology)
NAKAMORI, T. (Yamagata University)
SEKIGUCHI, K. (NAOJ)
on behalf of OISTER team

A millisecond pulsar (MSP) is believed to evolve from a dead pulsar in a binary system via mass accretion from a companion star that has spun up the pulsar for billions of years. Indeed, most MSPs are discovered in binary systems; however, isolated MSPs also exist. The missing link between the isolated MSPs and binary MSPs is black widow pulsars in which a sufficiently spun up pulsar is evaporating its companion with its powerful pulsar wind. In this study we focus on the newly found black widow pulsar 2 FGL J2339.6$-$0532 discovered by the Fermi gamma-ray observatory to clarify the intermediate stage between the accretion-driven phase and the rotation-powered phase utilizing optical and X-ray telescopes.

In optical we utilized the *Optical and Infrared Synergetic Telescopes for Education and Research: OISTER* for covering wide wave band from K_S to B-band and the entire orbital motion. The target was observed from 22 Sep to Oct 7 2011 with 14 telescopes. The resultant light curves folded with the orbital period of 4.63 hr are shown in Fig. 1—Left. Fig. 1—Right shows the SED at various orbital phases, indicating that the surface temperature varies from 3200 K to 8000 K coincident with the orbital motion. Assuming a simple geometry, we constrained the range of the inclination angle of the binary system to $50° < i < 59°$, which enables us to discuss the interaction between the pulsar wind and the companion in detail.

In X-rays the target was observed with the Suzaku X-ray observatory for 96 ks. The obtained X-ray spectrum was well fitted with a two component model function consists of a black body with a temperature of T_{BB} 0.15 ± 0.06 keV and a power law function with a photon index of $\Gamma = 1.14^{+0.14}_{-0.15}$. Fig. 2 shows X-ray light curves as functions of orbital phase for 3 energy bands. In low energy band below 1 keV, the intensity of the target seems uniform. Taking into account the size of black body emitter of $R \sim$ 0.28 km, the soft and steady component can be originated in the surface of pulsar. While in the Hard X-rays, the intensity shows periodic variation synchronized with the optical light curves, indicating that the hard X-rays are from the shocked pulsar wind covering the companion surface rather than the pulsar itself. Assuming a thin emitting region covering the companion, we constrained the magnetization parameter to $\sigma < 0.1$. This result means that the pulsar wind from the central MSP is already in the particle-dominant stage at 10^{11} cm from the pulsar. This may critically constrain the acceleration mechanism of the pulsar wind.

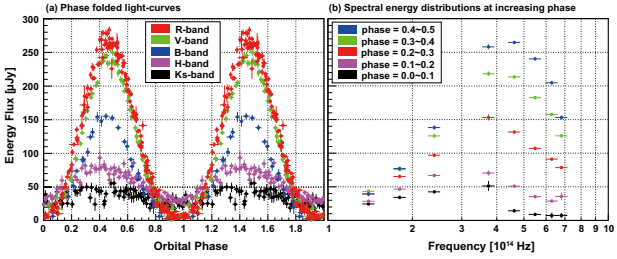


Figure 1: Left—Multi-color light curves from K_S to B-band. Right—SEDs for various orbital phases.

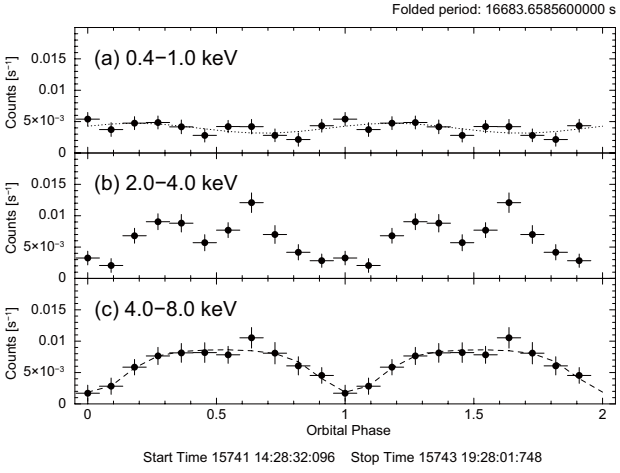


Figure 2: X-ray light curves at various energy band.

Reference

[1] Yatsu, Y., Kataoka, J., Takahashi, Y., et al.: 2015, *ApJ*, **802**, 84.

Outer Rotation Curve of the Galaxy with VERA III: Astrometry of IRAS 07427+2400 and Test of the Density-wave Theory

SAKAI, Nobuyuki[1], NAKANISHI, Hiroyuki[2], MATSUO, Mitsuhiro[2], KOIDE, Nagito[2], TEZUKA, Daisuke[2]
KURAYAMA, Tomoharu[3], SHIBATA, Katsunori M.[1], UENO, Yuji[1], HONMA, Mareki[1]

1: NAOJ, 2: Kagoshima University, 3: Teikyo University of Science

Spiral arm is the most prominent structure in disk galaxies. However, the origin and evolution are still unknown. Since the 1960s theoretical and observational studies about the spiral arm have been conducted and "the density-wave theory" and "the dynamical spiral theory" were proposed. In the deinsity-wave theory, the spiral arm regarded as quasi steady structure (static external potential) is incorporated into a basic equation of stellar disk or gas disk, and one can explore the dynamical evolution of the disk. On the other hand, the dynamical spiral theory has been proposed based on a N-body simulation in which the spiral arm is destroyed and regenerated within several rotational periods.

A big issue on the spiral arm research is that there have been no observational data which can be compared with the theories. Since the 2000s astrometry observations (obtaining 6D kinematic information) by VLBI technology have been conducted on the Milky Way scale (~20 kpc). Especially for the Perseus arm as solar neighborhood arm, the Galactic shock predicted from the deinsity-wave theory has been observed in the arm. (e.g. Sakai et al. 2012 [1]). We aimed to do astrometry observation toward the infrared source IRAS 07427+2400 associated with the Perseus arm and to verify analytic solution based on the density-wave theory (Piñol-Ferrer et al. 2012 [2]) by combining previous VLBI results.

We conducted VLBI astrometry observations with VERA and measured a trigonometric parallax of 0.185 ± 0.027 mas for IRAS 07427+2400. Combined with previous VLBI results (total 27 sources), we compared those with the dynamical model. As a result, we succeeded to make a spiral potential model which can reproduce observed non-circular motions (= observables − circular motion model[1])(**Fig. 1**). In Fig. 1 gas orbit model (••) is also represented and we can see an offset between crowded gas orbits and the bottom of the spiral potential model.

Given that a dominant component in a galactic disk is star, fig. 1 suggests an offset between star and gas distributions. In external disk galaxies, it has been reported that galactic (spiral) morphology varies at different observing wavelengths (Griv et al. 2015 [3]). Recent N-body/hydrodynamic simulation has showed the "offset" described above (Baba et al. 2015 [4]).

In Autumun of 2016 stellar astrometry results will be provided by the Gaia satellite. It is expected to understand spiral arm physics in detail by directly confirming the "offset".

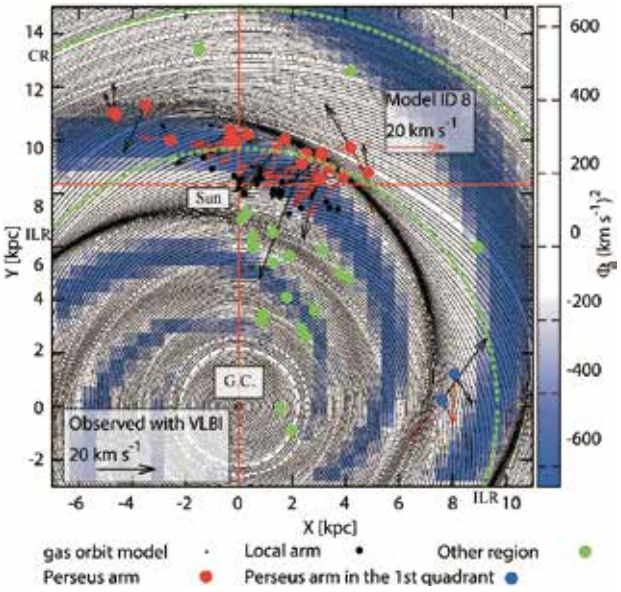


Figure 1: Sakai et al. (2015) [5]. Astrometry results for the Perseus arm (27 sources) and comparison with the dynamical model of the gas disk (Piñol-Ferrer et al. 2012). Blue denotes the bottom of the spiral potential model, which deviates from crowded gas regions.

References

[1] Sakai, N., et al.: 2012, *PASJ*, **64**, 108.
[2] Piñol-Ferrer, N., Lindblad, P. O., Fathi, K.: 2012, *MNRAS*, **421**, 1089.
[3] Griv, E., et al.: 2015, *MNRAS*, **453**, 1981.
[4] Baba, J., Morokuma-Matsui, K., Egusa, F.: 2015, *PASJ*, **67**, L4.
[5] Sakai, N., et al.: 2015, *PASJ*, **67**, 69.

[1] For a circular motion model, a flat rotation curve was assumed with $\Theta(R) = 240\,\mathrm{km\,s^{-1}}$.}

Optical and Near-Infrared Polarimetry for a Highly Dormant Comet 209P/LINEAR

KURODA, Daisuke[1], ISHIGURO, Masateru[2], WATANABE, Makoto[3], AKITAYA, Hiroshi[4], TAKAHASHI, Jun[5]
HASEGAWA, Sunao[6], UI, Takahiro[4], KANDA, Yuka[4], TAKAKI, Katsutoshi[4], Itoh, Ryosuke[4], MORITANI, Yuki[4/7]
IMAI, Masataka[3], GODA, Shuhei[3], TAKAGI, Yuhei[5], MORIHANA, Kumiko[5], HONDA, Satoshi[5], ARAI, Akira[5/8]
HANAYAMA, Hidekazu[1], NAGAYAMA, Takahiro[9], NOGAMI, Daisaku[10], SARUGAKU, Yuki[7], MURATA, Katsuhiro[11]
MOROKUMA, Tomoki[7], SAITO, Yoshihiko[12], OASA, Yumiko[13], SEKIGUCHI, Kazuhiro[1], WATANABE, Jun-ichi[1]

1: NAOJ, 2: Seoul National University, 3: Hokkaido University, 4: Hiroshima University, 5: University of Hyogo, 6: JAXA, 7: The University of Tokyo, 8: Kyoto Sangyo University, 9: Kagoshima University, 10: Kyoto University, 11: Nagoya University, 12: Tokyo Institute of Technology, 13: Saitama University

The linear polarization of light scattered by airless solar system objects (i.e. comets and asteroids) is a useful tool for investigating the physical properties of their surfaces. The phase-polarization curves display a common behaviour, having a negative polarization branch at $0 < \alpha \leq 20°$, positive branch at $\alpha \geq 20°$ and maximum polarization around $\alpha = 90°–100°$, where α denotes the solar phase angle (i.e. Sun-object-observer's angle). The phase-polarization curves of asteroids, usually observed in the main-belt at a low phase angle ($\alpha < 30°$), provide information about composition (i.e. taxonomic type), optical properties, porosity of the surface regolith layers, and so on (see [1,2,3]). In contrast, comets, which are usually enclosed in a dust coma plus gas contamination, have been observed with polarimeters at a wide range of phase angles, providing the composition, size and structure (fluffy or compact) of dust grains in comae [4,5].

Although several near-Earth asteroids and active comets were observed at large phase angles, little is known about the polarimetric properties of bare comet nuclei at large phase angles. Whenever comets are observed at large phase angles (i.e. $\alpha > 90°$), their nuclei are supposed to shrouded in thick cometary comae, because comets are located within 1 AU in the geometry where they are heated up, creating outflow of dust particles and sublimating ice.

In this work [6], we attempted to obtain unique data of the linear polarization degree, P, for a bare cometary nucleus as well as dust particles of the highly dormant Jupiter-Family Comet, 209P/LINEAR (hereafter 209P). Optical and near-infrared polarimetric observations of 209P were conducted for five nights in 2014 April-May using two telescopes: the Hiroshima Optical and Near-InfraRed camera (HONIR) on the 1.5-m Kanata telescope at the Higashi-Hiroshima Astronomical Observatory, Hiroshima, and the visible Multi-Spectral Imager (MSI) on the 1.6-m Pirka telescope at Hokkaido University's Nayoro Observatory in Hokkaido, Japan.

Our results suggested that no significant difference was found in R_c- and J-band. Because of its low activity, we were able to determine the linear polarization degrees of the coma dust particles and nucleus independently, that is $P_n = 30.3^{+1.3}_{-0.9}$ % at $\alpha = 92.2°$ and $P_n = 31.0^{+1.0}_{-0.7}$ % at $\alpha = 99.5°$ for the nucleus, and $P_c = 28.8^{+0.4}_{-0.4}$ % at $\alpha = 92.2°$ and $29.6^{+0.3}_{-0.3}$ % at $\alpha = 99.5°$ for the coma. By fitting with the Lumme and Muinonen function [7,8], we deduced the maximum polarization Pmax = 30.8 % (nucleus) and 29.6 % (coma), respectively.

High $P_{\max}$ value of the dust coma is consistent with a polarization classification scheme described by [9]. We employed an empirical function for relating $P_{\max}$ of the nucleus to the albedo [10] , and found that we obtained a good estimate of the albedo when we assumed the effective size of the regolith particles of ≈1–100 μm.

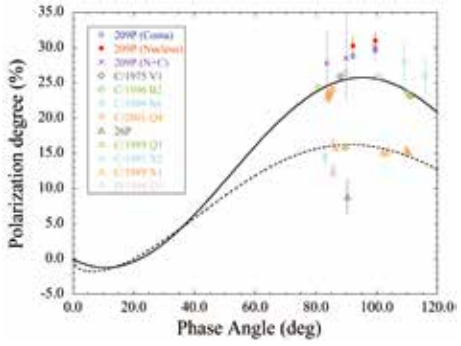


Figure 1: Phase angle dependence of polarization for 209P nucleus (filled circles) and coma (open circles) taken with MSI. Regarding data taken with HONIR (indicated by crosses), we adopted blended signals of nucleus and coma with relatively large aperture (3 × FWHM) due to inadequate tracking of the telescope. For comparison, we show polarization degrees of other comets in the R-band region (about 650 ± 50 nm), which are mostly attributed to light scattered by dust particles in comae. Two fit lines with the Lumme and Muinonen function [7,8], high $P_{\max}$ (solid line and open diamonds) and low $P_{\max}$ (dashed line and open triangles) comprise the PDS archive [11].

References

[1] Dollfus, A., et al.: 1989, Asteroids II, 594.
[2] Shkuratov, Yu., et al.: 2002, *Icarus*, **159**, 396.
[3] Gil-Hutton, R., et al.: 2014, *A&A*, **569**, A122.
[4] Zubko, E., et al.: 2011, J. *Quant. Spectrosc. Radiat. Transfer*, **112**, 1848.
[5] Kolokolova, L., et al.: 2007, *A&A*, **463**, 1189.
[6] Kuroda, D., et al.: 2015, *ApJ*, **814**, 156.
[7] Goidet-Devel, B., et al.: 1995, *Planet. Space Sci.*, **43**, 779.
[8] Penttilä, A., et al.: 2005, *A&A*, **432**, 1081.
[9] Levasseur-Regourd, A. C., et al.: 1996, *A&A*, **313**, 327.
[10] Dollfus, A.: 1998, *Icarus*, **136**, 69.
[11] Kiselev, N., et al.: 2006, *NASA PDS*.

Mapping Dark Matter by HSC via Weak Lensing

MIYAZAKI, Satoshi[1/2], OGURI Masamune[3], HAMANA, Takashi[1], TANAKA, Masayuki[1], MILLER, Lance[4]
UTSUMI, Yousuke[5], KOMIYAMA, Yutaka[1], FURUSAWA, Hisanori[1], SAKURAI, Junya[2/1]
KAWANOMOTO, Satoshi[1], NAKATA, Fumiaki[1], URAGUCHI, Fumihiro[1], KOIKE, Michitaro[1]
TOMONO, Daigo[1], LUPTON, Robert[6], GUNN, James[6], KAROJI, Hiroshi[7], AIHARA, Hiroaki[3]
MURAYAMA, Hitoshi[3], TAKADA, Masahiro[3]

1: NAOJ, 2: SOKENDAI, 3: University of Tokyo, 4: Oxford University, 5: Hiroshima University, 6: Princeton University, 7: NINS

Since the first discovery in 2001, 'Cosmic Shear: weak lensing by Large Scale Structure (LSS)' has become a standard tool to examine the LSS and its evolution. Because sparse sampling of background galaxies is sufficient (5 to 10 galaxies/arcmin^2), observation of relatively large and bright galaxies are only required. Thus, it is regarded as one of the most promising tool to probe the growth rate. However, because the observation does not directly map LSS, the discrimination of the signal from noise is not so straightforward.

Clusters of galaxies, on the other hand, is a classical probe of the growth rate but the key is how to sample clusters and measure the mass. Weak lensing could be potentially powerful again here but observation ally more demanding. In order to locate the dark matter concentration directly via lensing, sufficiently higher resolution mass map is crucial which requires high number density of faint background galaxies. Suprime-Cam has been one of the ideal facility instruments because it features unique combination of the large aperture and the sharp imaging which enables precise measurement of faint galaxies. Hyper Suprime-Cam (HSC) is developed to make the survey speed even faster and to realize a very wide survey (> 1000 deg^2).

HSC saw the first light in January 2013 and engineering observations followed. After the initial round of adjustments we obtained the scientific images on two contiguous HSC fields. The figure on the right shows the dark matter map reconstructed from the shapes of 220,000 galaxies over the field using weak lensing technique. The density reflects the strength of lensing signal. The locations of significant peaks on the map (signal-to-noise ratio > 4.5) are marked by circles where we expect the existence of dark matter concentrations.

We could also expect that galaxies are attracted by the dark matter gravity and these concentration would be recognized as clusters of galaxies. This expectation is indeed verified by the cross-correlation of the peaks on the mass map and clusters identified by multi-color images where color sequences of member galaxies are searched using CAMIRA algorithm. We confirmed that all the significant peaks accompany clusters of galaxies. This suggests the reliability of the mass map.

We are able to estimate the redshift to the dark matter concentration using the colors of associated galaxies. On the histogram inserted at the lower-right corner of the figure, we show the redshift distribution of the clusters. Two spikes are clearly visible which should stem from LSS accidentally located along the line of sight. This clearly suggests that we would have to observe much much wide field so that the local structures are averaged to obtain useful cosmological information.

This is exactly what we are working on right now. We started a wide field observation campaigns in March, 2014 as one of the Subaru Strategic Program in collaboration with more than 200 CoIs. We plan to cover 1400 deg^2 and it would take about five years to complete. Our primary objective of the survey is to test the currently standard ΛCDM with unprecedented precision. In particular, we are interested in whether modification of the Einstein's gravity theory is necessary because weak lensing technique, among other techniques such as SNIa and BAO, uniquely probes the effect of gravity. We will certainly measure the cosmic shear as other lensing survey projects do. In addition, using the same data, we will be able to detect more dark matter concentrations which, we expect, enables us to make a unique contribution to observational cosmology.

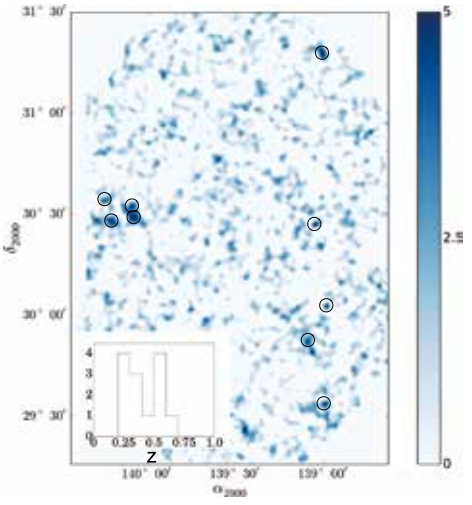


Figure 1: Weak lensing mass map (contour). Peak positions are designated by circle where dark matter halos are located. Histogram shows the redshift distribution of the halos estimated by the color of associated galaxies to these halos.

References

[1] http://www.subarutelescope.org/Projects/HSC/j_index.html
[2] Miyazaki, S., Oguri, M., Hamana, T., et al.: 2015, *ApJ*, **807**, 22.

The Host Galaxy of a Fast Radio Burst FRB150418

KEANE, E. F.[1/2/3], JOHNSTON, S.[4], BHANDARI, S.[2/3], BARR, E.[2], BHAT, N. D. R.[3/5], BURGAY, M.[6]
CALEB, M.[2/3/7], FLYNN, C.[2/3], JAMESON, A.[2/3], KRAMER, M.[8/9], PETROFF, E.[2/3/4], POSSENTI, A.[6]
VAN STRATEN, W.[2], BAILES, M.[2/3], BURKE-SPOLAOR, S.[10], EATOUGH, R. P.[8], STAPPERS, B. W.[9]
TOTANI, T.[11], HONMA, M.[12/13], FURUSAWA, H.[12], HATTORI, T.[14], MOROKUMA, T.[11], NIINO, Y.[12]
SUGAI, H. [11], TERAI, T.[14], TOMINAGA, N.[11/15], YAMASAKI, S.[11], YASUDA, N.[11], ALLEN, R.[2], COOKE, J.[2/3]
JENCSON, J.[16], KASLIWAL, M. M.[16], KAPLAN, D. L.[17], TINGAY, S. J.[3/5], WILLIAMS, A.[5], WAYTH, R.[3/5]
CHANDRA, P.[18], PERRODIN, D.[6], BEREZINA, M.[8], MICKALIGER, M.[9], BASSA, C.[19]

1: SKA Organisation, 2: Swinburne University of Technology, 3: CAASTRO, 4: CSIRO, 5: Curtin University, 6: INAF, 7: Australian National University, 8: MPIfR, 9: University of Manchester, 10: NRAO, 11: University of Tokyo, 12: NAOJ, 13: SOKENDAI, 14: Subaru Telescope, 15. Konan University, 16: California Institute of Technology, 17: University of Wisconsin-Milwaukee, 18: Tata Institute of Fundamental Research, 19: ASTRON

Fast Radio Burst (FRB) is a short radio burst lasting only 1 msec observed at GHz band. The nature of FRB is still mystery and various models are proposed ranging from a radio interference from the Earth to a burst of an astronomical object at a cosmological distance. FRBs show a large dispersion along the frequency, and its plausible interpretation is that the radio burst originates from a cosmological explosive event, and it is observed after long-distance travel through the inter-galactic plasma. However, there has been no detection of the host galaxy of any FRB or its redshift measurement.

FRB150418, detected on 18 April 2015, was first discovered with the Parkes telescope multi-beam receivers, and follow-up observations with ATCA detected a compact, variable radio source in one of the Parkes beams. The source has rapidly faded within 1 week after the burst, and showed larger flux variation in lower frequency, indicating that the source has a different nature from radio AGN and is most likely a radio afterglow of the FRB. The optical follow-up with the Subaru telescope detected an elliptical galaxy at the position of the radio afterglow, and the redshift measurement with Subaru revealed that the host has a redshift of 0.492. This is the first detection of the FRB host galaxy and its redshift. The host galaxy is an elliptical galaxy with little sign of star formation, which provides a strong constraint on the possible origin of the FRB. Meanwhile, the redshift is consistent with the expectation from the standard cosmology with missing baryons in the form of inter-galactic plasma, confirming that a large fraction of missing-baryon is in the inter-galactic medium.

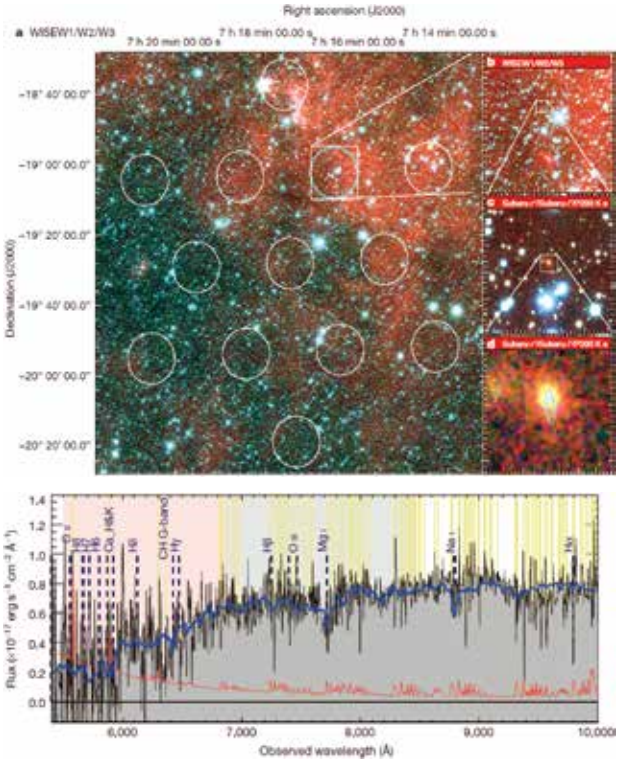


Figure 1: Upper-images: An optical image of the Parkes multi-beam fields (circles), with the zoom-up images on the right showing the FRB-host elliptical galaxy discovered with Subaru. Bottom-panel: The spectrum of the elliptical galaxy taken with Subaru, which matches well with the template of an elliptical galaxy at a redshift of 0.492.

Reference

[1] Keane, E., et al.: 2016, *Nature*, **539**, 453.

Mangetic Field Structure Near the Event Horizon of Sgr A*

JOHNSON, M. D.[1], FISH, V. L.[2], DOELEMAN, S. S.[1/2], MARRONE, D. P.[3], PLAMBECK, R. L.[4]
WARDLE, J. F. C.[5], AKIYAMA, K.[2/6/7], ASADA, K.[8], BEAUDOIN, C.[2], BLACKBURN, L.[1], BLUNDELL, R.[1]
BOWER, G. C.[8], BRINKERINK, C.[9], BRODERICK, A. E.[10/11], CAPPALLO, R.[2], CHAEL, A. A.[1], CREW, G. B.[2]
DEXTER, J.[12], DEXTER, M.[4], FREUND, R.[3], FRIBERG, P.[13], GOLD, R.[14], GURWELL, M. A.[1], HO, P. T. P.[8]
HONMA, M.[6/15], INOUE, M.[8], KOSOWSKY, M.[1/2/5], KRICHBAUM, T. P.[16], LAMB, J.[17], LOEB, A.[1], LU, R.[2/16]
MACMAHON, D.[4], MCKINNEY, J. C.[14], MORAN, J. M.[1], NARAYAN, R.[1], PRIMIANI, R. A.[1], PSALTIS, D.[3]
ROGERS, A. E. E.[2], ROSENFELD, K.[1], SOOHOO, J.[2], TILANUS, R. P. J.[9/18], TITUS, M.[2]
VERTATSCHITSCH, L.[1], WEINTROUB, J.[1], WRIGHT, M.[4], YOUNG, K. H.[1], ZENSUS, J. A.[16], ZIURYS, L. M.[3]

1: Harvard-Smithsonian CfA, 2: MIT Haystack Observatory, 3: Steward Observatory, 4: UC Berkeley, 5: Brandeis U., 6: NAOJ, 7: U. Tokyo, 8: ASIAA, 9: Radboud U., 10: Perimeter Institute, 11. U. Waterloo, 12: MPE, 13: JCMT, 14: Maryland U., 15: SOKENDAI, 16: MPIfR, 17: OVRO, 18: Leiden Observatory

It is widely believed that the magnetic field plays an important role in the Active Galactic Nuclei through the accretion process as well as jet formation. However, to date there has been no direct confirmation of existence of magnetic field around the event horizon scale of super-massive black holes. In order to study the detailed physical properties of the vicinity of super-massive black holes, we have observed Sgr A*, the super-massive black hole at the Galactic center, with a 1-mm VLBI array in the US. The array consists of four telescopes at three stations, namely, CARMA in California, SMT in Arizona and SMA/JCMT in Hawaii, and has the maximum baseline of ~4000 km.

We have detected for the first time the linear polarization from the emission at a scale of ~6 black hole radii (Figure 1). The data indicate that the magnetic field structure is partially ordered as seen in Figure 2. The figure shows the relation of the polarization fraction against the visibility amplitude, and images A–D corresponds to models with various magnetic field structures. Model B matches well with the observations, and Model D, which is based on the GRMHD simulation, is also consistent with the observations. The first detection of magnetic field around the black hole certifies that the forthcoming observations of super-massive black holes with EHT (Event Horizon Telescope) will enable us to better understand the physical properties in the vicinity of the super-massive black holes.

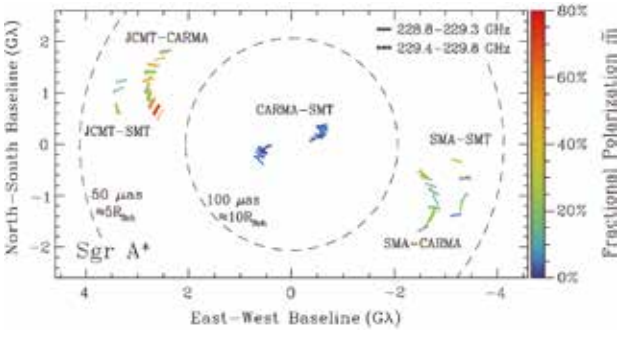


Figure 1: Fractional polarization and polarization angle of Sgr A* along the baselines. The direction of lines shows the polarization angle and the color shows the fractional polarization.

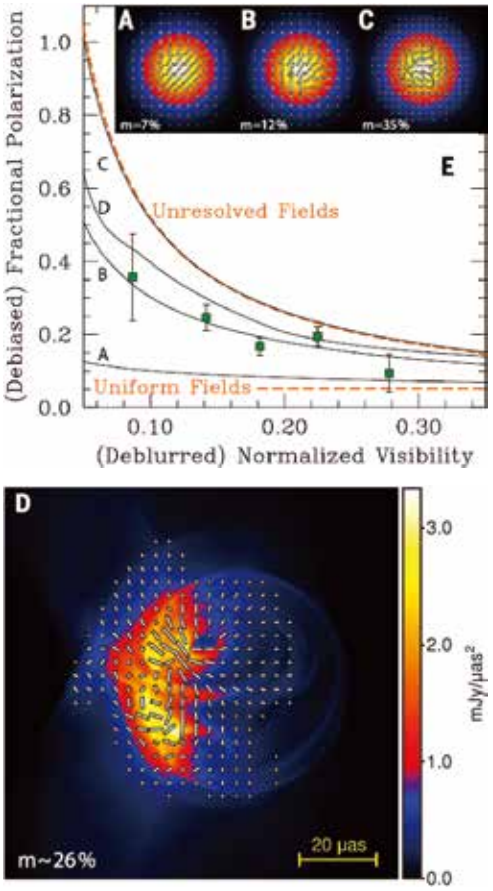


Figure 2: Relation with the polarization fraction and the visibility amplitude (top). Images A–D show models with various structure of magnetif field. Model B well matches with the observations, and model D, which is based on the GRMHD simulation is also consistent with the observations.

Reference

[1] Johnson., M. et al.: 2016, *Science*, **350**, 1242.

II Status Reports of Research Activities

1. Subaru Telescope

1. Subaru Telescope Staff

As of the end of FY 2015, the Subaru Telescope Project staff consisted of 18 dedicated faculty members (five of whom are stationed at Mitaka), five engineers, and three administrative staff members. Additional staff members include two specially appointed research staff, three specially appointed senior specialists, five research experts, and six administration associates, all of whom are stationed at Mitaka. Moreover, 13 research/teaching staff members, 12 of whom are stationed at Mitaka and one of whom is stationed at Pasadena; and three engineers, two of whom are stationed at Mitaka and one of whom is stationed at Nobeyama are posted concurrently. The project also has 79 local staff members dispatched from the Research Corporation of the University of Hawaii (RCUH), including scientific assistants; engineers in charge of software and observational instruments; technicians for facilities, machinery, vehicles, and laboratories; telescope/instrument operators; secretaries; librarians; administrative staff; researchers employed for Grant-in-Aid for Scientific Research; and graduate students. These staff members work together in operating the telescope, observational instruments, and observational facilities; and in conducting open-use observations, R&D, public outreach, and educational activities.

2. Science Highlights

In FY 2015, Subaru Telescope produced many outstanding scientific outcomes which were published in major international journals. Below are some examples:

(1) Deep NIR spectroscopy of 24 quiescent galaxies at around $z = 1.6$ (9.5 billion years ago) with MOIRCS provides us with a precise composite spectrum. By comparing it with a spectral synthesis model, it is found that the average stellar age in these galaxies is very old (1.5 billion years) and the duration of star formation is very short (<1 billion years). We are thus likely to be witnessing the progenitors of present-day elliptical galaxies.

(2) Super wide-field imaging of nearby spiral galaxy M81 and its two interacting companion galaxies with Hyper Suprime-Cam (HSC) has revealed that the young main-sequence stars in these galaxies nicely follow the neutral hydrogen gas distribution which bridges the multiple interacting galaxies. This suggests that the gas is tidally stripped due to interactions and the new stars are formed in the gas during the course of the hierarchical assembly and mergers of galaxies.

(3) High contrast camera HiCIAO, combined with the adaptive optics system which corrects for atmospheric disturbance in astronomical images, has been conducting high resolution imaging of circum-stellar disks around young stars. A circular gap at only 20 AU away from the central star is newly discovered. Together with another known outer gap already found by HST, this disk turns out to have a double ring gap structure. This suggests that multiple (two) planets are being formed simultaneously, and it gives us a new insight into the formation of planets in the proto-planetary disks.

(4) High Dispersion Spectrograph (HDS) targeted 50 solar-type stars with a "super-flare" event, a gigantic explosion at the surface of the star. The spectra have confirmed that (1) those stars are single systems, (2) spin velocities derived from the line widths match the periods of their light curves, and that (3) a shallow absorption line profile is seen as evidence of a strong magnetic field. These results all suggest that the appearance of a giant black spot on the stellar surface leads to the launch of a super-flare.

3. Open Use

The Subaru open use call for proposals is issued every six months. The periods are from February 1 to July 31 (S15A) and from August 1 to January 31 (S15B). The Mitaka office of the Subaru Telescope at the National Astronomical Observatory of Japan (NAOJ) campus accepts submitted proposals. The Subaru Time Allocation Committee, established under the NAOJ advisory committee for optical and infrared astronomy, selects accepted proposals, based on the evaluation and comments of referees. In S15A, 64 programs (102 nights) were accepted out of 162 submitted proposals, requesting 427 nights in total. In S15B, 57 proposals (97 nights) were accepted out of 161 submitted proposals, requesting 372.5 nights in total. Short duration service observations were also conducted. In S15A and S15B, 5 and 2 accepted open-use proposals were by foreign principal investigators, excluding University of Hawai`i observing time. The number of applicants in submitted proposals was 2083 for Japanese researchers (Japanese astronomers at any institute and non-Japanese astronomers belonging to Japanese institutes) and 748 for foreign researchers. The number of researchers in accepted proposals was 899 for Japanese astronomers and 274 for foreign astronomers.

In S15A and S15B, the number of open-use visiting observers was 343, of which 58 were foreign astronomers. 69 astronomers observed remotely from Mitaka. The Mitaka office of the Subaru Telescope takes care of proposal handling and evaluation, and travel procedures for observers and their travel support. The Hilo office makes the observing schedule and supports the accommodation and transportation of visiting observers in Hawai`i. In S15A and S15B, 95.7 % of the open-

use time (including University of Hawai`i time) was used for actual astronomical observations, after excluding weather factor and scheduled maintenance downtime. About 1.5 %, 0.3 %, and 2.5 % of observing time was lost due to instrument trouble, communication trouble, and telescope trouble, respectively.

In S15A and S15B, remote observations from Hilo were not conducted. However, remote observations from Mitaka, where observers in Mitaka can participate in observations remotely, in addition to on-site observers at the summit, were conducted for 24 programs with 47 nights. Service observations were made for 12 nights. To make the best use of limited resources at observatories on top of Maunakea, Subaru Telescope has been exchanging telescope time with W. M. Keck Observatory and Gemini Observatory. The number of time exchange nights between Subaru Telescope and Keck was 3 in S15A and 6 in S15B. That between Subaru Telescope and Gemini was 5 in S15A and 3 in S15B.

4. Telescope Maintenance and Performance Improvement

During scheduled maintenance work on the telescope and the enclosure on February 22, the optical-side mirror hatch got stuck. The mirror hatch was restored to its normal position as of February 27, then the open-use observations were resumed on February 29. The mirror hatch is not operational at the time of writing this text. Because normal performance of the mirror hatch is required for the primary mirror recoating work in the next year, we are considering making some repair plans.

Other general functions and capabilities of the Subaru Telescope are continuing to be maintained the same as the previous year.

This year, both the dome angle and the top screen position barcodes and these controllers were renovated. A laser distance meter was installed on the top unit exchanger (TUE) to improve the accuracy and reliability. Some acceleration measurements on the telescope were carried out for better understanding the telescope tracking performance. In addition, while promoting improvements in performance and operational efficiency of the Subaru Telescope, renovation was conducted on the telescope control units, which were installed more than 10 years ago. The local control units that were renovated or modified in this year were: the dome control unit (DCU), the dome rotation processor unit (DRPU), and the telescope control workstations (TWS).

The major causes of the telescope failures is considered to be aging, human error, and adverse weather. This year included a small amount glycol leakage, wind screen malfunction, dropping of the dome lateral guide roller (LGR), breakdown of the lower mirror cover, malfunction of the upper mirror cover, trouble in the Cassegrain-optical secondary mirror unit, top screen malfunction, failure of the 80-ton crane control, uninterruptible power supply (UPS) glitch, and the mirror hatch incident. Bad weather caused a malfunction of the dome shutter and the elevation axis angle sensors, forcing observations to be canceled. A small earthquake occurred, although there was no significant damage observed. Some dips and cracks on the dome rail were found. These dips and cracks should be repaired in the near future.

Additionally, the same as the previous year, we used the telescope status log for the preventive maintenance of the telescope and the enclosure.

5. Instrumentation

The nine open-use facility instruments of Subaru Telescope have been operated stably in FY 2015. Those instruments are Hyper Suprime-Cam (HSC), Subaru Prime Focus Camera (Suprime-Cam), Faint Object Camera And Spectrograph (FOCAS), High Dispersion Spectrograph (HDS), Infrared Camera and Spectrograph (IRCS), Cooled Mid-infrared Camera and Spectrograph (COMICS), Multi-Object Infrared Camera and Spectrograph (MOIRCS), Fiber Multi-Object Spectrograph (FMOS), and 188-elements Adaptive Optics and Laser Guide Star system (AO188/LGS).

Since the last fiscal year, there have been discussions on how we maintain or stop operations of the facility instruments. Following the instrument plan proposed in last January, it was decided to terminate the operation of FMOS by the end of April, 2016 in order to accept a next generation facility instrument PFS.

The operation of HSC has been stable, similar to the last fiscal year. To further stabilize the operation, the replacement of the instrument control computer (OBCP) with new hardware and an improvement of the filter exchange unit (FEU) have been performed while consulting closely with the HSC development team. In addition, the implementation of a new dome-flat lamp system with improved uniformity is ongoing to better calibrate HSC data. However, because of the increased number of observing runs of HSC, there are concerns over the limited amount of time for instrument maintenance works and the strong restrictions on the observing schedule due to the limited number of filters available in an observing run. We are trying to improve the instrument exchange procedures to resolve those concerns.

There are several upgrade projects for the other facility instruments. The installation of new detectors (HAWAII-2RGs) in MOIRCS has been done successfully and it achieved engineering first light in December, 2015. In preparation for the first open-use observation in 2016 after the upgrade, we have been working on the characterization of the instrument with the new detectors and further improvement of the operation. The other ongoing upgrade projects are the fiber MOS unit for HDS; the polarimetric function in thermal infrared for IRCS and in mid-infrared for COMICS; the integral field unit (IFU) for FOCAS and MOIRCS; and the Transponder-Based Aircraft Detector (TBAD) for the LGS system.

In FY 2015, three carry-in (PI-type) instruments HiCIAO (high-contrast coronagraph imager), Kyoto-3DII (optical integral field spectrograph), and SCExAO (Subaru Coronagraphic Extreme Adaptive Optics) have been offered through the Subaru open-use program. SCExAO has been commissioning a high-order wave-front correction mode, which realizes extreme adaptive optics correction. This mode has been offered through

the Subaru open-use program on a trial basis since S15A.

A Multi-Object Adaptive Optics (MOAO) science demonstrator (RAVEN), which has been developed in collaboration with Canadian institutes, has conducted additional test observations and science observations in S15A and demonstrated the performance of the MOAO system. RAVEN finished its operation at the Subaru Telescope and was transported back to Canada to be used as a test bed.

There are new PI-type instruments, IRD (InfraRed Doppler instrument) and CHARIS (Coronagraphic High Angular Resolution Imaging Spectrograph), which are currently being developed toward the first light observations expected in July 2016. Other than these approved new instruments, there are new PI-type instrument carry-in proposals from the University of Tokyo; SWIMS (Simultaneous-color Wide-field Infrared Multi-object Spectrograph) and MIMIZUKU (mid-infrared multi-field Imager and spectrograph). Considering the impacts to the existing observatory resources, the acceptance review process for these two instruments is currently suspended until the installation of the other new PI type instruments at the summit has been completed.

The Prime-Focus Spectrograph (PFS) is an optical/near-infrared multi-object spectrograph at the prime focus of the Subaru Telescope, which will be the next facility instrument following the successful implementation of Hyper Suprime-Cam (HSC). The PFS has about 2400 optical fibers distributed over the 1.3 degree field of view of the prime focus. The fibers feed the light from astronomical objects to four identical spectrographs which will be placed in the telescope dome. The spectrograph modules cover the wavelength range from 0.38 μm to 1.26 μm simultaneously. The subcomponents of PFS are being developed at each partner institute, aiming for engineering first light in 2018. Subaru Telescope is responsible for modifying the telescope and enclosure to accept PFS and the design work progressed. A Chinese consortium has officially joined PFS collaboration and NAOJ will handle their funds for PFS development.

We are conducting a conceptual study of the next large facility instrument following HSC and PFS, which will be one of the flagship instruments at the Subaru telescope in the era of TMT. We have studied the concept of a wide-field near-infrared imager and multi-object spectrograph assisted by a ground-layer adaptive optics (GLAO) system, which uniformly improves image quality over a wide field of view by correcting only for the turbulence at the ground layer of the Earth's atmosphere by using an adaptive secondary mirror. In FY 2015, the concepts for the GLAO, wide-field near-infrared instruments, and their science cases were summarized in the study report and reviewed by the external reviewers.

6. Computers and Network

One of our goals of this year was the same as a goal of the previous year - to stably operate the fourth generation system of computers and network called STN4. Stable operation was achieved without serious troubles or attacks/intrusions such as illegal access.

Observation data archiving has been ongoing from the previous year. The archive is operational without serious problems. We provide a user interface that is suitable to downloading large amounts of data in a batch process per requests by users who wish to download data taken by Hyper Suprime-Cam (HSC) during its Strategic Science Program (SSP).

The data archive system in Mitaka is also operating reliably.

We officially rolled out remote observations from Mitaka using the remote observation monitor system for a limited amount of time. During observation semesters from February 2015 through January 2016, 24 observation programs utilized the remote observation monitor system for 47 nights. This was a significant increase in the nights where the remote observation monitor system was used since last year, when 25 observation programs used 28 nights. In expectation of the increase in the number of nights when the remote observation monitor system is used, we hired research fellows to provide support to the users of the remote observation monitor system. The Proposal Management System (ProMS) also worked very well.

Computers for HSC data analysis (HSC On-site Data Analysis System) were procured in fiscal years 2010 and 2011. We added storage, an interactive processing server, and a database server to the system in 2015.

The current system requires fast transfer of large volumes of data between the storage and processing servers. Data transfer speed of the current system is not fast enough to meet our requirements. We must wait for over 30 minutes before data reduction starts; in cases of observations with very frequent exposures this causes delays in deciding whether or not to continue observation. Therefore, we experimented with replacing NFS with a fast data I/O software; the result was several times faster data I/O. We decided to continue the test in a test environment with more computers to simulate the production system. The additional hardware was delivered by the end of this fiscal year. Configuration and performance tests of the test system are planned in 2016.

The dedicated network link between Hawai`i and Mitaka has been procured with a single year contract since April 2014. Bidding was held to select the network link provider for 2016. The link speed will become 1 Gbps, based on the data rate form HSC and the actual data amount used during 2015. A provider was selected successfully and we prepared our own network system so that it can connect to the network service that the provider will offer starting from April 2016.

The online visitor forms for those who visit Subaru Telescope in Hilo for observation and for those who visit NAOJ in Mitaka for remote observation monitoring are operating.

7. Education (Under-graduate and Graduate Courses)

The number of Subaru Telescope staff members in Hilo who were concurrently appointed by SOKENDAI (graduate school) was ten. The number of SOKENDAI students who had primary supervisors affiliated with Subaru Telescope (including those

concurrently belonging to Subaru Telescope) was 16, which constituted half of the total 32 Sokendai students hosted in NAOJ. Of which eight had supervisors who belonged primarily to Subaru Telescope.

In FY 2015, Subaru Telescope hosted 7 graduate students for long stays, of which 2 were SOKENDAI students. On top of that, intensive education activities were seen also in Mitaka in cooperation with the Division of Optical and IR Astronomy. The numbers of graduate course students in all of Japan who obtained master's degrees and PhD's based on Subaru Telescope data were 17 and 6, respectively, of which one each belonged to the Division of Optical and IR Astronomy.

We also regularly hosted a series of educational programs at Subaru Telescope. In September 2015, we hosted a Subaru Autumn School in which 13 under-graduate students from all over Japan participated and learned the reduction and analysis of Subaru Telescope data and heard a series of lectures. Moreover, in October, we hosted two Subaru Telescope observation training courses, one for 8 undergraduate students from all over Japan, and the other for 7 new SOKENDAI students at NAOJ. In the Hilo Office, we had regular Subaru Telescope seminars in English 2-3 times a month, where open-use observers, visitors, and Subaru Telescope staff members presented their own new research. Also in the Subaru Telescope Mitaka office, we had many official and informal seminars, many of which were jointly organized with other divisions in NAOJ and/or neighboring universities.

8. Public Information and Outreach (PIO)

The Public Information and Outreach (PIO) office is tasked with addressing the accountability for what the Subaru Telescope does and is keenly aware of the importance of citizens understanding our work, for both the short-term and long-term success of the project. The increased importance of positive awareness in the local community has profound meaning for the next generation telescope project on Maunakea. Therefore PIO pays more attention to the interaction with the local community, in its three major areas of tasks.

Task 1: Disseminating information about the results from the Subaru Telescope and the work at the Subaru Telescope. The primary tools are the postings on our own website; providing press releases to the Japanese, local, and international media; and holding press conferences. During fiscal year 2015, there were 31 web-postings (14 in Japanese, 17 in English) about the discoveries from the Subaru Telescope. Articles about the instrument development, the work and the activities at the Subaru Telescope, and other announcement totaled 52 (25 in Japanese, 27 in English). Some postings are also distributed through the media as well as posting services such as the American Astronomical Society's mailing exploder. Many articles appeared in the Japanese newspapers, and some in the local newspapers; with more prevailing in the on-line postings.

In addition, newer tools such as Twitter, Facebook, and YouTube are becoming more useful in spreading awareness in a timely manner. The PIO office is making extra effort in providing striking visuals for such social media postings. Filming requests from outside totaled more than 22 (13 in Japanese, 9 in English), in addition to the numerous inquiries/questions from the media, educational institutions, and museums.

Task 2: Provide escorted tours for the public and special groups to see the facility. The public tour program that started in 2004 continues to provide opportunities to see the telescope up-close for guests from Japan and from around the world. Except for summer months when the tour program was suspended due to the access issues on Maunakea, a total of 421 people visited through this program. There were 131 additional groups who visited through special tour programs and resulted in a total head count of 923 people who visited the summit facility. The tours are all escorted by the assigned staff, in either Japanese or English language.

Facility tours of the Hilo Base Facility are most of the time accompanied by other activities described in the next major task area, namely: special lectures, hands-on sessions, or presentations by the student group. A total of 67 groups, with 393 people, visited the base facility this year.

Task3: Public outreach includes lectures in the local community, special presentations in the schools, and remote presentations for Japanese schools or museums. PIO provided/coordinated 93 lectures at the Hilo Base Facility or in its vicinity such as at the 'Imiloa Astronomy Center. There were 10 lectures outside of the island, and 15 remote lectures for off-site locations. The local lectures included 55 classroom presentations during the Journey through the Universe program.

In place of an open house, the staff of the Subaru Telescope participated in the annual AstroDay event at the local shopping mall. Observatories on Maunakea, 'Imiloa Astronomy Center, Maunakea Visitor Information Station, and other astronomy-related groups participated in this event. More than 2000 people visited this family-friendly event.

Another special local event where many astronomy observatories participate is the annual Onizuka Science Day at the University of Hawai`i at Hilo. Six-hundred selected students between grades 4 and 12 (upper elementary school to high school) with families and teachers from all over the island gathered for this event. PIO provided 4 hands-on workshops and an exhibit booth.

There was a very significant event in August 2015 which was the International Astronomical Union's General Assembly in Honolulu. PIO provided a booth and dispatched staff to answer questions, in addition to providing special tours of the telescope.

2. Okayama Astrophysical Observatory

Okayama Astrophysical Observatory, (hereafter the Observatory) serves as the observing and research base of the optical and infrared astronomy in Japan, and it promotes open use, primarily of the 188-cm telescope, to universities throughout the country. It also pursues joint R&D projects with universities, contributing toward forming stronger foundations for astronomy research at the universities. Concurrently, the Observatory pursues its own research activities, taking advantage of its location and observational environment.

Every year, about 240 nights at the 188-cm telescope are exploited for observations by researchers from across the country through the open use. The Observatory maintains and operates the observing instruments and provides the observers with support for observations, travel expenses, accommodations, everyday needs, etc. It also engages in improving the open-use observing instruments, developing new open-use instruments, and supporting carry-in instruments from other institutions.

Several joint projects with universities have been conducted, including Kyoto University's Okayama 3.8-m New Technology Optical and Infrared Telescope Project and the Tokyo Institute of Technology's Gamma-Ray Burst Optical Afterglow Follow-up Project. Meanwhile, the 188-cm telescope, the 50-cm telescope, and the 91-cm telescope of the Observatory are involved in "The Optical & Near-Infrared Astronomy Inter-University Cooperation Program" supported by MEXT, which commenced in 2011.

The Observatory's unique research activities include a project designed to convert the 91-cm telescope into an ultra-wide-field near-infrared camera (OAO-WFC). It also engages in a comprehensive survey of infrared-variable objects in the Galactic plane. Another project is the upgrade of the functionalities of the 188-cm telescope in order to significantly improve its planet searching capability through a Grant-in-Aid for Scientific Research (Basic Research (A), FY 2011–2015). Collaborations with foreign researchers are also continued actively.

The personnel breakdown as of March 2016 was five full-time staff members, including two associate professors, one assistant professor, one engineer, and one chief clerk; ten contracted staff members, including three research experts, one postdoctoral fellow, one research supporter, three administrative supporters, and two administrative maintenance staff members; and one temporary staff member.

1. Open Use

(1) Overview

The numbers of nights allotted to open use in 2015 were 115 for the first semester (2015A, January to June) and 124 for the second semester (2015B, July to December). Observing proposals were called for publicly each semester. The Okayama program subcommittee reviewed the submitted proposals and accepted 1 project observation program, 1 academic degree support program, 13 general observation proposals, and 1 miscellaneous observation proposal (introduced in 2015A) in 2015A, and accepted 1, 1, 13, and 0 in 2015B. One proposal from Hawai`i was accepted in 2015A, and one from Turkey and one from Hawai`i were accepted in 2015B. The Observatory supported their observations with human resources. Open-use observation generally proceeded without incident.

(2) Observation/Research Results

The majority of objects observed through the open use in 2015 were stellar sources and exoplanets. Others included supernovae, galaxies outside the Milky Way, AGNs, and quasi-stellar objects. The following primary observation themes were noted: exoplanet search and binary-mass determination via precise radial velocity measurements; exploration of the physical properties and activities of single and binary stars via high-dispersion spectroscopy; and the observation of exoplanet transits by precise near-infrared differential photometry. Optical low-dispersion spectroscopic observations of stars for classification remained significant. As in previous years, a number of observational studies were conducted by individual groups of researchers within the open-use framework, and their respective research results were reported in meetings and conferences or were published in peer-reviewed journals.

(3) Facility and Instrument Maintenance/Management

The 188-cm telescope and its dome had evolved into a stable and high-functioning observing system by FY 2014 after the major refurbishment in FY 2012. Efforts were made to improve the pointing accuracy and to automate the high dispersion spectroscopic observations with the fiber-feeding system in this FY 2015. The remote observing environment has been refined further since FY 2014 and has been made available for open use since 2015B. During the maintenance period in June, the annual re-aluminization of the primary mirror of the 188-cm telescope and the subsequent optical axis alignment of the smaller mirrors against the primary were completed. Efforts were made to simplify the re-aluminization process. The 1.5-m primary of the KANATA Telescope at Hiroshima University was also accepted for re-aluminization in the maintenance period this year. Participants in the aluminization work from that organization were given NAOJ-mandated safety and hygiene training as necessary. Lubrication of the telescope and dome was performed in July. Utmost efforts were made to maintain high observing efficiency by conducting monthly cleanings of the primary, secondary, and tertiary mirrors of the 188-cm telescope after October.

The dome was checked daily. Other maintenance work was also performed, including the repair of the iron part of the hatch opening on the second floor and repainting of the scaffold of the vacuum aluminizing chamber in May; repair of the worn-down guide rails for the lower slit door in October; and repair of the external panels of the dome hemisphere to prevent rain

leakage in November. Much attention was paid to the operation and maintenance of the facility and equipment. The wire rope of the dome slit door driver was inspected and investigations continued in order to determine the causes of the unusually rapid deterioration of the wire rope and possible measures to prevent the deterioration. Work safety was given priority in accomplishing the aforementioned maintenance work and observing instrument exchanges. The Administration Office and Reception Room on the first floor of the Main Building were renovated and the Director's Room was moved from the second floor to in-between these two rooms. The asphalt pavement of the parking spaces west of the main building and the access road from the city road to the parking lot were renewed as well.

(4) Conferences

The program subcommittee for the 188-cm telescope met on June 16 and November 17 to evaluate proposals for the open use of 2015B and 2016A (first semester of 2016), respectively, and formulated an observation program for each semester. The Okayama Users Meeting, also known as the 26th Optical and Infrared Users Meeting, was held in the Large Seminar Room of NAOJ Mitaka Campus on August 17 and 18. Various reports were made: current status of the Observatory, execution summary of the program subcommittee, full operation of the remote observing environment, automation of observing, etc. Reports on three new user-led instruments for the 188-cm telescope were also made. Discussions were held on the future operation of Target-of-Opportunity (ToO) observations and operation of open-use observing instruments. A special session was arranged on the era of the Kyoto 3.8-m telescope and detailed discussions were held among Okayama users, Kyoto University staff, and NAOJ staff (see the printed version of the Proceedings of the FY 2015 Users Meeting for details). Further reports were made on the research results from open-use projects, progress of the Kyoto University 3.8-m telescope project including observing instruments, and operations of other optical and infrared observational facilities such as the Higashi–Hiroshima Observatory.

2. Developing and Maintaining Open-Use Observing Instruments

(1) HIDES (High-Dispersion Echelle Spectrograph)

The instrument HIDES is a cross-dispersed high-dispersion echelle spectrograph, provided for open use. Development of the fiber-link system (HIDES-F) since FY 2006 has continued to improve its observing capabilities. Open use of the high-efficiency (HE) fiber link with approximately 50-K wavelength resolution has continued since 2011A. The HE link offers an improvement in throughput of nearly one magnitude over the previous value and radial velocity measurement precision of approximately 2 m/s, which is comparable to the case of the Coudé light path. The high-resolution (HR) link with nearly 120-K wavelength resolution started to be offered as a PI-type open-use instrument in 2016A. The HR link provides a 4 times better sensitivity at maximum than the case of the Coudé light path. This year the total numbers of accepted proposals to HIDES were 7 and 9 in 2015A and 2015B, including 1 and 1 project observations, respectively.

(2) ISLE (Near-Infrared Imager/Spectrograph)

The open-use instrument ISLE is a near-infrared imager and low- or mid-dispersion spectrograph, and has been available for project observations and the academic degree support programs since 2011B. It is the only open-use instrument in East Asia that offers near-infrared spectroscopic capability and is characterized as having the world's best low-noise readout capability (less than 10 electrons). Relative photometry at the one milli-magnitude level is regularly achievable with its imaging mode for bright sources. A YJH-band filter brought in by a user was installed in FY 2015, which extended the shorter wavelength limit for spectroscopy from J-band edge (~1.16 μm) to Y-band edge (~0.96 μm). By using the YJH-band filter and the existing HK-band filter, it became possible to obtain a well-connected spectrum from Y-band to K-band. The numbers of open-use programs using ISLE conducted in semesters 2015A and 2015B were 6 and 3, respectively; which included 1 and 1 academic degree support programs, respectively; and 1 and 0 miscellaneous category programs, respectively. Five of them were spectroscopy and the other four were imaging photometry.

(3) KOOLS (Kyoto-Okayama Optical Low-dispersion Spectrograph)

This instrument provides imaging and spectroscopic capability in the optical. It has been available for open use as a PI-type instrument since 2008A. High observing efficiency has been achieved by improving CCD output linearity and auto-guider functionality and by introducing CCD charge shuffling and VPH grisms. Non-sidereal motion objects can be tracked for long integration times. The integral field unit using a fiber-bundle developed by a team at Kyoto University was made available to observers as a PI-type open-use instrument starting from semester 2015B. When it is used, its input part is installed into the Cassegrain unit of the HIDES fiber link and so is its output part is installed into KOOLS. Accepted proposals were 4 and 2 for 2015A and 2015B, respectively.

(4) Others

MuSCAT (MUlti-color Simultaneous Camera for studying Atmospheres of Transiting exoplanets) was accepted as a carry-in observing instrument for open use on the 188-cm telescope. Its use in the open-use time began in 2015B. It can achieve 0.05 % accuracy in relative photometry for a star of 10th magnitude at V-band when it performs a series of one-minute exposures.

3. Joint Research with Universities

(1) Kyoto University's Okayama 3.8-m New Technology Optical and Infrared Telescope Project

The Observatory has participated in a cooperative implementation framework for the 3.8-m telescope project, which is spearheaded by Kyoto University, together with the

Nano-Optonics Institute (Astro-Aerospace, Inc.), regarding the 3.8-m telescope project as part of the future plan of the Observatory. Discussions were held on technological issues regarding the telescope and observing instruments through weekly TV conferences and in-person meetings held every three months. The project proceeded significantly with the telescope construction having been included in the supplementary budget of FY 2013 and the dome construction in the main budget of FY 2015.

(2) The Optical & Near-Infrared Astronomy Inter-University Cooperation Program

The Program has entered its fifth year since its commencement in 2011. The Observatory has contributed the 188-cm, 91-cm, and 50-cm telescopes to the Program, and has taken a leading role along with the Office of International Relations. Through the cooperative observational and educational network, OISTER, established by the Program, the Observatory provided a total of 49 nights worth of observational data on five objects this year. Two of the objects were targets of collaborative observations with the X-ray astronomical satellite "Suzaku" or of simultaneous VLBI observations with VERA. As for the immediate follow-ups of gamma-ray bursts, which are the main targets of the program, there were 19 alerts that were observable from the Observatory, observations were performed six times and afterglows were detected in two of them. Three peer-reviewed papers were published utilizing OISTER. Another 20 peer-reviewed papers that have something to do with the Program were published. The sixth workshop on the Program was held.

(3) Gamma Ray Burst (GRB) Optical Follow-up Project

Optical follow-up observations of GRBs are in progress in cooperation with the Tokyo Institute of Technology's Kawai Laboratory. During FY 2015, the automatic observation scheduler performed observations on nearly every possible night; 15 GRBs were observed, with optical afterglows successfully detected in two. Observation results were published as 12 GRB Coordinates Network (GCN) circulars. In addition, follow-up observations of candidate gravitational wave sources and monitoring of eclipsing binaries and comets were concurrently performed, which resulted in publication of two peer-reviewed papers. The telescope operation was suspended for a month due to a malfunction in the dome rotation mechanism. A worn-out roller in the machinery was replaced and measures were taken against abrasion.

(4) Other

The Observatory welcomed five third-year undergraduate students and their supervisor from the University of Tokyo between August 12 and 14 and provided them with an opportunity to conduct high-dispersion spectroscopic observations using the 188-cm telescope during the early half-night on August 12.

Development of a near-infrared observing system dedicated to bright star photometry (IR-TMT) continued in collaboration with researchers at Tohoku University. The system consists of a wide-field infrared camera with 30-mm aperture developed by researchers at Tohoku University being mounted on the equatorial mounting of a 30-cm class telescope housed in a 4-m dome at the Observatory. It aims to produce a high precision photometric catalog of bright stars in the near-infrared. The control system of the equatorial mounting was developed by the Observatory and the near-infrared camera by the Tohoku University researchers. The camera was placed on the mounting in December and various adjustments were carried out for test observations of astronomical objects.

4. Unique Research Projects

(1) Detection of afterglow from distant GRBs and survey of variable stars in the Galactic plane using the ultra-wide-field infrared camera

With the 91-cm reflector having been converted into an infrared camera with an ultra-wide field of view of currently 0.25 square degrees, observations were conducted to identify infrared counterparts for objects such as GRBs and gravitational wave sources. Along with them, a comprehensive survey of infrared variable stars in the Galactic plane was carried out. In FY 2015 a region of 6 square-degrees in the constellation Scutum was observed at the Ks-band about 70 times, and a region of 16 square-degrees in the constellation Cygnus was observed about 12 times. Many variable star candidates were identified.

(2) Automation of Exoplanetary System Searches

Through a Grant-in-Aid for Scientific Research (Basic Research (A), "Automation of exoplanetary system searches," representative: Hideyuki Izumiura, FY 2011–2015), a project is underway to improve the functionalities of the 188-cm telescope and its dome, to enhance the precision and stability of the telescope, to facilitate automation of observation, and to further expand the search for exoplanetary systems. The 188-cm telescope and its dome were refurbished in FY 2012 for this purpose. A new control system including the observing instruments was achieved in FY 2013. An automatic focus correction system was developed in FY 2014. Functionality was developed to improve the overall pointing accuracy by sensing small movements of the 188-cm reflector primary mirror in its cell. Also, development advanced for a system capable of performing automatic observations based on observing instruction.

(3) East Asian Planet Search Network

The Observatory also conducts studies focusing on the search for exoplanetary systems, involving researchers from South Korea, China, Turkey, and Russia. Efforts continued in FY 2015 to secure telescope time on the Korean 1.8-m telescope, Chinese 2.16-m telescope, Turkish 1.5-m telescope, and the Observatory's own 188-cm telescope for continued searches for exoplanetary systems around G-type giant stars. It should be noted that a system consisting of a G-type giant with possibly two mutually-retrograde planets was discovered from

the collaboration with Chinese colleagues and was published in a peer-reviewed journal.

5. PR/Awareness Promotion Activities

An Observatory representative delivered a lecture to nearly 20 people in Okayama City on Tuesday, July 7 as part of the Nation-Wide Tanabata Participatory Lectures. About 40 astronomy-related questions from the public were posed irregularly to the Observatory and were answered appropriately. The 4D2U screenings, co-hosted with the Okayama Astronomical Museum, attracted 4,740 visitors. Nineteen Observatory tours were conducted, including those for pupils from local elementary schools in Asakuchi City and Yakage Town. The Observatory also responded to three lecture requests made by local boards of education and community centers. It should be noted that the Observatory received special publicity during the NameExoWorlds campaign led by the IAU from 2014 to 2015. Of the first 20 stars with planets for naming, six had planets discovered by the 188-cm telescope and the high dispersion echelle spectrograph HIDES(-F) with fiber-link at the Observatory. The names of the stars and their planets were determined by public votes from all over the world and the names were announced by the IAU on December 15, 2015.

6. Contract Staff Transfers

The following transfers of contract staff members took place in FY 2015: Akihiko Fukui joined as a Project Research Fellow in April and Kouki Kamiya resigned as a Research Support Staff Member at the end of September.

3. Nobeyama Radio Observatory

1. Nobeyama 45-m Radio Telescope

(1) Open Use Observations

The 34th open use observations period started on December 1, 2015. In addition a new four pixel receiver FOREST with limited capabilities has been offered since Jan 6, 2016 as scheduled. The "Education Program" was not offered.

The statistics of the proposals are as follows, "General Proposals 1st period": 13 accepted including 2 from abroad (25 submitted), "General Proposals 2nd period": 8 accepted with none from abroad (21 submitted), "Short Programs": 5 accepted (9 submitted), "Backup Programs," which are carried out when weather is not acceptable for the main observations: 2 accepted (3 submitted). One proposal for "General Proposals 2nd period" was accepted as a "Backup Program" as recommended by the Time Allocation Committee. In addition, 2 proposals for the 45-m telescope's participation in VERA open use observations were conducted. The S80 and S100 receivers and the AOS were decommissioned.

(2) Improvements and Developments

Maintenance of the 45-m telescope, the receiver systems, the cryogenics, etc. was performed.

- The replacement of the subreflector servo system was completed. A plan was developed for the millimeter wave calibration drive system repairs to be conducted next year.
- Surface measurements with the holography system and surface adjustment were performed. Consequently the surface accuracy of the 45-m telescope was improved.
- Gold foil was put on the 2nd and 3rd mirrors to reduce the loss of the beam transmission system and decreasing the antenna noise temperature by about 10 K at 3 mm.
- Some parts of the new multi-pixel receiver FOREST were replaced and the gain stability and linearity were improved.
- New AD converters were installed in all the intermediate frequency lines and were used in open use observations.
- NRO supported user instruments including the Z45 receiver in the 45 GHz band, the digital spectrometer ROACH, and a 90/150 GHz continuum camera.

(3) Scientific Results

We are carrying out the (a) Star Formation Project, (b) Galactic Plane Survey, and (c) Nearby Galaxy Project as legacy projects with the 45-m telescope. The star formation project and the Galactic plane survey project obtained scientific data and their results are described below. Research results from open-use observations are given separately in the Scientific Highlights section of this document.

(a) Star Formation Legacy Project

In the Star Formation Legacy Project, we conducted large-scale mapping observations toward three nearby star-forming regions, Orion A, Aquila Rift, and M17 in ^{12}CO (1–0), ^{13}CO (1–0), C^{18}O (1–0), and N_2H^+ (1–0). Many cores and clumps have been identified from structure analysis of these data. We succeeded in finding a protostellar molecular outflow in the Orion Molecular Cloud data by using existing data taken by BEARS.

(b) Galactic Plane Survey Project (FUGIN: FOREST Ultra-wide Galactic plane survey In Nobeyama)

We are conducting the highest resolution simultaneous survey to date of the ^{12}CO (1–0), ^{13}CO (1–0), and C^{18}O (1–0) emission lines in the Galactic Plane using FOREST aboard the 45-m telescope. We plan to make maps of the inner Galaxy and the outer Galaxy including the spiral arms and bar structure. In 2015, we covered areas with 46 and 28 square degrees for a total of 74 square degrees. In the last two years, 115 square degrees have been mapped. As a result, we have revealed a wide range of molecular clouds and their fine structures and also found a new cloud-cloud collision system and an interacting region with a supernova.

(c) Nearby Galaxy Project (COMING: CO Multi-line Imaging of Nearby Galaxies)

We started COMING (CO Multi-line Imaging of Nearby Galaxies) in April 2015 to map more than 200 nearby galaxies in ^{12}CO, ^{13}CO, and C^{18}O J=1–0 emission lines using FOREST. As of now, mapping observations of more than 40 galaxies are complete. Among our samples, the precise ^{13}CO/^{12}CO line ratio has been obtained for a barred galaxy NGC 2903. Excitation analysis revealed that star formation efficiency is determined by molecular gas density. In addition, through comparison with archived data of CO (J=3–2), it became clear that gas content depends on the surface gas density in dwarf galaxy NGC 2976.

2. Radio Polarimeters

Nobeyama Radio Observatory took over operation of the Radio Polarimeters at the beginning of the H27 (2015) fiscal year. On a monthly basis, the data are examined by solar research groups in Kyoto University, in Ibaraki University, NICT, and NAOJ Solar Observatory and are archived as public data in the NAOJ Astronomy Data Center so that researchers all over the world can access them.

3. Research Support

(1) SPART (10-m telescope) (Osaka prefecture Univ.)

To better understand the influence of the activities of host stars on the atmospheric environments of habitable planets, we have been carrying out monitoring observations in the 100 and 200 GHz bands with a 10-m telescope, the Solar Planetary Atmosphere Research Telescope (SPART). In conjunction with the refurbishment of the Interferometer Building (IB), all the NMA systems were removed and the new control room

for SPART was installed. Hereafter, the SPART system and its observations will be exposed to visitors. For corrective maintenance in 2015, carbon dust in the Az/El motors was removed and the 4K-GM/JT compressor leakage was repaired.

Observations started in March 2015, and we successfully demonstrated that CO mixing ratios in Venus's middle atmosphere were gradually decreasing. Comparative studies with the Radio Polarimeter data in Nobeyama are now on-going. In the coming year, atmospheric conditions on Venus and Mars are predicted to vary as the solar activity moves toward its minimum. Monitoring observations enable us to study chemical networks, dynamics, and the effects of high energy particles. We initiated a joint study with the Japanese Venus Climate Orbiter AKATSUKI.

(2) Nobeyama Radioheliograph (Nagoya Univ.)

In FY 2015, an international consortium (ICCON) assumed operation of the Nobeyama Radioheliograph (NoRH, see http://hinode.stelab.nagoya-u.ac.jp/ICCON/). The remote operating system via internet has functioned very well. About 30 researchers from six countries (China, Japan, Korea, Russia, the UK, and the USA) participated in operation, including the system health check and data verification. Observational data are automatically transferred to NAOJ and Nagoya Univ. and are stored/maintained there. NoRH data are used by researchers all over the world to study short-time scale phenomena, such as solar flares, and to study long-term activity as well. Recently, a methodology to determine the magnetic field intensity in the solar corona has been established. Then a press release was issued in February 2016 and an article was inserted in a science newspaper. On March 9 in 2016, a partial solar eclipse was successfully observed and the microwave images during the eclipse are released on the homepage of the Institute for Space-Earth Environmental Research (ISEE), Nagoya Univ.

4. Public Outreach

(1) PR activities at Nobeyama Campus

The Nobeyama Campus received a cumulative total of 52,614 visitors throughout the year, including participants in special open house events. Staff members conducted 42 guided tours, including ones for Super Science High School (SSH) students and the Campus Tour Week, while 3 requests for lectures and 22 requests for on-site filming and interviews were granted. These requests, especially those by some local broadcast stations in Nagano prefecture, increased due to efforts to strengthen cooperation with local communities. The Campus Tour Week for educational institutions was scheduled during the summer. Though only 1 group took advantage of this opportunity, students in the group enjoyed the visit. For the workplace visit, 7 students from 4 schools, primarily local junior-high schools, visited the observatory. Also, we conducted a career educational program for local high-school students and experience training for local teachers. For SSH initiatives, two schools visited NRO and participated in lectures.

In the area for permanent public access, an antenna experience facility and some introduction movies are available along with posters and panel displays. In this year, we renovated all the panel displays and a brochure for children in order for visitors to become more familiar with NRO. The website of NRO presents introductory descriptions of radio astronomy and some events as well as observational results.

(2) Cooperation with Local Communities

The annual Nobeyama Special Open House was held with contributions by Nagano Prefecture as well as Minamimaki Village, the Minamimaki Chamber of Commerce, and its youth division. Moreover, Jimoto Kansha Day (Thanks Day for the Locals) was held as the Special Open House for locals (Minamimaki and Kawakami Village) at the forests of the University of Tsukuba. Special sponsorship was made to the sora-girl event "Tebura de Hoshizora Kansho-kai (Drop-by Star Gazing Event)," hosted by the Minamimaki Tourism Association. NRO has also participated in the "Three Major Scenic Locations for Star Gazing in Japan • Night Sky Summit" conducted with the sponsorship of the Minamimaki Tourism Association since the planning stage. Also, a training course and examinations were carried out through a special partnership with Shinshu-Saku Hoshizora Annai-nin, which was managed by Saku Koiki Rengo (the Union of local governments in the Saku area).

The "Artist in Residence" Program was carried out at NRO, organized by Siga-Kogen Romance Art Museum. Participating artists were inspired to make some artworks, which were exhibited in the special exhibition "Viewing the Universe", held in the Museum from July to October. Also, one of the old receivers from the 45-m radio telescope was displayed in the exhibition.

(3) Improvement Plan for the Nobeyama Millimeter Array Building

The building of the Nobeyama Millimeter Array will be improved to install an exhibition area highlighting NINS as well as NAOJ, in order to establish a PR center not only for astronomy but also for the natural science. The improvement work on the building and installation of the 4D2U theater were carried out in this year.

(4) NRO Conference Workshops

- Nov 2, 2015
  NRO Galactic Plane Survey Workshop 2015 (representative: Atsushi Nishimura)
- July 28-30, 2015
  NRO-ALMA Science/Development Workshop 2015 (representatives: Masao Saito (NRO), Daisuke Iono (Chile Observatory)
- Oct 20-22, 2015
  ALMA/45m/ASTE/Mopra Users Meeting 2015 (representative: Daisuke Iono (Chile Observatory), Masao Saito (NRO))

5. Education

NRO accepted two postgraduate students. One is a first-year Ph.D. student in SOKENDAI studying chemical reactions of carbon chain molecules. The other one is a visiting student from Kagoshima University whose research is a molecular cloud survey in the outer Galaxy and development of a new digital spectrometer using ROACH technology.

SOKENDAI held the workshop on Radio Astronomical Observation using the Nobeyama 45-m Radio Telescope from June 1 to 5, with 12 undergraduate students in attendance. The majority of the participants were 4th year students, just about to decide their course after graduation. While guiding the students, from observations to presentation of the results, requires significant effort, the event offers an invaluable opportunity for undergraduates to experience observations using a radio telescope and to think of their future career.

6. Misc. Activities

(1) Hiring

Hiroyuki Kaneko: Specially appointed research staff

Yusuke Miyamoto: Specially appointed research staff

(2)Transfer

Jun Nishimura: Specially appointed research staff (to Nagoya University)

4. Mizusawa VLBI Observatory

NAOJ Mizusawa VLBI Observatory operates VLBI (Very Long Baseline Interferometry) facilities such as VERA (VLBI Exploration of Radio Astrometry) and KaVA (KVN and VERA Array), and provides these unique facilities to the international user community to support the research activities at universities and research institutes. In the meantime, astronomical research using these VLBI arrays is conducted mainly on the Galactic structure, celestial masers, AGNs and so on. Using the unique dual-beam system which is capable of phase referencing by observing two sources simultaneously, VERA conducts high-accuracy astrometry of maser sources and determines the detailed structure of the Milky Way. In addition to the operation of VERA, maintenance and operation support were provided to the Yamaguchi 32-m Radio Telescope and two Ibaraki 32-m radio telescopes in collaboration with the local universities. International collaboration has been promoted particularly in the East Asia region through the joint operation of KaVA and the East Asian VLBI Network, the latter of which is a joint VLBI array between the People's Republic of China, Japan, and the Republic of Korea.

In addition to VLBI related activities, "The Central Standard Time" is kept at the observatory as an obligation of NAOJ, Esashi Earth Tides Station is operated for geophysical research, and Ishigakijima Astronomical Observatory is jointly operated with the local city for public outreach and astronomical research.

1. VERA

(1) Observations and Common Use Observations

The four stations of VERA were operated by remote control from AOC (Array Operation Center) at NAOJ Mizusawa Campus. In FY 2015, a total of 427 (3670 hours) VLBI observations were conducted with VERA, such as common-use observations, VERA project observations, fringe detection observations for maser and reference sources, geodesy observations, JVN (Japanese VLBI Network) observations, KaVA (KVN and VERA Array) observations, and others. These VLBI data, except for KaVA, were processed at the Mitaka VLBI Correlation center in NAOJ Mitaka Campus until 2014; in 2015 these processing functions were moved to the Mizusawa correlation center. The correlated data were sent to each researcher for the case of common-use and JVN observations and to persons in charge of data analysess in the case of project data and geodesy data. Iriki station was damaged by a typhoon at the end of August. Due to this damage, Iriki station was unavailable for VERA observations for about two months.

VERA common-use calls-for-proposals with the 43, 22, and 6.7 GHz bands for semesters 2015B and 2016A were released in May and November, respectively. A total of 11 proposals, which requested a total time of 462 hours, were submitted, including 3 proposals for 130 hours from overseas. Based on the evaluations by referees elected from scientists in related fields, the VLBI program committee decided to accept a total of 7 proposals (227 hours) in 2015B and 2016A.

(2) Science Research

In FY 2015, the second part of the PASJ VERA special issue has been published as a continuation from the one in FY 2014. The FY 2015 part included 6 papers, and in total there have been 13 papers in the VERA special issues in 2014—2015. This has been the third PASJ VERA special issue after the ones in FY 2008 and FY 2011.

As the results of the project observations of VERA, the parallaxes and proper motions have been reported for five galactic star-forming regions, namely, G48.99−0.30, G49.19−0.34, IRAS 20126+4104, IRAS 21379+5106, and IRAS 07427−2400. The last source is located in the Perseus spiral-arm, and together with the previously published sources associated with the arm, non-circular motion associated with the Perseus spiral-arm was successfully detected, showing systematic inward motion toward the Galactic center and lagging behind the Galactic rotation. It has been shown that the motions can be described well by a density-wave-type spiral model. This is the first result on the Galactic non-circular motion based on VERA astrometry, and thus it is one of the milestones of the Galactic structure study with VERA. Simulation studies have been performed to evaluate the expected accuracy with which future VLBI astrometry will be able to constrain the Galactic parameters. It is demonstrated that astrometric measurements for ~300 sources will provide accuracies of a few % for the Galactic fundamental parameters and accuracies of about 10 % for the parameters associated with the non-circular motion and asymmetric structure, such as spiral arms and/or bar.

Astrometric results are also published for a late-type star U Lyn, and the data are used to calibrate the Period-Luminosity relation of Mira-type variables based on U Lyn and 8 other sources for which accurate distances have been measured so far.

Other than the Galactic astrometry, astrometric observations of the core position of TeV blazar Mrk 501 have been used to constrain the Lorentz factor of the jet, demonstrating that accurate VLBI astrometry has a wide range of possible applications other than Galactic structure studies.

2. JVN (Japanese VLBI Network)

The Japanese VLBI Network (JVN) is operated as a joint research project of NAOJ and seven universities. JVN consists of VERA and radio telescopes operated by universities and research institutes such as ISAS/JAXA, NICT, and GSI. VLBI observations by JVN were done for 250 hours at 3 bands of 6.7, 8, and 22 GHz in FY 2015. Single Dish Observations related to JVN were also done about 2000 hours at each telescope. The major research topics are AGNs, masers, and star forming regions.

The main subjects of research are active galactic nuclei and masers in star-forming regions. Scientific results obtained

with JVN were published as four papers, while ten more papers reported JVN related scientific studies. Fujinaga et al. (2016) reported the results of a gamma-ray-emitting-AGN survey through high-sensitivity VLBI observations. Sugiyama et al. (2016) reported the first results of internal motion in a 6.7 GHz methanol maser source obtained by EAVN (East-Asian VLBI Network) including JVN. Yonekura et al. (2016) reported on the telescope and observing system of Ibaraki station. Nine papers including the above four will be published as a special issue of PASJ in FY 2016.

Education is also one of the main aims of university collaboration in VLBI. Twenty-nine students conducted undergraduate studies using JVN and related research activities. Sixteen master-course students completed their master's theses using JVN, and two Ph.D. students finished their theses using JVN. Many university students made presentations and talks in research meetings related to JVN.

3. Japan-Korea Joint VLBI (KaVA)

(1) Observations and Common-Use Observations

In 2015, a total of 121 (1023 hours) VLBI observations, common-use observations and test observations, were conducted by KaVA (KVN and VERA Array) with the 43 and 22 GHz bands. The data of the seven VLBI stations were correlated at the Korea-Japan Joint Correlation Center at KASI Daejeon Campus in South Korea.

KaVA common-use call-for-proposals for semesters 2015B and 2016A were made in May and November of 2015, respectively. In total, 20 proposals requesting a total time of 736 hours were submitted. Through the evaluations by referees elected from scientists in related fields and subsequent decisions made by the VERA and KVN combined Time Allocation Committee, a total of 15 proposals (507 hours) were accepted in 2015B and 2016A.

(2) Results of Research

Following the successful opening of KaVA common-use observations and the first publications of KaVA papers in FY 2014, the science productivity of KaVA is growing satisfactorily with the stable array operation throughout FY 2015. As for AGN science, the detailed motions of relativistic jets are now regularly monitored for a number of sources; three refereed papers were published on several bright blazars including 3C345 during FY 2015. Moreover, our KaVA monitoring of the M87 jet made the first discovery of a superluminal motion near the black hole. The talk on this result was selected for a press release at the ASJ meeting in March 2016 and was picked up by many media outlets, returning scientific results from KaVA to the broad general public. Another refereed paper reporting a detailed imaging of SiO masers around the late-type star WX Psc was also accepted.

The KaVA Large Program has finally started from late FY 2015, which aims at performing ambitious, high-scientific-impact studies with KaVA by spending a large amount (typically more than 100 hours per year) of the machine time. Currently three large programs are ongoing, each of which is led by one of the three KaVA science working groups (AGN, star-forming regions, and late-type stars). Not only researchers in NAOJ/KASI but also many external researchers (universities in Japan/Korea, Australia, Italy, etc.) are joining these projects. Scientific outcomes based on these programs will be expected to emerge from the next year.

4. EAVN

Aiming at expanding the capability of international VLBI over East Asia, the development of the East-Asian VLBI Network (EAVN) is currently underway as a collaboration between Japan, South Korea, and China. Technical assessment of the array and test observations are promoted by the Japan-Korea-China joint task force (the so-called Tiger Team), and in FY 2015 a report summarizing the successful detections of fringes over the last few years was published in the proceedings of an international conference (Wajima et al. 2015). Following this success, in FY 2015 further test observations were conducted to evaluate the imaging performance of the EAVN array at 8, 22, and 43 GHz. Detailed reports of these data will appear next year.

Meanwhile, recently there is a growing discussion toward the future construction of a new VLBI facility in Thailand (Thailand VLBI Network; TVN). In these circumstances, in FY 2015 a KaVA science workshop was held in Thailand in collaboration with local astronomers, and discussed the possibility and potential impact of the future extension of TVN by joining the EAVN.

In FY 2015 the annual EAVN workshop was held at Hokkaido University, and the next meeting in FY 2016 will take place in China.

5. Geodesy and Geophysics

The regular geodetic sessions of VERA are allocated two or three times per month to maintain baseline accuracy of the array. VERA internal geodetic observations are performed once or twice per month using K-band, and the VERA Mizusawa station participates in IVS sessions using S- and X-bands on a once-per-month basis. In order to improve stability among the geodetic results, experimental geodetic VLBI observations which use newly developed high speed samplers and recorders were started and geodetic results were obtained from 8-Gbps recording data.

In FY 2015, 11 IVS sessions and 17 sessions of VERA internal geodetic observations were conducted. The final estimation of geodetic parameters is derived by using the software developed by the VERA team.

After "The 2011 off the Pacific coast of Tohoku Earthquake" (Mw=9.0), VERA Mizusawa was displaced by co-seismic crustal movement, and post-seismic creeping continued to be detected in FY 2015. According to the newest analysis, the co-seismic steps are $X = -2.066$ m, $Y = -1.420$ m, and $Z = -1.064$ m; and the displacement by creeping during FY 2015 is $X = -0.101$ m, $Y = -0.056$ m, and $Z = -0.015$ m.

Continuous GPS observations at VERA stations are carried out in order to detect short term coordinate variations and to estimate atmospheric propagation delays. The results of GPS positioning also show a post-seismic motion to the East-south-east of Mizusawa even though 5 years have passed since the occurrence of the 2011 off the Pacific coast of Tohoku Earthquake. Continuous gravity observations with superconducting gravimeters are carried out at Mizusawa and Kamioka. Similar observation is carried out at Ishigakijima as a joint project with other institutes and university groups. The features of the annual change are observed and studied by several techniques including VLBI, GPS, and gravimeters. The strain and tilt observation data obtained at Esashi Earth Tides station are distributed in real time to several institutes based on the research agreement between the Earthquake Research Institute, the University of Tokyo and Mizusawa VLBI Observatory.

6. System Development

In 2015, the magnetic tape recorders were replaced with new hard disk drive recorders, and the Mitaka FX correlator was also replaced with a newly developed software correlator. The software correlator is located at Mizusawa Campus and is now in regular operation. The modifications to the KJCC (Korea Japan Correlation Center) system were done based on the feed-back from scientific evaluation of the KaVA observations. Discussions on future development have been done in particular toward high frequency VLBI and SKA as future extensions of VLBI activities. Basic design and development were done including a low power consumption optical transmitter, ultra-wideband A/D convertors, high accuracy surface reflectors, and balloon-borne radio interferometry.

7. Timekeeping Office Operations

The Timekeeping Office operates four cesium atomic clocks together with a hydrogen maser atomic clock at VERA Mizusawa station. The facilities have been operating stably, contributing to the determination of UTC (Coordinated Universal Time) through continuous management and operation of the time system. The NTP (Network Time Protocol) server at the Timekeeping Office provides "Japan Central Standard Time" on a network. This service has been in great demand with more than 1,500,000 daily visits recorded last year.

8. Ishigakijima Astronomical Observatory

FY 2015 is the 10th year since Ishigakijima Astronomical Observatory (IAO) was opened in FY 2006. Since "Room for Learning the Starlit Sky" was established as an annex to the observatory by Ishigaki City in FY 2013 to screen 4D2U (Four-Dimensional Digital Universe), the number of visitors per year has increased to more than 14,000 people in FY 2015.

In terms of the research at IAO, observations of transient objects such as gamma-ray bursts and Solar System objects were performed in collaboration with Japanese universities. There were six published refereed papers for which the observations at IAO played an important role, including the study of the comet 17P/Holmes.

The number of participants in the "Southern Island Star Festival," which has been held for 14 times, has also been increasing, and 9000 people attended the light-down stargazing party. Since FY 2015 is the 70th anniversary of the end of World War II, the movie "Vega shining over the battlefield," produced by the Yamanashi Prefectural Science Center, was screened in the astronomy lecture room, and a Japanese Tanka contest on "Stars and Peace" was held by inviting famous Tanka poet Machi Tawara to be a selector. Eventually about 11,000 people participated in the festival.

The Chura-boshi Research Team Workshop for high school students and the observational experiment for undergraduate students of the University of the Ryukyus were held. The asteroid (372024) that was discovered by the high school students who participated in the workshop in 2008 was named "Ayapani" by public subscription.

On the other hand, interaction and personnel exchange with Japanese public astronomical observatories were promoted. The star summit was held in Minamimaki, Nagano, where Nobeyama Radio Observatory is located. The special rice-fish called "Space Medaka" were donated from by Saji Observatory in Saji, Tottori, and they are being bred in Ishigaki City, Nagura elementary and junior-high school.

9. Public Relations (PR) and Awareness

In order to promote public outreach, special open house events were done as follows, and regular campus visits are also offered throughout all the seasons as summarized below.

(1) Open House Events

April 19, 2015

The Sixth Open Observatory Event held at the Ibaraki University Center for Astronomy, and NAOJ Mizusawa VLBI Observatory, Ibaraki station, with approximately 230 visitors.

July 4

The 23rd Tanabata Star Festival at the site of the 6-m antenna at Kinko Bay Park in Kagoshima City co-hosted with Kagoshima City and Kagoshima University, with approximately 100 visitors.

August 8

The special open house of VERA Iriki station held jointly with "The Yaeyama Highland Star Festival 2015," with approximately 4000 visitors in attendance.

August 15–23

The "Southern Island Star Festival 2015" held together with a special open house event at the VERA Ishigakijima station and Ishigakijima Astronomical Observatory with 10,930 visitors

to the whole "Star Festival." Events included an astronomical observation party at Ishigakijima Astronomical Observatory, attended by 877 visitors; and a special public opening of the VERA station attended by 238 visitors.

August 22

"Iwate Galaxy Festival 2015", open house of NAOJ Mizusawa Campus, held with 660 visitors in attendance.

February 14, 2016

"Star Island 15," open house event of VERA Ogasawara Station held with 222 visitors in attendance.

(2) Regular Public Visiting

Throughout the year, the following stations are open to public on a regular basis.

The numbers of visitors to each facility is as follows,

a) VERA Mizusawa Observatory 17,415
The open house event is held at the campus with the cooperation of the Oshu Space and Astronomy Museum (OSAM: Yugakukan) located in the campus.
b) VERA Iriki Station 1551
c) VERA Ogasawara Station 8540
d) VERA Ishigakijima Station 2713
e) Ishigakijima Astronomical Observatory 13,906

Stargazing sessions: Evenings on Saturdays, Sundays.

The "Room for Learning the Starlit Sky" (featuring the 4D2U "Four-Dimensional Digital Universe"), constructed adjacent to the observatory in FY 2013 by Ishigaki City, was very popular, welcoming 3925 guests.

(3) Access Statistics of the Website Contents

Websites related to Mizusawa VLBI Observatory and the number of visitors are:

Contents List	Sessions	Internet Users	Page Views
Mizusawa VLBI Observatory	24,201	17,337	72,608
VERA	11,678	6,778	39,952
Kimura Hisashi Memorial Museum	5,726	5,057	8,646
Ishigakijima Astronomical Observatory	80,769	50,319	161,242

10. Education

(1) University and Post-Graduate Education

Regarding postgraduate education, the Mizusawa VLBI Observatory assisted two graduate students from the University of Tokyo and two from SOKENDAI for their PhD/master's research. One of the students from the University of Tokyo completed his master's thesis. One master's student from Tokai University was accepted as a visiting graduate student. Undergraduate students from Tohoku University and Tokai University were accepted as summer students of SOKENDAI. The Observatory staff organized "The Radio Astronomy Winter School 2016" in collaboration with NARIT (National Astronomical Research Institute in Thailand) and UST (University of Science and Technology, South Korea). The school was held February 15-19, 2016 at Chiang Mai in Thailand. About 30 students from Asian countries attended the School. The University of the Ryukyu and NAOJ have offered a joint course on astronomy from FY 2009. Classroom lectures at the university took place August 24-27, and observational workshops were held in Ishigakijima from September 1 to 4, with a total of 25 participants. In addition, staff members of Mizusawa VLBI Observatory give lectures at the University of Tokyo and Tohoku University as visiting professors.

(2) Research Experience for High School Students

"The 9th Z Star Research Team Event" was held August 1-3 to use the VERA Mizusawa antenna for observation. Eleven high school students from Iwate Prefecture attended. During August 12-14, the VERA Ishigakijima station and The Ishigakijima Astronomical Observatory held "The Chura-boshi Research Team Workshop" for 18 high school students from Ishigakijima. It was organized under support from JSPS. One of the groups detected a new maser source using the VERA Ishigakijima station, and presented the results in the open-house of VERA Ishigakijima station. Mizusawa VLBI Observatory supported the SSH (Super-Science High-school) research activities for Yokote Seiryo High School in Akita Prefecture to use the Mizusawa 20-m antenna. The observational results were presented in "The Junior Session" in the annual meeting of "The Astronomical Society of Japan".

5. Solar Observatory

The Solar Observatory primarily engages in the operation of solar observational facilities on the west side of Mitaka Campus and in the development of new observational instruments. It conducts both observational and theoretical studies of the structure of the outer solar atmosphere, including the photosphere, chromosphere, corona, and solar wind; and active phenomena such as sunspots, faculae, prominences, and flares. This observatory performs regular observations using instruments such as the Solar Flare Telescope (SFT) and also conducts expeditions to observe total solar eclipses. It is also engaged in the planning of future ground-based solar observations. Regular observations of sunspots and flares have been carried out for extended periods, and the resulting data are provided to researchers.

1. Observational Facilities in Mitaka

(1) Magnetic Field Observation

The SFT, which has been the main instrument of the Observatory at Mitaka Campus, has continued observations of active region photospheric vector magnetic fields and H-alpha flares since its full completion in 1992. The main instrument on the SFT since 2010 is an infrared Stokes polarimeter. Whereas previous magnetic field observations covered part of the solar surface, this instrument is designed to perform full-disk polarimetric observation to obtain high accuracy vector magnetic field information in order to shed light upon the origins of the solar activity cycle. This polarimeter is equipped with a 15-cm infrared-transmitting lens and performs slit scanning observations using infrared spectral lines (photosphere: iron, 1.56 μm line; chromosphere: helium, 1.08 μm line), which are sensitive to the magnetic field. This allows for constant acquisition of unprecedented infrared polarization data for the photosphere and chromosphere of the entire solar disk. It had taken about two hours to cover the full Sun with a slit scan for each wavelength range, but a new system enables us to observe two wavelength ranges simultaneously using two cameras installed in 2014. The data acquisition is now conducted more efficiently. To further improve the data quality, the installation of an advanced infrared camera with a large format and low read-out noise is being conducted, using a grant from the Project for Solar-Terrestrial Environment Prediction (PSTEP), Grants-in-Aid for Scientific Research on Innovative Areas.

(2) Regular Observation of Sunspots/Faculae/H-alpha Flares

Sunspot observations have been performed continuously since 1929. These observations are currently conducted via automatic detection of sunspots in digital images captured with a 10-cm refractor and a 2 k × 2 k pixel charge coupled device (CCD) camera mounted on the new (full-disk) sunspot telescope. Observations were conducted for 241 days in FY 2015, from April to March.

Although full-disk solar image data are a widely needed resource in the astrophysics/geophysics community, some of these synoptic instruments are becoming out of date. Efforts are underway to update the photospheric and chromospheric imaging instruments and to further flesh out the data. For instance, the SFT has started advanced observations in the H-alpha line to acquire full-disk, high-resolution images. It can obtain Doppler velocity information based on imaging at multiple wavelengths around H-alpha. High temporal resolution allows it to more completely capture active phenomena, and a combination of multiple exposure times allows for a broad dynamic range. Further improvement in dynamic range and read-out noise was accomplished using sCMOS cameras installed in this year. This advancement has enabled us to observe many phenomena, such as flares and prominence eruptions, even during the recent downturn in solar activity. The Observatory also uses the SFT to conduct regular imaging observations in the G-band (430 nm) and continuum wavelengths. In addition, CaII K (393 nm) filter observation has started this year.

The regular observational data described above, including real-time images, are available on the website of the Observatory. Using a Grant-in-Aid for Scientific Research, a spectrograph system with a coelostat is under development to perform long-term, full-disk observations, including more quantitative velocity and magnetic field observations. An improvement to the spectrograph room was conducted this year. The Observatory maintains other existing equipment to allow for everyday observation, as well as experimental use.

2. Opening of Data Archives to the Public

The Solar Observatory has made nearly 16.2 TB of data available to the public online, including data from the current observations of white light, H-alpha, and magnetic fields as well as those from nearly 100 years of various types of solar observations. The various phenomena occurring in the solar-terrestrial environment must be studied in terms of both sudden, short-term events (space weather) and in terms of gradual changes occurring over years or decades (space climate). The Observatory will continue providing fundamental data for these studies. The Observatory possesses nearly 100 years of accumulated records, including continuum images, Ca II K-line images, and H-alpha images recorded on film, photographic plates, and hand-drawn sketches, all of which have an importance of their own. The Observatory will make these available to the public as well when they are digitized and organized. As some of the world's oldest records of solar activities, these materials are expected to add particular insight into future research. Higher bit digitization of old Ca II K line images improving the data quality was conducted this year as a part of research activity for the PSTEP, Grants-in-Aid for Scientific Research on Innovative Areas.

Data publicized via the website were previously stored on a server owned by the Observatory. The information has

since been transferred to the Astronomy Data Center, where all relevant data servers have been managed in an integrated fashion. The same data are stored at multiple locations in the data center, serving as a backup in case of disaster.

3. Other Activities/Personnel Transfers

International cooperation includes support for the Japan–Peru collaborative solar observations, with which the Solar Observatory has been involved since 2004. In addition to the collaboration in solar spectrograph installation and operation in Peru, relocation of the 10-cm coronagraph which had been used in Norikura Solar Observatory is envisioned. For this purpose, the coronagraph was reassembled and used to run test observations at Norikura Corona Observatory, this year. The Solar Observatory also supports the operation of another 10-cm coronagraph with a NOGIS filter system in a Chinese observatory (3200 m elevation) in Yunnan province. This coronagraph was relocated from Norikura in 2013 to observe two dimensional intensity and velocity fields of the solar corona in the coronal green line of Fe XIV (530.3 nm).

The solar optical observations at Hiraiso Solar Observatory of the National Institute of Information and Communications Technology are considered to be terminated. To examine the possibility of utilizing the instruments in the future at other institutes, their removed H-alpha Lyot filter and telescope/coelostat for solar magnetic field measurements were placed in storage at Mitaka this year.

A research plus business conference, dubbed as the annual users meeting, has been held every year jointly with other organizations. The meeting is combined with the solar research symposium for the entire solar community, where topics related to open use and future plans are also discussed. The conference was held at NAOJ between February 15 and 17, 2016.

Observation of the total solar eclipse of March 9, 2016 in Indonesia was conducted by Drs. Hanaoka and Morita. The observation was not so successful because of a cloudy sky, but some data of prominence and corona through the clouds were obtained.

Because the Observatory deals with fundamental solar data, there are often requests to use images from the Solar Observatory database in school textbooks, to contribute to articles in newspapers or magazines, and to help public events held by museums. The Observatory actively responded to these requests.

Regarding personnel transfers, Dr. Masaoki Hagino replaced a previous research expert, Dr. Naomasa Kitagawa. Dr. Anand Joshi will take a position as specially appointed research staff at the start of the new fiscal year, after the departure of Dr. Ken'ichi Otsuji. Prof. Takashi Sakurai was honorably discharged in the end of FY 2015, March 2016.

6. NAOJ Chile Observatory

The ALMA Project is a global partnership of East Asia (led by Japan), Europe, and North America (led by the United States) in cooperation with other nations to construct and operate a gigantic millimeter/submillimeter radio telescope deploying 66 high-precision parabolic antennas in the 5000-m altitude Atacama highlands in northern Chile. ALMA aims to achieve a spatial resolution nearly ten times higher than that of the Subaru Telescope or the Hubble Space Telescope. Early scientific observations with ALMA began in FY 2011 with a limited number of antennas and full operation commenced in FY 2012. This report describes the progress of the ALMA project, which includes the results of the open-use scientific observations and public outreach activities. The ASTE telescope is a single-dish 10-m submillimeter telescope located in the Atacama highlands. It has been operated to make headway into submillimeter observations toward the ALMA Era. This report also describes the progress of the ASTE telescope.

1. ALMA Project Progress

Along with scientific observations, ALMA commissioning observations have been underway, including polarization tests and solar observation tests.

NAOJ staff members played leading roles in the polarization tests and solar observation tests. As demonstrated by Koichiro Nakanishi and Hiroshi Nagai for polarization, and Masumi Shimojo for solar observation tests, East Asian researchers have been taking the initiative in the international teams. Also Band 10 receivers, the highest observing frequency band, became available for scientific operations starting from the fourth round of open-use observations of ALMA (Cycle 3) which started in FY 2015. The sub-components developed by Japan, such as the antennas, correlators, and receivers (Bands 4, 8, and 10), are working properly for the operations.

2. ALMA Open-Use and Scientific Observations

The fourth round of open-use observations of ALMA commenced in October 2015 as Cycle 3. The Cycle 3 main capabilities include: interferometric observations using thirty-six 12-m parabolic antennas; Atacama Compact Array (ACA) observations (interferometric observation with ten 7-m antennas and single-dish observations with two 12-m antennas); seven frequency bands (Bands 3, 4, 6, 7, 8, 9, and newly-added Band 10); maximum baselines greatly extended from 1.5 km to 10 km (for Bands 3 to 6), 5 km (for Band 7) and 2 km (for Band 8 to 10); and polarization for continuum observations. In response to the Cycle 3 call for proposals, 1578 observation proposals were submitted from all over the world. This figure exceeded the world's highest number of proposals ever recorded, which was submitted to the Hubble Space Telescope. Such a high submission rate to ALMA shows high expectations for "the global telescope ALMA" with the potential to contribute to a wide-range of fields such as galaxy formation, star and planet formation, the Solar System, astrobiology, and interstellar chemistry.

An open call for the fifth round of open-use observations was issued as Cycle 4. The anticipated capabilities of Cycle 4 include: interferometric observations using forty 12-m antennas; ACA observations (interferometric observation with ten 7-m antennas and single-dish observations with three 12-m antennas); seven frequency bands (Bands 3, 4, 6, 7, 8, 9, and 10), maximum baselines of 12.6 km (for Bands 3 to 6), 6.8 km (for Band 7), and 3.7 km (for Bands 8 to 10). Cycle 4 also provides new opportunities for large programs that require long observations exceeding 50 hours; millimeter-wavelength VLBI observations; ACA stand-alone mode; solar observations; and polarization for spectral line and continuum observations. The public call for Cycle 4 proposals is set to close at 00:00 JST on April 22, 2016. Cycle 4 is scheduled to start in October 2016.

Open use of ALMA has already produced a number of scientific achievements. This section describes some of them, focusing mainly on East Asian projects. A research group led by Yoichi Tamura at the University of Tokyo found several dust clouds with a size of 500 light-years distributed inside SDP.81 through detailed analyses of the image of the gravitationally lensed galaxy SDP.81 captured by high-resolution observations with ALMA and comparison of this image to its gravitational lens model. The results of their study also indicate the existence of a supermassive black hole over 300 million times more massive than the Sun at the center of the foreground galaxy. A research group led by Kyoko Onishi at SOKENDAI (The Graduate University for Advanced Studies) observed the barred spiral galaxy NGC 1097 with ALMA and through a detailed study on the kinematics of molecular gas at the center of the galaxy found that this galaxy harbors a supermassive black hole 140 million times more massive than the Sun. This research result is based on the ALMA observation data obtained within a two-hour observation, which demonstrates the outstanding capability of ALMA in the mass measurement of supermassive black holes. A research team led by Hideki Umehata successfully captured a cluster of nine starburst galaxies in a cluster of young galaxies 11.5 billion light years away from the Earth (at the center of a "proto-Great Wall" known as the largest structure in the Universe). This result supports the idea that the proto-Great Wall is the matrix that supports the formation of galaxies. This could lead to unveiling the formation process of starburst galaxies and their subsequent evolutionary process. A research team led by Yusuke Aso at the University of Tokyo and Nagayoshi Ohashi at NAOJ observed a proto-star called TMC-1A and revealed the movements of the inner rotating gas disk around the proto-star and the outer gas envelope with the highest accuracy ever achieved. The high-sensitivity observations with ALMA made it possible to directly observe the boundary between the disk surrounding the proto-star and the outer infalling gas envelope. These results are very important in

finding out when the proto-planetary disk appears in the process of star formation and how it evolves.

3. Educational Activities and Internship

Two undergraduate students joined research activities on an internship at the NAOJ Chile Observatory office in Mitaka: one came from the University of Science and Technology of Hanoi in Vietnam from June through September 2015; and the other from the FTP University in Vietnam from January through March 2016.

4. Public Outreach Activities

Approximately 35 newspaper/journal articles were published in Japan, reporting the achievements of scientific observations and test observations with ALMA, while there were 14 Japanese television/radio programs that featured ALMA. In these programs, they showed the results of ALMA observations in various fields of astronomy; in particular, a news program called "News 7" on NHK G channel covered ALMA focusing on the field of astrobiology. In online media, "IFLScience!" (a scientific website with a great number of subscribers) posted an article on ALMA observation results delivered by Japanese researchers, which was shared and liked on Facebook by 17,000 users. As seen in this example, the scientific results by Japanese researchers have been increasingly propagated worldwide.

The NAOJ ALMA website posted 43 news articles and eight press releases. A mailing-list-based newsletter has been issued on a monthly basis with approximately 2,500 subscribers. Updated, detailed information is available on Twitter (@ALMA_Japan), with nearly 27,500 followers as of the end of FY 2015.

In May 2015, NAOJ Chile Observatory hosted a week-long ALMA booth at the Japanese Geoscience Union Meeting held in Makuhari Messe. NAOJ Chile Observatory organized public lectures and science cafe events on 26 occasions in FY 2015 to provide updated information and increase interest in ALMA and its scientific achievements through conversation with a large number of visitors. Especially, the 21st ALMA public lecture titled "Star and Planet Formation Explored by ALMA" held in Osaka Science Museum on December 12, 2015 attracted a big audience exceeding 200, which was a great opportunity to provide the latest scientific results to the public.

As part of the construction film project continuing since FY 2003, NAOJ Chile Observatory produced a new film that shows the development of the receivers at the Advanced Technology Center (ATC), focusing on the development and production of receiver cartridges in FY 2014. In addition to this, interviews with developers of the ACA correlators were also filmed.

The NAOJ newsletter featured ALMA in the September 2015 issue with an article summarizing the ALMA project and its scientific achievements so far, including interviews with ALMA staff members at the ALMA Regional Center to widely cover the staff members supporting the open use and promoting their scientific activities, including their enthusiasm and passion for the work.

From mid-March 2015, ALMA started to welcome public visits to the ALMA Operations Support Facility (OSF) at an altitude of 2900 meters. Every Saturday and Sunday, ALMA admits up to 40 people/day (advance registration is required). Visitors to the OSF can have a guided tour including the control room, and watch videos on ALMA. Each time, registration reaches full capacity soon after the start of registration. Public visits to ALMA are now becoming good opportunities to provide many people live experience of the workplace of ALMA researchers.

5. International Collaboration (committees, etc.)

Two agreements concerning the operations and development of ALMA were concluded between the National Institutes of Natural Sciences (NINS) and Academia Sinica in Taiwan (AS) on July 21, 2015, and between the National Astronomical Observatory of Japan (NAOJ) and Academia Sinica Institute of Astronomy and Astrophysics in Taiwan (ASIAA) on July 27, 2015 respectively. On December 15, 2015, representatives of the National Institutes of Natural Sciences (NINS), the European Southern Observatory (ESO) and the U.S. National Science Foundation (NSF) gathered in Tokyo and signed a trilateral agreement concerning the operations of ALMA.

Since ALMA is an international collaboration project, meetings are held frequently by various committees. In FY 2015, the ALMA Board met face-to-face once, and the ALMA Scientific Advisory Committee (ASAC) twice. In addition to these, teleconferences have been held on a near-monthly basis among the members of the ALMA Board and ASAC. In addition, face-to-face meetings and teleconferences have been held on a quarterly basis among the East-Asia ALMA Science Advisory Committee (EASAC). Each working group holds meetings and teleconferences more frequently to maintain close communication in implementing their tasks in the international project.

6. Workshops and Town Meetings

- July 28 to 30, 2015 NAOJ Nobeyama Radio Observatory (NRO)
  NRO-ALMA Science/Development Workshop 2015
- October 20 to 22, 2015 NAOJ Mitaka
  ALMA/45-m/ASTE/Mopra Users Meeting
- December 8 to 11, 2015 I-site Nanba
  International Workshop "EA ALMA Science Workshop"
- March 9, 2016 Ehime University
  ALMA Cycle 4 Town Meeting
- March 22 to 23, 2016 Kagoshima University
  ALMA Cycle 4 Town Meeting
- March 25, 2016 Kyoto University
  ALMA Cycle 4 Town Meeting
- April 4, 2016 NAOJ Mitaka
  ALMA Cycle 4 Town Meeting

7. Obtained External Grants Other Than Grants-in-Aid for Scientific Research including Industry –University Collaboration Expenses

- Daisuke Iono: Inamori Grant Program by the Inamori Foundation
- Satoru Iguchi: Grant for Japan-related Research Projects by the Sumitomo Foundation

8. Research Staff Changes

(1) Hired
- Kana Matsui: specially appointed research staff
- Fumi Egusa: specially appointed research staff
- Tatsuya Takekoshi: specially appointed research staff

(2) Departed or transferred
- Rie Miura: specially appointed research staff, hired as a specially appointed assistant professor at NAOJ Chile Observatory
- Junko Ueda: specially appointed research staff, transferred to the Harvard-Smithsonian Center for Astrophysics as a post-doctoral fellow
- Yasutaka Kurono: specially appointed research staff

9. Main Visitors

- April 23, 2015
  Mr. Naoto Nikai Ambassador of Japan to Chile, visited the ALMA Operations Support Facility (OSF) and the Array Operations Site (AOS)
- May 6, 2015
  A group of researchers from universities in Taiwan visited the OSF and AOS
- May 8, 2015
  Mr. Kosaburo Nishime, State Minister for Internal Affairs and Communications (MIC) and his party; Dr. Fumihiko Tomita, Vice President of the National Institute of Information and Communications Technology (NICT), Dr. Shinro Mashiko, Vice President of NICT, and Mr. Pedro Huichalaf, Vice Minister (Undersecretary) of Telecommunications, visited the OSF and AOS
- October 16 to 18, 2015
  Dr. Akihiro Kubota, Professor at Tama Art University visited the OSF and AOS

10. Progress of ASTE Telescope

The ASTE telescope has been operated to promote full-fledged submillimeter astronomical research in the southern hemisphere and to develop/verify observational equipment and methods. With the ALMA telescope entering its operation phase in FY 2012, ASTE will be engaged mainly to provide observational evidence for strengthening ALMA observation proposals and to pursue development for enhancing ALMA's future performance.

Other than ALMA, there are only two large-scale submillimeter telescopes with a 10-m-class antenna that can observe the southern sky in the world: one is ASTE and the other is APEX operated by ESO. Therefore, having ASTE operated by Japan will be a big advantage in strengthening ALMA proposals and in implementing our strategies for further extending the capabilities of observing equipment. Looking to the future, ASTE is also important since it provides opportunities for nurturing young researchers who will play key roles in the equipment development for the next generation. In the near future, ASTE will be incorporated into the open-use program to have organic collaboration with the Nobeyama 45-m Radio Telescope.

Three public calls were made in FY 2015 for open-use observation proposals: the first call (2015a) for spectroscopic observations in 345 and 460 GHz bands was from June to September, the second call (2015b) and an additional call for spectroscopic observations only in the 345 GHz band (2015c) from October to December. To render support for researchers contributing to enhancing the observational performance of ASTE, the Guaranteed Time Observation (GTO) scheme has been offered since FY 2013. This allows them exclusively to make proposals for the GTO slots. A total of 53 proposals for open-use observations and GTO slots had been made including 25 for open use and one for GTO in the first call; 12 for open use in the second call; and 15 for open use in the additional call. These proposals were reviewed by the NAOJ Chile Observatory program subcommittee and 41 proposals were subsequently adopted, including 22 for open use and one for GTO in the first call; 11 for open use in the second call; and seven in the additional call. Open-use observations were carried out from the ASTE Mitaka operation room, other universities or research institutes between June 8 and December 18, 2015.

7. Center for Computational Astrophysics

1. Overview

The Center for Computational Astrophysics (CfCA) has been operating a system of open-use computers for simulations centered around a general-purpose supercomputer and the special-purpose computers for gravitational many-body problems; carrying out research and development of computational astrophysics; and performing astronomical research with simulations. The main supercomputer of the present system, ATERUI (Cray XC30), has a theoretical peak performance of 1 Pflops, which makes it the world's fastest supercomputer for astronomy. The Center also continued operation of other computers such as GRAPE-DR and GRAPE-9 that are dedicated for gravitational many-body problems, in addition to general-purpose servers. Efforts in visualizing astronomical data also continue.

2. Open Use

(1) Computer Systems

This year marked the third year of the upgraded astronomical simulation system, which includes the open-use supercomputer Cray XC30. The main supercomputer installed and under operation at Mizusawa VLBI Observatory had all of its CPUs upgraded last year, and its theoretical peak performance is now as high as 1 Pflops. The users have been making academically significant progress as before.

While XC30 is leased for five years from Cray Japan Inc., the Center has built the following equipment to aid the open-use computer operations: a series of dedicated computers for gravitational N-body problems, known as GRAPEs; PC cluster for small to medium-scale computation; large-scale file servers; a group of servers for processing computational output data; and networking instruments to encompass the overall computer system. These components are central to numerical simulations by researchers in Japan and overseas. In particular, to encourage effective open use of the GRAPE system, the Center undertook development, improvement, and maintenance of both hardware and software for the system this year. Major events of this year were the end of GRAPE-7 operations and the official operation of GRAPE-9. This system offers a roughly 10-fold performance improvement over GRAPE-7.

Computational resources are allocated from the XC30, GRAPEs, and smaller computational PC cluster in accordance with a formal review process. The statistics of applications and approvals for this year are listed below. Our Center conducted a survey this year on the number of peer-reviewed papers published in English in FY 2014 on studies that involved the project's open-use computers. It turned out that 75 refereed papers (written in English) were published in this fiscal year.

The Center uses Drupal, a content management system introduced for data exchange with users of open-use computers, for providing users with information and transmitting various application forms as necessary. The regular CfCA News is an additional channel of information dissemination. The Center leverages this newsletter to inform people of all useful and necessary information regarding the computer system. A subsidy system for publishing and advertising is continuing this year for research papers whose major results were obtained by using the Center's computers. No paper was accepted in FY 2014 for payout in FY 2015, while four papers were accepted in FY 2015 for payout in the same year at approximately 500,000 JPY.

□ Statistics on the Cray XC30
Operating hours
- Annual operating hours: 8561.0
- Annual core operating ratio: 87.13 %

Users
- Category S: 1 adopted in the first term, 0 in the second term; total 1
- Category A: 13 adopted at the beginning of the year, 2 in the second term; total 15
- Category B: 70 adopted at the beginning of the year, 15 in the second term; total 85
- Category MD: 15 adopted at the beginning of the year, 3 in the second term; total 18
- Category Trial: 45, year total
- Category I: 0, year total

□ Statistics on the GRAPE system
Users
- Category A: 3 adopted at the beginning of the year, 0 in the second term; total 3
- Category B: 6 adopted at the beginning of the year, 0 in the second term; total 6
- Category Trial: 0, year total

□ Statistics on PC cluster
Operating hours
- Annual operating hours: 7764.7
- Annual job operating ratio: 73.3 %

Total users: 37, year total

(2) Tutorials and Users Meeting

The Center organized various lectures and workshops to provide the users of the open-use computer system with educational and promotional opportunities, as well as to train young researchers. The details are shown below. In addition, the CfCA Users Meeting was held to serve as a forum for direct information exchange. Many participated in the meeting, and discussions were fruitful. Note that in FY 2015, the CfCA Users Meeting was held at Mizusawa VLBI Observatory, Iwate.

□ Cray XC30 workshop for intermediate users: January 15, 2016, 4 attendees

□ N-body simulation Winter School: January 20-22, 2016, 16 attendees

□ Users meeting: January 28-29, 2016, 63 attendees

3. PR Activities

CfCA took part in the special open house of Mizusawa Campus, Iwate Galaxy Festival 2015, held on August 22, 2015. About 150 visitors attended the ATERUI guided tours and experienced a close-up look at the facility. Dr. Tomoaki Ishiyama, Associate Professor at Chiba University and one of the users of ATERUI, was invited to this event as a special lecturer and talked about the latest results of his research obtained through ATERUI's simulations. At the Mitaka open house held on October 24, 2015, CfCA made the computer room accessible to the public and introduced simulation astronomy with GRAPE and the PC cluster. A live broadcast was also arranged by connecting the supercomputer operation room in Mizusawa Campus to Mitaka Campus to introduce ATERUI to those visiting Mitaka. In addition to the open house, CfCA has accepted two groups of high school students to tour the computer room in Mitaka Campus. Moreover, CfCA ran a booth at the 19th NINS Symposium "From the Universe to Brains "Big Bang" of the Natural Science Researches" held at Nagoya University on September 20, 2015 and introduced research results from simulation astronomy calculated by the CfCA system.

In FY 2015, two press releases were issued from CfCA: "The World's Largest Scale Dark Matter Simulation from the Beginning of the Universe to the Present Performed by Supercomputers" (May 1, 2015, Tomoaki Ishiyama, Associate Professor at Chiba University) and "Origin of Saturn's F Ring and Its Shepherd Satellites Revealed" (August 18, 2015, Ryuki Hyodo, Graduate Student at Kobe University). In addition, the press release from the NAOJ Hinode Science Center, "Hinode, IRIS, and ATERUI Cooperate on 70 year old Solar Mystery, Magnetically driven resonance helps heat the Sun's atmosphere!" (August 24th, 2015), included a result of calculations by ATERUI (Dr. Patrick Antolin, NAOJ). A Twitter account @ CfCA_NAOJ and YouTube channel have been operated to provide information about CfCA.

4. 4D2U Project

In FY 2015, the 4D2U project continued to develop and provide movie contents and software. A movie about simulations titled "Formation and Evolution of Dark Matter Halos (II. Formation of the Large-Scale Structure of the Universe) ver.2" was released on the 4D2U website in May 2015. Distribution of the dome master format data was also started. Other movies, "Giant Impact of protoplanets", "Dynamics of Saturn's Ring (II. Propeller Structure)", and "Formation of plametesimals" have been developed. Updated versions of the four-dimensional digital universe viewer, "Mitaka," were released in June 2015 (ver.1.2.4), July 2015 (ver.1.2.5), November 2015 (ver.1.3.0) and March 2016 (ver.1.3.1). These versions of Mitaka included the new functions, e.g. displaying probes like New Horizons and Hayabusa2, multilingual displays, and depiction of solar and lunar eclipses. On February 9, 2016, the 4D2U Project put out a press release about the multilingualization of Mitaka. The imaging speed of Mitaka was made faster and faster with every update.

On April 2, 2015, the 4D2U Project and Public Relations Center (PRC) held a press tour of the renewed 4D2U Dome Theater. A total of 26 of media affiliates from 22 companies attended and various news outlets picked up the renewed theater as news. In cooperation with PRC, we enhanced English contents, such as the English websites of 4D2U and Mitaka, the English manual of Mitaka, English instructions for 4D2U movies, and terms of use. We started to accept applications for usage of 4D2U contents in English in October 2015. The 4D2U Project supported and provided content for exhibitions held in museums and galleries, including "Moon + Sun Exhibition" (Konica Minolta Plaza, Apr. 22 - May 8, 2015), "The Feeling of the Four-Dimensional Universe" (Ehime University Museum, May 20 - Jul. 27, 2015) and "Forms of the state-of-the-art Network" (Chiba Museum of Science and Industry, Oct. 17 - Dec. 6, 2015). The dome master data of the latest movie contents "Formation and Evolution of Dark Matter Halos (II. Formation of the Large-Scale Structure of the Universe) ver.2", "Giant Impact of Protoplanets," and "Dynamics of Saturn's Ring (II. Propeller Structure)" were provided for a planetarium program "Cyber Universe Ver.2" screened at Katsushika City Museum (Oct. 6 - Dec. 27, 2015). In addition, Mitaka and some movie contents were used in the 5 minute TV program "Planet Kanko (Site seeing) Taxi" (total 5 stories, produced by Office Raft) broadcast on NHK. Moreover, 4D2U contents were provided for TV programs, planetarium programs, lecture presentations, books, and so on. In FY 2015, the 4D2U Project gave Mitaka (Standard version and Head Mounted Display version) demonstrations at the open houses of Mizusawa and Mitaka campuses and the 19th NINS Symposium "From the Universe to Brains "Big Bang" of the Natural Science Researches." Many visitors enjoyed Mitaka outside of the 4D2U Dome Theater. A Twitter account @4d2u and YouTube Channel have been operated to provide information about 4D2U.

5. External Activities

(1) Joint Institute for Computational Fundamental Science

The Joint Institute for Computational Fundamental Science (JICFuS) is an inter-organizational institute established in February 2009 as a collaboration base between three organizations: the Center for Computational Sciences (CCS) of the University of Tsukuba; the High Energy Accelerator Research Organization, known as KEK; and NAOJ to provide active support for computational scientific research. The CfCA forms the core of NAOJ's contribution to the JICFuS. In particular, the institute engages primarily in computer-aided theoretical research into fundamental physics in elementary particle physics, nuclear physics, and astrophysics. The scientific

goal of the institute is to promote fundamental research based on computational science by encouraging interdisciplinary research between elementary particle physics, and astrophysics. In addition to its abilities as a single organization, a major feature of the institute is the cooperation of its three member organizations and their communities to provide considerate and rigorous support to present and future researchers. Another important mission of the institute is to provide researchers around Japan with advice regarding efficient supercomputer use and the development of novel high-performance computing algorithms to meet research goals from the perspective of computer specialists. In addition in FY 2014, JICFuS was adopted as one of the "Research and Development, Application Development of scientific/social issues that require particular attention by the use of a Post-K computer." The program started this year.

In order to implement research plans, Hiroyuki Takahashi was engaged as a project assistant professor, and Tomohisa Kawashima was engaged as a project researcher. Takahashi developed a new plasma simulation code to solve basic equations of general relativistic radiation magnetohydrodynamics (MHD). By performing global simulations of black hole accretion disks, he revealed that jet power and gas temperature increase via the extraction of the rotational energy of the black hole. He also developed a radiation-MHD code by which the radiation transport is more exactly solved. Kawashima developed a radiation transfer code in curved space-time. In addition, he performed numerical simulations of gas accretion onto neutron stars polar regions, since some of the candidates thought to be black holes have been identified as neutron stars instead. As a result, he revealed that the observed large luminosities can be reproduced even in the neutron star accretion flows.

Representing the CfCA, Professor Kohji Tomisaka and Assistant Professors Ken Ohsuga and Tsuyoshi Inoue of NAOJ participate in bimonthly JICFuS steering committee meetings to engage in deliberations on spurring computational science-based developments in astrophysics research through discussions with other committee members who specialize in nuclear and elementary particle physics.

(2) HPCI Consortium

As a participant in the government-led High-Performance Computing Infrastructure (HPCI) project since its planning stage in FY 2010, the Center has engaged in the promotion of the HPC research field in Japan, centering on the use of the national "K" supercomputer. Note that although the Center is involved with the JICFuS-led HPCI Strategic Program Field 5 as well as Priority Issue 9 to be tackled using a Post-K computer as mentioned in (1), the activities in the HPCI consortium are basically independent from them. The HPCI consortium is an incorporated association established in April 2012, and the Center is currently an associate member that is able to express views, obtain information, and observe overall trends in the planning, although we lack voting rights as well as the obligation to pay membership fees. Continuing from last year, a number of conferences and WGs have been held where participants discussed a next-generation national supercomputing framework to follow the "K." As of this year, the post-K project has officially started with some budget from the Ministry of Education, Culture, Sports, Science, and Technology (MEXT). The concrete details of its operation are being disused actively. Now the detailed discussions as to how we fully exploit the resources of the post-K system have begun in relevant communities and organizations. The Post-K generation equipment is scheduled to commence operation after FY 2019. In principle, therefore, it is possible for NAOJ to play a central role in the post-K generation HPCI through participation in this discourse.

6. Contract Staff Transfers

The following staff members were hired on a contract basis in this FY:
(Research experts) n/a
(Postdoctoral fellows) Yuta Asahina
(Research associates) n/a

The following contract staff members departed in this FY:
(Research experts) Yayoi Narazaki
(Postdoctoral fellows) Shun Furusawa, Tomohisa Kawashima
(Research associates) Yukihiko Hasegawa, Yuji Matsumoto

8. Hinode Science Center

The scientific satellite Hinode is an artificial satellite that was launched on September 23, 2006, by the ISAS division of JAXA, as Japan's third solar observational satellite following Hinotori (1981) and Yohkoh (1991). NAOJ implemented this satellite project under a joint research agreement with ISAS/JAXA. A major theme of the scientific goals of the Hinode mission is to shed light on the coronal heating mechanism through a more multifaceted understanding of magnetohydrodynamic (MHD) phenomena occurring in the solar atmosphere. The satellite has actually made a lot of discoveries related to these subjects.

Hinode is equipped with three telescopes including the solar optical telescope (SOT), the X-ray telescope (XRT), and the extreme ultraviolet (EUV) imaging spectrometer (EIS). It engages in simultaneous observations of the detailed magnetic fields and velocity fields on the surface of the photosphere and the brightness and velocity fields from the chromosphere to the corona. The onboard telescopes were developed as part of a wide-ranging international collaboration with assistance from ISAS/JAXA. SOT was developed mainly by NAOJ, and the focal plane package (FPP) was developed by the US National Aeronautics and Space Administration (NASA) and Lockheed Martin.

With regard to the XRT, NASA and the Smithsonian Astrophysical Observatory (SAO) are responsible for the optics system and frame, and Japan (ISAS/JAXA, NAOJ) is responsible for the focal plane camera. EIS is the result of an even broader international cooperation. The structure and electrical system were developed by the UK Science and Technology Facilities Council (STFC) and University College London; the optics system was developed by NASA and the Naval Research Laboratory (NRL); and the University of Oslo in Norway assisted with the terrestrial testing equipment and the Quick Look system. NAOJ actively participated in the development of the EIS/satellite interface, satellite integration testing, and launch experiments. After a successful launch, NAOJ has continued its active involvement by acting as the main institution for collecting and analyzing data acquired by the satellite.

The Hinode Science Working Group (SWG), composed of representatives from the international team, offers support in scientific operation and data analysis. Together with two members from the European Space Agency (ESA), the WG has a total of 15 members three from the Hinode Science Center (HSC) including Sakurai, Chairman/project scientist; Suematsu, SOT; and Watanabe, EIS. Science Schedule Coordinators have been organized to leverage the open-use observation system. Many of the Japanese coordinators are NAOJ staff members, including Watanabe (Chairman/EIS) and Sekii (SOT).

FY 2015 marks the ninth year since the satellite's launch. The 2015 NASA Senior Review results for Hinode were ranked in the top 3 among 15 missions under the control of NASA's Heliophysics Division, which assured adequate NASA funding for the near future. ESA will continue to support Hinode with the current level of funding at least until the end of FY 2017. The funding from STFC was also renewed for Hinode until March 2019. The request for the Hinode mission extension will also be submitted to ISAS/JAXA in FY 2016.

1. The Hinode Satellite: Onboard Telescopes and Scientific Operation

The SOT is a telescope used for obtaining photospheric magnetic field vectors via polarimetric observations of absorption lines. It has the capacity for continuous observation at the diffraction limit with a spatial resolution of 0.2–0.3 arcsec and an effective aperture of 50 cm without atmospheric seeing. The focal plane package consists of three types of optics systems and imaging functions for maintaining the desired performance level. Operational modifications have enabled longterm maintenance of a sound field of view even in the narrow band filter imager system, in which image degradation was initially detected in part of the field of view. The power supply for the filtergraph (FG) camera failed on February 25, 2016. The FG system has been powered off, and stopped operation since then. Currently the cause of the trouble and the possibility for recovery are under investigation.

The XRT has the capacity of capturing the solar coronal plasma via soft X-rays. The telescope has inherited the grazing incidence optics system and has improved in spatial resolution. Its wavelength characteristics have been improved to allow for observation of the solar coronal plasma over a broader temperature range. Resolution is close to 1 arcsec. Calibration is now possible for temporal variations in spectral characteristics due to surface contamination on the detector, and the telescope is available for analysis via its spectral characteristics.

The EIS obtains temperatures, densities, and velocities of the chromosphere, transition region, and coronal plasma thorough the spectroscopic observation of EUV emission lines. The instrument allows for spectroscopy and imaging at multiple wavelengths via the operation of slits and slots. Its purpose is to investigate the manner in which energy is conveyed from its generation in the photosphere until its dissipation in the corona by observing from the chromosphere (located between the photosphere and the corona) through the transition region to the corona.

A mission data processor (MDP) was installed to manage observations and to acquire data via the three telescopes. Coordinated observations using the three telescopes, in which the MDP plays a crucial oversight role, are vital to achieve the scientific goals of the Hinode satellite. Particularly for the XRT, functions such as the exposure time adjustment, the region of interest (ROI) selection, and the flare detection logic are handled by the MDP, which requires close coordination with the telescopes.

Data from the Hinode satellite is primarily downlinked at the Kagoshima station (USC) and at Norway's Svalsat station

through collaboration with ESA, allowing for data acquisition for every orbit. Scientific operation was again performed in FY 2015 via S-band data reception. The S-band reception frequency was increased with help from ESA and NASA, allowing for continuation of regular, stable scientific operation.

Obtained data is collected at ISAS/JAXA, converted into the FITS format, and provided to researchers around the world in the form of Level-0 data, which is close to raw data. HSC staff members and students took part in satellite operation for a total of 200 days in FY 2015, 119 days of which were for contracted work. Moreover, the contribution rates to the scientific operation of the HSC were 27.3 % (domestic) and 17.2 % (overall). Instantaneous publication of all data acquired by Hinode began on May 27, 2007, with stable continuation, implemented by HSC.

Calls for Hinode Operation Plans (HOP), which encourage proposals for open-use observations together with other satellites and terrestrial observational equipment, promote joint observations among solar researchers worldwide. As of March 2016, a total of 302 applications have been accepted. In particular, core HOP proposals made by members of the scientific instrument team became refined over multiple implementations, and systematic observations have yielded extensive results that can help develop studies on solar activity cycles.

2. Hinode Satellite Data Analysis

NAOJ HSC aims to construct an analytical environment and database for scientific analysis of data from the Hinode satellite in a central organization, allowing it to function as a research center. The goals are to maximize the scientific outputs gained from the Hinode satellite by offering researchers in Japan and other countries a data analysis environment; and to promote rigorous collaborative research between researchers in Japan and abroad by facilitating access to Hinode observational data thorugh distribution of the analyzed data and construction of a data search system.

As part of its educational and public outreach (E/PO) activities, HSC also uses the latest observational data to raise public awareness of the relationship between solar research and everyday life so that the importance of solar research is appreciated. The Center has offered press releases, web releases, and media appearances; responded to interview requests from television programs and journals; and provided materials for publicizing scientific results.

In FY 2015, HSC staff members and students published 9 peer-reviewed papers related to Hinode (among the total of 20 papers), bringing the total to 250 papers by the end of March 2016. Cumulatively, a total of 887 peer-reviewed papers have been published on Hinode-related topics. Publications of papers in this category continue at a pace of nearly 100 papers per year 9 1/2 years after the satellite's launch. Intensified collaborative research with newly launched missions and advanced ground-based facilities near the solar activity maximum will further enhance the number of research papers for solar activity.

3. Other Activities

In FY 2015, two postdoctoral fellows were engaged as members of HSC, and both of them were project assistant professors. One fellow was hired as a ministry office college lecturer in September. The contract term of the other fellow expired at the end of March 2016, but he had an offer to become a researcher at the University of St. Andrews in the United Kingdom.

The Hinode Science meetings for Japanese and international researchers have been held regularly to advance reserarch in fields related to solar physics thorugh use of the Hinode satellite. The ninth Hinode Science meeting took place during September 14 – 18, 2015, in Queen's University, Belfast (Northern Ireland, UK).

In addition to the aforementioned activities, HSC research and educational staff members have presented scientific observation results at numerous symposia on solar-related subjects either by invitation or by active participation. HSC has also invited international researchers to engage in collaborative research. The following researchers have visited the Center from overseas on a long-term stay of at least one month:

Name	Organization (Country)
Cheung, Mark C. M.	Lockeed Martin Solar and Astrophysical Laboratory (USA)
Gizon, Lorent	Max-Planck Institut für Sonnensystem (Germany)

Table 1. Long-term Visitors.

9. Gravitational Wave Project Office

2015 has been marked by the first detection of a gravitational wave from the coalescence and merger of binary black holes made by LIGO in the United States. This observation, announced by the LIGO and Virgo collaborations last February, demonstrates that gravitational wave observatories able to detect the coalescence of binary black holes within 1 Gpc can contribute to the start of gravitational wave astronomy. In the meantime, the Gravitational Wave Project Office (GWPO) of NAOJ has pursued the construction of KAGRA in Kamioka. In particular, the office contributed to the installation of initial KAGRA and its operation. To facilitate this activity, a branch of the office was opened at Kamioka. In parallel, the preparation of the components for baseline KAGRA (bKAGRA) continued with the goal of starting its operation in 2018.

1. Development of KAGRA

KAGRA is an interferometric gravitational wave detector being constructed at an underground site in Kamioka, Gifu-prefecture. In addition to the quiet underground environment, the use of cryogenic mirrors to reduce the thermal noise makes KAGRA a unique instrument among other large gravitational wave detectors. At the end of FY 2015, KAGRA successfully conducted the first test operation of the 3 km interferometer at room temperature with a simplified interferometer configuration called iKAGRA. The test run provided us with opportunities to test some of the key facility issues, such as the alignment of the 3 km beam ducts, and to gain important insights into the upgrade of the interferometer to the final configuration.

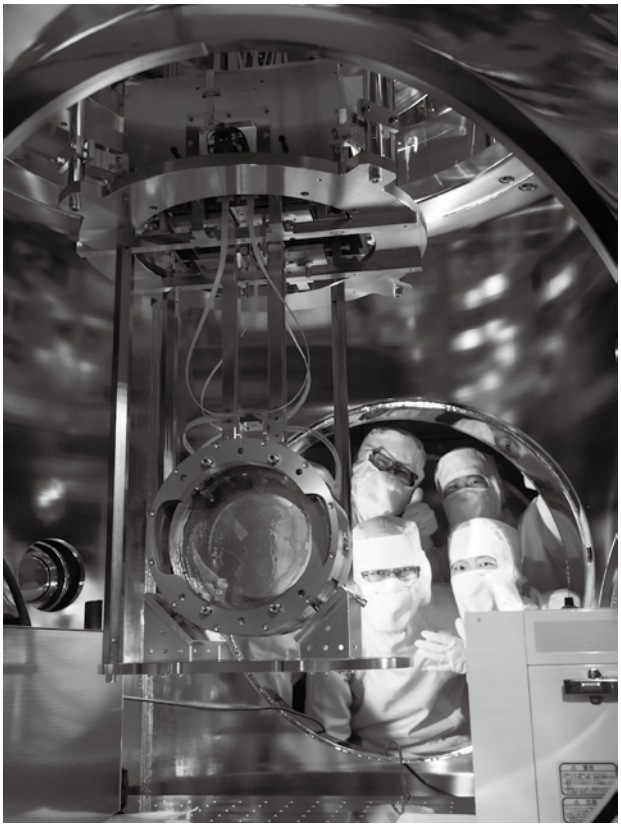


Figure 1: Happy faces after the installation of the PR3 suspension system into a vacuum chamber.

NAOJ is contributing to several aspects of KAGRA. The largest responsibilities are development and installation of ultra-high performance vibration isolation systems for the interferometer mirrors. Other technical contributions include the auxiliary optics, mirror characterization facility, and the design of the optical configuration and the control strategy for the main interferometer. NAOJ is also contributing to the project management through the activities of the executive office, the system engineering office, the committee for publication control, the publication relation committee, the safety committee, and the KAGRA Scientific Congress (KSC) board.

(1) Vibration Isolation

The vibration isolation system (VIS) is composed of the suspensions required to isolate all the interferometer components from ground vibrations. Four different types of suspensions having different complexities to meet the varied isolation requirements of different components have been developed at NAOJ for this purpose. In FY 2015, one of the large suspensions was installed into a KAGRA vacuum chamber to support a mirror called PR3. The suspension worked successfully during the iKAGRA test operation. Based on the experience gained from the installation and operation of the PR3 suspension, we are preparing other large suspensions for the upgraded interferometer (bKAGRA). In addition to this, a total of five small suspensions were prepared and used for the mode cleaner mirrors and the end test masses of iKAGRA.

(2) Auxiliary Optics

The auxiliary optics subsystem consists of several kinds of optical components including optical baffles, beam dumps, beam reducing telescopes (BRT), high quality viewports, cameras to monitor the beam spots on the mirrors, and the optical local sensors (optical levers) for the mirrors. Many view ports were installed in FY 2015 and used in iKAGRA. Seven optical levers were installed and reliably provided the alignment information of the mirrors during the operation of iKAGRA. Ten digital video cameras were also installed to provide real-time, on-demand, pictures of the interferometer beams at various locations.

Tests of materials for high quality optical baffles and high power beam dumps continued using scatterometers developed by our group. Some of the additional large baffles necessary for bKAGRA were designed and delivered. Optical parts of the beam reducing telescopes (BRTs) for bKAGRA were purchased and the design work of the vibration isolation stage for them has progressed.

(3) Mirror Characterization

The optical absorption measurement system delivered last year was adjusted and is fully operational now. Validation of the calibration and simulations to separate the absorptions on the surface and the absorptions in the bulk of a sample were performed. We measured a small sample of a candidate sapphire crystal for KAGRA mirrors and found a very low absorption value. Preparation for the measurement of large size samples is ongoing.

(4) iKAGRA Interferometer Operation

The KAGRA main interferometer commissioning team, including GWPO members, successfully aligned and locked the iKAGRA interferometer in a relatively short time (3 weeks). The calibration of the interferometer was also performed by GWPO members. GWPO members took shifts at the Kamioka site to operate the interferometer during the test run.

2. R&D

(1) R&D for Upgrades of KAGRA

While building bKAGRA, the GWPO pursues research and development to investigate and prepare for future upgrades to KAGRA. In this context, the TAMA infrastructure is being used to develop frequency dependent squeezing, one of the most promising solutions to improve the sensitivity of detectors like KAGRA that are limited by quantum noise. To this purpose, a 300-m long high-finesse cavity is being built. Thanks to this experiment we established collaborations and received students from abroad. The absorption measurement bench developed to characterize the KAGRA mirror is also used to study the performances of crystalline coatings, a possible solution to reduce coating thermal noise. Thermal noise investigations are also the objective of another experiment now starting at ATC and aiming at the direct measurement of mirror thermal noise at cryogenic temperature. Finally, crackling noise is being investigated in collaboration with ICRR.

(2) DECIGO

The DECIGO group continued discussion on the design of DECIGO satellites as well as its precursor, Pre-DECIGO. After the first detection of gravitational waves, we started to reconsider the sensitivity of Pre-DECIGO and its achievable angular resolution for the signals based on its orbit from the viewpoint of science.

3. Education

In FY 2015 the office includes three PhD students and one master's student. In addition, we received an undergraduate student from Toyama University under the SOKENDAI summer students program. We also received a visit by a master's student from Beijing Normal University for 1.5 months and a PhD student from CNRS/APC (France) for a duration of three months.

4. Outreach

KAGRA held an inauguration ceremony for the completion of the 1st phase facility in November. GWPO members contributed to the organization and the operation of this ceremony. Some GWPO members were featured in broadcast programs on NHK international TV and NHK radio. The NAOJ annual lecture was organized as part of the lecture series celebrating 100 years of general relativity. A GWPO member gave a talk at the event. GWPO members also gave public lectures at the NINS president's press conference, Tamarokuto Science Center, and the National Science Museum. The office contributed to the NAOJ open house days in October by showing the TAMA facility and the ATC clean room for assembling KAGRA components to the public. TAMA300 continued to serve as one of the featured facilities for visitors to Mitaka Campus by accepting many of them throughout the year. GWPO Kamioka branch members took care of some of the visitors to the KAGRA site.

5. International Collaboration and Visitors

GWPO is a member of the KAGRA collaboration, a scientific collaboration which includes also members from abroad. Apart from KAGRA, GWPO has collaborations with CNRS/APC (France), Beijing Normal University (BNU, China), the University of Hamburg (Germany), and CNRS/LMA (France) in the context of R&D for future upgrades to KAGRA. In this framework we received visits by Dr. Barsuglia from CNRS and by Prof. Zhu from BNU. We also had several exchanges with the Virgo collaboration, with which one of the office members is affiliated. We received a visit by Dr. Vocca from the University of Perugia (Italy) who then joined the KAGRA collaboration. As usual we received several visitors at TAMA including Dr. Nguyen Quynh Lan from Hanoi (Vietnam), Dr. Gilles Hammond from the University of Glasgow (Scotland), the Japan Society of Mechanical Engineering, and a group of students from an educational project in Romania.

6. Publications, Presentations and Workshops Organization

The members of the office have authored 17 peer reviewed publications, including the paper reporting the "Observation of a binary black hole merger" which received a lot of interest both in the scientific community and in the public. Moreover 9 presentations were given by the office members at international conferences. On the occasion of the 100th anniversary of the establishment of general relativity, we participated in organizing a series of public lectures across Japan.

7. Acquisition of External Funds

GWPO did not receive external funds apart from those related to 8 grants allocated by JSPS.

8. Staff

There were no transfers of non-regular staff members. One administrative supporter and one research engineer retired and were replaced this year. One JSPS postdoc joined the Project in April 2015 to work on KAGRA. Overall in FY 2015 the Project included 2 faculty members, 8 research staff, 4 engineers, 3 administrative staff, and 4 graduate students.

10. TMT-J Project Office

The TMT Project is a project to build an extremely large 30-meter telescope under the collaboration of five partner countries including Japan, the United States of America, Canada, China, and India. Heading the project for NAOJ is the TMT-J Project Office. In 2014, an agreement was executed between the participating organizations, TMT International Observatory was founded to assume the construction and operation of the observatory, and construction commenced. Japan is responsible for the fabrication of the telescope primary mirror, the design and fabrication of the telescope structure as well performing its onsite installation and adjustment, and the design and production of science instruments.

Although the commencement of full-fledged construction was planned for Fiscal Year 2015, construction was halted due to a protest movement against construction. Additionally, the Supreme Court of Hawai`i ruled in favor of a claim that cited a problem in the approval process of the land use permit for the Maunakea Conservation District and remanded it in December 2015. Although this has caused delays to construction onsite, mass production of the telescope primary mirror, detailed design of the telescope structure, and the design and development of science instruments have proceeded according to plan in Japan for Fiscal Year 2015.

The TMT-J Project Office currently has 2 Professors, 4 Associate Professors, 1 Chief Research Engineer, 1 Specially Appointed Associate Professor, 3 Specially Appointed Senior Specialists, 1 URA employee, 2 Research Experts, 2 Research Supporters, 2 Specially Appointed Research Staff Members, 2 Administrative Supporters, and 1 RCUH employee in full-time positions. In addition, 1 Professor, 5 Associate Professors, 2 Assistant Professors, and 1 Research Engineer from the Advanced Technology Center, Subaru Telescope, and the NAOJ Chili Observatory (ALMA) have concurrent positions in the TMT-J Project Office and take part in activities that include the development of TMT science instruments at the Advanced Technology Center.

1. TMT Project Progress and Status of the Hawai`i Construction Site

The construction of TMT is spearheaded by participating countries and organizations under the TMT International Observatory established in 2014. The current officially participating countries and organizations are the National Institute of Natural Sciences (Japan), National Astronomical Observatories of Chinese Academy of Sciences, University of California, California Institute of Technology, Department of Science and Technology of India, and National Research Council of Canada. The Association of Universities for Research in Astronomy (AURA, USA) participating as an Associate Member is taking steps for the USA to eventually participate as an official participant. TMT International Observatory, operated according to deliberations and decisions made in quarterly Board meetings of the TMT Board of Governors, is overseeing the construction work performed in each country as well as developing the onsite infrastructure. The board meetings were attended by 3 representatives from Japan, one of whom served as the Vice Chairperson of the Board.

Although full-fledged construction at the summit of Maunakea was slated to begin in April 2015, construction was forced to halt due to building momentum in the protest movement at Maunakea. Efforts were made to resume construction with the aid of the University of Hawai`i, but in December the Supreme Court of Hawai`i ruled the land use permission approval process for the Maunakea Conservation District, the site of planned construction, to be flawed, consequently invalidating the Conservation District Use Permit. The permit was initially approved by the State of Hawai`i in April 2013, but a claim was filed regarding the permit review process. Although the ruling did not find fault in the content of the permit itself, because a redo of the review process is necessary, a new review process will be commenced by the State of Hawai`i sometime after February 2016, the month in which the ruling was officially remanded.

In Japan, the construction of TMT was approved as one of the new projects for the Promotion of Large Scientific Research Projects in Fiscal Year 2013. Fabrication of the primary mirror and design of the telescope structure have been performed since then. In Fiscal Year 2015, along with making progress in the fabrication of the primary mirror, detailed design of the telescope structure, and development of science instruments (explained below), payments were initiated as part of Japan's contribution to cover operating expenses for the TMT International Observatory and contribute to the progress of this international-scale construction.

2. Japan's Progress on Its Work Share – the Telescope Structure and Fabrication of the Primary Mirror

For the construction of TMT, Japan is responsible for the design/fabrication of the telescope structure and a portion of the fabrication of the primary mirror and science instruments as according to the executed agreements. Progress made in Fiscal Year 2015 is described below.

(1) Fabrication of the mirror segments of the primary mirror

The TMT primary mirror is comprised of 492 mirrors segments. Including replacements, a total of 574 mirror segments must be fabricated. The processes required in the fabrication of mirror segments are: fabrication of the mirror blanks, spherical grinding of the front and back surfaces, polishing of the back surface, aspherical surface grinding/polishing, machining and mounting them onto a support assembly. These processes are followed by the final finish and coating process before a mirror segment is installed on the telescope. Of these processes, the

plan calls for Japan to fabricate the mirror blanks and to perform spherical grinding on all 574 segment mirrors. In Fiscal Year 2015, 65 mirror blanks were fabricated and spherical grinding was performed on 63. The plan is also for Japan to perform aspherical grinding/polishing and mounting to a support assembly for approximately 30% of the mirror segments. In Fiscal Year 2015, aspherical grinding was completed for 33 mirrors, and a mass production line for aspherical polishing had begun, producing 6 polished mirrors.

(2) Design of the telescope structure and its control system

Japan is responsible for the design and production of the telescope structure which functions as a mount for the science instruments and optics systems, including the primary mirror, and points them in the direction of a target astronomical object. Work on the detailed design of the telescope structure was initiated in Fiscal Year 2014 using the baseline design received in Fiscal Year 2013. The first international design review was held in February 2015 and was followed by international reviews of the control system and detailed design held respectively in July 2015 and February 2016, all of which were passed.

(3) Science instruments

Japan is responsible for fabricating a portion of the first-light instruments as part of the international collaboration.

In regards to the Infrared Imaging Spectrometer (IRIS), Japan is responsible for fabricating its imaging component. Work in Fiscal Year 2015 included preliminary design and performance assessment of the optics in the imager and preliminary design for the mechanics of the support system of the optics. Also, in coordination with the team of IRIS international collaborators, Japan made contributions toward preparation of a requirements document for the overall instrument and evaluation of the system. Vibration analysis of the overall IRIS system in particular was spearheaded by Japan's development team.

For the Wide Field Optical Spectrometer (WFOS), conceptual study is underway with Japan expected to be responsible for the camera system. In Fiscal Year 2015, corrections were made to the assumed effects of the heterogeneous properties of the fluorite lens on the imaging performance as well as corrections to the optics design of the camera system associated with the change in the layout of WFOS.

3. Evaluation of Scientific Research by TMT and Public Relations Activities

Japan held a key role in the TMT scientific research evaluation spearheaded by the Science Advisory Committee of TMT International Observatory through continued participation in the International Science Development Teams (ISDTs) established in 2013. In Fiscal Year 2015, a report (Thirty Meter Telescope Detailed Science Case: 2015) was compiled and published. The TMT Science Forum held once a year since 2013 was held in Washington DC in June 2015 where the possibilities of key scientific observation programs were debated. Preparations were made for the 2016 TMT Science Forum expected to be held in Kyoto in May.

In Japan, continued effort is being made to reflect the

Figure 1: Conceptual image of a constructed TMT.

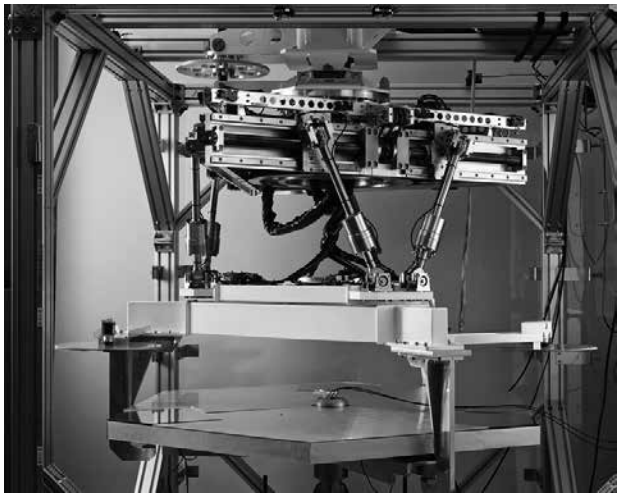


Figure 2: Segment Handling System (SHS) (provided by Mitsubishi Electric).

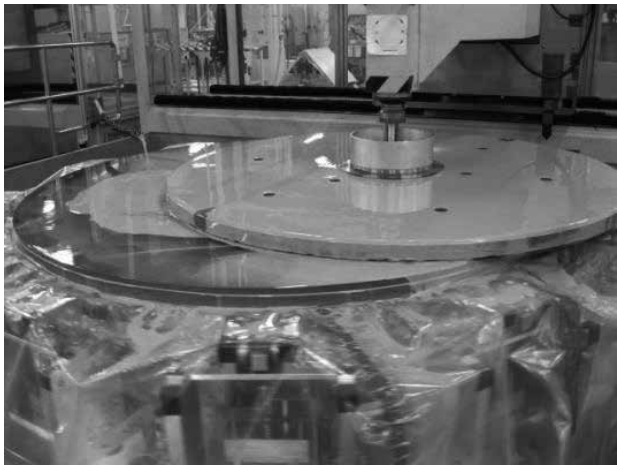


Figure 3: Aspherical grinding of a mirror segment of the primary mirror (provided by Canon).

opinions of the community through organizations such as the TMT-J Science Advisory Committee (JSAC). Public chances to support TMT related science meetings were offered for the purpose of promoting plan proposals for scientific observation research and new science instruments utilizing TMT. Additionally, the strategic fundamental research fund for the purpose of elementary technology development for the development and design of next generation science instruments continued to be made available. As a result, funding support was awarded to 5 development plans, including those requested by universities.

The TMT Project, particularly Japan's role in the project and the status of the project itself are introduced in the TMT-J Project Office website. Additionally, TMT Newsletters No.44 through 46 were delivered. Efforts were made in public awareness through lectures held in various areas throughout Japan and exhibits at the National Institutes of Natural Sciences Symposium and Inter-University Research Institute Symposium. Approximately 50 lectures and requested classes were held for the public.

Contributions were also made by making an on-demand lecturer available for the science/technology education and PR event "Journey through the Universe" (March 2016) held in Hawai`i where TMT is to be constructed.

Donations to the TMT project raised continually; one corporation and approximately 1000 individuals provided donations in 2015 (from January to December).

11. JASMINE Project Office

1. Planning and Development of the JASMINE (Japan Astrometry Satellite Mission for Infrared Exploration) Project

(1) Overview

The JASMINE mission seeks to survey virtually the entire 20° × 10° Galactic Bulge around the center of the Galaxy and to perform infrared (Kw-band: 1.5–2.5 μm) measurements of the annual parallaxes, proper motions, and celestial coordinates of the stars at a high accuracy of 1/100,000 arcsecond (10 μas) in order to determine with high reliability the distances and transverse velocities of stars within approximately 10 kpc of the Earth in the surveyed direction. Nearly 1 million stars can be measured with high precision in the Galactic Bulge with a relative error for annual parallaxes less than 10 %. This is necessary for accurate distance determination. By using observational data to construct a phase space distribution of gravitational matter, astrometric surveys of the bulge of the Milky Way promise to make major scientific breakthroughs in our understanding of the structure of galactic bulges and the causes of their formation; the history of star formation within bulges; and the co-evolution of bulges and supermassive black holes, which is closely related to the aforementioned phenomena.

Prior to commencement of the JASMINE mid-sized scientific satellite project, an ultra-small size project and a small size project were implemented to progressively build up scientific results and to accumulate the necessary technical knowledge and expertise. The Nano-JASMINE micro-satellite project, with a primary mirror aperture of 5 cm is currently underway. It aims to test part of the technologies to be used in JASMINE and to produce scientific results based on the astrometric information for bright objects in nearby space. Despite its small aperture, the satellite is capable of observational precision comparable to the Hipparcos satellite. The combination of observational data from Nano-JASMINE and the Hipparcos Catalogue is expected to produce more precise data on proper motion and annual parallax. The satellite is scheduled for launch in the near future. An additional plan is underway to launch a small-scale JASMINE satellite (Small-JASMINE), with a primary mirror aperture of about 30 cm, in FY 2022. This satellite will engage in observations of a limited area around the nuclear bulge and certain specific astronomical objects. This small-sized version has the goal of obtaining advanced scientific results at an early stage. The mid-sized JASMINE satellite, with a main aperture of approximately 80 cm, is designed for surveying the entire bulge and is targeted for launch in the 2030's. Internationally, Japan shares responsibilities with ESA. With the Gaia Project, ESA performs visible-light observation of the entire sky at a precision of 10 μas, while Japan engages in infrared observation of the bulge, which is a method suitable for observations in the direction of the Galactic Center.

(2) Major Progress in FY 2015

1) Organization of the Office

The JASMINE Project Office is composed of five full-time staff members, six staff members with concurrent posts, two postdoctoral fellows, one research associate, one technical associate, and five graduate students. Significant contributions were made by members of the following organizations: Kyoto University's Graduate School of Science; the Systems Engineering (SE) Office, Aerospace R&D Directorate (ARD), and ISAS at JAXA; the University of Tokyo's School of Engineering; Tokyo University of Marine Science and Technology; the University of Tsukuba; and the Institute of Statistical Mathematics.

2) Progress of the Nano-JASMINE Project

The project will engage in spaceborne observations using an ultra-small satellite to accomplish the following objectives: to make Japan's first foray into space astrometry; to accumulate the technical experience in onboard data acquisition, and the like, necessary for the upcoming JASMINE project; to achieve scientific results in the study of dynamical structures in the vicinity of the Solar System; and to analyze star formation based on stellar motions in star formation regions.

The satellite was scheduled to be launched from a Brazilian launch site operated by Alcantara Cyclone Space using a Cyclone-4 rocket built by Yuzhnoye, a Ukrainian rocket developer. The launch has been impossible due to the adverse influence of international situations. On the other hand, we now have the possibility that the Europena Space Agency (ESA) can launch the Nano-JASMINE satellite. We are now negotiating for the launch. Assembly of the flight model that will actually be launched into space was completed in FY 2010. The extra time yielded by the launch delay has been used for additional testing to further ensure project success. Maintenance of the satellite has also been performed. Steady progress was also made in the development of the algorithms and software required to determine astrometric information from raw observational data at the required level of precision. International cooperation with the data analysis team for the Gaia Project has been conducted smoothly. A Japanese WG led by Ryoichi Nishi of Niigata University continued to actively engage in investigating the scientific results to be obtained in the future by Nano-JASMINE.

3) Overview of planning and developing the Small-JASMINE Project

The objective of the small-sized JASMINE project is to use a three-mirror optical system telescope with a primary mirror aperture of 30 cm to perform infrared astrometric observations (Hw band: 1.1–1.7 μm). A goal is to measure annual parallaxes at a precision of less than or equal to 20 μas and proper motions, or transverse angular velocities across the celestial sphere, at less than or equal to 50 μas/year in the direction of an area of

a few degrees from the Galactic Center within the bulge and in the directions of a number of specific astronomical objects of interest in order to create a catalogue of the positions and movements of stars within these regions. The project is unique in that unlike the Gaia Project, the same astronomical object can be observed frequently and observation will be performed in the near-infrared band, in which the effect of absorption by dust is weak. This project will help to achieve revolutionary breakthroughs in astronomy and basic physics, including the formation history of the superrmassive black hole at the Galactic Center; the gravitational field in the Galactic Nuclear Bulge and the activity around the Galactic Center; the orbital elements of X-ray binary stars and the identification of the compact object in an X-ray binary; the physics of fixed stars; star formation; planetary systems; and gravitational lensing. Such data will allow for the compilation of a more meaningful catalog when combined with data from terrestrial observations of the line-of-sight velocities and chemical compositions of stars in the bulge. Conceptual planning and design of the Small-JASMINE satellite system and detailed planning of the subsystems began in November 2008 with cooperation from nearly 10 engineers from JAXA's SE Office, ARD, and ISAS with a focus on the satellite's vital elements such as thermal structure, attitude control, and orbit.

Against this background, in-house discussions and manufacturers' propositions, which started in 2009, continued to consider the design of the satellite system to ascertain the target precision in astrometric measurement as a general objective in preparation for submitting a mission proposal to the ISAS call for small-sized scientific satellite mission proposals. The SWG, led by Masayuki Umemura of the University of Tsukuba and including volunteers from diverse fields in Japan, continued to make scientific considerations. Other activities such as conceptual planning, design, technical testing and international project collaboration have been continued.

International partnerships to gain further understanding of the Galactic Bulge have been formed with multiple overseas groups engaging in terrestrial high-dispersion spectroscopic observation to determine the line-of-sight velocities and chemical compositions for bulge stars. In particular, Steven Majewski of the University of Virginia, the principal investigator (PI) of the US Apache Point Observatory (APO) Galactic Evolution Experiment (APOGEE) Project, offered a joint proposal for the APOGEE-2 project as an extension of the original APOGEE project to engage in bulge observations in the southern hemisphere because the project is suitable for bulge observations. The telescope employed will be equipped with a high-dispersion spectroscope, identical to that of APOGEE. The joint proposal has been submitted. An official memorandum of understanding has been exchanged among the APOGEE-2 team and members of the fourth Sloan Digital Sky Survey (SDSS-IV) Collaboration and Small-JASMINE to strengthen international partnerships and to achieve scientific goals related to the Galactic Bulge.

As planning has progressed so far, the full mission proposal was prepared and submitted in January 2016 to the ISAS call for small-sized scientific satellite mission proposals.

12. Extra-Solar Planet Detection Project Office (Exoplanet Project Office, EPO)

The Extra-Solar Planet Detection Project Office cooperates with researchers interested in extra-solar planet at various universities, centered around NAOJ to promote the development of overall technologies and organize related observations with the goal of observing exoplanets and their formation sites. We conduct observational instrument development, research promotion, mission planning, and R&D to develop common basic technologies. We also promote international partnerships related to exoplanets, which are the focus of this project office. Specifically, research and development have continued centered around the following 4 themes:

(1) The development/maintenance/operation of high-contrast observational instruments using the Subaru Telescope to directly observe exoplanets: HiCIAO, SCExAO, and CHARIS; and the promotion of the SEEDS survey and post-SEEDS projects.
(2) The development of the new IR Doppler instrument IRD and planning its observations.
(3) The development of the high-contrast instrument TMT/SEIT, and promoting technological review and related international collaborations for the WFIRST/CGI, and HabEx missions.
(4) Research into star and planet formation and the interstellar medium through wide field-of-view polarimetric imaging with the IRSF telescope located in South Africa.

There were 38 refereed papers in English, 2 non-refereed papers in English, 36 presentations in English, 1 refereed paper in Japanese, 8 non-refereed papers in Japanese, 2 books in Japanese, and 57 presentations in Japanese.

1. Development of the Subaru Next Generation Exoplanet Instruments and Exoplanet Observational Research

(1) HiCIAO (High Contrast Instrument for the Subaru Next Generation Adaptive Optics)

HiCIAO is a coronagraph camera for direct imaging of exoplanets and circumstellar disks for the 8.2-m Subaru Telescope, which can simultaneously utilize various imaging modes to differentiate by polarizations, multi-bands, and angle. The first Subaru Strategic Program SEEDS (Strategic Explorations of Exoplanets and Disks with Subaru) with more than 100 participants continued from October 2009 to January 2015 without any serious troubles. In this year, HiCIAO was used mainly in combination with SCExAO.

(2) IRD (Infrared Doppler Instrument)

IRD is a high precision (~1 m/s) radial velocity spectrometer working at near-infrared wavelengths, whose aim is to detect habitable Earth-like planets around M dwarfs and brown dwarfs. The budget is based on JSPS Grant-in-Aid for Specially Promoted Research FY 2010-2014 (PI: Motohide Tamura). Fiber experiments, laser frequency comb completion, and total assemble were conducted. It was then shipped to Hawai`i. Science discussions on habitable planets around M dwarfs are also proceeding.

(3) SCExAO (Subaru Coronagraphic Extreme Adaptive Optics) and CHARIS IFU

EPO has been involved in the development of these next-generation high-contrast instrumentations being carried out at Hawai`i and Princeton, respectively.

2. Exoplanet instrument development for future space and ground-based telescopes and international collaborations

(1) WFIRST Coronagraph and HabEx (Habitable Planet Explorer)

These missions aim to directly image and characterize the Earth-like planets and super-Earths for signatures of life. As a member of the WACO working group (currently WFIRST

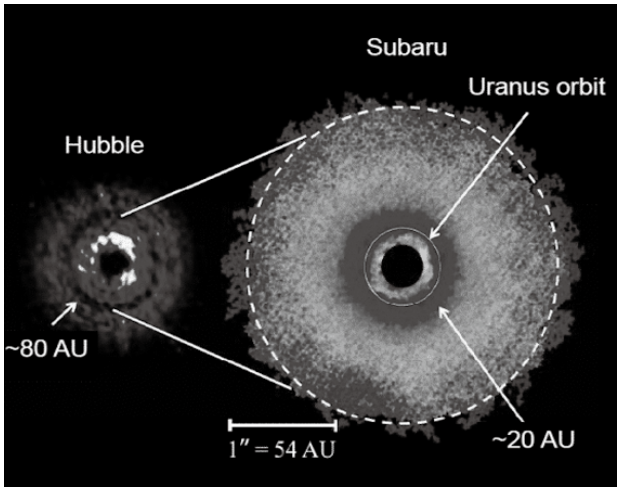


Figure 1: Multiple gaps in the TW Hya disk observed in near-IR.

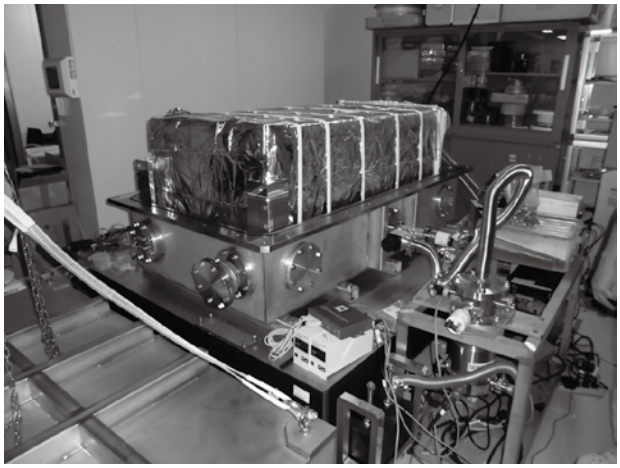


Figure 2: IRD spectrometer. Top cover removed.

WG), a coronagraph performance test at JPL testbed is being conducted with collaborators.

(2) SEIT (Second Earth Imager for TMT)

The aim of this project is the direct imaging and characterization with the SEIT instrument on the Thirty Meter Telescope (TMT). Both technical and science discussions are made, including optical demonstration tests.

3. Science research, education, and outreach

The SEEDS project successfully finished in January 2015 without any major troubles. A review paper was published. Other major results are: direct imaging discovery of a gap at 20 au in the protoplanetary disk around TW Hya (multiple gaps); direct imaging discovery of a unique disk around SU Aur; revealing gapped disks around DoAr 28 and HD 169142; and discovery of a tilted inner disk around LkCa 15.

International collaborations using HiCIAO brought the discovery of interesting features originating from gravitational instabilities arising from mass accretion in the disks around FU Ori stars.

Ten graduate students are supervised for exoplanets and related topics. Many public talks, publication, and press releases are made on exoplanets, disks, and other astronomical fields.

13. RISE (Research of Interior Structure and Evolution of Solar System Bodies) Project Office

1. Project Overview

In FY 2015, calibration data for the Laser Altimeter (LIDAR) of Hayabusa2 was collected and its laser-link experiment was carried out. Also, a conceptual design of the Ganymede Laser Altimeter (GALA) for the Jupiter Icy Moons Explorer (JUICE) mission was made. The Hayabusa2 asteroid explorer was launched on December 3, 2014; initial test operations finished in January; and Hayabusa-2 is underway to C-type asteroid, Ryugu. Before rendezvous with Ryugu will start in the summer of 2018, the RISE Project Office collected calibration data necessary for two major scientific goals of the laser altimeter, that is, albedo observation and dust detection. An engineering model of the laser altimeter was used for this calibration. The collected data and their evaluation were published in January in an international journal for future use with observation results. From October to December in FY 2015, taking advantage of Hayabusa2's Earth swing-by, RISE Project Office members attempted a laser-link experiment with Hayabusa2. Laser pulses transmitted from Mt. Stromlo station in Canberra were successfully received by Hayabusa2's laser altimeter, and established a one-way link over 6.6 million km between a ground station on the Earth and the spacecraft in interplanetary space. This is the third successful experiment conducted beyond the lunar orbit. For GALA, the RISE Project Office members developed a tool to simulate the quality of laser signals starting from the laser oscillator, reflecting on the surface of the icy satellite, and finally being received by the electric circuits of the receiver system. An increase of noise in the laser signal is taken into account in the simulation. Thus this tool allows us to constrain the instrument requirements quantitatively. At the same time, the members studied variations of slope and roughness at the surface of the icy satellites using the highest resolution images in order to narrow the most ambiguous options of the simulation.

2. Educational Activities/Internship

Seven RISE members delivered 18 lectures on a part-time basis to graduate students at the University of Aizu; and two RISE members served as part-time lecturers at Iwate University for half a year each. Also at Kyoto University and Kyushu University, two members served as part-time lecturers. The Office accepted two third-year undergraduate students of Iwate University for a week, and one fourth-year undergraduate student from Kazan University in Russia for a 2 month-long internship. As summer students of the Graduate University for Advanced Studies, two third-year undergraduate students of the University of Aizu and the University of Tokyo were accepted for three weeks. In January, a third-year undergraduate student of Taiwan Central University visited the Office for 3 weeks and studied crater statistics of the Moon under the supervision of the Office members.

3. Outreach/PR

In FY 2015, the Office members volunteered for Ihatove Science School of Oshu City 11 times as well as Fureai Astronomy classes 4 times.

4. Joint Research/International Collaborations

One member of the RISE Project Office served as a section president of Asia Oceania Geosciences Society. From Russia, a researcher of Vernadsky Institute of Geochemistry and Analytical Chemistry visited the Office for two months for joint research on thermo-mineralogical modeling of the lunar interior. The RISE Project Office invited five researchers from Russia, the U.S.A., Germany, South Korea, and China to promote international partnerships.

5. Career Development

One research expert left the RISE Project Office in March as his term ended. To fill this vacancy, the Office opened an announcement of a job opportunity for specially appointed research staff. On the other hand, another specially appointed research staff member left the Office in March and is now employed as a lecturer at Kougakuin University.

14. Solar-C Project Office

The SOLAR-C Project Office has engaged in planning the next solar observation satellite project, SOLAR-C, and has executed the launch operation of a sounding-rocket experiment, the Chromospheric Lyman-Alpha SpectroPolarimeter (CLASP). In addition, since the middle of Fiscal Year 2015, the Project has started preparatory activity for proposing a re-flight program of a German solar balloon experiment, Sunrise-3.

1. SOLAR-C Project

SOLAR-C is a planned project and may become Japan's fourth solar observation satellite, after Hinotori, Yohkoh, and Hinode. The plan is to realize the launch in the mid-2020's. The project is intended to investigate the solar magnetic plasma activities that influence the space weather and space climate around the Earth. The investigations involve the measurement of magnetic fields in the chromosphere and high-resolution imaging/spectroscopic observations that have not been previously achieved. The themes include major problems in solar research: the heating of the chromosphere/corona, the origin of solar explosive events, and the variation of solar spectral irradiance. Since its establishment, the SOLAR-C project WG has involved many non-Japanese specialists in addition to Japanese researchers. Provisionally, Japan will be responsible for the launch vehicle, satellite, and one of the major science instruments, whereas the US and European space agencies and institutions will deal with the other major instruments through international collaborations.

The main body in this project is the Next Solar Observation Satellite Project Working Group led by Prof. Watanabe, NAOJ, set up within the Advisory Committee for Space Science at ISAS/JAXA; NAOJ researchers play key roles in the project activities. The SOLAR-C Planning Office was set up at NAOJ in FY 2008 as a sub-project in the Hinode Science Center (HSC), dedicated to the SOLAR-C project. It was promoted to the SOLAR-C Project Office in FY 2013 as an A-project independent from HSC, continuing the preparatory work for the realization of the satellite project with five full-time staff members and eleven members with concurrent positions/ postdoctoral fellows.

2. CLASP Project

The CLASP project is an observational sounding rocket experiment aiming to detect solar magnetic fields in the chromosphere and transition region through polarization observations of the hydrogen Lyman-alpha (H Lyα) spectrum. Planning and basic development of the project started in FY 2009. The project involves an international research team with participation from Japan, the USA, and other countries. The CLASP project entered the development stage fully in the latter half of FY 2012 and carried out its first flight experiment in mid-2015. The payload consists of a far-ultraviolet (FUV) telescope and a spectro-polarimeter that were prepared in Japan to conduct polarization observations, with components contributed by the USA (CCD cameras and control computers) and France (a spherical concave grating). In the CLASP program, an American sounding rocket is used for the flight operation at the US White Sands launch site.

3. Major Activity in FY 2015

The SOLAR-C proposal, which was submitted to JAXA in February 2015, was not selected in the mission definition review as the candidate of the 1st JAXA Strategic Middle-class Satellite Mission. The SOLAR-C plan involves large international contributions, but in January of the same year, a proposal aiming to win approval for these international collaborations was not adopted by the European Space Agency (ESA). One of the major reasons cited in the JAXA review is that the large international collaborations assumed in the proposal have not yet been established. So the SOLAR-C WG is conducting the refinement of science objectives and the optimization of the mission size for the next opportunity. In FY 2015, the Project also studied the feasibility and cost estimate for a large telescope of reduced aperture and the thermal structure of the spectropolarimeter, and carried out test production of polarimetric optical components for performance verification.

The CLASP sounding-rocket experiment was carried out on September 3, 2015 at the US White Sands launch site. The flight was successful, returning the world's first polarimetric spectra of the H Lyα lines with a high precision of 0.1%. While doing the data analysis, the international CLASP team has started the preparations for the 2nd flight.

After receiving notification that the JAXA review committee for the Strategic Middle-class Satellite Mission had not adopted the SOLAR-C proposal, the Project received an invitation from a German solar research group to participate in the German balloon re-flight project, Sunrise-3, scheduled for around 2020. A spectropolarimeter with a performance similar to the SOLAR-C payload is to be developed. The Project aims to demonstrate the development of the state-of-the–art remote-sensing instrument needed for SOLAR-C and overcome the challenges of conducting leading-edge science observatinos from an experiment balloon.

4. Others

Although the SOLAR-C Project Office is reimbursed by NAOJ for its general operation and emergencies, a large part of the expenses for supporting the project preparation is funded by other sources, including the Grant-in-Aid for Scientific Research, JAXA's strategic R&D fund for basic development and experiment of onboard instruments, and research grants from the private sector.

Prof. K. Ichimoto of Kyoto University became a

concurrently appointed professor in the Project in April 2015. T. Bando moved to Subaru Telescope after April 2015. R. Kano got promoted to associated professor in October. Prof. T. Sakurai retired at the end of FY 2015. K. Watanabe, who started as a project research fellow in April 2015, left NAOJ in October 2015 to become a faculty member of a university.

15. Astronomy Data Center

1. Introduction

The Astronomy Data Center (ADC) is a central core of computing and archiving for astronomical data. It supports scientists worldwide by providing a variety of data center services. In addition, ADC is driving forward research and development programs for future generations of service. Our activities are organized into the DB/DA Project, Network Project, JVO Project, HSC Data Analysis/Archiving Software Development Project, and open-use computer system service.

2. ADC Report

(1) DB/DA Project

The DB/DA-project conducts research and development on astronomical Data Bases and Data Analysis. Various astronomy data are made available to the public, such as astronomical catalogs, the Astrophysical Data System (ADS), and all-sky imaging data (DSS, DSS2). It also makes various astronomical data available to researchers and educators (http://dbc.nao.ac.jp/).

SMOKA (http://smoka.nao.ac.jp/) is the core of the DB/DA-project. It provides archival data of the Subaru Telescope, OAO 188-cm Telescope, Kiso 105-cm Schmidt Telescope (the University of Tokyo), MITSuME 50-cm telescopes (Tokyo Institute of Technology), and KANATA 150-cm Telescope (Hiroshima University). Stable operation continued through cooperation with each observatory, producing many scientific results. The total amount of open data (excluding environmental and atmospheric data) is more than 12 million frames (71 TB) as of May 2016. There were 16 papers published in major peer reviewed journals which were produced using SMOKA data. The cumulative number of refereed papers using SMOKA data is 192. Continuing from the previous year, in 2015 system improvements were implemented to develop and streamline advanced retrieval functions (e.g. moving celestial object retrieval). In addition, in September 2015, data from HONIR on the Kanata Telescope at Higashi-Hiroshima Observatory was opened to the public; and starting from January 2016, position correction data for the Tokyo Institute of Technology MITSuME Telescopes was offered.

(2) HSC Data Analysis/Archiving Software Development Project

This project started in January 2009. The main purpose is to develop the data analysis pipeline and data archiving software for the Subaru Telescope's wide-field-of-view prime-focus camera, Hyper Suprime Cam (HSC), using 104 CCD's. Most of our efforts are concentrated on the implementation of the software for: effective data analysis/archiving by parallel and distributed processing; precise photometric and astrometric calibrations; and correction of various effects originating from the camera system.

From March 2014, the Strategic Survey Program (SSP) using HSC started and we began to have consistent large data output (about 300–400 GB per night). We preformed data analysis of the SSP data, produced a database storing the results, and made the third and fourth data releases to the SSP team collaborators during this fiscal year (in September 2015 and January 2016). In the latest data release in January 2016, the image data involve 1.5 million files with a total size reaching about 200 TB. The catalog database stores about 280 million objects in a 10 TB database volume. We have developed various user interface software for retrieving image or catalog data using the database through web browsers; many of these functions have been offered to collaborators. The computers/hardware for the data release are in stable operation and the software is in the operational phase with minimum functions. Major problems in the pipeline software have been significantly reduced, although further improvements to functions in the pipeline software are still necessary to achieve the planned accuracies for calibrations/measurements of celestial objects in the images. The on-site data analysis system developed from 2011 is now in the operational phase, and performed well in the SSP and open-use observations. It features observer support tools, such as the observation log viewer, which allows browsing of the data analysis results through a web browser. Although there are still little problems, this system has made large contributions to the smooth operation of the Subaru Telescope.

(3) Network Project

The Network Project designs and operates NAOJ information network infrastructure for the Mitaka Headquarters and branch offices. Noteworthy topics of this fiscal year are as follows.

1) 100 Gbps Network service development and operation: We acquired and operated circuit links faster than 100 Gbps between Otemachi—Mitaka, Otemachi—Higashi-Shinagawa and Mizusawa–Sendai. Transmission equipment has been constructed and operated for each link. Between Mizusawa and Sendai 40 Gbps of the 160 Gbps cables, and 100 Gbps cables between Mitaka—Otemachi and Otemachi—Higashi-Shinagawa were laid and have started operation. The Mizusawa–Sendai circuit has been connected to SINET5 and JGN. The Mitaka—Otemachi circuit increased the Data Center's base connection speed. The Otemachi—Higashi-Shinagawa circuit has been connected to the 100 Gbps circuit to the United States of America.

2)100 Gbps capability network beta service: Wide area 100 Gbps circuits such as the 100 Gbps circuit to the USA, WIDE, and SINET were maintained. To make the best use of these circuits, equipment has been increased in part of the host network, making capability on the NAOJ network service equivalent to 100 Gbps.

3) ADC Relocation: For more effective network operation, racks

to consolidate the circuits and transmission devices located in the Otemachi data center were relocated next to the racks operated by the WIDE project's data center.

(4) JVO Project

The trial version of JVO portal 2, with a greatly revised user interface to improve its usability, was released. JVOSky, where data can be retrieved from a map of the sky, was updated from a GoogleSky base to a new sky-map GUI using Aladin-Lite developed by CDS. This update enabled it to display the data taken at high latitude without distortion. All of the observation data of Suprime-Cam taken before April 6, 2014 was reprocessed using the most recent reduction pipeline. The data was released on the JVO portal. JVO ALMA archive was updated to implement a new feature that enables users to search data based on object names defined in the Simbad database. ALMA WebQL for quick-look images of ALMA data was updated. Utilizing ultra-high-speed SSDs with a PCI-Express interface enabled users to start a quick look of an ALMA data cube within a few second, even for 10 GB of data. The design of the GUI was greatly modified and improved, as a result access to the ALMA archive was significantly increased.

(5) HSC Data Analysis/Archiving Software Development Project

This project started in January 2009. The main purpose is to develop the data analysis pipeline and data archiving software for the Subaru Telescope's wide-field-of-view prime-focus camera, Hyper Suprime Cam (HSC), using 104 CCD's. Most of our efforts are concentrated on the implementation of the software for: effective data analysis/archiving by parallel and distributed processing; precise photometric and astrometric calibrations; and correction of various effects originating from the camera system.

From March 2014, the Strategic Survey Program (SSP) using HSC started and we began to have consistent large data output (about 300–400 GB per night). We preformed data analysis of the SSP data, produced a database storing the results, and made the third and fourth data releases to the SSP team collaborators during this fiscal year (in September 2015 and January 2016). In the latest data release in January 2016, the image data involve 1.5 million files with a total size reaching about 200 TB. The catalog database stores about 280 million objects in a 10 TB database volume. We have developed various user interface software for retrieving image or catalog data using the database through web browsers; many of these functions have been offered to collaborators. The computers/hardware for the data release are in stable operation and the software is in the operational phase with minimum functions. Major problems in the pipeline software have been significantly reduced, although further improvements to functions in the pipeline software are still necessary to achieve the planned accuracies for calibrations/measurements of celestial objects in the images. The on-site data analysis system developed from 2011 is now in the operational phase, and performed well in the SSP and open-use observations. It features observer support tools, such as the observation log viewer, which allows browsing of the data analysis results through a web browser. Although there are still little problems, this system has made large contributions to the smooth operation of the Subaru Telescope.

(6) Open-use Computer System and Services

The new rental open-use computer system, "National Astronomical Observatory of Japan: Data analysis, archive and service system," has been in operation since March, 2013. The system plays a leading role as part of the Inter-University Research Institute.

The system consists of the "Multi-Wavelength data analysis subsystem", "Large data archive and service subsystem (MASTARS, SMOKA, HSC science, ALMA, VERA, NRO, Okayama, and Catalog archive service)", "JVO subsystem", "Solar data archive, analysis and service subsystem", "Data analysis subsystem in Mizusawa campus", and "Development subsystem".

The total storage, memory, and number of CPU cores within the system are about 6 PB, 13 TB, and 2000 cores, respectively. In JFY 2015, the total number of users was 372 (including 53 users of overseas institutes).

In the course of inter-university research we held and supported some workshops on using the software and systems, and offered a computer environment for data reduction practice. The dates and numbers of participants in JFY 2015 were as follows.

1. SOKENDAI Summer School (Reduction Environment Support), Aug. 3–Sep. 4 2015, 7 users
2. IDL School for FITS Data Analysis (Sponsor), Sep. 15–16 2015, 9 users
3. Subaru Autumn School 2015 (Co-sponsor), Sep. 28–Oct. 1 2015, 13 users
4. Subaru Experiential Observation and Research (Reduction Environment Support), Nov. 11, 2015–Mar. 31 2016, 8 users
5. C Language School (Sponsor), Nov. 17–19 2015, 10 users
6. N-body Simulation School (Co-sponsor), Jan. 20–22 2016, 16 users
7. SOKENDAI Asian Solar Physics Winter School (Co-sponsor), Jan. 26–28 2016, 30 users
8. IRAF/PyRAF School (Sponsor), Feb. 16–17 2016, 10 users
9. ALMA Data Science Experience (Reduction Environments Support), Mar. 7–11 2016, 3 users

The total number of participants of the schools in JFY 2015 was 106 users.

3. Others

As part of outreach and promotion activities, 45 issues of "ADC News" were published from No. 437 to No. 482 in JFY 2015. The newsletters were distributed by E-mail to users and appeared on the ADC web pages.

16. Advanced Technology Center (ATC)

1. Organization and Summary of Activities in ATC

The Advanced Technology Center has been working on developments for astronomy instruments in general. Our programs are divided into "prioritized area developments" and "advanced technology developments" to meet requirements both for current on-going astronomy programs and for future programs.

Development, fabrication, and shipment of the ALMA receivers for band-4, 8, and 10, which had proceeded as "prioritized area developments," were concluded in FY 2013. In the middle of FY 2014, the ALMA receiver development group was reformed and divided into three groups: the ALMA receiver maintenance group, the ALMA advanced receiver development group, and the telescope receiver development group. In FY 2015, the ALMA receiver maintenance group was responsible for repairing the problems in shipped receivers; the ALMA advanced receiver development group conducted basic research on the extension of RF and IF frequencies as well as the multi-beam receiver; and the telescope receiver development group was responsible for upgrading the performance of the 45-m FOREST receiver and ASTE receivers. In the middle of FY 2015, the ASTE radio camera development group was moved to ATC from Nobeyama Radio Observatory to strongly support its activity for the commissioning observations at the ASTE telescope to be held in early FY 2016.

For prioritized area development, in FY 2015 we pushed forward the development of Thirty Meter Telescope (TMT) observation equipment such as IRIS, WFOS/MOBIE, and the development of control and vibration isolation equipment and mirror holders for the gravity wave telescope, KAGRA. The design and production of those devices have been supported by the mechanical engineering shop (ME Shop). The optical system of IRIS has been largely modified utilizing all reflective mirrors, followed by the re-design and re-analysis of opto-mechanical system and optical performance. In parallel, experiments using prototype system are proceeding. Since Hyper Suprime-Cam (HSC) has started observing runs from March, 2014, HSC was moved to "advanced technology development" from "prioritized area development" and the HSC development group was responsible for improvements and repairing the problems of HSC.

The "advanced technology developments" includes developments for radio imaging arrays, the solar-observing rocket-borne instrument CLASP, and others. Concerning CLASP, the development of the device was completed in 2014 and it was sent to the White Sands launching site in early 2015. Then it was successfully launched in September, 2015 and successful observation of the solar chromosphere has been achieved.

The oversight committee of ATC, including non-NAOJ members, has been discussing about ATC activities on current projects and R&D for future programs, based on requests from the Director General. In FY 2015, ATC activities for the development of TMT and KAGRA were reviewed and will feedback to ongoing programs. R&D programs for the radio camera and infrared detectors were also reviewed in FY 2015 accordingly.

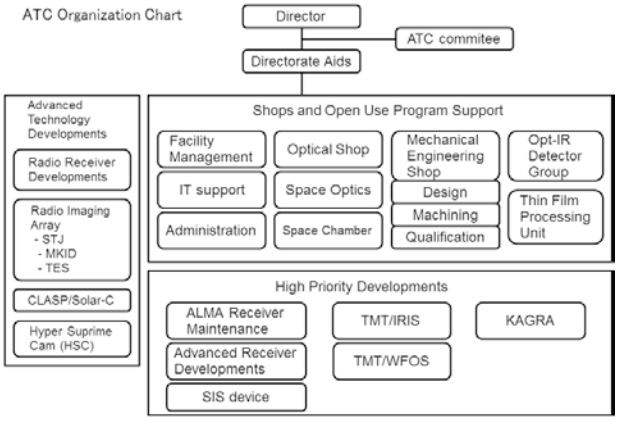


Figure 1: New Organization Chart of ATC (FY 2015).

2. Workshops and Development Support Facilities

(1) Mechanical Engineering Shop (ME shop)

The Mechanical Engineering (ME) Shop engages in a comprehensive manufacturing process to fabricate experimental and observational instruments, from design to fabrication and shape measurements. Three teams including design, fabrication, and measuring/ultra-precision fabrication teams, cooperate to advance projects by leveraging their expertise.

The design team has been taking charge of mechanical designs for KAGRA auxiliary optics and TMT/IRIS imager and working on several challenges such as

[Mechanical design of KAGRA]
- Design of the vibration isolation table for the Beam Reducing Telescope
- Design of the five-axis lens positioner for the Beam Reducing Telescope
- Design of the winch mechanism for the main mirrors in the Power Recycler and Beam Splitter
- Assembly of Bottom Filters for the vibration isolation system for the KAGRA auxiliary optics subsystem

[Design of TMT/IRIS]
- Design and thermal structural analysis of an optical element holder in cryogenic conditions
- Seismic response analysis of overall IRIS structure
- Cryogenic endurance test of mechanical components (ball bearing and ball screw) for the Imager

- Cryogenic endurance test of a drive mechanism on the filter exchanger for the Imager for TMT/IRIS.

The fabrication team has been working on the vibration isolation system of KAGRA since last year, and delivered internal parts for 11 sets of Bottom Filters. And the cylinders, made of Ti-6Al-4V, to be used as Recoil Masses for payloads of the suspension systems were also delivered. Fabrication of the five axis-lens positioner for the Beam Reducing Telescope has started recently. For TMT/IRIS, mechanical parts for the cryogenic endurance test were machined and supplied upon request from the design team. In addition, the team finished test parts made of super invar for thermal testing of the Small-JASMINE structure. And, as for the holders of the pupil mirror array and the slit mirror array for the integral field unit on the Subaru Telescope, final production has started based on experience gained from prototyping. Manufacturing of a 37-pixel corrugated horn array was initiated in collaboration with the ultra-precision fabrication team.

The ultra-precision fabrication and measurement team has responded to fabrication requests and also has enhanced collaborative research with external institutes. The team established an ultra-precision milling process for the wideband corrugated horn array, the development of which has been led by ATC, and the horn array with 4 pixels was successfully finished. Manufacturing has started for the 37-pixel horn array that is regarded as the next subject. Also, in regards to the corrugated horn for the ALMA Band 10 receiver, the data required for machining was obtained and manufacturing is about to start. Regarding the collaborative research with the Mechanical Engineering Center of KEK, ultra-precision milling using single-crystal diamond cutting tools has been discussed. Technical cooperation in trial machining and evaluation was conducted to investigate the specific machinery that is capable of an efficient mirror finishing for the X-band acceleration disk. The collaborative research with the Institute for Molecular Science and Nagoya University has continued in consideration of achievements up until present.

The ME Shop accepted 90 machining or repair requests in FY 2015. With 4 programs carried over from FY 2014, 89 out of 94 programs have been concluded and 5 programs are carried over to FY 2016. There were 9 programs requested from external organizations. The following table shows the requests in FY 2015.

Table 1: The requests in FY 2015.

	From FY2014	FY2015	To FY2016
ATC	1	22	1
TMT/IRIS		4	
KAGRA	2	9	2
ALMA		5	
ASTE		2	
CLASP, CLASP2, SOLAR-C		6	
HSC		1	
JASMINE		3	
Exoplanet Project Office		17	
Public Relations Center		1	
Solar Observatory		9	
Nobeyama Radio Observatory		1	
Subaru Telescope		1	1
External organizations			
IoA, Univ. of Tokyo		5	
JAXA/ISAS	1	2	
Ibaraki University		1	1
Other		1	
Total	4	90	5

(2) Optical Shop

1) Management and maintenance
- Maintenance of measuring instruments (such as daily inspections)
- Technical consulting for users (47)
- Repair and upgrade
  - Exchange of PC for NH-3SP (Mitaka Kohki Co. Ltd.)
  - Installation of Keyence VR-3000.

And others

2) Open use of measurement instruments (April 2015 - March 2016)
- Number of user: 286
  NAOJ: 211(including 107 from ATC)
  External organizations: 75
- Use of LEGEX910 (large-scale 3-D measurement machine): 6
  Number of operating days: 10

(3) Thin Film Processing Unit

We evaluated the wideband anti-reflection coating on the microlenses in front of the optical fiber input for the SuMIRe (Subaru Measurement of Images and Redshifts) project, which was fabricated in the last fiscal year. We confirmed the required quality and performance for this purpose, but also determined that we have reached the limits of current techniques. For further improvement of anti-reflection coatings, fundamental experiments are carried out to design and develop the concrete processes for coating, which takes into account the application and expected performance of inhomogeneous multilayers.

(4) Optical and Infrared Detector Group

We have executed a joint purchasing program for MESSIA6, a focal plane array controller for astronomical instruments, as one of the open-use devices of the Advanced Technology Center. MESSIA6 was build based on the electronics developed for Hyper Suprime-Cam in cooperation with the University of Tokyo, and the High Energy Accelerator Research Organization (KEK). It is optimized for general purpose to control astronomical instruments which use focal plane arrays. In this year, a total of 14 sets were purchased for 2 divisions of NAOJ and 4 other organizations. We are providing the documentation, and will support the users for installing MESSIA6 onto their instruments.

(5) Space Optics

Activities to observe astronomical objects from space by sounding rockets and science satellites have been pursued to realize future space science missions. In FY 2015, basic development was conducted for flight operation of a sounding rocket mission CLASP, which aimed to observe magnetic fields at the height of the solar chromosphere and the transition region, and for a future satellite mission SOLAR-C. The development activity for a future satellite mission WISH has terminated within ATC.

Immediately after the completion of the CLASP instrument, it was transported to the U.S. at the beginning of the fiscal year. The flight experiment was executed on September 3, 2015 at a sounding-rocket launch site in the U.S. It has become the first successful flight for observing high-precision polarimetry of the H Lyα from the Sun. The design and fundamental experiments for the next flight started in the latter half of the fiscal year.

For a planned future solar observing satellite mission SOLAR-C, the development and testing of prototype components have been carried out for the waveplate and narrow-bandpass filters meeting space-qualified specifications, in addition to the performance evaluation of a near-infrared imaging device for the high-speed spectro-polarimetry.

(6) Facility Management Unit

The Facility Management Unit conducts the management of ATC facilities including the buildings, electric facilities; daily maintenance of the Cold Evaporator (CE); maintenance of building equipment; oversight of construction; and management of hazardous material and laboratory equipment.

Concerning the buildings facilities and equipment, we replaced four draft chambers. We attached a scrubber decontamination device to the draft chamber using hydrogen fluoride-based solvent for washing in order to remove the toxic substances included in the exhaust, so that the amount in the exhaust gas is less than the regulation value. Because the discharge ventilation performance was lower than the regulation value, we changed the motor of the blower and increased the ventilation performance to more than the regulation values. In the other 3 draft chambers, we changed the motors of the blowers to increase the ventilation performance to more than the regulation value as well. Many problems occurred in the air conditioner. Three rooms in the radio development laboratory were broken at the same time and restoration required two months. Because deterioration of the water pipes increases the degree of coolant pollution, we increased checks of the circulation coolant facilities to prevent pollution of the water. We cooperated with an advanced technology experiment building (TMT) construction plan completed in March 2015.

The main users of the laboratories were 11 projects including ATC members, KAGRA, TMT, Radio Department/Chile Observatory, HSC, JASMINE, Optical and Infrared Department, Exo-planet team, Subaru Telescope, Hinode Science team, and SOLAR-C/CLASP. Programs that used clean rooms were KAGRA in the south building and CLASP in the north building. After completion in March, CLASP was launched in the United States in September 2015 and successfully observed the Sun.

3. Open Use Programs

In FY 2015, ATC called for and accepted open use programs twice a year. ATC facilities were used for 8 “collaborative development programs” and 30 “facilities use programs”. Information about these programs is presented in “Common use of ATC facilities” with the names and research titles of the program leaders. Reports from the open use programs are also presented on the ATC homepage.

4. Prioritized Area Developments

(1) ALMA Band 4, 8, 10

For the ALMA project, the mass-production and shipment to Chile of the Band 4, 8 and 10 receiver cartridges, which were assigned to Japan, were completed in FY 2013. In Chile, most of the receivers have been installed and are operating in the ALMA antennas, and many scientific results have been published. At the Advanced Technology Center (ATC), the ALMA receiver maintenance team has the responsibility to correct receiver defects, and repaired one Band 8 receiver and six Band10 receivers during FY 2015.

Table 2: Total number of failed receivers.

Receiver	Total	Breakdown	
		Initial failure	Aging failure
Band 4	6	3	3
Band 8	17	14	3
Band 10	15	6	9

Table 2 shows the total number of failed receivers broken down into “initial failure” and “aging failure.” The initial failures of Band 4 receivers included improper design at the initial development phase, and the number of failures has decreased after the design was revised. Similarly, most of the initial failures of Band 8 receivers were due to the improper design, and the number of failures has decreased after the design was revised. In contrast, the initial failures of Band 10 receivers pertained to the turn-on sequence for several amplifiers. This problem was handled by replacing the amplifiers. The aging failure of Band 10 receivers is from degradation of electrical devices; we have already identified the lots with high degradation possibilities. It is expected that the defects will decrease by replacing the devices from such lots with those from lots with low degradation possibilities.

Although the number of failing Band 4 and Band 8 receivers seems to be decreasing in FY 2015, this is not enough to judge the defect frequency owing to aging failure, because it has not been long since they started operation in ALMA. It is very important to keep the long-term maintenance system in ATC.

(2) Development of advanced receivers

Development of ultra-wideband, terahertz, and multibeam

heterodyne receivers has been started as future ALMA upgrades. Dr. Wenlei Shan was appointed Associate Professor in the Advanced Technology Center in November 2015, and consequently, the structure of the receiver development team has been reorganized.

1) Ultra wideband receiver

We have proceeded with the development of a band 7+8 receiver covering the frequency range 275-500 GHz. We have successfully fabricated SIS junctions with high current density, ranging from 10 to 50 kA/ cm2, and high quality, which is one of the key technologies for future receiver development. Based on this new junction technology, we have also demonstrated low-noise and wider RF band mixer performance than typical band-8 mass-produced SIS mixers. As a parallel project, we have started research and development of a multiband low-noise receiver aiming at improved sensitivity and simultaneous observation of multi-line spectra.

2) Terahertz receivers

We have pushed forward with the establishment of a reconfigurable beam pattern measurement system and with the development of superconducting mixers and corrugated feed horns for the 1.2-1.6 THz band. We have demonstrated heterodyne response using a waveguide HEB mixer in collaboration with the University of Tokyo. We have also demonstrated competitive performance of the corrugated horn antenna with respect to ALMA specifications by using the established beam pattern measurement system.

3) Multibeam receiver

We have started the conceptual design of a novel multibeam receiver based on planar circuits. Additionally, together with the Korea Astronomy and Space Science Institute (KASI), we have started collaborative research and development aiming at the installation of a wideband multibeam receiver on the ASTE telescope. This later project is led by KASI.

(3) SIS junction development

In order to fabricate a millimeter- and sub-millimeter-wave low-noise receiver having either an octave signal bandwidth or a signal frequency higher than 1 THz, we conducted research and development for high quality Nb/Al type SIS junctions with extremely high current densities (15 – 30 kA/ cm2), which are expected to be essential key devices for those receivers. According to the study of I-V characteristics as well as the detailed analysis of the distribution profiles of Al and Nb observed by the STEM (scanning transmission electron microscope) for the conventional Nb/Al/AlOx/Nb type SIS junction, we found that the AlOx is considerably damaged by the upper Nb, and that an increase of the subgap leakage current might result from such damage. A Nb/Al/AlOx/Al/Nb type SIS junction with an ultra-thin (~ 5 nm) Al film inserted between the AlOx film and the upper Nb film was designed to prevent direct contact between the Nb and AlOx film to minimize the damage to the AlOx film. We tried to make the Nb/Al/AlOx/Al/Nb type SIS junction and found that a very high-quality (RSG/RN>20) SIS junction with an extremely high current density (~45 kA/ cm2) can be obtained in this way. Although, up to now, it has been considered quite difficult to produce a high-quality SIS junctions with such an extremely high current density, we have recently succeeded in producing a SIS junction, which has not only a high quality but also an extremely high current density, for the first time in the world. This achievement gives us a bright outlook, particularly for the development of receivers covering the frequency band (275-500 GHz) of ALMA band 7 and 8.

(4) TMT

We have been continuing development of the first generation Thirty Meter Telescope (TMT) instrument IRIS since 2011.

Light Preliminary Design Phase extension, LPDP-E (Jan. – Dec. 2015) and Light Preliminary Design Phase 2016 extension, LPDP-2016E (Jan. – Dec. 2016) continued in FY 2015. We proceed with the optical design of the IRIS imager which NAOJ has a responsibility to develop, focusing on the opto-mechanical design. We have improved the optical design with all reflective surfaces, which meet the requirements for wave-front error across the entire field of view of 34 arcsec square by optimizing the symmetry of optical parameters. Further, we proposed a solution for packaging the imager optics into the science cryostat and started designing the opto-mechanical components to support all optics.

We introduced the progress and status of opto-mechanical design of the IRIS imager and integration plan at the mechanical and integration mini review on August 13, 2015 in Pasadena California. Also we presented the latest optical design in the face-to-face meeting on November 5 and 6, 2015. IRIS team members have approved the solution for the optical design of the IRIS imager.

In parallel, the IRIS-J team has been continuing vibration analysis for IRIS combined with the adaptive optics system for TMT, NFIRAOS. In prototype experiments and trial fabrications looking ahead to the coming final design phase and fabrication phase, major issues are the durability of the bearings under the cryogenic conditions, the cooling characteristics of the optical substrate, and trail production of the high-reflectivity coating.

We have been working on a conceptual study for a camera system of WFOS, which is another first generation instrument of TMT. We have investigated the degradation of image quality caused by the inhomogeneity of lens made of fluorite crystal. Also we made a modification and upgrade to the optical design for the camera system due to a change in the layout of WFOS.

(5) Gravitational wave telescope KAGRA

We developed KAGRA's auxiliary optics subsystem (AOS) and vibration isolation subsystem (VIS) with the Gravitational Wave Project Office.

About AOS, we have continued the design and manufacture of some parts of the transmission monitor system (TMS). The telescope system will be located at the end of each 3-km arm optical cavity of KAGRA to monitor the tilt and shift of the beam line, and make feedback signals to the control system. The

beam reducing telescope (BRT), which is a part of the TMS, need to be aligned in ultra high vacuum after laser light will be finally resonant in the 3-km optical cavities; for example, 5-axes lens holders have been designed for the BRTs. In addition, the BRTs need to be isolated from vibrations as done for the other mirrors of the KAGRA interferometer, and the design of the vibration isolation stages for BRTs are ongoing.

KAGRA-VIS is a system to suspend mirrors required for the KAGRA interferometer to isolate them from seismic fluctuation. The system consists of multi-stage isolation mechanical filters; ME shop has finished manufacturing all the parts for the bottom filters, and also done assembly works, tests before the shipping. The ME shop has also manufactured all the pieces of recoil masses (made of 64-Ti), which will be suspended to reduce fluctuations of the mirrors. In addition, design, manufacture, and the tests of some jigs to hang the mirrors (the hanging frame) and winch system for the mirrors and recoil masses have been done. Then, ME shop have involved in the final design, manufacture, and the tests of most of the suspension chain by which the PR3 mirror (among the main mirrors, only this mirror in initial-phase KAGRA will be also used for the next stage) has been suspended and the hanging jig. As a result, iKAGRA was able to start the test run in the end of March of 2016.

5. Advanced Technology Developments

(1) Telescope Receiver Developments

Based on the technical skills acquired through the development of ALMA receivers, the "telescope receiver development" team has responsibility for the development of the Nobeyama FOREST receiver and the fabrication and tests of a cryostat for enabling simultaneous use of multiple receivers in the ASTE telescope. And also, we maintain good collaboration with other radio telescopes pursued by universities, such as NANTEN2 pursued by Nagoya University and the receiver for the Greenland Telescope (GLT) pursued by Osaka Prefecture University.

ATC can increase the technology standards of the community by giving feedback using the technologies and knowledge accumulated through development of specific projects, and can provide technology developments to other projects, universities and research institutions. It is also important to make the best use of the achievement of the projects.

(2) MKID Camera

The MKID (Microwave Kinetic Inductance Detector) group of the Advanced Technology Center is developing a superconducting camera in millimeter and submillimeter wavelengths for the Antarctica terahertz telescope, which observes distant galaxies with a wide field of view, and for the LiteBIRD satellite, which detects CMB B-mode polarization, in collaboration with the University of Tsukuba, Saitama University, KEK, ISAS, Kavli IPMU, and RIKEN. The following papers were published in FY 2015.

1) Study of superconducting Bi-layer MKID (A. Dominjon et al. 2016 IEEE AS)
2) Broadband (Octave band) corrugated horn array (S. Sekiguchi et al. 2015 LTD)
3) Design of MKID focal plane array for LiteBIRD (Y. Sekimoto et al. 2015)
4) Radiation tolerance of MKID (K. Karatsu et al. 2016 JLTP)

(3) Hyper Suprime-Cam (HSC)

HSC has been used for regular science operations since March 24, 2014. This includes both the Subaru Strategic Program and the normal open-use observations. During FY 2015, 111 nights were allocated to HSC programs (among these 53 nights were for Subaru Strategic Programs). Minor problems occurred in the mechanism of shutter and filter exchange and some of the main CCDs, however, there were no nights where instrument problems completely prevented observations, fortunately. These problems were handled and settled through the comprehensive support from the ATC engineering staff. On-site maintenance service of the filter exchanger was conducted. Fabrication, integration, testing and adjustment of a spare for the shutter was completed in Mitaka. This spare is scheduled to be shipped to Hawai`i early in FY 2016. For the CCD failures, it has to be coped with changes in the operating conditions, by verifying the testing unit of CCD in a Mitaka laboratory. On the other hand, it turned out that the uniformity of the existing flat lamp modules on the telescope was not sufficiently good considering the target accuracy of HSC photometry. So a new flat lamp produced by a single light source has been installed on the ceiling of the camera. Some adjustments related to this flat lamp still remain and underway. In the next fiscal year, FY 2016, we plan to install new

calibration unit for HSC camera using monochrometer.

(4) Near-IR Imaging Sensor Developments

In areas of electronics and detector developments, we have made a trial chip of a low noise Indium Gallium Arsenide (InGaAs) image sensor based on a commercial product, for which the cost is expected to be lower than existing near-infrared sensors, in cooperate with KEK, Hiroshima University, and Kagoshima University. We also investigated making a larger format sensor and new readout electronics to use the InGaAs image sensor in a near-infrared wide field camera.

17. Public Relations Center

1. Overview

The Public Relations Center engages in the publication, promulgation, and promotion of scientific achievements made not only by NAOJ but also by others in the field of astronomy in general to raise public awareness; responds to reports of discoveries of new astronomical objects; and provides the ephemeris and other astronomical information directly related to people's everyday activities, such as sunrise and sunset times. Starting from FY 2014 with the addition of the IAU Office for Astronomy Outreach (OAO), the Center has been comprised of 7 offices and 1 unit: the Public Relations Office, the Outreach and Education Office, the Ephemeris Computation Office, the Museum Project Office, the Library Unit, the Publications Office, the IAU Office for Astronomy Outreach (OAO), and the General Affairs Office.

2. Personnel

In FY 2015, the Public Relations Center was composed of Director Toshio Fukushima and the following staff members: 2 professors, 1 associate professor, 2 assistant professors (both hold concurrent posts), 2 research engineers, 1 senior engineer, 1 engineer, 1 Chief of the Library, 2 specially appointed senior specialist, 4 research experts (1 holding a concurrent post), 20 public outreach officials, 1 research supporter, and 2 administrative supporters.

On April 1, 2015 Chief of the Library Tatsuya Todoriki arrived and public outreach official Takao Ibaraki and public outreach official Taiga Hamura arrived in the Outreach and Education Office. On April 6, 2015, specially appointed senior specialist Pires Canas Lina Isabel arrived in the IAU Office for Astronomy Outreach; on June 1, research supporter Chie Tsuchiya arrived; on September 1, Naomi Ishikawa was promoted to specially appointed senior specialist; on October 1, public outreach official Noriko Takabatake arrived in the Outreach and Education Office; and on December 8, public outreach official Diaz Rosas Elian Abril arrived in the IAU Office of Astronomy Outreach.

On March 31, research engineer Goro Sasaki and public outreach official Diaz Rosas Elian Abril finished their terms. In addition research supporter Chie Tsuchiya transferred to the Hinode Science Center.

3. Public Relations Office

Through press conferences and web releases, the Public Relations Office actively developed public outreach activities focused around the results of each Project, first and foremost ALMA and Subaru Telescope, including open use and collaborative results with other universities and research institutes. In addition, in cooperation with the Outreach and Education Office, the Public Relations Office also conducted observation campaigns to promote astronomical phenomena of interest to the public, like the solar eclipse and meteor showers.

(1) Online-Based Information Sharing

The Public Relations Office runs the NAOJ website (http://www.nao.ac.jp/en/), disseminating information via the internet. Table 1 shows the access counts for the website.

NAOJ e-mail newsletters No.143-158 were issued, containing headlines for major news events with hyperlinks to pages with further details. The Astronomy Information Telephone Service, which provides voice news updated on a semimonthly basis, issued 24 messages in total. This service was discontinued at the end of this fiscal year.

Through the Twitter social networking service, employed since October 2010, the Office disseminates information on the status of various NAOJ projects such as open house events, regular stargazing parties at Mitaka Campus and position openings. As of the end of March 2016, the number of followers exceeds 60,000. Starting from this fiscal year,we utilized the English versions of Twitter and Facebook to strengthen our English language information distribution.

(2) Press Releases and Media Relations

There were 25 research result announcements (compared to 16 in FY 2014 and 26 in FY 2013). For press releases aimed towards overseas audiences, we have increased the use of the American Astronomical Society and AlphaGalileo which have been employed up to now, and from FY 2015 have started to use EurekAlert! which is operated by the American Association for the Advancement of Science.

In the perennially popular Astronomy Lectures for Science Journalists program, the 22nd lecture entitled "What does the Rikanenpyo (Chronological Scientific Tables) Tell Us Now" was held on November 24, 2015. Thirty-nine people

Month	Access counts	Month	Access counts	Month	Access counts
April 2015	1,187,930	August 2015	1,026,205	December 2015	850,441
May 2015	542,548	September 2015	544,748	January 2016	535,655
June 2015	513,154	October 2015	623,754	February 2016	523,145
July 2015	595,883	November 2015	466,582	March 2016	533,022
Total: 7,943,067					

Table 1: Monthly website access statistics for the Public Relations Office website, NAOJ Public Relations Center (April 2015–March 2016).

April 7, 2015	Unprecedented views of lensed galaxy and asteroid Juno taken with ALMA
May 12, 2015	Great Progress towards the Origin of R-process
June 1, 2015	Astronomers Discover a Young Solar System Around a Nearby Star
June 9, 2015	ALMA uses 'Natural Telescope' to Image Monstrous Galaxy near the Edge of the Universe
June 18, 2015	ALMA Precisely Measures Black Hole Mass
June 23, 2015	Astronomers Discover More than 800 Dark Galaxies in the Famous Coma Cluster
June 26, 2015	Unexpectedly Little Black-hole Monsters Rapidly Suck up Surrounding Matter
August 5, 2015	The Ghostly Remnants of Galaxy Interactions Uncovered in a Nearby Galaxy Group
August 24, 2015	Hinode, IRIS, and ATERUI Cooperate on 70 year old Solar Mystery: Magnetically driven resonance helps heat the Sun's atmosphere!
August 27, 2015	Discovering Dust-Obscured Active Galaxies as They Grow
September 10, 2015	Oxygen is not Definitive Evidence of Life on Habitable Extrasolar Planets
September 25, 2015	"Fossils" of galaxies reveal the formation and evolution of massive galaxies
September 30, 2015	Mechanism of explosions and plasma jets associated with sunspot formation revealed
October 15, 2015	ALMA telescope unveils rapid formation of new stars in distant galaxies
December 4, 2015	Event Horizon Telescope Reveals Magnetic Fields at Milky Way's Central Black Hole
December 5, 2015	ALMA Spots Monstrous Baby Galaxies Cradled in Dark Matter
December 7, 2015	Radio Shadow Reveals Tenuous Cosmic Gas Cloud
December 18, 2015	Final Results of NameExoWorlds Public Vote Released
January 15, 2016	Signs of Second Largest Black Hole in the Milky Way - Possible Missing Link in Black Hole Evolution
February 4, 2016	A Violent Wind Blown from the Heart of a Galaxy Tells the Tale of a Merger
February 25, 2016	Subaru-HiCIAO Spots Young Stars Surreptitiously Gluttonizing Their Birth Clouds
February 25, 2016	New Fast Radio Burst Discovery Finds 'Missing Matter' in the Universe
March 3, 2016	ALMA Spots Baby Star's Growing Blanket
March 10, 2016	Deciphering Compact Galaxies in the Young Universe
March 10, 2016	Mysterious Infrared Light from Space Resolved Perfectly

Table 2: Web releases.

July 2, 2015	Dark Matter Map Begins to Reveal the Universe's Early History
November 6, 2015	KAGRA's Initial Operation To Begin Soon

Table 3: Press Conferences.

Video Visualization of TMT When Complete	
The First Dark Matter Map Drawn by Hyper Suprime-Cam on the Subaru Telescope	
Undertaking Galactic Archeology in M81 using the Very Wide Field of View Prime Focus Camera	
Geminid meteor shower	Japanese, English Versions
ALMA 12-Meter Antenna Paper Model	Japanese, English Versions
What is a Meteor Shower? (Long version/Short version)*	Japanese, English Versions of Each
Mitaka Open House Day Report*	
Fureai (Friendly) Astronomy PR	
The Opening of the Information Space of Science and Astronomy	

Table 4: Table 4: Summary of Produced Videos (* in preparation for release)

participated in lectures and panel discussions about the history and articles of the Rikanenpyo, which started 90 years ago.

(3) Supporting NAOJ-wide Public Outreach Activities

The following activities were pursued in addition to the Center's regular task of aiding research result releases.

We continued to produce videos explaining research results, videos explaining astronomical phenomena, and videos introducing outreach and education activities. Including English versions, 14 were produced (including those in preparation for public release). These videos introduce a wide range of general activities, not just NAOJ research. As of the end of March 2016, these videos have accumulated a total of 15,000 views.

The Office also helped Projects with their own lectures for the general public. The NAOJ lecture meeting "The Challenge which Exceeded Space-Time: General Relativity's 100th Anniversary and Gravitational Wave Astronomy," was held on September 18, 2015 and the ALMA public lecture/Osaka Science Museum Special Night "Exploring the Mysteries

of Star and Galaxy Formation with ALMA" was held on November 4, 2015.

In addition, we provided media support for a facility tour and press conference on November 6, 2015, corresponding to the completion of the initial experiment facility for the large-scale gravitational wave telescope KAGRA; and for the opening ceremony for the Astrobiology Center National Institutes of Natural Sciences, held on November 20.

As cooperation for the renewal of NAOJ Project webpages, we provided support to the Gravitational Wave Project Office and the Hinode Science Center.

Last fiscal year, "Multiwavelength Universe" a special site providing explanations of astronomical observations for the general public was opened. This year we opened an English language version.

4. Outreach and Education Office

(1) Handling General Inquiries

The Office received inquiries from the media, government offices, and the general public. The Outreach and Education Office responded to 6,606 telephone inquiries (Table 5) and 156 letters, 66 of which were official documents. The Office stopped accepting inquiries via the internet in April 2014.

(2) Educational and Outreach Activities

The astronomical phenomena awareness campaigns started as bidirectional information sharing initiatives in FY 2004. This year, 3 were conducted: "Let's Observe the Total Lunar Eclipse 2015" April 2015 (434 responses); "Summer Nights: Let's Count Shooting Stars 2015" August 2015 (2,875 responses); "Let's Watch the Geminid Meteor Shower 2015" December 2015 (1,550 responses).

The "Fureai (Friendly) Astronomy" project, now in its 6th year, provided events to 60 schools out of the 71 which applied, reaching 5,743 students. A total of 42 lecturers participated.

On July 23 (Thursday) and July 24 (Friday) during summer vacation "Summer Vacation Junior Star-Gazing Party" events were held for elementary, junior high, and high school students (application required, maximum capacity 50 participants each day). Lectures about the assembly and use of planetarium projection machines and telescopes, and star gazing parties were held. A total of 103 people participated.

The Public Relations Center participated as the secretariat for the Mitaka Open House Day, a special public event held at Mitaka Campus and organized by the steering committee. This two-day event was held on October 23 (Friday) and 24 (Saturday) with the theme "The Challenges Awaiting Astrobiology." It was co-hosted by the Astrobiology Center, National Institutes of Natural Sciences; the Institute of Astronomy, the School of Science, the University of Tokyo; and the Department of Astronomical Science at the School of Physical Sciences of the Graduate University of Advanced Studies. The 23rd was cloudy, but the 24th was clear. The event flourished: over the 2 days, a record high of 5,036 guests attended. Each Project offered a selection of activities based on their own expertise which were suitable for a wide range of age groups. Activities included the viewing of facilities not normally open to the public, interactive panel displays, mini-lectures, and popular quizzes and games.

The 6th International Science Film Festival was co-hosted between August 1 (Saturday) and September 30 (Wednesday), in cooperation with 69 collaborating organizations and groups, with the main theme of the "International Year of Light (IYL2015)" declared by the United Nations. Screenings of science films and other events such as a stamp-collection rally were held at 49 science museums, planetariums, and film theaters in Japan, with more than 1 million people participating. The Kickoff Event (Nakano Zero Planetarium) and Dome Festa (Koriyama City Fureai Science Center) were held as the core events.

The "NAOJ Tours" cohosted each year with Tamarokuto Science Center were held on Sunday March 20. They were popular with a total of 80 guests, 40 in the morning and 40 in the afternoon, participating in tours of the 4D2U Dome Theater, a sunspot observation event at the 20-cm Telescope Dome, and self-guided tours along the tour course. In addition, group tours (self-guided) held on Saturday July 18, Sunday July 19, and Saturday August 22 were well received with 70 guests attending each, for a total of 210.

From November 15 (Sunday) to 17, "The 11th Workshop for Popularizing Cutting-Edge

Astronomy" was held with the theme "Astrobiology" at NAOJ Mitaka Campus and Japan Agency for Marine-Earth Science and Technology Yokosuka Headquarters. A total of 67 researchers and people connected to education and outreach participated.

The "You are Galileo!" program received support from the Nonprofit Public Organization: Foundation for Promotion of Astronomy, and was held this year in Indonesia, in cooperation with the Office of International Relations and OAO. A "You are Galileo!" workshop was conducted on March 11 and a public lecture was conducted on March 12 at Mulawarman University in Samarinda City. The workshop was attended by 25 people, and the lecture by 140 people.

The data reduction software Makali`i, developed to enable FITS data obtained from Subaru Telescope science observations and other sources to be used in astronomy

	Solar info	Lunar info	Ephemeris info	Time	Solar System	Universe	Astronomy	Other	Total
April–June	210	118	50	21	201	81	102	827	1610
July–September	179	189	78	18	232	109	177	896	1878
October–December	201	133	84	5	361	99	125	665	1673
January–March	250	130	79	11	170	150	150	505	1445

Table 5: Telephone inquiries made to the Outreach and Education Office of the NAOJ Public Relations Center (April 2015–March 2016).

education and outreach, was distributed via the internet to domestic and international users. Starting from March 2016, the distribution method was changed so that the software can be downloaded freely without registering.

We participated in the International Year of Light 2015 "Cosmic Light" events: a special website "Matters of Cosmic Light" was opened to the public and updated; Cosmic Light astronomical object photo panels were produced and displayed; in cooperation with Konicaminolta Plaza, the "Hubble Space Telescope Astrophotography Exhibit" was held; etc.

(3) Community Activities

The "Mitaka Picture Book House in the Astronomical Observatory Forest" welcomed 42,401 visitors in FY 2015. The Outreach and Education Office is conducting events at Mitaka Picture Book House in the Astronomical Observatory Forest including the "Dou Ugoku? Ochiru Korogaru (How do You Move? Fall and Roll)" exhibit, modern and traditional Tanabata events, moon viewing, etc. in cooperation with the Mitaka City Municipal Office and local volunteers. In addition, through the "Mitaka Picture Book House in the Astronomical Observatory Forest, Picture Book Original Drawings Hallway Exhibit Contest" which started from FY 2013, the Outreach and Education Office cooperated in the selection of 3 winning books. The grand prize winner "Noboreboshisama (Rising Star, made by Tomoaki Kunii)" is scheduled to be published as part of the "Picture Book House in the Astronomical Observatory Forest Compilation Series" in FY 2016.

The Outreach and Education Office conducted the 7th "Mitaka Solar System Walk" in cooperation with Mitaka City and the non-profit organization (NPO) Mitaka Network University Promotion Organization. Held from September 20 (Saturday) to October 25 (Sunday). Stamps were placed at 170 shops and 67 facilities, including NAOJ Mitaka Campus and the Mitaka City Municipal Office, for a total of 237 locations around Mitaka. Approximately 18,000 guide-maps/stamp-sheets were distributed, of which 3,296 people turned theirs in for a prize. The total number of stamps was 413,425; the average number of stamps collected was 125.4 per person. The number of participants who collected all of the stamps was 339. It was a good chance to tour the Solar System while promoting commerce and industry and providing families with a way to enjoy Mitaka and rediscover the city's charm.

The event "Astronomy Pub" has been held at Mitaka Network University and hosted by the NPO Mitaka Network University Promotion Organization since FY 2009. It provides for 25 participants at a time and is held in the evening on the 3rd Saturday of every month except August. The Outreach and Education Office also provided the venue for "Astronomy Course for Apprentice Starry Sky Guides, Star Sommelier Mitaka, Let's Become Apprentice Starry Sky Guides!-" hosted by Mitaka Network University and also assisted in providing presentations, telescope operation workshops, and other related events.

With the aim of creating a meeting point suitable for "Mitaka, a Town with an Observatory," the "Information Space of Science and Astronomy" opened along Mitaka's Chuo Dori, near the South Exit of JR Mitaka Station, on September 26, 2015. Established jointly by 4 partners: NAOJ, Mitaka City, Mitaka Network University, and Mitaka City Planning Board, it depends of the coordinated efforts of 11 groups, including those aiming to invigorate the area in front of Mitaka Station and the groups related to science and astronomy. NAOJ offered photograph panels for the planned exhibitions; held collaborative lecture meetings; offered outreach and monthly astronomical information images through large-scale information displays; and cooperated on the M Marche Project conducted the 4th Sunday of every month. In addition, we are also conducting the "Cosmic Reading Bookstore Corner," a display of sample books available to read which changes themes once every 2 months. In the half-a-year from September 26 to March 31, the "Information Space of Science and Astronomy" welcomed 9,981 guests and was acknowledged as a location in town where science can be easily accessed.

5. Ephemeris Computation Office

The Ephemeris Computation Office (ECO) estimates calendrical phenomena such as the apparent positions of the Sun, Moon, and planets on the basis of international standards and publishes the "Calendar and Ephemeris" as part of the compilation of almanacs, which is one of NAOJ's raisons d'être.

(1) ECO published the 2016 edition of the Calendar and Ephemeris, the 2016 version of the calendrical section of the Rikanenpyo (Chronological Scientific Tables), and the 2017 edition of the Reki Yoko (posted in the official gazette on February 1, 2016). The Calendar and Ephemeris webpage was updated to match what was published in the Reki Yoko. In addition the 22nd lecture entitled "What does the Rikanenpyo Tell Us Now" was held in cooperation with the Public Relations Office.

(2) As for the website (http://eco.mtk.nao.ac.jp/koyomi/index.html.en), ECO continuously updated the contents of the Ephemeris Wiki. ECO cooperated with the astronomical phenomena awareness campaigns again this year. The radiant points of the Perseid and Geminid meteor showers were published in the Astronomical Information section of the website. There were about 25 million page views for this fiscal year.

(3) The Japan Association for Calendars and Culture Promotion hosted its 5th General Meeting, the Calendar Presentation Ceremony, and a symposium on the Traditional Calendar 2033 A.D. Problem.

(4) ECO hosted regular exhibitions in collaboration with the Library, selecting from NAOJ's invaluable collection of historical archives written in Chinese/Japanese. The themes of the 52nd and 53rd exhibitions were "Official Documents from the Meiji Era to the beginning of the Showa Era" and

"Achievements of Harumi Shibukawa - II" respectively. These exhibits can also be viewed at the Rare Materials Exhibition of the Library's website, in Japanese only (http://library.nao.ac.jp/kichou/open/index.html).

(5) Four staff members, including one full-time and three part-time, handled reports of new astronomical objects and other communications submitted to NAOJ. In this fiscal year, there was a total of 16 reports including confirmation requests for new celestial object candidates and other reports. The contents were: 9 novae/supernovae, 3 comets, 3 luminous objects, and 1 asteroid. Among the many examples of reporting a variable star or asteroid as a new object, 2 novae reported in October, were communicated via NAOJ to the IAU Central Bureau for Astronomical Telegrams and were recognized as an independent discovery of Nova Ophiuchi 2015 No. 2 (V2949 Oph) and the discovery of Nova Sagittarii 2015 No. 4 (V5850 Sgr). Again in November, a supernova was reported. The discoverer himself reported it to NAOJ and the IAU Central Bureau simultaneously. It was recognized as the discovery of Supernova 2015as.

6. Museum Project Office

For the 3 Fiscal Years from 2013 to 2015, part of the duties for managing public access to the facilities was separated from the Outreach and Education Office and handled as the "Museum Project Office." But at the end of fiscal year 2015, the mission of the Museum Project Office ended. So starting from FY 2016, it was reintegrated back into the Outreach and Education Office.

(1) Facility Opening Events

With regards to the opening of the 4D2U Dome Theater in FY 2015, at the end of the previous fiscal year, renovations were performed to repair equipment and increase seating. In April, it was reopened to the public. Starting from this fiscal year, regular showings were held at the 4D2U Dome Theater 3 times per month (the day before the 2nd Saturday, the 3rd Saturday, and the 4th Saturday). Advance reservations were required. In this 1 year period, a total of 35 events were held, in which 4,446 guests participated. An additional 70 group screenings were held with 1,983 participants, and 119 tours were organized with 1,670 participants. In total, 224 screenings were held and a total of 8,099 guests enjoyed 4D2U's stereoscopic images.

Regular stargazing parties held with the 50-cm Telescope for Public Outreach were held twice a month (the day before the 2nd Saturday and the 4th Saturday). These were held regardless of cloudy or rainy weather. Advance booking (300 people for each session) was introduced in FY 2012 for these events. A total of 23 sessions were held with 4,717 participants.

A total of 19,729 people visited the Mitaka Campus Visitors' Area in FY 2015. In addition the group tours in 2015, consisted of 129 general tours (4,797 guests), and 37 workplace visits by schools (536 guests), for a total of 166 tours accommodating 5,333 guests. Note that in the workplace visits, lectures by researchers and question-and-answer sessions also took place.

The name of the Mitaka Campus Tour was changed to "Tangible Cultural Heritage Tour." Advanced reservations are required, 20 person capacity. This year a total of 204 people participated. The "Tangible Cultural Heritage Tours" ceased operation at the end of March 2016.

(2) Museum Planning and Archive Management

To prevent historically important observations, measuring devices, and documents from being scattered and lost, the Office is conducting investigations to continue improving the collection, sorting, and preservation of articles and improve the methods and environment for displaying them. In cooperation with Mizusawa Campus and Nobeyama Campus, the Office also established the basic concept for the NAOJ Museum (tentative name) including both facility opening efforts and archive works.

The Office sponsored the International Symposium on the NAOJ Museum for 3 days, September 27-29, 2015, at Mitaka Headquarters. This symposium summarized the research results of the "Forming an International Space for Learning Based on Research in the Natural Sciences" Project (Discretionary Budget of the Head of National Institutes of Natural Science, provided from FY 2010 to FY 2015). It was also planned with the goals of domestic and international publicity and exchanging opinions about the "NAOJ Museum Concept Plan" focusing on the newly created limited time office "Museum Project Office" within the Public Relations Center. The symposium received support from the Nonprofit Public Organization: Foundation for Promotion of Astronomy. Ninety-four guests from 9 countries (China, South Korea, Thailand, Indonesia, Germany, Netherlands, Portugal, U.S.A., and Japan) attended the event in person while 7 people in 6 locations in Japan and overseas (Mizusawa, Nobeyama, Okayama, Subaru Telescope Summit Facility and Hilo Base Facility, Indonesia, and U.S.A.) participated via the TV conference system. The results of the 3 days of discussion are summarized in "The Mitaka Declaration." In addition, there were indications that the consensus among all participants regarding the NAOJ Museum Plan was that it should aim to be open by 2020.

Proposed at the initiative of the participants, "The Mitaka Declaration"is addressed to NAOJ and JAXA, urging them to change their copyright rules regarding astronomical images, videos, etc. to be more generous, in line with other organizations such as NASA and ESO/ESA.

7. Library Unit

The Library Unit collects and sorts scientific journals and books in order to make them available for the research and study of NAOJ researchers and students. In recent years, with the continuing digitalization of scientific materials, the portion of the materials in electronic format has increased.

For non-NAOJ personnel who wish to use the Mitaka Library materials, the Library is open to the public on weekdays. In FY 2015, 323 non-NAOJ personnel came to use the Library. Also for researchers and students belonging to

other organizations, we loan books or provide photocopies via the institute's library. In FY 2015, photocopies or loans were provided in a total of 86 cases.

Important documents, especially those originating from the Edo Era Tenmonkata (Shogunate Astronomer), are preserved while taking into account the environment of a specialist library. Images of some of the important documents are available to the public on the Library Unit homepage.

During the Mitaka Open House Day festivities in October, part of the Mitaka Library is opened to the public so that people can freely examine the documents, focusing primarily on documents which appeal to the general public and younger age groups.

The number of books and journals owned by Mitaka Library and each observatory and the condition of continuing NAOJ publications are published in Section XI Library, Publications.

8. Publications Office

The Publications Office continued its activities in planning, editing, and printing NAOJ's original materials for PR and promotions. The following periodicals were also published this year:

- NAOJ Pamphlet (Japanese)
- NAOJ Pamphlet (English)
- NAOJ News, No. 261–No. 272 (April 2015–March 2016)
- Annual Report of the National Astronomical Observatory of JAPAN Volume 27 Fiscal 2014 (Japanese)
- Annual Report of the National Astronomical Observatory of JAPAN Volume 17 Fiscal 2014 (English)
- Radio Astronomy Public Relations comic "Almar's Adventure" (#5)
- NAOJ Publicity Poster Series (#2, #3)

Continuing from the previous year, in FY 2015 the Publications Office strove to strengthen its international publication ability and digital publication ability. In particular, as the first step in the production of an international edition of the Rikanenpyo (Chronological Scientific Tables), an English translation of the entire volume was created. Accompanying this, a publishing partner was selected and a production schedule was set, putting us on a concrete business plan. In digitalization and the conversion of contents produced/published (to be published) to digital format, the Publications Office developed "NAOJ-Universal Multi-Publication System (NAO-JUMPS)" a system capable of automatically collecting material about any arbitrarily chosen subject. The digital data for the past 12 years of the ANNUAL REPORT OF THE NATIONAL ASTRONOMICAL OBSERVATORY OF JAPAN Research Highlights articles (approximately 1300 pages), and fixed layout NAOJ News articles (approximately 1300 pages) were input and test operations were conducted. In addition, looking ahead we developed a general-purpose electronic book distribution platform capable of distributing to the general market via the internet, "NAOJ-Delivering next-generation e-books (NAOJ-Deneb)," which will work in concert with JUMPS in the future; and we started production of the first book for NAOJ-Deneb. In normal business, the Office produced and distributed the NAOJ pamphlets and the ANNUAL REPORT OF THE NATIONAL ASTRONOMICAL OBSERVATORY OF JAPAN. In the systematic production of special editions with the goal of developing project outreach support in NAOJ News, extra copies of each of the special editions ("ALMA Special Edition" September; "Okayama Astrophysical Observatory/Search for Exoplanets Special Edition" October; "CLASP Solar Observations Special Edition" January; and "Solar Observatory Special Edition" March) were printed and these aided the outreach efforts of each project. From now on, to develop and share NAOJ News articles as a resource to be used as outreach content for each project, we plan to promote the production of overall, basic articles through close cooperation. Other than periodicals, the 2016 calendar "Collection of ALMA Observational Images" (the 11th since 2005) was created. In addition, like in other years the Office also helped to create the poster for the Mitaka Special Open House Event again this year, and support was also given to the publication of the "Rikanenpyo, Chronological of Scientific Tables)."

9. International Astronomical Union Office for Astronomy Outreach (IAU/OAO)

In FY 2012 the International Astronomical Union (IAU) and NAOJ exchanged a memorandum of understanding to establish the IAU Office for Astronomy Outreach (OAO) at NAOJ Mitaka Campus. In FY 2014 the IAU OAO was established in the Public Relations Center. In FY 2015 the Office primarily conducted International Year of Light 2015 "Cosmic Light" activities and the Name ExoWorlds Contest.

As advocated by the European Physical Society (EPS), on December 20, 2013 the United Nations declared the International Year of Light (IYL2015). IAU also decided to participate in the theme of Cosmic Light in March 2014. Overall, IYL2015 was conducted in 94 countries with over 100 organizations participating. Under the overall broad theme of "Light and Light-based Technologies" for the International Year of Light, IAU developed the stance of "Protecting the Darkness of the Night Sky." IAU solicited proposals from the entire world and selected the following 5 cornerstone projects: 1. Gallieoscope – 16,000 constructible telescopes were distributed. 2. Light Beyond the Bulb - Over 30 countries participated, holding astrophotography exhibits in approximately 675 locations. 3. EDU kit (Teaching Materials Related to Cosmic Light) – These materials were used at more than 140 events in more than 40 countries. 4. DARK SKY METER App. – This free to use 2015 edition application was downloaded 3,442 times, and 7,290 reports were filed. 5. Quality Lighting Teaching Kit – 100 sets of this light pollution study kit were shipped.

In addition OAO, in cooperation with the Japanese Society for Education and Popularization of Astronomy, sponsored the

Japanese closing ceremony of the International Year of Light on January 11, 2016 at Tokyo University of Science. There were a total of 95 participants, including the 15 oral presentations, 16 poster presentations, and 17 activity report power point presentations. In addition, in cooperation with the Outreach and Education Office and the Office of International Relations, on March 8, on the occasion of the March 9 Indonesia solar eclipse, the Office conducted a solar eclipse viewing workshop at SMK Negeri 2 (Technical Collage) Ternate City, Indonesia, for a total of 500 on-island school teachers and students.

As part of the Name ExoWorlds Contest, 644 groups (166 groups in Japan) registered in the worldwide call for group registration (deadline June 1, 2015). The 20 planetary systems to be named this time were chosen by a vote of the registered organizations. The planetary system names proposed by the registered groups were accepted until June 15 of the same year; 247 naming proposals were submitted from 45 countries. The proposals were received and a web election where everyone could vote was held from August 11 to October 31; 573,242 votes were cast from 182 countries. (A total of 5,411 votes were cast from Japan, 0.94 % of the total.) The results of this naming were published on December 15. Excluding tau Bootis (where the highest scoring name didn't meet the naming guidelines), 19 planetary systems (14 stars and 31 planets) had names decided.

In addition, OAO conducted the development of cooperative relations with National Outreach Contacts (NOC) (outreach facilitators in each country); construction of a network between skill-holders, including amateur astronomers and astronomy clubs, for the advancement of astronomy education; establishment and maintenance of a database of world astronomy clubs, observatories, and research institutions; production of information distribution media, such as the IAU Newsletter, pamphlets, videos, etc.; the management of IAU's social media; and cooperation for NAOJ's international relations and education and outreach activities.

18. Division of Optical and Infrared Astronomy

1. Overview

The primary objectives of divisions in NAOJ are facilitating and invigorating projects and individual research through personnel exchanges to place researchers in environments more suitable for their individual projects. While pursuing challenging exploratory research on observation and development, the division furthers these goals to launch new projects as necessary. The division also actively engages in graduate education efforts to foster next-generation talent. These activities are based on the concept that the Division of Optical and Infrared Astronomy is a center for personnel exchange between Subaru Telescope, which engages in open use, and universities and research institutes in Japan, which focus on developmental research into new instruments and observational research. This fundamental principle has been developed since the Subaru Telescope was constructed.

The Division of Optical and Infrared Astronomy oversees OAO (Okayama Astrophysical Observatory) and Subaru Telescope (C Projects); the TMT-Japan (TMT-J) Project Office and the Gravitational Wave Project Office (B Projects); and the JASMINE Project Office and the Extrasolar Planet Detection Project Office (A Projects). The Division and the Projects carry equal weight in organizational terms. Almost all NAOJ members in optical- and infrared-related fields have positions in the Division and engage in either the Division or one of the A, B, or C Projects. At times, they may also have concurrent positions in other projects. The primary staff of the Division of Optical and Infrared Astronomy in FY 2015 consisted of two professors, four assistant professors (including one specially appointed assistant professor), and three JSPS research fellows.

The Division coordinates educational, research, and administrative activities for Subaru Telescope Mitaka Office and Extrasolar Planet Detection Project Office. Since personnel transfer often occurs within the Division of Optical and Infrared Astronomy, the Division plays an increasingly important role in coordinating between Subaru Telescope and TMT-J Project Office. The Division as a whole maintains and operates facilities which are auxiliary to research, such as mailing lists and web servers for Division of Optical and Infrared Astronomy-related projects such as Subaru Telescope, TMT-J, Extrasolar Planet Detection Project Office, Gravitational Wave Project Office, and JASMINE Project Office. The remainder of this report will focus on the research projects conducted by the primary staff of the Division of Optical and Infrared Astronomy and the activities of projects that support open use.

2. Observational Research

(1) Observational Research Using Various Types of Telescopes

Observational research utilizing the Subaru Telescope focuses on a wide variety of fields such as cosmology; galaxy formation and evolution; the formation of stars and planets; the structure and evolution of the Milky Way; stellar spectroscopy; solar system bodies; and the search for exo-planets. A survey of high-z quasars was conducted in the survey data of Hyper Suprime-Cam (HSC) on the Subaru Telescope. Ionized hydrogen clouds around a nearby star-burst merger were observed, and the investigation into the merging history and gas ejection was published. The search for extrasolar planets continued using direct imaging methods. In cooperation with researchers in universities using the Optical and Infrared Synergetic Telescopes for Education and Research (OISTER) network, observational studies were conducted on transient objects and moving objects, which include Gamma-ray bursts, supernovae, X-ray novae, novae, dwarf novae, and Near-Earth Objects.

(2) International Cooperative Observational Research

The Division also engages in international collaborative studies with overseas researchers. A study on a companion dwarf galaxy was conducted with researchers in the USA, France, and Spain. The galaxy was found by chance in data acquired for studying star formation in the outer regions of nearby galaxies. The site survey in western Tibet continues in cooperation with the National Astronomical Observatories, Chinese Academy of Sciences (NAOC). Discussions for the site assessment and construction of a telescope were held with researchers of NAOC, the Purple Mountain Observatory and Hiroshima University. Installation work of the NDU (Notre Dame University-Louaize in Lebanon) 60-cm telescope, which was previously used at Geisei Observatory, Kochi Prefecture and refurbished by NAOJ were supported.

(3) Research Using Archives

The celestial map on the ceiling of the stone chamber of the Kitora Tumulus was analyzed in detail. Studies of astronomical phenomena based on old ephemerides and other documents continued. A statistical study on Ultra Diffuse Galaxies in the Coma Cluster was conducted using archive data from the Subaru Telescope. The study of the host galaxies of active galactic nucleus (AGN) using SDSS imaging/spectroscopy data continued. The catalog of Kiso Ultraviolet-excess Galaxies (KUG) was updated using recent image surveys such as SDSS. The results were opened to the public. Digitization of Kiso Schmidt plates was also started.

3. Observational Instrument Development

The effect of the environment inside the dome on seeing size at the Subaru Telescope has been studied through collaboration with Chofu Aerospace Center of JAXA (Japan Aerospace Exploration Agency), Tokyo Denki University, and RIKEN. A fluid calculation and a water-flow experiment were performed, and the procedure to compare the results with the data from the Subaru Telescope environment sensors in the dome has been investigated. Analysis of the ghost images of bright stars in the

Subaru prime focus camera was conducted and a presentation was made about correction methods. Commissioning of the telescope at Hosei University and their observations using it were supported.

4. Operational Support for Subaru Telescope

The Division of Optical and Infrared Astronomy offers support for the open use of the Subaru Telescope. This includes organizing open calls for open-use programs, program selection, administration, management of open-use-related travel expenses, and promoting PR activities for Subaru Telescope. The Division also supported the Subaru Autumn School co-hosted with Subaru Telescope and Astronomy Data Center; and Subaru Telescope observation classes.

5. Research Environment Maintenance

The Division manages the printers and rented multi-function photocopiers in the Subaru Building; teleconferencing systems on the second and third floors; sub-networks; and data backup servers for Subaru Telescope Mitaka Office as part of its efforts to maintain the research environment. The Division maintains the web servers and their contents, and also gives assistance for setting-up computers for new administrative supporters.

6. Planning of Next-generation Large-Scale Projects

The Division is engaged in planning post-Subaru large projects in optical and infrared astronomy, such as TMT and the JASMINE series. A framework for collaboration between ISAS/JAXA (Institute of Space Astronautical Science) and NAOJ also needs to be established. The preparation for the assessment of new infrared detectors has started.

7. PR, Outreach, and Discovery of New Astronomical Objects

The Division cooperates with the Public Relations Center in supporting matters related to the discovery of new astronomical objects and PR/outreach activities such as publications and press conferences related to Subaru Telescope research results. The Division actively participates in a special public event held at Mitaka Campus (Mitaka Open House Day).

8. Educational Activities

The Division of Optical and Infrared Astronomy provides postgraduate education to 23 graduate students from the Graduate University of Advanced Studies, the University of Tokyo, Hiroshima University, Tokyo University of Agriculture and Technology, Nihon University, International Christian University, and Hosei University. Division staff members made active contributions to seminars and self-directed studies. Since April 2015 we have held a 30-minute seminar in the afternoon every day throughout the year. In December, we held the annual workshop of the Division of Optical and Infrared Astronomy so that staff members and graduate students can understand the current studies and interests of each other. The Division participated in the “Fureai Astronomy” project, dispatching lecturers to various schools around the country, providing pupils at elementary and junior high schools with opportunities to learn about and appreciate astronomy.

19. Division of Radio Astronomy

The Division of Radio Astronomy oversees Nobeyama Radio Observatory, Mizusawa VLBI Observatory, the RISE Lunar Exploration Project, and NAOJ Chile Observatory operating the Atacama Large Millimeter/submillimeter Array (ALMA) and Atacama Submillimeter Telescope Experiment (ASTE). The scientists and engineers of these projects are attached to the Division of Radio Astronomy, which promotes radio astronomy research to harmonize these radio astronomy projects. The research themes of the Division of Radio Astronomy are represented by keywords such as Big Bang, early Universe, galaxy formation, black holes, galactic dynamics, star formation, planetary system formation, planets and satellites, the Moon, the evolution of interstellar matter, and the origin of life in the context of the evolution of the Universe. Radio astronomy unravels mysteries and phenomena in the Universe through radio waves, which are invisible to human eyes. The detailed research results are reported in each project's section and in the research highlights. The Radio Astronomy Frequency Subcommittee has been established within the division, engaging in discussions on protection against artificial interference generated by electrical equipment, which causes major obstacles in radio astronomical observations.

1. Radio Astronomy Frequency Subcommittee

The mission of the Radio Astronomy Frequency Subcommittee is to protect the environment for radio astronomy observations. In 1932, Karl Jansky of the U.S.A. first discovered radio waves emitted by astronomical objects, albeit accidentally. Since then, dramatic advances have been made in radio observation methods, showing us new perspectives of the Universe invisible at the optical spectrum. The fact is that four Novel Prizes have been awarded to achievements made in the field of radio astronomy.

Just as light pollution from artificial light sources is an obstacle in optical observation, artificial radio interference generated by the electronic devices which surround us is a major obstacle in radio observations. Breathtaking advancement has been achieved in wireless communication technologies in recent years, and wireless commercial products such as mobile phones, wireless LANs, and automotive radars are widely used. The areas of radio applications will further expand in the future owing to its ubiquitous nature. But because of its unique capabilities, compatibility among various radio services, including both active and passive ones, will become a serious issue. Frequency is a finite resource and its sharing is an unavoidable issue. Therefore, further efforts will be necessary for maintaining the sky free from artificial interference for better radio astronomy observations.

(1) Role and Organization

The purpose of the Radio Astronomy Frequency Subcommittee is to ensure that radio astronomical observations are free from artificial interference and to raise public awareness of the importance of the protection activities. Radio astronomical observation does not emit radio waves; thus, it does not interfere with other wireless communications. A proactive approach is needed to widely raise awareness of the efforts to protect the environment for radio observations. Regular explanatory sessions are provided at the Ministry of Internal Affairs and Communications (MIC) and regional Bureaus of Telecommunications to solicit appreciation of the importance of protecting the field.

The coordination between the community of radio astronomy and commercial wireless operators is led by the MIC within Japan and internationally by the International Telecommunication Union (ITU) Radiocommunication Sector (ITU-R) of the United Nations. As part of the activities for FY 2015 the Subcommittee took an active role in formulating the opinion of the Japanese radio astronomical community (on behalf of the Japanese radio astronomers) in these coordination efforts.

The Subcommittee is composed of members from NAOJ and representatives of universities and research institutes in Japan.

(2) Current Challenges

A sharing study between active radio services and radio astronomy is crucial for compatibility under the condition of limited availability of frequency resources. Some rules and regulations have been established to address the issue of interference cooperatively. The Radio Astronomy Frequency Subcommittee remains responsible for taking measures for new developments in wireless services including the following challenges:

- Significant increase in wireless activities in response to natural disasters. New operations involving wireless communications have increased following the Great East Japan Earthquake in 2011, resulting in an increase in radio interference.
- Development of new radio applications. The ultra-wide-band (UWB) technology does not require an operator license because it is operated at low-levels and wide bandwidths. On the other hand, there has been a rapid increase in demand for higher frequencies. For example, 76 and 79 GHz automotive radars are being introduced, aiming to reduce car accidents resulting in injury or death. And, transportation of high speed and high volume data, such as HDTV quality video, is becoming possible through 60 GHz radio transmission systems.
- Reassigning of vacant frequency bands resulting from enhanced efficiency in radio use. The digitization of television broadcasting has created vacant frequency bands, which have been reassigned for mobile phones and other applications.

The effect of interference arising from such radio applications (e.g. wireless business) varies widely depending on

the frequency band used. Radio astronomy observations have been given priority in a number of frequency bands within the range between 13.36 MHz and 275 GHz under the ITU Radio Regulations (RR). However, negotiations will be necessary between some radio services and radio astronomy if the same priority level is to be shared within a certain band or under adjacent/proximity conditions. Unwanted out-of-band signals (spurious signals), even extremely faint ones, can have a chance of substantial adverse effects on radio astronomy observations.

Sources of interference that need to be addressed continue to increase and include the following devices and systems: the 23 GHz CATV wireless transmission system used in emergencies, where ammonia observations are affected; 21 GHz next-generation satellite broadcasting, where water maser observations are affected; 1600 MHz mobile satellite phones used in emergencies, where the observation of pulsars and the like are affected; a number of new UWB wireless applications used by logistics and manufacturing industries, where geodetic observations are affected; and high-speed power line communications (PLC), where decameter-band observations are affected. 79 GHz automotive radars around Nobeyama Radio Observatory will cause deterioration in its observation results, or rather tend to make its observations impossible in the near future. Although radio astronomy observations in the 60 GHz band are not common because of the high rate of absorption in the atmosphere, the 60 GHz system must be watched closely because its second harmonic can have adverse effects on CO observations in the 115 GHz band.

(3) International Activities

The ITU' Radio Regulations (RR), which allocate radio frequencies to wireless applications, are revised once every three to four years in the World Radiocommunication Conference (WRC). The RR includes frequency bands in which radio astronomy observation is prioritized. Among these meetings, the Radio Astronomy Frequency Subcommittee is regularly involved in the WP7D (radio astronomy) and WP1A (frequency management) meetings. The Subcommittee also takes part in various international conferences, representing the Japanese community of radio astronomy researchers.

In FY 2015, the Subcommittee participated in the ITU-R WP7D meetings held in May, the WP1A meeting in June, and WRC-15 meeting in November in Geneva.WRC-15 resolved to provide a wider regulatory option for realizing global flight tracking of commercial airplanes and allocated additional frequency bands to the Maritime-mobile satellite service and the Earth exploration-satellite (active) service.

One major point of contention in WRC-15 was additional frequency band allocation to international mobile telephones (IMT). Finally, an agreement was reached for possible allocation of some frequency bands in 30–50 GHz to IMT at WRC-19 to be held in 2019. Also, WRC-15 agreed to add the allocation of active services at frequencies above 275 GHz to the WRC-19 agenda.

(4) Activities in Japan

The three major domestic activities of the Radio Astronomy Frequency Subcommittee include: participation in various committees and working groups hosted by the MIC, direct negotiations for the MIC's authorization with wireless operators who generate radio interference, and promotion to raise public awareness about radio interference to radio astronomical observations. Negotiations with wireless operators to reduce interference sources represent a major part of the Subcommittee's activities in Japan.

The committees and working groups hosted by the MIC are held to organize domestic tactics in preparation for international conferences, defining Japan's positions on various wireless issues. Other MIC-related meetings provide opportunities for discussing the radio application technologies related to MIC's wireless policy, and for negotiating with wireless operators on interference issues under MIC authorization. Negotiations directly affecting the protection of radio astronomy observations have been conducted concurrently to dealing with the interference problems related to societal and technological trends.

Several examples of the interference problems discussed in section (2) above are given below.

For 24 GHz automotive radars, new regulations have been prepared to make an automatic turn-off function a mandatory standard feature so that the device is disabled upon reaching certain areas around radio observatories.

In November 2015 WRC-15 resolved to allocate 77.5–78 GHz to the radiolocation service, allowing automotive vehicles to utilize the whole 76–81 GHz band for their radar, which may invite large scale commercial use of automobile radars. Of particular concern are the possible effects of interference from these radars on the 45-m radio telescope at Nobeyama Radio Observatory, which engages in observations of spectral-lines of deuterated compounds and other molecules in interstellar matter. The observations with the Nobeyama 45-m Radio Telescope located in Japan will continue to carry significance in relation to the international project ALMA, which is based in Chile and involves 66 high-performance radio telescopes at an altitude of 5,000 m. Since automotive radars are highly relevant to human life safety, negotiations have been conducted with careful analysis in order to reach a mutually acceptable agreement.

A new radio wave application is being planned for 21 GHz next-generation satellite broadcasting with a picture resolution 16-fold higher than that of the current HDTV. This band is near the 22 GHz radio astronomy band, which is important for water maser observation. The radio signals from the satellite approach the ground from outer space. Their detrimental effects need to be alleviated with a filter at the output stage of the satellite. In FY 2015, the NHK Science & Technology Research Laboratories developed a prototype bandpass filter to suppress spurious signals to an acceptable level. NHK plans to verify its performance further on a future satellite set to launch in December, 2017.

Radio observations in the 60 GHz band are not common because of the high atmospheric absorption rate in that frequency range. Albeit in fact, the 60 GHz system must be

watched closely in terms of its proliferation in the market, since interference from it may affect CO observations in the 115 GHz band, which is within the band of the second harmonics of the 60 GHz radio system.

To further improve disaster measures, the MIC will evaluate the approval of a U.S. mobile satellite phone service using 1.6 GHz signals (Earth to space) in FY 2016. Its out-of-band signal, however, may affect the adjacent RAS band observing OH masers. In FY 2015, the Subcommittee started evaluation of new operating conditions proposed by Global Star Inc. (U.S.).

The Cabinet Office of the Japanese government is planning to launch three (#2–#4) Quasi-Zenith Satellites in FY 2017 to improve the accuracy of the radiolocation service. Since there was a risk that the message communications signal in the 2.2 GHz band could affect the VLBI observations, sharing and compatibility studies were performed by the Subcommittee and Cabinet Office. They found mutually agreeable operating conditions and signed a compatibility study confirmation document.

Additionally, radio astronomy observations could be adversely affected by some of the new wireless technologies: high speed image data transmissions from drones to ground receivers, wireless power transmission (WPT) for electric vehicle energy charging (non-beam), WPT from space-based solar power satellites to Earth (beam), and so on. The Subcommittee continues to monitor their progress and shares this information with related radio astronomers.

Moreover, the Subcommittee engages in making applications to the MIC, requesting frequency protection for NAOJ telescopes, in addition to those owned by the Japanese community of radio astronomers on their behalf.

The collection of actual interference cases at every observatory is also important. To raise public awareness about "Interference to Radio Astronomy" these collected cases are effectively used in presentations by our community members. We are also preparing tutorial material for the general public. As optical astronomers are engaging in protection of their observation environment against artificial light, we, radio astronomers, are making the same efforts for the sake of continuing observations in radio astronomy in coming ages.

20. Division of Solar and Plasma Astrophysics

The Division of Solar and Plasma Astrophysics is mainly made of staff members from the Solar Observatory, the Hinode Science Center, and the Solar-C Project Office. It conducts research on the Sun in close coordination with these projects. An NAOJ fellow and graduate students supervised by the staff of the above-mentioned projects also belong to the Division. All of the permanent staff of these projects is affiliated with the Division.

The Division conducts both theoretical and observational research into the inner structure of the Sun and outer solar atmosphere including the photosphere, chromosphere, corona, and solar wind; and various phenomena in the magnetized plasma such as flares, sunspots, solar faculae, and prominences. The Division's theoretical research includes helioseismology studies of the internal structure of the Sun, and applications of plasma physics and magnetohydrodynamics to various phenomena on the Sun as well as on Sun-like stars. The solar group at NAOJ started observations from space in the very early stages of Japan's space program. The Division has participated in the development of the Hinode satellite, which is currently in orbit, and is playing a major role in its scientific operation. Research is also being carried out using the Solar Flare Telescope and other telescopes in Mitaka Campus. In ground based observations, the Division conducted research to introduce and utilize new technologies in the Solar Flare Telescope and has been conducting long-term monitoring observations of solar activity, and the obtained data are open to the community.

1. Research in Solar Physics

NAOJ fellow S. Toriumi published two papers in refereed journals as lead author. Both of them are on the energy release phenomena occurring suddenly and periodically at light-bridges in sunspots. In these papers he (1) revealed the energy release mechanism based on observational data taken with Hinode and IRIS, and (2) elucidated the cause of the periodicity based on numerical simulations. He also has been promoting collaborative research with international partners; he invited Dr. M. Cheung of the Lockheed Martin Solar and Astrophysical Laboratory as a guest associate professor, and organized two scientific meetings including Dr. M. Cheung as a guest.

The Division has a seminar (on Friday afternoon, roughly twice a month) whose speakers are from both inside and outside of the Division. This year's organizers were K. Watanabe and S. Toriumi.

2. Educational Activities

The teaching staff of the Division supervised three graduate students from the Graduate University for Advanced Studies (SOKENDAI). Among them, Gabriel Giono obtained a Ph.D. in March. The Division, in cooperation with Kyoto University and Nagoya University, supported the annual "Leading-edge Solar Research-Experience Tour" in March for undergraduate students; about ten students visited solar-related research organizations and experienced the latest research in the field.

3. International Cooperation

Y. Katsukawa has been a member of the Science Working Group of the Daniel K. Inouye Solar Telescope, a 4-m telescope under construction at Haleakala, Hawai`i. Several plans are also under consideration for future ground-based telescopes that would involve collaborations with East Asian countries and Peru.

21. Division of Theoretical Astronomy

1. Overview

The Division of Theoretical Astronomy (DTA) engaged in research activities in FY 2015 aimed at achieving internationally outstanding research results in both quality and quantity, based on the following four goals that were set by the NAOJ Board:

- Advance world class cutting-edge theoretical research.
- Pursue theoretical astronomy research, particularly in areas that utilize the NAOJ supercomputer or large-scale observational instruments to give further insight into the development of new observational instruments.
- Encourage collaborations among researchers in Japan and strengthen domestic theoretical astronomy research.
- Invigorate postgraduate education.

The Division handles a wide variety of themes in theoretical astronomy research, addressing a diversity of hierarchical structures of the Universe in terms of formation and evolution processes, dynamics, and the physical state of matter. This research covers a span from the early Universe to galaxies, stars, planetary formation, activities of compact objects, and plasma phenomena in astronomy and astrophysics. The Division of Theoretical Astronomy aims to facilitate Japan's high competitiveness on the international plane through continuous production of world leading research results and offers a superb research environment as a base for theoretical research accessible to researchers in Japan and overseas. It has accepted a wide range of both Japanese and international researchers as visiting professors, visiting project research fellows, and long-term research fellows who actively engage in various research projects in the Division. In particular, the Division has fostered research developments to create a powerful research center for young researchers and is actively engaged in personnel exchanges with many universities and research institutes. The Division's full-time professors, associates, assistants, and project assistant professors, together with NAOJ postdoctoral fellows and JSPS fellows, conduct a variety of unique research projects involving postgraduate students from the Graduate University of Advanced Studies, the University of Tokyo, the Graduate School of Ochanomizu University and the Graduate School of Shizuoka University; joint research with observational astronomy using satellite campuses observing various frequency bands such as the Subaru Telescope, ALMA, and Nobeyama radio telescopes; and interdisciplinary research with the physics of elementary particles and atomic nuclei. In addition, the Division actively organizes numerous cross-disciplinary international conferences, domestic meetings, and seminars for the fields of theoretical astronomy and astrophysics, observational astronomy, and experimental physics. The Division also leads research activities in various fields related to astronomical science.

2. Current Members and Transfers

In FY 2015, the dedicated faculty of the Division of Theoretical Astronomy included two professors, two associate professors, and four assistant professors. In addition, one adjunct professor and one adjunct assistant professor concurrently hold primary positions at the Center for Computation Astrophysics. In addition to these research and educational members, the Division was served by five project assistant professors, one project research associate, one JSPS fellow, three EACOA fellows, and one administration associate who gave full support to all activities of the Division. Among these members, Michiko Fujii, a specially appointed Associate Professor, transferred to an associate professor position at the University of Tokyo; and Tomoya Takiwaki, an assistant professor, joined us from February in 2016.

3. Research Results

The number of research papers in listed Section IV, Publications, published by the Division member(s) as author(s) or presenter(s) are listed below. Categories with fewer than 10 publications have been omitted.

- Peer-reviewed papers in English: 89
- Papers in English (conference proceedings, non-reviewed papers, etc.): 14
- Reports in English (talks at international conferences): 65
- Reports in Japanese (talks at national meetings, etc.): 45

Some of the research results are presented in the research highlights listed at the beginning of this report. The following highlights include research in which the Division members took leading roles:

- Polarization Structure of Filamentary Clouds (Kohji Tomisaka)
- Rapidly Rising Transients from Subaru/HSC Transient Survey (Masaomi Tanaka, et al.)
- A New Multi-energy Neutrino Radiation-Hydrodynamics Code in Full General Relativity and Its Application to the Gravitational Collapse of Massive Stars (Tomoya Takiwaki, et al.)
- Enrichment of r-process Elements in Dwarf Spheroidal Galaxies in Chemo-dynamical Evolution Model (Yutaka Hirai, et al.)
- Physical Conditions of Supernova Ejecta as Viewed from the Sizes of Presolar Al_2O_3 Grains (Takaya Nozawa)
- Pitch Angle of Self-Gravity Wakes in Dense Planetary Ring (Shugo Michikoshi, et al.)
- Initializing relativistic velocity distribution functions in plasma simulations (Seiji Zenitani, et al.)
- All-sky simulations of gravitational lensing (Masato Shirasaki, et al.)

- A Numerical Scheme for Special Relativistic Radiation Magnetohydrodynamics Based on Solving Time-dependent Radiative Transfer Equation (Ken Ohsuga, et al.)
- Radiation Drag Effects in Black Hole Outflows from Super-critical Accretion Disks via Special Relativistic Radiation Magnetohydrodynamics Simulations (Hiroyuki Takahashi, et al.)
- Nuclear Fission and Solution of r-Process Underproduction Problem (Shota Shibagaki, et al.)
- Effect of Stellar Encounters on Comet Cloud Formation (Arika Higuchi, et al.)
- R-process Nucleosynthesis in the MHD+neutrino-heated Collapsar Jet (Toshitaka Kajino, et al.)
- Constraints on the birth of the universe and origin of cosmic dark flow (Toshitaka Kajino, et al.)
- Pion Production from Proton Synchrotron Radiation under Strong Magnetic Fields in Relativistic Quantum Approach (Toshitaka Kajino, et al.)
- Possible Evidence for Planck-scale Resonant Particle Production during Inflation from the CMB Power Spectrum (Toshitaka Kajino, et al.)
- Constraints on Pre-inflation Fluctuations in a Nearly Flat Open _CDM Cosmology (Toshitaka Kajino, et al.)
- Universality of the Supernova r-Process and Radioactive Nuclei (Toshitaka Kajino, et al.)

The following research results were released on the Division's website (http://th.nao.ac.jp/index_en.html) as research highlights:

- Conversion of Hadronic Matter to Quark Matter in Neutron Stars (Shun Furusawa, et al.)
- New Model on the Origin of the Heavy Elements: Solving the Underproduction Problem of the r-Process (Shota Shibagaki, Toshitaka Kajino, et al.)
- Galactic Spiral Arms by Swing Amplification (Shugo Michikoshi, Eiichiro Kokubo, et al.)
- Large-scale structure of magnetic reconnection by means of kinetic simulations (Keizo Fujimoto, et al.)
- Origin of r-process elements in galactic chemodynamical evolution (Yutaka Hirai, Michiko Fujii, Toshitaka Kajino, et al.)
- Pitch Angle of Self-Gravity Wakes in Saturn's rings (Shugo Michikoshi, Eiichiro Kokubo, et al.)
- Probing the Stellar Explosions with Presolar Grains (Takaya Nozawa, et al.)
- All sky simulations of gravitational lensing (Masato Shirasaki, Takashi Hamana, et al.)
- Polarization Structure of Magnetically Supported Molecular Filaments (Kohji Tomisaka)
- Great Progress towards the Origin of R-process (Shota Shibagaki, Toshitaka Kajino, et al.)
- Loading relativistic velocity distributions in particle simulations (Seiji Zenitani, et al.)
- The initial mass function of star clusters (Michiko Fujii, et al.)
- Quantum theoretic approach to in-medium effects on the neutrino scattering (Toshitaka Kajino, et al.)

4. Domestic Collaborations

The Division of Theoretical Astronomy played leading roles in organizing the following domestic conferences:

- National Meeting on Galactic Evolution 2015, Sakata-Hirata Hall at Nagoya University, June 3 – 5 in 2015.
- UKAKUREN (Japan Forum of Nuclear Astrophysics) Meeting, NAOJ Mitaka Campus, February 22 – 24 in 2016.
- Winter School on Nuclear Matter in Neutron Stars investigated by Experiments and Astronomical Observations (Grant-In-Aid for Scientific Research on Innovative Areas), NAOJ Mitaka Campus, February 24 – 26 in 2016.
- National Meeting on Frontier of Cosmic Plasma; beyond Heliosphere, Solar-Terrestrial Environment Laboratory at Nagoya University, March 2 – 4 in 2016.
- TDA Symposium on Time-domain Astronomy, NAOJ Mitaka Campus, March 4 – 5 in 2016.
- National Meeting on Frontier and Perspective of the Research of Magnetic Reconnection, NAOJ Mitaka Campus, March 28 – 29 in 2016.

5. International Collaborations

Toshitaka Kajino performed duties in the following posts: review panel member of the Institute of Physics (Journal of Physics G.); international referee for the Science, Technology and Innovation Council of Canada; international associate for the European Centre for Theoretical Studies in Nuclear Physics and Related Areas (ECT*); and international referee for the Swiss National Science Foundation (SNSF).

The Division of Theoretical Astronomy played leading roles in organizing the following international conferences:

- 3rd DTA Symposium on The Origins of Planetary Systems: from the Current View to New Horizons, NAOJ Mitaka Campus, June 1 – 4 in 2015.
- International Symposium on Physics and Astronomy of Neutron Stars and Supernovae, NAOJ Mitaka Campus, June 22 – 23 in 2015.
- Star Formation Workshop 2015, NAOJ Mitaka Campus, June 29 – July 1 in 2015.
- The 8th meeting on Cosmic Dust, Chiba Institute of Technology Sky Tree Campus, August 17 – 21 in 2015.
- Symposium on Hierarchy and Holism in Natural Science, NAOJ Mitaka Campus, February 5 – 6 in 2016.

6. Educational Activities

The basic information for the adjunct lecture-ship activities of research and education staff at universities and graduate schools is listed in Section III. The lecture subjects are listed below to supplement that information.

Eiichiro Kokubo: "Planetary Science" at the University

of Tokyo; "Origin and Structure of Planetary Systems" at the University of the Ryukyus.

Toshitaka Kajino: "Lectures on Fundamentals of Theoretical Astronomy" at the Graduate University for Advanced Studies; "Science of Time, Space, and Matter" and "Fundamentals of Physics" at Gakushuin University; "Astrophysics and Modern Physics" at Japan Women's University; "Astrophysics" at Jissen Women's University; "Nuclear Physics" at Meiji University; "Astronomy Investigation I & II," "Reading Papers in Turn I & II," and "Special Astronomy Investigation II" at the Graduate School of the University of Tokyo.

Takashi Hamana: "Geology" at the Tokyo University of Agriculture and Technology.

Keizo Fujimoto: "Computational Science and Genesis of Nature" at the Graduate University for Advanced Studies.

Eiichiro Kokubo delivered SSH lectures entitled "Simulation Astronomy" and "Cosmo-science" at Hibiya High School and Kanazawa Izumigaoka High School, respectively.

7. Outreach Activities

The Division of Theoretical Astronomy actively engaged in public promotions and outreach activities by offering lectures to the general public. The following lectures were delivered this year:

Eiichiro Kokubo; "Origin of the Solar System – Kyoto model" at Chushiro Hayashi Memorial Lecture; "What is Pluto?" at Ikebukuro Community College; "Hometown of Planets" Hiroshima University and Chiba University; and "Earth in the Universe" at Asahi Culture Center Fukuoka.

Toshitaka Kajino; "Frontiers in Cosmo-nuclear astrophysics" at Osaka City University, and "Introduction to Element Genesis: The birth of the Universe and origin of matter, elements in the cosmos" at Asahi Culture Center Yokohama.

Seiiji Zenitani; "The Importance is Invisible: looking at the explosive phenomena in Earth's backyard" at the National University Corporation Tsukuba University of Technology.

8. Awards

Masaomi Tanaka received a 2015 Research Encouragement Award of the Astronomical Society of Japan.

9. Main Visitors from Overseas

The Division of Theoretical Astronomy strives to fulfill its roles as a center of excellence in Japan for theoretical studies in astronomy and astrophysics and also as an international research institution by providing an excellent research environment. It engages in various joint research projects with visiting researchers from overseas, with the help of Grants-in-Aid for Scientific Research, government subsidies for operating expenses, and the NAOJ budget for visiting research fellows and others. The main international visitors to the Division in FY 2015 are listed below:

Myung-Ki Cheoun (Soongsil University, South Korea)
Tjarda Boekholt (Laiden Observatory, Netherland)
Grant J. Mathews (University of Notre Dame, U.S.A.)
Motohiko Kusakabe (University of Notre Dame, U.S.A.)
Zhi-Yun Li (University of Virginia, U.S.A.)
Wing-Kit Lee (Academia Sinica, Taiwan)
Anaelle J. Maury (Saclay Nuclear Research Centre, France)
John J. Tobin (Laiden Observatory, Netherland)
Akif B. Balantekin (University of Wisconsin–Madison, U.S.A.)
Michael A. Famiano (Western Michigan University, U.S.A.)
Ghil-Seok Yang (Soongsil University, South Korea)
Eun-ja Ha (Soongsil University, South Korea)
Kyun-jin Kwak (Ulsan National Institute of Science & Technology, South Korea)
Yichen Zhang (University of Chile, Chile)
James M. Lattimer (State University of New York, U.S.A.)
Friedrich Thielemann (University of Basel, Switzerland)
Yamac Deliduman (Mimar Sinan Fine Arts University, Turkey)

22. Office of International Relations

The Office of International Relations, along with performing information-gathering/–provision and other activities related to international research and educational cooperation, strives to promote and facilitate further internationalization at NAOJ by providing the various services and environments required for multi-cultural researchers and students to engage in research and educational activities in cooperation with each other. Specifically, the office's main activities include supporting international collaborative projects; liaising with overseas astronomical research organizations; gathering and providing information on international activities; offering support for hosting international conferences, workshops, and seminars; providing support for visiting international researchers and students; and assisting Japanese universities and research organizations in international partnerships. In FY 2015 the Office's working scheme changed and the Office started working closely with the Executive Advisor to the Director General in charge of international research coordination.

1. International Collaborative Project Support

The Office gathers and provides information necessary for pursuing international research collaborations on its own initiative. It also serves as a liaison point for international activities; engages in international agreements or provides support for doing so; and accumulates procedural and administrative knowledge, through consultations or investigations on individual cases, to enter into and implement collaboration with overseas universities or research institutions. Other matters handled by the Office include administrative coordination in approval processes to sign agreements and memoranda for international collaborations, support for signing ceremonies, and export security control for the export of goods or transfer of technology. In FY 2015, ten international agreements, new and renewed, were signed including ones under the name of NINS. In the area of security export control, the activities included review and processing of 37 cases and security export control briefings for improving the knowledge and awareness of NAOJ staff held seven times at Mitaka, Mizusawa, Nobeyama, and Okayama with more than 100 attendees.

2. Liaison Work for Overseas Astronomical Research Organizations

The Office of International Relations organized the annual directorate meeting of the East Asian Core Observatories Association (EACOA) on October 11, 2015 at Incheon, South Korea. The signing ceremony for the renewed Memorandum of Understanding (MOU) of EACOA was held at the meeting. This MOU extends the term of EACOA activities, including the EACOA postdoctoral fellowship program, for another 5 years. The four institutions forming EACOA include NAOC (China), NAOJ (Japan), KASI (South Korea), and ASIAA (Taiwan). The Office also coordinated with the other 3 institutes for selection of 2016 EACOA postdoctoral fellowship program. The office also cooperated with NAOC for the East Asia Ground-based Telescope Construction Sites Survey. In addition, it presented NAOJ's projects and research results by displaying an exhibit at the 29th IAU General Assembly held August 3 - 15 at Honolulu, Hawai`i in the USA. Furthermore, the office supported the activities of the IAU Office for Astronomy Outreach. The Office of International Relations also cooperated with EACOA member organizations in supporting the activities of the IAU Office for Astronomy Development (OAD).

3. Support for Hosting International Research Conferences, Workshops, and Seminars

The Office of International Relations offers support for the planning and implementation of international research conferences, workshops, and seminars hosted or supported by NAOJ. The work involves consultation and responses to inquiries regarding administrative issues. The office also offers advice about organizations or individuals to contact as appropriate, coordinates between organizations, and gathering relevant information. In FY 2015 the office supported international research conferences and other conferences by preparing the documentation required for Japanese visa applications for 50 foreign participants in total.

4. Support for Hosting International Researchers and Students

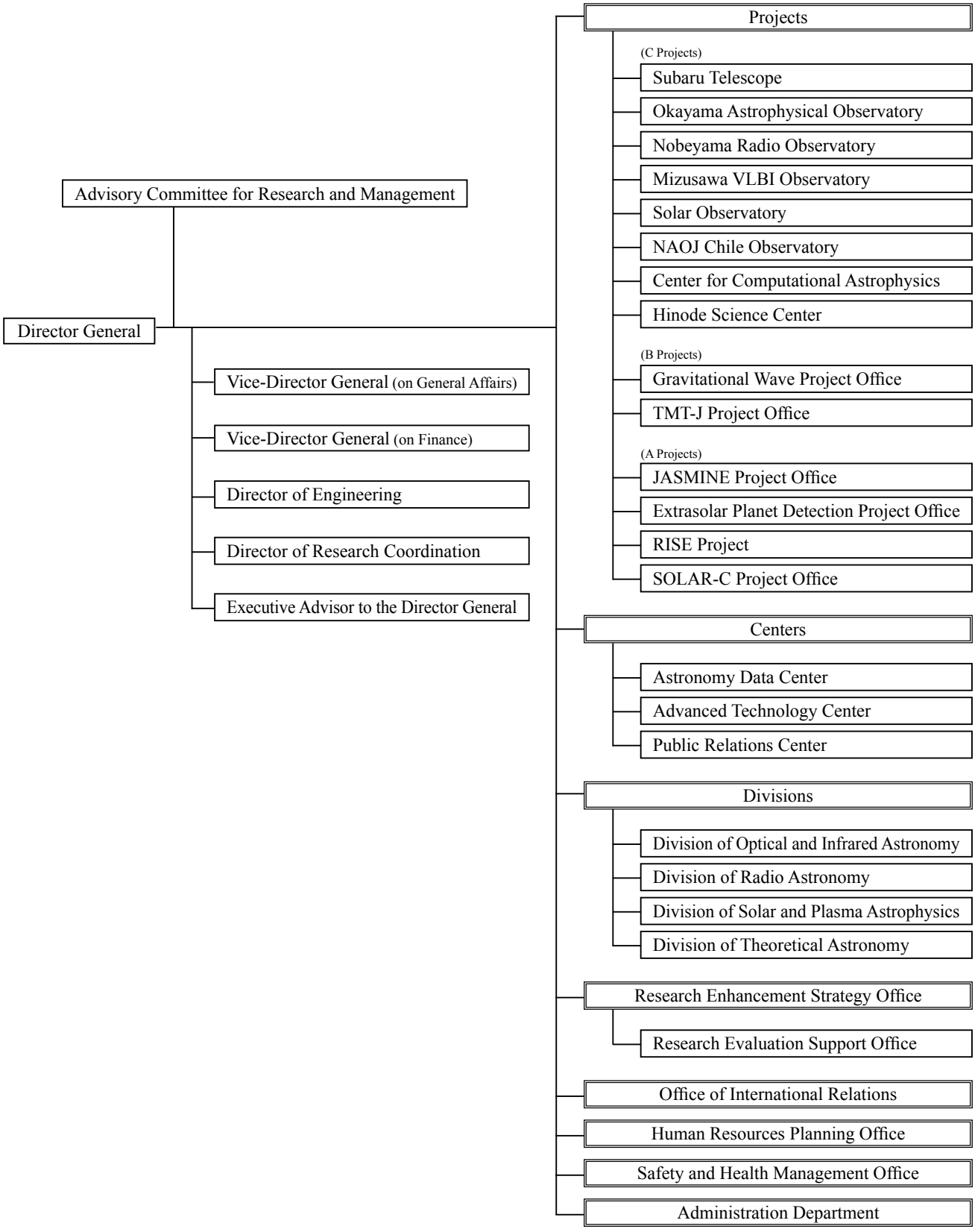
The office enhanced its framework for offering organizational support for research, education, and living arrangements for foreign researchers and exchange students. The Support Desk offers support services to ease difficulties for foreigners living in Japan. It offers support, on-site if required, covering various matters such as administrative procedures at municipal and other governmental offices; finding and moving into an apartment; various other procedures and applications for starting up a new life; consultation on shopping, children's education, health and other subjects; and gathering/providing useful information relating to everyday life. The Support Desk has been highly appreciated by users. Besides daily life matters, the office expanded its activities as an intermediary between administrative staff and non-Japanese speaking researchers by translating/interpreting in-house procedures, applications and notices. The office continued the Japanese language lessons, helping foreign members of NAOJ to acquire beginner level capability, for FY 2015 with E-learning features added to the classroom lessens. Including renewals, support was given to 37 visa applications: 8 for staff and family members, 13 for invited researchers, and 16 of visitor/long stay researchers.

5. Assistance in International Partnerships Involving Japanese Research Organizations

The Office of International Relations assists universities and other educational and research organizations in Japan to engage in international partnerships. It also liaises with the International Strategy Headquarters and the International Cooperation Office at NINS to coordinate international collaborations. The Office oversaw the Optical and Infrared Synergetic Telescopes for Education and Research (OISTER) project conducted by OAO, Ishigakijima Astronomical Observatory, and nine Japanese universities.

III Organization

1. Organization



2. Number of Staff Members

(2016/3/31)

Regular Employees	
Director General	1
Research and Academic Staff	153
Professor	27
Executive Engineer	0
Associate Professor	41
Chief Research Engineer	10
Assistant Professor	57
Research Associate	0
Research Engineer	18
Engineering Staff	36
Administrative Staff	55
Research Administrator Staff	9
Employees on Annual Salary System	99
Fixed-term Employees	
Full-time Contract Employees	59
Part-time Contract Employees	134

3. Executives

Director General	Hayashi, Masahiko
Vice-Director General	
on General Affairs	Watanabe, Junichi
on Finance	Kobayashi, Hideyuki
Director of Engineering	Takami, Hideki
Director of Research Coordination	Gouda, Naoteru
Executive Advisor to the Director General	Ogasawara, Ryusuke Sekiguchi, Kazuhiro

4. Research Departments

Projects

C Projects

Subaru Telescope

Director	Arimoto, Nobuo
Professor	Arimoto, Nobuo
Professor	Mizumoto, Yoshihiko
Professor	Ohashi, Nagayoshi
Professor	Usuda, Tomonori
Specially Appointed Professor	Renzini, Alvio
Associate Professor	Aoki, Wako
Associate Professor	Hayano, Yutaka
Associate Professor	Hayashi, Saeko
Associate Professor	Ichikawa, Shinichi
Associate Professor	Iwata, Ikuru
Associate Professor	Kashikawa, Nobunari
Associate Professor	Kodama, Tadayuki
Associate Professor	Miyazaki, Satoshi
Associate Professor	Noumaru, Junichi
Associate Professor	Takata, Tadafumi
Associate Professor	Takato, Naruhisa
Associate Professor	Takeda, Yoichi
Associate Professor	Terada, Hiroshi
Chief Research Engineer	Iwashita, Hiroyuki
Assistant Professor	Furusawa, Hisanori
Assistant Professor	Imanishi, Masatoshi
Assistant Professor	Komiyama, Yutaka
Assistant Professor	Koyama, Yusei
Assistant Professor	Minowa, Yosuke
Assistant Professor	Nakaya, Hidehiko
Assistant Professor	Okita, Hirofumi
Assistant Professor	Onodera, Masato
Assistant Professor	Pyo, Tae-soo
Assistant Professor	Shirasaki, Yuji
Assistant Professor	Yagi, Masafumi
Specially Appointed Assistant Professor	Tanaka, Masayuki
Research Engineer	Bando, Takamasa
Research Engineer	Tazawa, Seiichi
Chief Engineer	Kamata, Yukiko
Chief Engineer	Kurakami, Tomio
Chief Engineer	Namikawa, Kazuhito
Chief Engineer	Negishi, Satoru
Chief Engineer	Omata, Koji
Chief Engineer	Tamura, Tomonori
Chief Engineer	Uraguchi, Fumihiro
Engineer	Sato, Tatsuhiro
Specially Appointed Research Staff	Ichikawa, Kohei
Specially Appointed Research Staff	Toshikawa, Jun
Specially Appointed Senior Specialist	Hayashi, Yusuke
Specially Appointed Senior Specialist	Ikeda, Hiroyuki
Specially Appointed Senior Specialist	Momose, Rieko ~2015.10.31
Specially Appointed Senior Specialist	Oishi, Yukie
Specially Appointed Senior Specialist	Sakamoto, Ken ~2015.12.31
Research Expert	Kawanomoto, Satoshi
Research Expert	Koike, Michitaro
Research Expert	Mineo, Sogo
Research Expert	Yamada, Yoshihiko
Research Expert	Yamanoi, Hitomi
Administrative Supporter	Kuwata, Hitomi
Administrative Supporter	Mochinaga, Chizuru
Administrative Supporter	Noguchi, Masumi
Administrative Supporter	Takamoto, Masami
Administrative Supporter	Yamada, Narumi
Administrative Supporter	Yoshida, Chie

Administration Department

Manager	Seto, Yoji
General Affairs Section	
Chief	Seto, Yoji
Staff	Sugawara, Satoshi
Accounting Section	
Chief	Furuhata, Tomoyuki
RCUH	
RCUH	Alpiche, Dex
RCUH	Aoki, Kentaro
RCUH	Aso, Yusuke
RCUH	Balbarino, Michael
RCUH	Berghuis, Jennie
RCUH	Bergstrom, Andrew (Will)
RCUH	Birchall, Daniel
RCUH	Bulger, Joanna
RCUH	Castro, Timothy
RCUH	Clergeon, Christophe
RCUH	Cook, David
RCUH	Currie, Thayne
RCUH	Doi, Yoshiyuki
RCUH	Doughty, Danielle
RCUH	Elms, Brian
RCUH	Endo, Mari
RCUH	Fabricius, Maximilian
RCUH	Ferre Mateu, Anna
RCUH	Ferreira, James
RCUH	Finet, Francois
RCUH	Formanek, Keiko
RCUH	Fujiwara, Hideaki
RCUH	Fujiyoshi, Takuya

RCUH	Gaskin, Roberta
RCUH	Gorman, William
RCUH	Guthier, Debbie
RCUH	Guyon, Olivier
RCUH	Hasegawa, Andrew
RCUH	Hasegawa, Kumiko
RCUH	Hattori, Takashi
RCUH	Helminiak, Krzysztof
RCUH	Hopkins, James
RCUH	Inagaki, Takeshi
RCUH	Iwasaki, Alan
RCUH	Jeschke, Eric
RCUH	Jovanovic, Nemanja
RCUH	Kackley, Russell
RCUH	Kakazu, Yuko
RCUH	Kim, Ji Hoon
RCUH	Koshida, Shintaro
RCUH	Koyamatsu, Shin ~2015.06.03
RCUH	Kudo, Tomoyuki
RCUH	Kyono, Eiji
RCUH	Lee, Chien-Hsiu
RCUH	Lemmen, Michael
RCUH	Leonard, Alex ~2015.08.07
RCUH	Letawsky, Michael
RCUH	Lozi, Julien
RCUH	Micheva, Genoveva
RCUH	Morris, Marita
RCUH	Murai, Rieko
RCUH	Nabeshima, Yoshitake
RCUH	Nakano, Wakako
RCUH	Nakata, Fumiaki
RCUH	Niimi, Yuka
RCUH	Nishimura, Tetsuo
RCUH	Otsuki, Noriko
RCUH	Pathak, Prashant
RCUH	Ramos, Lucio
RCUH	Roth, Noriko
RCUH	Saito, Yuriko ~2016.03.08
RCUH	Shubert, Kiaina
RCUH	Singh, Garima ~2015.11.04
RCUH	Spencer, Robin
RCUH	Sur, Ryoko
RCUH	Tait, Philip
RCUH	Tajitsu, Akito
RCUH	Takiura, Koki
RCUH	Tamae, Richard
RCUH	Tanaka, Makoto
RCUH	Tanaka, Yoko
RCUH	Terai, Tsuyoshi
RCUH	Thunell, Johnathan
RCUH	Tomono, Daigo
RCUH	Toyofuku, Ralph
RCUH	Tsang, Emiko
RCUH	Wages, Keith ~2015.11.27
RCUH	Walawender, Joshua ~2016.02.05
RCUH	Weber, Mark
RCUH	Williams, Joshua
RCUH	Winegar, Tom
RCUH	Wung, Matthew
RCUH	Yeh, Sherry (Chia-Chen)
RCUH	Yoshiyama, Naomi

Okayama Astrophysical Observatory

Director	Izumiura, Hideyuki
Associate Professor	Izumiura, Hideyuki
Associate Professor	Ukita, Nobuharu
Assistant Professor	Yanagisawa, Kenshi
Specially Appointed Assistant Professor	Kambe, Eiji
Engineer	Tsutsui, Hironori
Specially Appointed Research Staff	Fukui, Akihiko
Research Expert	Kuroda, Daisuke
Research Expert	Maehara, Hiroyuki
Research Supporter	Kamiya, Koki ~2015.09.30
Research Supporter	Toda, Hiroyuki

Administration Office

Administration Section

Chief	Setou, Nobuyoshi
Administrative Supporter	Katayama, Kumiko
Administrative Supporter	Shibukawa, Hiroko
Administrative Supporter	Yamashita, Ayako
Administrative Maintenance Staff	Koyama, Shoji
Administrative Maintenance Staff	Watanabe, Noriaki

Nobeyama Radio Observatory

Director	Saito, Masao
Associate Professor	Nakamura, Fumitaka
Associate Professor	Saito, Masao
Chief Research Engineer	Kanzawa, Tomio
Chief Research Engineer	Kawashima, Susumu
Assistant Professor	Ishizuki, Sumio
Assistant Professor	Minamidani, Tetsuhiro
Assistant Professor	Umemoto, Tomofumi
Research Engineer	Mikoshiba, Hiroshi
Senior Engineer	Handa, Kazuyuki
Senior Engineer	Miyazawa, Chieko
Senior Engineer	Miyazawa, Kazuhiko
Senior Engineer	Shinohara, Noriyuki
Chief Engineer	Kurakami, Tomio
Engineer	Nishitani, Hiroyuki
Engineer	Wada, Takuya

Specially Appointed Research Staff	Kaneko, Hiroyuki
Specially Appointed Research Staff	Miyamoto, Yusuke
Specially Appointed Research Staff	Nishimura, Atsushi
Research Expert	Kinugasa, Kenzo
Research Expert	Maekawa, Jun
Research Expert	Oya, Masaaki
Research Expert	Takahashi, Shigeru
Research Expert	Tatamitani, Yoshio
Technical Expert	Nishioka, Makiko
Research Supporter	Arai, Hitoshi
Administrative Supporter	Hatakeyama, Eiko
Administrative Supporter	Ide, Hidemi
Consultant	Saito, Yasufumi
Research Assistant	Matsuo, Mitsuhiro

Administration Office

Deputy Manager	Otsuka, Tomoyoshi

General Affairs Section

Chief	Otsuka, Tomoyoshi
Administrative Supporter	Kikuchi, Kikue
Administrative Supporter	Shinkai, Hisako
Administrative Supporter	Yoda, Chizuko
Administrative Maintenance Staff	Fuji, Shigeru
Administrative Maintenance Staff	Ide, Hiroko
Administrative Maintenance Staff	Kadoshima, Junko
Administrative Maintenance Staff	Kikuchi, Michiko
Administrative Maintenance Staff	Kikuchi, Tsuyoshi
Administrative Maintenance Staff	Koike, Ikuko
Administrative Maintenance Staff	Kurane, Tsugeru
Administrative Maintenance Staff	Saito, Arayo
Administrative Maintenance Staff	Tsuchiya, Junko
Administrative Maintenance Staff	Yoshizawa, Usaji

Accounting Section

Chief	Shimizu, Hidetoshi
Senior Staff	Iijima, Kunio
Staff	Kobayashi, Kazuhito ~2015.07.31
Administrative Supporter	Kodaira, Toshiko
Administrative Supporter	Takasawa, Mitsue
Administrative Supporter	Takemura, Miwako
Administrative Supporter	Tokui, Chisato

Mizusawa VLBI Observatory

Director	Honma, Mareki
Professor	Honma, Mareki
Professor	Kobayashi, Hideyuki
Associate Professor	Agata, Hidehiko
Associate Professor	Hanada, Hideo
Associate Professor	Shibata, Katsunori
Chief Research Engineer	Sato, Katsuhisa
Assistant Professor	Hada, Kazuhiro
Assistant Professor	Hirota, Tomoya
Assistant Professor	Jike, Takaaki
Assistant Professor	Kameya, Osamu
Assistant Professor	Kono, Yusuke
Assistant Professor	Sunada, Kazuyoshi
Assistant Professor	Tamura, Yoshiaki
Research Engineer	Asari, Kazuyoshi
Research Engineer	Ishikawa, Toshiaki
Research Engineer	Suzuki, Syunsaku
Chief Engineer	Ueno, Yuji
Engineer	Hirano, Ken
Engineer	Shizugami, Makoto
Specially Appointed Research Staff	Kim, Jeoung Sook
Specially Appointed Research Staff	Matsumoto, Naoko
Specially Appointed Research Staff	Motogi, Kazuhito
Specially Appointed Research Staff	Sakai, Nobuyuki
Specially Appointed Research Staff	Tazaki, Fumie
Specially Appointed Research Staff	Wu, Yuanwei
Specially Appointed Senior Specialist	Kanaguchi, Masahiro
Specially Appointed Senior Specialist	Miura, Mitsuo
Specially Appointed Senior Specialist	Nagayama, Takumi
Specially Appointed Senior Specialist	Oyama, Tomoaki
Research Expert	Hanayama, Hidekazu
Technical Expert	Asakura, Yu
Technical Expert	Sato, Kaori
Technical Expert	Funayama, Hiroshi
Technical Expert	Matsukawa, Yuki
Technical Expert	Miyaji, Takeshi
Technical Expert	Nishizawa, Akihisa
Technical Expert	Yoshida, Toshihiro
Research Supporter	Akiyama, Kazunori ~2015.08.31
Research Supporter	Isono,Yoko
Research Supporter	Matsueda, Chika
Administrative Supporter	Komori, Akiyo
Administrative Supporter	Uekiyo,Hatsue

Administration Office

Deputy Manager	Hommyo, Susumu

General Affairs Section

Chief	Hommyo, Susumu
Staff	Iida, Naoto
Administrative Supporter	Kikuchi, Sachiko
Administrative Supporter	Oizumi, Yuka
Administrative Supporter	Sasaki, Mie

Accounting Section

Chief	Ito, Hiromasa
Chief	Koseki, Tatsuya ~2015.06.30
Administrative Supporter	Sasaki, Mie
Administrative Supporter	Takahashi, Yumi

Ishigaki-jima Astronomical Observatory

Director	Miyaji, Takeshi
Associate Professor	Agata, Hidehiko
Research Expert	Hanayama, Hidekazu
Technical Expert	Miyaji, Takeshi

Time Keeping Office

Head	Sato, Katsuhisa
Research Engineer	Asari, Kazuyoshi

Solar Observatory

Director	Hanaoka, Yoichiro
Professor	Sakurai, Takashi
Associate Professor	Hanaoka, Yoichiro
Associate Professor	Suematsu, Yoshinori
Senior Engineer	Shinoda, Kazuya
Specially Appointed Research Staff	Otsuji, Kenichi ~2015.09.30
Research Expert	Hagino, Masaoki
Research Expert	Morita, Satoshi
Research Expert	Yaji, Kentaro
Administrative Supporter	Nishino, Hideko
Administrative Supporter	Sugimoto, Junko

NAOJ Chile Observatory

Director	Hasegawa, Tetsuo
Professor	Hasegawa, Tetsuo
Professor	Iguchi, Satoru
Professor	Kameno, Seiji
Professor	Ogasawara, Ryusuke
Professor	Sakamoto, Seiichi
Professor	Tatematsu, Kenichi
Associate Professor	Asaki, Yoshiharu
Associate Professor	Asayama, Shinichiro
Associate Professor	Espada, Fernandez Daniel
Associate Professor	Iono, Daisuke
Associate Professor	Kiuchi, Hitoshi
Associate Professor	Kosugi, George
Associate Professor	Mizuno, Norikazu
Associate Professor	Oishi, Masatoshi
Associate Professor	Okuda, Takeshi
Specially Appointed Associate Professor	Erik, Muller
Specially Appointed Associate Professor	Fukagawa, Misato
Specially Appointed Associate Professor	Kawamura, Akiko
Specially Appointed Associate Professor	Koda, Jin
Specially Appointed Associate Professor	Nagai, Hiroshi
Specially Appointed Associate Professor	Nakanishi, Koichiro
Chief Research Engineer	Kikuchi, Kenichi
Chief Research Engineer	Watanabe, Manabu
Assistant Professor	Ezawa, Hajime
Assistant Professor	Hiramatsu, Masaaki
Assistant Professor	Hirota, Akihiko
Assistant Professor	Kamazaki, Takeshi
Assistant Professor	Matsuda, Yuichi
Assistant Professor	Sawada, Tsuyoshi
Assistant Professor	Shimojo, Masumi
Assistant Professor	Takahashi, Satoko
Assistant Professor	Umemoto, Tomofumi
Specially Appointed Assistant Professor	Akiyama, Eiji
Specially Appointed Assistant Professor	Hatsukade, Bunyo
Specially Appointed Assistant Professor	Herrera Contreras, Cinthya Natalia ~2015.08.31
Specially Appointed Assistant Professor	Miura, Rie
Research Engineer	Ashitagawa, Kyoko
Research Engineer	Nakazato, Takeshi
Senior Engineer	Kobiki, Toshihiko
Senior Engineer	Nakamura, Kyoko
Chief Engineer	Ito, Tetsuya
Chief Engineer	Kato, Yoshihiro
Specially Appointed Research Staff	Ao, Yiping
Specially Appointed Research Staff	Egusa, Fumi
Specially Appointed Research Staff	Kurono, Yasutaka
Specially Appointed Research Staff	Morokuma, Kana
Specially Appointed Research Staff	Sanhueza Nunez, Patricio Andres
Specially Appointed Research Staff	Takekoshi, Tatsuya
Specially Appointed Research Staff	Ueda, Junko ~2015.09.30
Specially Appointed Senior Specialist	Fukui, Hideharu
Specially Appointed Senior Specialist	Furutani, Akio
Specially Appointed Senior Specialist	Horie, Yosaku
Specially Appointed Senior Specialist	Ikeda, Emi

Specially Appointed Senior Specialist	Kawakami, Kazuyuki
Specially Appointed Senior Specialist	Kawasaki, Wataru
Specially Appointed Senior Specialist	Kobayashi, Tsuyoshi
Specially Appointed Senior Specialist	Konuma, Mika
Specially Appointed Senior Specialist	Kuniyoshi, Masaya
Specially Appointed Senior Specialist	Matsui, Takayuki
Specially Appointed Senior Specialist	Miel, Renaud
Specially Appointed Senior Specialist	Morita, Eisuke
Specially Appointed Senior Specialist	Nakamoto, Takashi
Specially Appointed Senior Specialist	Nakamura, Koji
Specially Appointed Senior Specialist	Nukatani, Sorahiko
Specially Appointed Senior Specialist	Otawara, Kazushige
Specially Appointed Senior Specialist	Saito, Motoi
Specially Appointed Senior Specialist	Shimoda, Takanobu
Specially Appointed Senior Specialist	So, Ryoken
Specially Appointed Senior Specialist	Sugimoto, Kanako
Specially Appointed Senior Specialist	Yamada, Masumi
Specially Appointed Senior Specialist	Yoshino, Akira
Research Expert	Fujimoto, Yasuhiro
Research Expert	Inoue, Norio
Research Expert	Sakuma, Naoko
Research Expert	Shibuya, Masaru
Research Expert	Tomimuro, Hisashi
Research Expert	Yasui, Takashi ~2015.08.31
Administrative Expert	Kamada, Masako
Research Supporter	Saito, Tomoki
Research Supporter	Uchida, Ayako
Research Supporter	Yamazaki, Toshitaka
Administrative Supporter	Kohno, Izumi
Administrative Supporter	Matsunaga, Choko
Administrative Supporter	Otawara, Hikaru
Administrative Supporter	Saito, Naoko
Consultant	Hyuga, Tadayuki
AUI Staff	Krapivka Flores, Gabriela
AUI Staff	Collao, Joaquin
AUI Staff	Toro, Lorena

Administration Department

Manager	Okumura, Yuji
General Affairs Section	
Chief	Tsukano, Satomi
Accounting Section	
Chief	Okumura, Yuji
Staff	Hiramatsu, Naoya

Center for Computational Astrophysics

Director	Kokubo, Eiichiro
Professor	Kokubo, Eiichiro
Professor	Tomisaka, Kohji
Assistant Professor	Inoue, Tsuyoshi
Assistant Professor	Ito, Takashi
Assistant Professor	Ohsuga, Ken
Assistant Professor	Takiwaki, Tomoya
Assistant Professor	Tanaka, Masaomi
Specially Appointed Assistant Professor	Takahashi, Hiroyuki
Research Engineer	Ishikawa, Toshiaki
Engineer	Shizugami, Makoto
Specially Appointed Research Staff	Asahina, Yuta
Specially Appointed Research Staff	Furusawa, Shun
Specially Appointed Research Staff	Kawashima, Tomohisa
Research Expert	Kato, Tsunehiko
Research Expert	Nakayama, Hirotaka
Research Expert	Narazaki, Yayoi ~2015.09.30
Research Expert	Oshino, Shoichi
Research Expert	Wakita, Shigeru
Research Supporter	Fukushi, Hinako
Research Supporter	Hasegawa, Yukihiko
Research Supporter	Matsumoto, Yuji
Administrative Supporter	Kimura, Yuko

Hinode Science Center

Director	Watanabe, Tetsuya
Professor	Sakurai, Takashi
Specially Appointed Professor	Gizon, Laurent Claude ~2015.08.31
Associate Professor	Hara, Hirohisa
Associate Professor	Sekii, Takashi
Associate Professor	Suematsu, Yoshinori
Assistant Professor	Ishikawa, Ryoko
Assistant Professor	Kano, Ryouhei
Assistant Professor	Katsukawa, Yukio
Assistant Professor	Kubo, Masahito
Assistant Professor	Shimojo, Masumi
Specially Appointed Research Staff	Antolin, Patrick
Technical Expert	Inoue, Naoko
Research Supporter	Ishii, Shuichi
Research Supporter	Tsuchiya, Chie

B Projects

Gravitational Wave Project Office

Director	Flaminio, Raffaele
Specially Appointed Professor	Flaminio, Raffaele
Associate Professor	Aso, Yoichi
Affliated Associate Professor	Ando, Masaki
Assistant Professor	Akutsu, Tomotada
Assistant Professor	Oishi, Naoko
Assistant Professor	Takahashi, Ryutaro
Assistant Professor	Tatsumi, Daisuke
Research Engineer	Ishizaki, Hideharu
Research Engineer	Torii, Yasuo
Chief Engineer	Tanaka, Nobuyuki
Specially Appointed Research Staff	Barton, Mark Andrew
Specially Appointed Research Staff	Pena Arellano, Fabian Erasmo
Specially Appointed Research Staff	Zeidler, Simon
Specially Appointed Senior Specialist	Hirata, Naoatsu
Research Supporter	Harada, Mikiko
Administrative Supporter	Kondo, Mihoko ~2016.02.29
Administrative Supporter	Yoshizumi, Mizuho

TMT-J Project Office

Director	Usuda, Tomonori
Professor	Takami, Hideki
Professor	Usuda, Tomonori
Professor	Yamashita, Takuya
Associate Professor	Aoki, Wako
Associate Professor	Hayano, Yutaka
Associate Professor	Kashikawa, Nobunari
Associate Professor	Kodama, Tadayuki
Associate Professor	Kosugi, George
Associate Professor	Miyazaki, Satoshi
Associate Professor	Sugimoto, Masahiro
Associate Professor	Takato, Naruhisa
Associate Professor	Terada, Hiroshi
Specially Appointed Associate Professor	Oya, Shin
Specially Appointed Associate Professor	Packham, Christopher Charles ~2015.08.11
Chief Research Engineer	Miyashita, Takaaki
Assistant Professor	Imanishi, Masatoshi
Assistant Professor	Suzuki, Ryuji
Research Engineer	Tazawa, Seiichi
Specially Appointed Research Staff	Harakawa, Hiroki
Specially Appointed Research Staff	Hashimoto, Tetsuya
Specially Appointed Senior Specialist	Chapman, Junko
Specially Appointed Senior Specialist	Kozu, Akihito
Specially Appointed Senior Specialist	Sugiyama, Motokuni
Research Expert	Ishii, Miki
Research Expert	Ozaki, Shinobu
Research Supporter	Inatani, Junji
Research Supporter	Tajima, Toshiyuki
Administrative Supporter	Haranaka, Miyuki
Administrative Supporter	Yamaguchi, Chiyu
RCUH	Iye, Masanori

A Projects

JASMINE Project Office

Director	Gouda, Naoteru
Professor	Gouda, Naoteru
Professor	Kobayashi, Yukiyasu
Specially Appointed Professor	Hensler, Georhard Max Franz ~2015.11.25
Associate Professor	Hanada, Hideo
Associate Professor	Takato, Naruhisa
Chief Research Engineer	Tsuruta, Seiitsu
Assistant Professor	Araki, Hiroshi
Assistant Professor	Noda, Hirotomo
Assistant Professor	Tsujimoto, Takuji
Assistant Professor	Ueda, Akitoshi
Assistant Professor	Yano, Taihei
Research Engineer	Asari, Kazuyoshi
Specially Appointed Research Staff	Shirahata, Mai ~2015.12.31
Specially Appointed Research Staff	Yamaguchi, Masaki
Research Supporter	Utsunomiya, Shin
Technical Supporter	Kashima, Shingo

Extrasolar Planet Detection Project Office

Director	Tamura, Motohide
Professor	Kokubo, Eiichiro
Affiliated Professor	Tamura, Motohide
Associate Professor	Izumiura, Hideyuki
Assistant Professor	Kotani, Takayuki
Assistant Professor	Morino, Jun-ichi
Assistant Professor	Nakajima, Tadashi
Assistant Professor	Nishikawa, Jun
Assistant Professor	Suto, Hiroshi
Specially Appointed Assistant Professor	Hashimoto, Jun
Specially Appointed Assistant Professor	Hori, Yasunori
Specially Appointed Assistant Professor	Narita, Norio
Specially Appointed Research Staff	Omiya, Masashi

Specially Appointed Senior Specialist	Kusakabe, Nobuhiko
Research Supporter	Kandori, Ryo
Research Supporter	Kurokawa, Takashi
Administrative Supporter	Miyamae, Miwako

RISE Project

Director	Namiki, Noriyuki
Professor	Gouda, Naoteru
Professor	Kobayashi, Yukiyasu
Professor	Kokubo, Eiichiro
Professor	Namiki, Noriyuki
Associate Professor	Hanada, Hideo
Associate Professor	Matsumoto, Koji
Chief Research Engineer	Tsuruta, Seiitsu
Assistant Professor	Araki, Hiroshi
Assistant Professor	Kono, Yusuke
Assistant Professor	Noda, Hirotomo
Assistant Professor	Tsujimoto, Takuji
Assistant Professor	Yano, Taihei
Research Engineer	Asari, Kazuyoshi
Research Engineer	Tazawa, Seiichi
Specially Appointed Research Staff	Oshigami, Shoko
Specially Appointed Research Staff	Yamada, Ryuhei
Research Expert	Kikuchi, Fuyuhiko
Administrative Supporter	Sato, Sayaka

SOLAR-C Project Office

Director	Hara, Hirohisa
Professor	Sakurai, Takashi
Professor	Watanabe, Tetsuya
Affiliated Professor	Ichimoto, Kiyoshi
Associate Professor	Goto, Motoshi
Associate Professor	Hara, Hirohisa
Associate Professor	Kano, Ryouhei
Associate Professor	Sekii, Takashi
Associate Professor	Suematsu, Yoshinori
Assistant Professor	Ishikawa, Ryoko
Assistant Professor	Katsukawa, Yukio
Assistant Professor	Kubo, Masahito
Senior Engineer	Shinoda, Kazuya
Specially Appointed Research Staff	Narukage, Noriyuki
Specially Appointed Research Staff	Watanabe, Kyoko ~2015.09.30
Technical Expert	Inoue, Naoko
Administrative Supporter	Fujiyoshi, Marie

Centers

Astronomy Data Center

Director	Oishi, Masatoshi
Professor	Kokubo, Eiichiro
Professor	Mizumoto, Yoshihiko
Associate Professor	Ichikawa, Shinichi
Associate Professor	Kosugi, George
Associate Professor	Noumaru, Junichi
Associate Professor	Oishi, Masatoshi
Associate Professor	Shibata, Katsunori
Associate Professor	Takata, Tadafumi
Assistant Professor	Furusawa, Hisanori
Assistant Professor	Ito, Takashi
Assistant Professor	Oe, Masafumi
Assistant Professor	Shimojo, Masumi
Assistant Professor	Shirasaki, Yuji
Research Engineer	Inoue, Goki
Engineer	Fukui, Asami ~2015.11.15
Specially Appointed Research Staff	Higuchi, Yuichi
Specially Appointed Research Staff	Yoshida, Tetsuo
Specially Appointed Research Staff	Zapart, Christopher Andrew
Research Expert	Asano, Eiji
Research Expert	Furusawa, Junko
Research Expert	Isogai, Mizuki
Research Expert	Tanaka, Nobuhiro
Research Supporter	Fujikawa, Makiko
Research Supporter	Noda, Sachiyo
Research Supporter	Taguchi, Shoya
Administrative Supporter	Ishii, Yuko
Research Assistant	Suzuki, Taiki

JVO Project

Head	Mizumoto, Yoshihiko
Associate Professor	Oishi, Masatoshi
Assistant Professor	Shirasaki, Yuji

Advanced Technology Center

Director	Noguchi, Takashi
Professor	Noguchi, Takashi
Professor	Takami, Hideki
Associate Professor	Hara, Hirohisa
Associate Professor	Hayano, Yutaka
Associate Professor	Iwata, Ikuru
Associate Professor	Kano, Ryouhei
Associate Professor	Matsuo, Hiroshi
Associate Professor	Miyazaki, Satoshi
Associate Professor	Sekimoto, Yutaro
Associate Professor	Shan, Wenlei
Chief Research Engineer	Fujii, Yasunori
Chief Research Engineer	Kikuchi, Kenichi
Chief Research Engineer	Okada, Norio
Assistant Professor	Akutsu, Tomotada
Assistant Professor	Kojima, Takafumi
Assistant Professor	Nakaya, Hidehiko
Assistant Professor	Oshima, Tai
Assistant Professor	Suzuki, Ryuji

Specially Appointed Assistant Professor	Gonzalez Garcia, Alvaro
Research Engineer	Fukushima, Mitsuhiro
Research Engineer	Iizuka, Yoshizo
Research Engineer	Noguchi, Motokazu
Research Engineer	Obuchi, Yoshiyuki
Research Engineer	Sato, Naohisa
Senior Engineer	Kubo, Koichi
Senior Engineer	Miyazawa, Chieko
Senior Engineer	Takahashi, Toshikazu
Chief Engineer	Fukuda, Takeo
Chief Engineer	Ikenoue, Bungo
Chief Engineer	Inata, Motoko
Chief Engineer	Iwashita, Hikaru
Chief Engineer	Kamata, Yukiko
Chief Engineer	Kaneko, Keiko
Chief Engineer	Mitsui, Kenji
Chief Engineer	Tamura, Tomonori
Chief Engineer	Uraguchi, Fumihiro
Chief Engineer	Waseda, Koichi
Engineer	Tsuzuki, Toshihiro
Specially Appointed Research Staff	Dominjon, Agnes Micheline
Specially Appointed Research Staff	Karatsu, Kenichi ~2015.07.31
Specially Appointed Research Staff	Narukage, Noriyuki
Specially Appointed Senior Specialist	Ezaki, Shohei
Specially Appointed Senior Specialist	Karatsu, Miki
Specially Appointed Senior Specialist	Niizeki, Yasuaki
Specially Appointed Senior Specialist	Uemizu, Kazunori
Research Expert	Matthias, Kroug
Research Expert	Ozaki, Shinobu
Research Expert	Saitou, Sakae
Technical Expert	Nishino, Tetsuo
Technical Supporter	Hayashi, Ritsuko
Administrative Supporter	Kuroda, Kyoko
Administrative Supporter	Murakami, Hiromi
Administrative Supporter	Yoshida, Taeko

Public Relations Center

Director	Fukushima, Toshio
Professor	Fukushima, Toshio
Professor	Watanabe, Junichi
Associate Professor	Agata, Hidehiko
Specially Appointed Associate Professor	Kinoshita, Daisuke ~2016.02.15
Specially Appointed Associate Professor	Kozak, Pavlo ~2015.07.10
Assistant Professor	Hiramatsu, Masaaki
Assistant Professor	Soma, Mitsuru
Research Engineer	Katayama, Masato
Research Engineer	Sasaki, Goro
Chief Senior Engineer	Matsuda, Ko
Chief Engineer	Nagayama, Shogo
Library Chief	Todoriki, Tatsuya
Specially Appointed Senior Specialist	Cheung, Sze Leung
Specially Appointed Senior Specialist	Ishikawa, Naomi
Specially Appointed Senior Specialist	Lundock, Ramsey Guy
Specially Appointed Senior Specialist	Pires Canas, Lina Isabel
Research Expert	Komiyama, Hiroko
Research Expert	Ono, Tomoko
Research Expert	Takata, Hiroyuki
Research Expert	Usuda-Sato, Kumiko
Reaearch Supporter	Kume, Kaori
Reaearch Supporter	Tsuchiya, Chie
Public Outreach Official	Diaz, Rosas Elian Abril
Public Outreach Official	Endo, Isao
Public Outreach Official	Fujita, Tokiko
Public Outreach Official	Futami, Hiroshi
Public Outreach Official	Hamura, Taiga
Public Outreach Official	Hatano, Satomi
Public Outreach Official	Ibaraki, Takao
Public Outreach Official	Ishizaki, Masaharu
Public Outreach Official	Iwashiro, Kuninori
Public Outreach Official	Koike, Akio
Public Outreach Official	Kubo, Maki
Public Outreach Official	Mikami, Naotsugu
Public Outreach Official	Naito, Seiichiro
Public Outreach Official	Natsugari, Satomi
Public Outreach Official	Nemoto, Shiomi
Public Outreach Official	Oguri, Junko
Public Outreach Official	Ohgoe, Osamu
Public Outreach Official	Shibata, Yukiko
Public Outreach Official	Shioya, Yasuhisa
Public Outreach Official	Takabatake, Noriko
Public Outreach Official	Takeda, Takaaki
Administrative Supporter	Aoki, Makiko
Administrative Supporter	Noguchi, Sayumi

Public Relations Office

Head	Hiramatsu, Masaaki
Chief Engineer	Nagayama, Shogo
Research Expert	Komiyama, Hiroko
Research Expert	Ono, Tomoko
Research Supporter	Kume, Kaori
Public Outreach Official	Mikami, Naotsugu
Public Outreach Official	Natsugari, Satomi
Public Outreach Official	Shioya, Yasuhisa

Outreach and Education Office

Head	Agata, Hidehiko
Specially Appointed Senior Specialist	Ishikawa, Naomi
Public Outreach Official	Endo, Isao

Public Outreach Official	Fujita, Tokiko
Public Outreach Official	Hamura, Taiga
Public Outreach Official	Hatano, Satomi
Public Outreach Official	Ibaraki, Takao
Public Outreach Official	Ishizaki, Masaharu
Public Outreach Official	Naito, Seiichiro
Public Outreach Official	Ohgoe, Osamu
Public Outreach Official	Takabatake, Noriko

Museum Deliberation Office

Head	Agata, Hidehiko
Research Engineer	Sasaki, Goro
Senior Engineer	Matsuda, Ko
Research Expert	Usuda-Sato, Kumiko
Public Outreach Official	Endo, Isao
Public Outreach Official	Fujita, Tokiko
Public Outreach Official	Futami, Hiroshi
Public Outreach Official	Koike, Akio
Public Outreach Official	Nemoto, Shiomi
Public Outreach Official	Takeda, Takaaki

Ephemeris Computation Office

Head	Katayama, Masato
Senior Engineer	Matsuda, Ko
Public Outreach Official	Endo, Isao

Library

Chief	Todoriki, Tatsuya
Public Outreach Official	Kubo, Maki
Public Outreach Official	Oguri, Junko

Publications Office

Head	Fukushima, Toshio
Research Expert	Takata, Hiroyuki
Public Outreach Official	Iwashiro, Kuninori
Public Outreach Official	Kubo, Maki

The Office for Astronomy Outreach of the IAU

Head	Agata, Hidehiko
Specially Appointed Senior Specialist	Cheung, Sze Leung
Specially Appointed Senior Specialist	Pires Canas, Lina Isabel
Research Expert	Usuda-Sato, Kumiko
Public Outreach Official	Diaz, Rosas Elian Abril
Public Outreach Official	Shibata, Yukiko

General Affairs Office

Head	Matsuda, Ko
Administrative Supporter	Aoki, Makiko
Administrative Supporter	Noguchi, Sayumi

Divisions

Division of Optical and Infrared Astronomy

Division Chair	Mizumoto, Yoshihiko
Professor	Arimoto, Nobuo
Professor	Gouda, Naoteru
Professor	Kobayashi, Yukiyasu
Professor	Mizumoto, Yoshihiko
Professor	Ohashi, Nagayoshi
Professor	Sekiguchi, Kazuhiro
Professor	Usuda, Tomonori
Professor	Yamashita, Takuya
Associate Professor	Aoki, Wako
Associate Professor	Aso, Yoichi
Associate Professor	Hayashi, Saeko
Associate Professor	Iwata, Ikuru
Associate Professor	Izumiura, Hideyuki
Associate Professor	Kashikawa, Nobunari
Associate Professor	Kodama, Tadayuki
Associate Professor	Noumaru, Junichi
Associate Professor	Sugimoto, Masahiro
Associate Professor	Takato, Naruhisa
Associate Professor	Takeda, Yoichi
Associate Professor	Terada, Hiroshi
Associate Professor	Ukita, Nobuharu
Chief Research Engineer	Iwashita, Hiroyuki
Chief Research Engineer	Miyashita, Takaaki
Assistant Professor	Akutsu, Tomotada
Assistant Professor	Imanishi, Masatoshi
Assistant Professor	Komiyama, Yutaka
Assistant Professor	Koyama, Yusei
Assistant Professor	Minowa, Yosuke
Assistant Professor	Morino, Jun-ichi
Assistant Professor	Nakajima, Tadashi
Assistant Professor	Nishikawa, Jun
Assistant Professor	Oishi, Naoko
Assistant Professor	Okita, Hirofumi
Assistant Professor	Onodera, Masato
Assistant Professor	Pyo, Tae-soo
Assistant Professor	Soma, Mitsuru
Assistant Professor	Takahashi, Ryutaro
Assistant Professor	Tatsumi, Daisuke
Assistant Professor	Tsujimoto, Takuji
Assistant Professor	Ueda, Akitoshi
Assistant Professor	Yagi, Masafumi
Assistant Professor	Yanagisawa, Kenshi
Assistant Professor	Yano, Taihei
Specially Appointed Assistant Professor	Matsuoka, Yoshiki
Research Engineer	Bando, Takamasa
Research Engineer	Ishizaki, Hideharu
Research Engineer	Torii, Yasuo
Chief Engineer	Namikawa, Kazuhito
Chief Engineer	Negishi, Satoru
Chief Engineer	Omata, Koji
Chief Engineer	Tamura, Tomonori
Chief Engineer	Tanaka, Nobuyuki
Engineer	Sato, Tatsuhiro
Engineer	Tsutsui, Hironori
Administrative Supporter	Kimura, Hiroko
Research Assistant	Onoue, Masafusa
Research Assistant	Shimakawa, Rizumu
Research Assistant	Ui, Takahiro ~2015.12.31
JSPS Postdoctoral Fellow	Hayashi, Masao

JSPS Postdoctoral Fellow	Niino, Yu
JSPS Postdoctoral Fellow	Uchiyama, Mizuho

Division of Radio Astronomy

Division Chair	Iguchi, Satoru
Professor	Hasegawa, Tetsuo
Professor	Honma, Mareki
Professor	Iguchi, Satoru
Professor	Kameno, Seiji
Professor	Kawabe, Ryohei
Professor	Kobayashi, Hideyuki
Professor	Namiki, Noriyuki
Professor	Ogasawara, Ryusuke
Professor	Sakamoto, Seiichi
Professor	Tatematsu, Kenichi
Associate Professor	Asaki, Yoshiharu
Associate Professor	Asayama, Shinichiro
Associate Professor	Espada, Fernandez Daniel
Associate Professor	Hanada, Hideo
Associate Professor	Iono, Daisuke
Associate Professor	Kiuchi, Hitoshi
Associate Professor	Kosugi, George
Associate Professor	Matsumoto, Koji
Associate Professor	Mizuno, Norikazu
Associate Professor	Okuda, Takeshi
Associate Professor	Saito, Masao
Associate Professor	Shibata, Katsunori
Chief Research Engineer	Kanzawa, Tomio
Chief Research Engineer	Kawashima, Susumu
Chief Research Engineer	Kikuchi, Kenichi
Chief Research Engineer	Sato, Katsuhisa
Chief Research Engineer	Tsuruta, Seiitsu
Chief Research Engineer	Watanabe, Manabu
Assistant Professor	Araki, Hiroshi
Assistant Professor	Ezawa, Hajime
Assistant Professor	Hada, Kazuhiro
Assistant Professor	Hiramatsu, Masaaki
Assistant Professor	Hirota, Akihiko
Assistant Professor	Hirota, Tomoya
Assistant Professor	Ishizuki, Sumio
Assistant Professor	Jike, Takaaki
Assistant Professor	Kamazaki, Takeshi
Assistant Professor	Kameya, Osamu
Assistant Professor	Kono, Yusuke
Assistant Professor	Matsuda, Yuichi
Assistant Professor	Minamidani, Tetsuhiro
Assistant Professor	Miyoshi, Makoto
Assistant Professor	Noda, Hirotomo
Assistant Professor	Sawada, Tsuyoshi
Assistant Professor	Shimojo, Masumi
Assistant Professor	Sunada, Kazuyoshi
Assistant Professor	Takahashi, Satoko
Assistant Professor	Tamura, Yoshiaki
Assistant Professor	Umemoto, Tomofumi
Research Engineer	Asari, Kazuyoshi
Research Engineer	Ashitagawa, Kyoko
Research Engineer	Ishikawa, Toshiaki
Research Engineer	Mikoshiba, Hiroshi
Research Engineer	Nakazato, Takeshi
Research Engineer	Suzuki, Syunsaku
Research Engineer	Tazawa, Seiichi
Senior Engineer	Handa, Kazuyuki
Senior Engineer	Kobiki, Toshihiko
Senior Engineer	Miyazawa, Chieko
Senior Engineer	Miyazawa, Kazuhiko
Senior Engineer	Nakamura, Kyoko
Senior Engineer	Shinohara, Noriyuki
Chief Engineer	Ito, Tetsuya
Chief Engineer	Kato, Yoshihiro
Chief Engineer	Kurakami, Tomio
Chief Engineer	Ueno, Yuji
Engineer	Hirano, Ken
Engineer	Nishitani, Hiroyuki
Engineer	Shizugami, Makoto
Engineer	Wada, Takuya
Specially Appointed Senior Specialist	Takebayashi, Yasuo
Research Expert	Tatsuzawa, Kaichi
Research Supporter	Tsuneyama, Junko

Division of Solar and Plasma Astrophysics

Division Chair	Sakurai, Takashi
Professor	Sakurai, Takashi
Professor	Watanabe, Tetsuya
Associate Professor	Hanaoka, Yoichiro
Associate Professor	Hara, Hirohisa
Associate Professor	Kano, Ryouhei
Associate Professor	Sekii, Takashi
Associate Professor	Suematsu, Yoshinori
Assistant Professor	Ishikawa, Ryoko
Assistant Professor	Katsukawa, Yukio
Assistant Professor	Kubo, Masahito
Specially Appointed Assistant Professor	Toriumi, Shin
Senior Engineer	Shinoda, Kazuya

Division of Theoretical Astronomy

Division Chair	Tomisaka, Kohji
Professor	Kokubo, Eiichiro
Professor	Tomisaka, Kohji
Professor	Yoshida, Haruo
Specially Appointed Professor	Balantekin, Akif Baha ~2015.11.23
Specially Appointed Professor	Cheoun, Myung-Ki ~2016.02.24
Specially Appointed Professor	Deliduman, Yamac ~2015.11.23
Specially Appointed Professor	Mathews, Grant James ~2015.11.09
Associate Professor	Kajino, Toshitaka
Associate Professor	Nakamura, Fumitaka

Specially Appointed Associate Professor	Famiano, Michael Andrew ~2015.11.23
Assistant Professor	Hamana, Takashi
Assistant Professor	Inoue, Tsuyoshi
Assistant Professor	Ohsuga, Ken
Assistant Professor	Takiwaki, Tomoya
Assistant Professor	Tanaka, Masaomi
Specially Appointed Assistant Professor	Fujii, Michiko ~2015.12.31
Specially Appointed Assistant Professor	Fujimoto, Keizo
Specially Appointed Assistant Professor	Nozawa, Takaya
Specially Appointed Assistant Professor	Sotani, Hajime
Specially Appointed Assistant Professor	Zenitani, Seiji
Specially Appointed Research Staff	Michikoshi, Shugo
Administrative Supporter	Izumi, Shioko
Administrative Supporter	Kano, Kaori

5. Research Support Departments

Research Enhancement Strategy Office

Director	Kobayashi, Hideyuki
Specially Appointed Senior Specialist	Chapman, Junko
Specially Appointed Senior Specialist	Chiba, Kurazo
Specially Appointed Senior Specialist	Fukui, Hideharu
Specially Appointed Senior Specialist	Hori, Kuniko
Specially Appointed Senior Specialist	Lundock, Ramsey Guy
Specially Appointed Senior Specialist	Miura, Mitsuo
Specially Appointed Senior Specialist	Ota, Masahiko
Specially Appointed Senior Specialist	Yamamiya, Osamu

Research Evaluation Support Office

Director	Watanabe, Junichi
Specially Appointed Senior Specialist	Hori, Kuniko

Office of International Relations

Director	Yamaguchi, Takahiro
Specially Appointed Senior Specialist	Yamaguchi, Takahiro
Research Expert	Komiyama, Hiroko
Research Expert	Yoshida, Fumi

Administration Office

Deputy Manager/Senior Specialist	Onishi, Tomoyuki
International Academic Affairs Section	
Staff	Takada, Miyuki
Administrative Supporter	Ito, Yoshihisa
Administrative Supporter	Momma, Yoko

Human Resources Planning Office

Director	Yamamiya, Osamu

Safety and Health Management Office

Director	Takami, Hideki
Specially Appointed Senior Specialist	Ota, Masahiko
Technical Expert	Kashiwagi, Yuji

Engineering Promotion Office

Director	Takami, Hideki
Specially Appointed Senior Specialist	Chiba, Kurazo

Administration Department

General Manager	Sasaki, Tsuyoshi

General Affairs Division

Manager	Harada, Eiichiro
Deputy Manager	Onishi, Tomoyuki
Administrative Supporter	Torii, Makiko
Information Technology Specialist	
Specialist	Yoshikawa, Ikuko
Graduate School Specialist	
Specialist	Kikkawa, Hiroko
Administrative Supporter	Okuda, Yutaka
Personnel Accounting Specialist	
Specialist	Watanabe, Yukika
General Affairs Section	
Chief	Yoshikawa, Ikuko
Senior Staff	Goto, Michiru
Staff	Mochimaru, Shiori
Staff	Yoshimura, Tetsuya
Specially Appointed Senior Specialist	Noguchi, Koki
Vehicle Driver	Amemiya, Hidemi
Administrative Expert	Murakami, Sachiko
Administrative Supporter	Kobayashi, Kayo
Administrative Supporter	Noguchi, Utako
Administrative Supporter	Seki, Kumi
Personnel Section	
Chief	Yamanochi, Mika
Staff	Isozaki, Yuka
Staff	Sakamoto, Misato
Payroll Section	
Chief	Watanabe, Yukika
Staff	Furukawa, Shinichiro
Specially Appointed Senior Specialist	Yamamoto, Chieko
Administrative Supporter	Aiba, Narukazu
Employee Affairs Section	
Chief	Yamaura, Mari
Staff	Ouchi, Kaori
Staff	Saito, Masahiro
Research Support Section	
Chief	Sato, Yoko
Administrative Expert	Haruki, Mutsumi
Administrative Supporter	Takeuchi, Kaori

Financial Affairs Division

Manager	Nemoto, Nobuyuki
Senior Specialist	Miura, Norio
Audit Specialist	
Specialist	Ishikawa, Junya
External Funding Section	
Specialist	Chiba, Satoko
Staff	Yamafuji, Yasuto
Administrative Supporter	Komoda, Chizuru
Administrative Supporter	Sato, Chieko
Administrative Supporter	Urushibata, Kozue
Administrative Supporter	Yasuda, Masako

General Affairs Section
- Chief — Yamamoto, Shinichi
- Administrative Supporter — Okada, Kazuko

Budget Section
- Chief — Akaike, Makoto
- Staff — Yokota, Banri
- Administrative Supporter — Matsubara, Michiko

Asset Management Section
- Chief — Sato, Kanako
- Administrative Supporter — Komoda, Chizuru

Purchase Validation Center
- Chief — Sato, Kanako
- Administrative Supporter — Hosoi, Chiho
- Administrative Supporter — Nakagomi, Kimitoshi
- Administrative Supporter — Taniai, Tomoko
- Administrative Supporter — Tanigaki, Yukio

Accounting Division
- Manager — Tanaka, Masaru

Contract Specialist
- Specialist — Chiba, Yoko

Accounting Section
- Chief — Sukigara, Yuji
- Staff — Miyata, Yusuke
- Administrative Supporter — Kobayashi, Rina
- Administrative Supporter — Nagasawa, Fumi

Procurement Section
- Chief — Chiba, Yoko
- Staff — Kayamori, Shinji
- Staff — Sugimoto, Naomi
- Staff — Takai, Tetsuya
- Consultant — Hyuga, Tadayuki
- Administrative Expert — Sato, Masako

Childcare Leave
- Administrative Supporter — Takano, Ayako

Facilities Division
- Manager — Watanabe, Matsuo
- Administrative Expert — Asada, Tsuneaki

General Affairs Section
- Senior Staff — Kawashima, Ryota
- Staff — Nakagawa, Yukie
- Administrative Supporter — Hasegawa, Chisato

Planning Section
- Chief — Murakami, Kazuhiro
- Administrative Supporter — Tsukamoto, Izumi

Maintenance Section
- Chief — Sato, Takashi
- Staff — Hayashigura, Koji

6. Personnel change

Research and Academic Staff

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2015/4/1	Koyama, Yusei	Hired	Division of Optical and Infrared Astronomy (Subaru Telescope), Assistant Professor	
2015/5/15	Asaki, Yoshiharu	Hired	Division of Radio Astronomy (NAOJ Chile Observatory), Associate Professor	(Japan Aerospace Exploration Agency)
2015/11/1	Shan, Wenlei	Hired	Division of Radio Astronomy (NAOJ Chile Observatory), Associate Professor	
2015/12/1	Minamidani, Tetsuhiro	Hired	Division of Radio Astronomy (Nobeyama Radio Observatory), Assistant Professor	(Nobeyama Radio Observatory, Specially Appointed Assistant Professor)
2016/2/1	Hada, Kazuhiro	Hired	Division of Radio Astronomy (Mizusawa VLBI Observatory), Assistant Professor	
2016/2/1	Takiwaki, Tomoya	Hired	Division of Theoretical Astronomy, Assistant Professor	
2016/3/1	Onodera, Masato	Hired	Division of Optical and Infrared Astronomy (Subaru Telescope), Assistant Professor	
2015/6/30	Nakanishi, Kouichiro	Resigned	(NAOJ Chile Observatory, Specially Appointed Associate Professor)	Division of Radio Astronomy (NAOJ Chile Observatory), Assistant Professor
2016/3/31	Hasegawa, Tetsuo	Resigned	(NAOJ Chile Observatory, Specially Appointed Professor)	Division of Radio Astronomy (NAOJ Chile Observatory), Professor
2016/3/31	Iizuka, Yoshizo	Resigned		Advanced Technology Center, Research Engineer
2016/3/31	Sakurai, Takashi	Retired		Division of Solar and Plasma Astrophysics (Solar Observatory), Professor
2016/3/31	Torii, Yasuo	Retired		Division of Optical and Infrared Astronomy (Gravitational Wave Project Office), Research Engineer
2016/3/31	Sasaki, Goro	Retired		Public Relations Center, Research Engineer
2015/4/1	Sugimoto, Masahiro	Promoted	Division of Optical and Infrared Astronomy (TMT-J Project Office), Associate Professor	Division of Radio Astronomy (NAOJ Chile Observatory), Assistant Professor
2015/8/1	Hayano, Yutaka	Promoted	Division of Optical and Infrared Astronomy (TMT-J Project Office), Associate Professor	Division of Optical and Infrared Astronomy (Subaru Telescope), Assistant Professor
2015/8/1	Espada Fernandez, Daniel	Promoted	Division of Radio Astronomy (NAOJ Chile Observatory), Associate Professor	Division of Radio Astronomy (NAOJ Chile Observatory), Assistant Professor
2015/11/1	Kano, Ryohei	Promoted	Division of Solar and Plasma Astrophysics (SOLAR-C Project Office), Associate Professor	Division of Solar and Plasma Astrophysics (SOLAR-C Project Office), Assistant Professor
2016/1/1	Fujii, Yasunori	Promoted	Advanced Technology Center, Chief Research Engineer	Advanced Technology Center, Research Engineer
2015/4/1	Suto, Hiroshi	Reassigned	Astrobiology Center, Assistant Professor	NAOJ Division of Optical and Infrared Astronomy (Extrasolar Planet Detection Project Office), Assistant Professor

2015/4/1	Kotani, Takayuki	Reassigned	Astrobiology Center, Assistant Professor	NAOJ Division of Optical and Infrared Astronomy (Extrasolar Planet Detection Project Office), Assistant Professor
2016/1/1	Obuchi, Yoshiyuki	Reassigned	Advanced Technology Center, Research Engineer	Advanced Technology Center, Chief Engineer

Engineering Staff

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2016/3/1	Hirano, Ken	Hired	Division of Radio Astronomy (Mizusawa VLBI Observatory), Engineer	
2015/11/15	Fukui, Asami	Resigned		Astronomy Data Center, Engineer
2015/4/1	Shinoda, Kazuya	Promoted	Division of Solar and Plasma Astrophysics (Solar Observatory), Senior Engineer	Division of Solar and Plasma Astrophysics (Solar Observatory), Chief Engineer
2015/4/1	Handa, Kazuyuki	Promoted	Division of Radio Astronomy (Nobeyama Radio Observatory), Senior Engineer	Division of Radio Astronomy (Nobeyama Radio Observatory), Chief Engineer
2015/4/1	Miyazawa, Chieko	Promoted	Division of Radio Astronomy (Nobeyama Radio Observatory), Senior Engineer	Division of Radio Astronomy (Nobeyama Radio Observatory), Chief Engineer
2015/7/1	Ueno, Yuji	Promoted	Division of Radio Astronomy (Mizusawa VLBI Observatory), Chief Engineer	Division of Radio Astronomy (Mizusawa VLBI Observatory), Engineer
2015/8/1	Mitsui, Kenji	Promoted	Advanced Technology Center, Chief Engineer	Advanced Technology Center, Engineer
2015/8/1	Nagayama, Syogo	Promoted	Public Relations Center, Chief Engineer	Public Relations Center, Engineer

Administrative Staff

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2015/4/1	Watanabe, Matsuo	Hired	Administration Department Facilities Division, Manager	(National Museum of Nature and Science,Tokyo)
2015/4/1	Watanabe, Yukika	Hired	Administration Department General Affairs Division Payroll Section, Chief	(Tokyo Gakugei Univerisity)
2015/4/1	Todoriki, Tatsuya	Hired	Public Relations Center Administration Office Library Section, Chief	(The University of Tokyo)
2015/4/1	Miyata, Yusuke	Hired	Administration Department Accounting Division Accounting Section, Staff	(The Graduate University for Advanced Studies)
2015/4/1	Mochimaru, Shiori	Hired	Administration Department General Affairs Division General Affairs Section, Staff	
2015/4/1	Saito, Masahiro	Hired	Administration Department General Affairs Division Employee Affairs Section, Staff	
2015/7/1	Akaike, Makoto	Hired	Administration Department Financial Affairs Division Budget Section, Chief	(The University of Tokyo)
2015/7/1	Ito, Hiromasa	Hired	Mizusawa VLBI Observatory Administration Office Accounting Section, Chief	(Iwate University)
2015/8/1	Iijima, Kunio	Hired	Nobeyama Radio Observatory Administration Office Accounting Section, Senior Staff	(Shinshu University)

2015/6/30	Koseki, Tatsuya	Resigned	(Ministry of Economy, Trade and Industry)	Mizusawa VLBI Observatory Administration Office Accounting Section, Chief
2015/6/30	Fujiwara, Kenichi	Resigned	(The University of Tokyo)	Administration Department Financial Affairs Division Budget Section, Chief
2015/7/31	Kobayashi, Kazuhito	Resigned	(Shinshu University)	Nobeyama Radio Observatory Administration Office Accounting Section, Staff
2016/3/31	Sasaki, Tsuyoshi	Resigned	(Nagoya University)	General Manager
2016/3/31	Miura, Norio	Resigned	(The University of Tokyo)	Administration Department Financial Affairs Division, External Funding Senior Specialist
2016/3/31	Yoshikawa, Ikuko	Resigned	(Hitotsubashi University)	Administration Department General Affairs Division General Affairs Section, Chief
2016/3/31	Sukigara, Yuji	Resigned	(Tokyo Gakugei Univerisity)	Administration Department Accounting Division Accounting Section, Chief
2016/3/31	Sato, Takashi	Resigned	(The University of Tokyo)	Administration Department Facilities Division Maintenance Section, Chief
2016/3/31	Setou, Nobuyoshi	Resigned	(Okayama University)	Okayama Astrophysical Observatory Administration Office Administration Section, Chief

2015/4/1	Kawashima, Ryota	Promoted	Administration Department Facilities Division General Affairs Section, Senior Staff	Administration Department General Affairs Division Employee Affairs Section, Staff
2015/7/1	Goto, Michiru	Promoted	Administration Department General Affairs Division General Affairs Section, Senior Staff	Administration Department General Affairs Division General Affairs Section, Staff
2015/10/1	Sato, Kanako	Promoted	Administration Department Financial Affairs Division Asset Management Section, Chief	Administration Department Financial Affairs Division Asset Management Section, Senior Staff
2015/10/1	Chiba, Satoko	Promoted	Administration Department Financial Affairs Division, External Funding Specialist	Administration Department Financial Affairs Division, External Funding Senior Staff

2015/4/1	Yamada, Tomohiro	Reassigned	Okazaki Administration Center, Financial Affairs Department Financial Affairs Division, Specialist	NAOJ Administration Department Facilities Division General Affairs Section, Chief
2015/7/1	Mizokawa, Yuko	Reassigned	Administrative Bureau Financial Affairs Division Financial Affairs Section, Staff	NAOJ Administration Department Financial Affairs Division General Affairs Section, Staff
2015/7/1	Tanaka, Masaru	Reassigned	NAOJ Administration Department Accounting Division, Manager	Administrative Bureau General Affairs Divison, Deputy Manager
2016/1/1	Ishikawa, Junya	Reassigned	NAOJ Administration Department Financial Affairs Division, Audit Specialist	Administrative Bureau Laison and Planning Division, Specialist

Employee on Annual Salary System

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2015/4/1	Muller, Erik Michael	Hired	NAOJ Chile Observatory, Specially Appointed Associate Professor	
2015/4/1	Fukagawa, Misato	Hired	NAOJ Chile Observatory, Specially Appointed Associate Professor	

2015/4/1	Miura, Rie	Hired	NAOJ Chile Observatory, Specially Appointed Assistant Professor	(NAOJ Chile Observatory, Specially Appointed Research Staff)
2015/4/1	Herrera Contreras, Cinthya Natalia	Hired	NAOJ Chile Observatory, Specially Appointed Assistant Professor	(NAOJ Chile Observatory, Specially Appointed Research Staff)
2015/4/1	Hashimoto, Tetsuya	Hired	TMT-J Project Office, Specially Appointed Research Staff	
2015/4/1	Toshikawa, Jun	Hired	Subaru Telescope, Specially Appointed Research Staff	
2015/4/1	Ichikawa, Kohei	Hired	Subaru Telescope, Specially Appointed Research Staff	
2015/4/1	Egusa, Fumi	Hired	NAOJ Chile Observatory, Specially Appointed Research Staff	
2015/4/1	Morokuma, Kana	Hired	NAOJ Chile Observatory, Specially Appointed Research Staff	
2015/4/1	Matsumoto, Naoko	Hired	Mizusawa VLBI Observatory, Specially Appointed Research Staff	
2015/4/1	Sakai, Nobuyuki	Hired	Mizusawa VLBI Observatory, Specially Appointed Research Staff	
2015/4/1	Motogi, Kazuhito	Hired	Mizusawa VLBI Observatory, Specially Appointed Research Staff	
2015/4/1	Oshigami, Shoko	Hired	RISE Project, Specially Appointed Research Staff	
2015/4/1	Kaneko, Hiroyuki	Hired	Nobeyama Radio Observatory, Specially Appointed Research Staff	
2015/4/1	Miyamoto, Yusuke	Hired	Nobeyama Radio Observatory, Specially Appointed Research Staff	
2015/4/1	Otsuji, Kenichi	Hired	Solar Observatory, Specially Appointed Research Staff	
2015/4/1	Watanabe, Kyoko	Hired	SOLAR-C Project Office, Specially Appointed Research Staff	
2015/4/1	Fukui, Akihiko	Hired	Okayama Astrophysical Observatory, Specially Appointed Research Staff	
2015/4/1	Asahina, Yuta	Hired	Center for Computational Astrophysics, Specially Appointed Research Staff	
2015/4/1	Michikoshi, Shugo	Hired	Division of Theoretical Astronomy, Specially Appointed Research Staff	
2015/4/1	Karatsu, Kenichi	Hired	Advanced Technology Center, Specially Appointed Research Staff	
2015/4/1	Momose, Rieko	Hired	Subaru Telescope, Specially Appointed Senior Specialist	
2015/4/1	Okumura, Yuji	Hired	NAOJ Chile Observatory Administration Department, Specially Appointed Senior Specialist	
2015/4/1	Furutani, Akio	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2015/4/1	Konuma, Mika	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2015/4/1	Nukatani, Sorahiko	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2015/4/1	Nakamura, Koji	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2015/4/1	Otawara, Kazushige	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	

2015/4/1	Kanaguchi, Masahiro	Hired	Mizusawa VLBI Observatory, Specially Appointed Senior Specialist	
2015/4/1	Oyama, Tomoaki	Hired	Mizusawa VLBI Observatory, Specially Appointed Senior Specialist	
2015/4/1	Nagayama, Takumi	Hired	Mizusawa VLBI Observatory, Specially Appointed Senior Specialist	(Mizusawa VLBI Observatory, Specially Appointed Research Staff)
2015/4/1	Niizeki, Yasuaki	Hired	Advanced Technology Center, Specially Appointed Senior Specialist	
2015/4/1	Ezaki, Shohei	Hired	Advanced Technology Center, Specially Appointed Senior Specialist	
2015/4/1	Karatsu, Miki	Hired	Advanced Technology Center, Specially Appointed Senior Specialist	
2015/4/1	Uemizu, Kazunori	Hired	Advanced Technology Center, Specially Appointed Senior Specialist	
2015/4/6	Pires Canas, Lina Isabel	Hired	Public Relations Center, Specially Appointed Senior Specialist	
2015/6/1	Packham, Christopher Charles	Hired	TMT-J Project Office, Specially Appointed Associate Professor	
2015/6/1	Miel, Renaud Jean Christophe	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2015/7/1	Nakanishi, Kouichiro	Hired	NAOJ Chile Observatory, Specially Appointed Associate Professor	(Division of Radio Astronomy (NAOJ Chile Observatory), Assistant Professor)
2015/7/1	Sakamoto, Ken	Hired	Subaru Telescope, Specially Appointed Senior Specialist	
2015/7/1	Noguchi, Koki	Hired	Administration Department General Affairs Division, Specially Appointed Senior Specialist	
2015/8/1	Gizon, Laurent Claude	Hired	Hinode Science Center, Specially Appointed Professor	
2015/8/1	Kawakami, Kazuyuki	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2015/9/1	Takebayashi, Yasuo	Hired	Division of Radio Astronomy, Specially Appointed Senior Specialist	
2015/9/1	Ishikawa, Naomi	Hired	Public Relations Center, Specially Appointed Senior Specialist	
2015/10/1	Oya, Shin	Hired	TMT-J Project Office, Specially Appointed Associate Professor	
2015/10/9	Mathews, Grant James	Hired	Division of Theoretical Astronomy, Specially Appointed Professor	
2015/10/22	Balantekin, Akif Baha	Hired	Division of Theoretical Astronomy, Specially Appointed Professor	
2015/10/22	Deliduman, Yamac	Hired	Division of Theoretical Astronomy, Specially Appointed Professor	
2015/10/23	Famiano, Michael Andrew	Hired	Division of Theoretical Astronomy, Specially Appointed Associate Professor	
2015/12/1	Horie, Yosaku	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2016/1/1	Ikeda, Emi	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2016/1/1	Nakamoto, Takashi	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2016/1/1	Yoshino, Akira	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	

2016/1/15	Ikeda, Hiroyuki	Hired	Subaru Telescope, Specially Appointed Senior Specialist	
2016/1/28	Renzini, Alvio	Hired	Subaru Telescope, Specially Appointed Professor	
2016/2/1	Hayashi, Yusuke	Hired	Subaru Telescope, Specially Appointed Senior Specialist	
2016/3/1	Oishi, Yukie	Hired	Subaru Telescope, Specially Appointed Senior Specialist	

2015/7/31	Karatsu, Kenichi	Resigned		Advanced Technology Center, Specially Appointed Research Staff
2015/8/31	Herrera Contreras, Cinthya Natalia	Resigned		NAOJ Chile Observatory, Specially Appointed Assistant Professor
2015/9/30	Ueda, Junko	Resigned		NAOJ Chile Observatory, Specially Appointed Research Staff
2015/9/30	Otsuji, Kenichi	Resigned		Solar Observatory, Specially Appointed Research Staff
2015/9/30	Watanabe, Kyoko	Resigned		SOLAR-C Project Office, Specially Appointed Research Staff
2015/10/31	Momose, Rieko	Resigned		Subaru Telescope, Specially Appointed Senior Specialist
2015/11/30	Minamidani, Tetsuhiro	Resigned	(Division of Radio Astronomy (Nobeyama Radio Observatory), Assistant Professor)	Nobeyama Radio Observatory, Specially Appointed Assistant Professor
2015/12/31	Fujii, Michiko	Resigned		Division of Theoretical Astronomy, Specially Appointed Assistant Professor
2015/12/31	Shirahata, Mai	Resigned		JASMINE Project Office, Specially Appointed Research Staff
2015/12/31	Sakamoto, Ken	Resigned		Subaru Telescope, Specially Appointed Senior Specialist
2016/3/31	Fukagawa, Misato	Resigned		NAOJ Chile Observatory, Specially Appointed Associate Professor
2016/3/31	Gonzalez Garcia, Alvaro	Resigned	(Division of Radio Astronomy (NAOJ Chile Observatory), Assistant Professor)	Advanced Technology Center, Specially Appinted Assistant Professor
2016/3/31	Ichikawa, Kohei	Resigned		Subaru Telescope, Specially Appointed Research Staff
2016/3/31	Oshigami, Shoko	Resigned		RISE Project, Specially Appointed Research Staff
2016/3/31	Antolin, Patrick	Resigned		Hinode Science Center, Specially Appointed Research Staff
2016/3/31	Furusawa, Shun	Resigned		Center for Computational Astrophysics, Specially Appointed Research Staff
2016/3/31	Nishimura, Atsushi	Resigned		Nobeyama Radio Observatory, Specially Appointed Research Staff
2016/3/31	Yamada, Masumi	Resigned	(Division of Radio Astronomy (NAOJ Chile Observatory), Research Engineer)	NAOJ Chile Observatory, Specially Appointed Senior Specialist

2015/8/11	Packham, Christopher Charles	Contract Expired		TMT-J Project Office, Specially Appointed Associate Professor
2015/8/31	Gizon, Laurent Claude	Contract Expired		Hinode Science Center, Specially Appointed Professor
2015/11/9	Mathews, Grant James	Contract Expired		Division of Theoretical Astronomy, Specially Appointed Professor

2015/11/23	Balantekin, Akif Baha	Contract Expired		Division of Theoretical Astronomy, Specially Appointed Professor
2015/11/23	Deliduman, Yamac	Contract Expired		Division of Theoretical Astronomy, Specially Appointed Professor
2015/11/23	Famiano, Michael Andrew	Contract Expired		Division of Theoretical Astronomy, Specially Appointed Associate Professor
2016/3/31	Renzini, Alvio	Contract Expired		Subaru Telescope, Specially Appointed Professor
2016/3/31	Fujimoto, Keizo	Contract Expired		Division of Theoretical Astronomy, Specially Appointed Assistant Professor
2016/3/31	Hashimoto, Tetsuya	Contract Expired		TMT-J Project Office, Specially Appointed Research Staff
2016/3/31	Yamaguchi, Masaki	Contract Expired		JASMINE Project Office, Specially Appointed Research Staff
2016/3/31	Kawashima, Tomohisa	Contract Expired		Center for Computational Astrophysics, Specially Appointed Research Staff
2016/3/31	Michikoshi, Shugo	Contract Expired		Division of Theoretical Astronomy, Specially Appointed Research Staff
2016/3/31	Yoshida, Tessei	Contract Expired		Astronomy Data Center, Specially Appointed Research Staff
2016/3/31	Kurono, Yasutaka	Contract Expired		NAOJ Chile Observatory, Specially Appointed Research Staff

2015/4/1	Narita, Norio	Reassigned	Astrobiology Center Specially Appointed Assistant Professor	NAOJ Extrasolar Planet Detection Project Office, Specially Appointed Assistant Professor

Research Administrator Staff

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2015/4/1	Yamaguchi, Takahiro	Hired	Research Enhancement Strategy Office, Office of International Relations, Specially Appointed Senior Specialist	(NAOJ Chile Observatory Administration Department, Specially Appointed Senior Specialist)

2016/3/31	Chiba, Kurazo	Contract Expired		Research Enhancement Strategy Office, Engineering Promotion Office, Specially Appointed Senior Specialist

Foreign Visiting Researcher

Name	Period	Affiliated Institute
Hensler, Gerhard Max Franz	2015/4/10 ~ 2015/5/20 2015/10/7 ~ 2015/11/25	University of Vienna (Austria)
Cheoun, Myung-Ki	2015/12/26 ~ 2016/2/24	Soongsil University (South Korea)
Kinoshita, Daisuke	2015/7/2 ~ 2015/9/5 2016/1/21 ~ 2016/2/15	Institute of Astronomy, National Central University (Taiwan)
Kozak, Pavlo	2015/5/12 ~ 2015/7/10 2015/7/21 ~ 2015/9/19	Astronomical Observatory of Kyiv, Taras Shevchenko National University (Ukraine)
Koda, Jin	2016/1/1 ~ 2016/3/31	The State University of New York at Stony Brook (U.S.A)

In the Research and Academic Staff personel list, we only listed reassignments from Engineering Staff.

In the Research and Academic Staff and Administrative Staff personel lists, we only listed reassignments from/to other NINS organizations.

7. Advisory Committee for Research and Management

Members

From universities and related institutes

	Umemura, Masayuki	Faculty of Pure and Applied Sciences, University of Tsukuba
	Ohta, Kouji	Graduate School of Science, Kyoto University
	Okumura, Sachiko	Graduate School of Science, Japan Women's University
	Kajita, Takaaki	Institute for Cosmic Ray Research, The University of Tokyo
○	Kusano, Kanya	Institute for Space-Earth Environmental Research, Nagoya University
	Sugita, Seiji	Graduate School of Science, The University of Tokyo
	Nakagawa, Takao	Institute of Space and Astronautical Science
	Murakami, Izumi	National Institute for Fusion Science
	Momose, Munetake	College of Science, Ibaraki University
	Yamada, Toru	Institute of Space and Astronautical Science

From NAOJ

	Arimoto, Nobuo	Subaru Telescope
	Usuda, Tomonori	TMT-J Project Office
	Gouda, Naoteru	JASMINE Project Office
	Kobayashi, Hideyuki	Mizusawa VLBI Observatory
	Sakurai, Takashi	Solar Observatory
	Takami, Hideki	Advanced Technology Center
	Tomisaka, Kohji	Division of Theoretical Astronomy
	Noguchi, Takashi	Advanced Technology Center
	Hasegawa, Tetsuo	NAOJ Chile Observatory
●	Watanabe, Junichi	Public Relations Center

● Chairperson ○ Vise-Chairperson

Period: April 1, 2014 – March 31, 2016

8. Professors Emeriti and Staffs Emeriti

Professors Emeriti (NAOJ)

Kakuta, Chuichi
Hiei, Eijiro
Yamashita, Yasumasa
Nishimura, Shiro
Kozai, Yoshihide
Hirayama, Tadashi
Miyamoto, Masanori
Nariai, Kyouji
Okamoto, Isao
Nakano, Takenori
Kodaira, Keiichi
Yokoyama, Koichi
Oe, Masatsugu
Kinoshita, Hiroshi
Nishimura, Tetsuo
Kaifu, Norio
Ishiguro, Masato
Inoue, Makoto
Kawano, Nobuyuki
Andou, Hiroyasu
Karoji, Hiroshi
Chikada, Yoshihiro
Noguchi, Kunio
Fujimoto, Masakatsu
Manabe, Seiji
Miyama, Shoken
Kawaguchi,Noriyuki
Iye, Masanori
Shibasaki,Kiyoto

Professors Emeriti (Tokyo Astronomical Observatory)

Akabane, Kenji
Moriyama, Fumio
Kozai, Yoshihide

IV Finance

Revenue and Expenses (FY2015)

(Unit: ¥1,000)

Revenue	Budget	Final Account	Budget − Final Account
Management Expenses Grants	12,323,709	12,809,347	−485,638
Facilities Maintenance Grants	2,445,830	2,151,220	294,610
Subsidy Income	49,900	49,900	0
Miscellaneous Income	42,286	244,370	−202,084
Industry-Academia Research Income and Donation Income	728,722	239,092	489,630
Reversals of Reserves for Specific Purposes	268,528	264,995	3,533
Total	15,858,975	15,758,924	100,051
Expenses	Budget	Final Account	Budget − Final Account
Management Expenses	12,634,523	13,318,712	−684,189
Employee Personnel Expenses	3,528,180	3,499,935	28,245
Operating Expenses	9,106,343	9,818,777	−712,434
Facilities Maintenance Expenses	2,445,830	2,151,220	294,610
Subsidy Expenses	49,900	49,900	0
Industry-Academia Research Expenses and Donation Expenses	728,722	230,173	498,549
Total	15,858,975	15,750,005	108,970
Revenue-Expenses	Budget	Final Account	Budget − Final Account
	0	8,919	−8,919

V KAKENHI (Grants-in-Aid for Scientific Research)

1. Series of Single-year Grants for FY 2015

Research Categories	Number of Selected Projects	Budget (Unit: ¥1,000)		
		Direct Funding	Indirect Funding	Total
Scientific Research on Innovative Areas (Research in a proposed research area)	10	89,600	26,880	116,480
Scientific Research (S)	2	53,300	15,990	69,290
Scientific Research (A)	13	114,100	34,230	148,330
Scientific Research (B)	4	19,700	5,910	25,610
Young Scientists (A)	1	7,100	2,130	9,230
JSPS Fellows	9	10,400	2,820	13,220
Research Activity Start-up	2	1,700	510	2,210
Grant-in-Aid for Publication of Scientific Research Results	1	1,000	0	1,000
Total	42	296,900	88,470	385,370

2. Multi-year Fund for FY 2015

Research Categories	Number of Selected Projects	Budget (Unit: ¥1,000)		
		Direct Funding	Indirect Funding	Total
Scientific Research (C)	19	20,700	6,210	26,910
Challenging Exploratory Research	4	7,400	2,220	9,620
Young Scientists (B)	17	14,500	4,350	18,850
Total	40	42,600	12,780	55,380

3. Partial Multi-year Fund for FY2015

Research Categories	Number of Selected Projects	Budget (Series of Single-year Grants) (Unit: ¥1,000)			Budget (Multi-year Fund) (Unit: ¥1,000)		
		Direct Funding	Indirect Funding	Total	Direct Funding	Indirect Funding	Total
Scientific Research (B)	3	2,500	750	3,250	500	150	650
Young Scientists (A)	2	1,500	450	1,950	0	0	0
Total	5	4,000	1,200	5,200	500	150	650

VI Research Collaboration

1. Open Use

Type	Project/Center	Category	Number of Accepted Proposal	Total Number of Researcher	Note
Open Use at Project/Center	Okayama Astrophysical Observatory	188cm Reflector Telescope (Project Program)	2	36 (0)	2 Institutes
		188cm Reflector Telescope (Normal Program)	26	146 (5)	16 Institutes, 3 Countries
		188cm Reflector Telescope (Student Program)	2	18 (0)	3 Institutes
		188cm Reflector Telescope (Miscellaneous Program)	1	5 (0)	1Institutes
	Subaru Telescope		121	343 (58)	64 Institutes, 15 Countries
	Solar Observatory		*	*	*
	Nobeyama Radio Observatory	45-m Telescope (General Proposal)	21	204 (79)	64 Institutes, 14 Countries
		45-m Telescope (Short Program)	5	32 (3)	15 Institutes, 1Countries
		45-m Telescope (Back-up Program)	3	85 (62)	41Institutes, 13 Countries
	Mizusawa VLBI Observatory	VERA	22	116 (62)	28 Institutes, 10 Countries
	Astronomy Data Center		372	372 (53 at foreign institutes)	80 Institutes, 16 Countries
	Center for Computational Astrophysics		210	210	46 Institutes, 8 Countries
	Hinode Science Center		116	116 (33)	40 Institutes, 11Countries
	Advanced Technology Center	Facility Use	30	124	53 Institutes
		Joint Research and Development	8	43	18 Institutes
	NAOJ Chile Observatory	ALMA (Cycle2)	353	3,523 (3,049)	324 Institutes, 35 Countries
		ASTE	41	251 (38)	40 Institutes, 8 Countries
		Mopra	19	144 (35)	24 Institutes, 7 Countries
Joint Development Research			12		9 Institutes
Joint Research			1		1 Institutes
Research Assembly			20		16 Institutes
NAOJ Symposium			0		

The number of foreign researchers shown in brackets ( ) is included in the total.

Notes show the number of institutes and foreign countries represented by the proposal PIs. The country count does not include Japan.

The period of ALMA (Cycle2) is September, 2015 from June, 2014.

* The observation data is open to the public on the web. No application is needed to use the data.

2. Commissioned Research Fellows

Visiting Scholars (Domestic)

Period: April 1, 2015 – March 31, 2016

Name	Position at NAOJ	Affiliated Institute	Host Project/Center/Division
Uzawa,Yoshinori	Visiting Professor	NICT,Terahertz Technology Research Center	NAOJ Chile Observatory
Onishi, Toshikazu	Visiting Professor	Osaka Prefecture University	NAOJ Chile Observatory
Oka, Tomoharu	Visiting Professor	Keio University	NAOJ Chile Observatory
Tanihata,Isao	Visiting Professor	Osaka University	Division of Theoretical Astronomy
Nagao,Toru	Visiting Professor	Ehime University	TMT-J Project Office
Hayashi,Shousuke	Visiting Professor	Kobe University	Center for Computational Astrophysics
Momose, Munetake	Visiting Professor	Ibaraki University	NAOJ Chile Observatory
Kotake, Kei	Visiting Associate Professor	Fukuoka University	Division of Theoretical Astronomy
Kobayashi, Kaori	Visiting Associate Professor	Toyama University	NAOJ Chile Observatory
Komugi, Shinya	Visiting Associate Professor	Kogakuin University	NAOJ Chile Observatory
Sagawa,Hideo	Visiting Associate Professor	Kyoto Sangyo University	NAOJ Chile Observatory
Sorai,Kazuo	Visiting Associate Professor	Hokkaido University	Nobeyama Radio Observatory
Takahashi, Keitaro	Visiting Associate Professor	Kumamoto University	Division of Radio Astronomy
Niinuma, Koutaro	Visiting Associate Professor	Yamaguchi University	Mizusawa VLBI Observatory
Oshima, Akitoshi*	Visiting Associate Professor	Chubu University	Center for Computational Astrophysics
Asaki, Yoshiharu	Visiting Research Fellow	Japan Aerospace Exploration Agency	NAOJ Chile Observatory
Kurayama, Tomoharu	Visiting Research Fellow	Teikyo University of Science	Mizusawa VLBI Observatory

* Vititing Research Fellow until July, 12, 2015.

JSPS (Japan Society for the Promotion of Science) Postdoctoral Research Fellows

Name	Research Subject	Host Researcher
Hada, Kazuhiro	Probing a relativistic jet in a supermassive black hole with high-resolution radio monitoring observations	Honma, Mareki
Niinou, Yuu	Probing Cosmic Star Formation at High Redshifts via Afterglows and Host Galaxies Gamma-Ray Bursts	Kashikawa, Nobunari
Hayashi, Masao	Formation and evolution of elliptical galaxies revealed by internal structures of growing progenitors in galaxy clusters	Kodama, Tadayuki
Arimatsu, Kou	Exploring the outer solar system by stellar occultations observed with wide-field high-speed cameras	Watanabe, Junichi
Uchiyama, Mizuho	Studying stellar evolution of forming massive young stellar objects with the mid-infrared variability observations	Yamashita, Takuya
Shouda, Ayaka	Development of the multi-messenger observation system for a gravitational-wave detector	Flaminio, Raffaele
Shirasaki, Masato	Probing Cosmic Dark Matter and Dark Energy with Higher-Order Statistics of Weak Gravitational Lensing	Hamana, Takashi
Shinnaka, Yoshiharu	Physicochemistry of the early solar nebula: Thermal history of cometary dust and isotopic fractionation of cometary volatile	Watanabe, Junichi
Yamauchi, Aya	Research in the structure of a distant region of our galaxy using a new distance measurement method with VERA	Honma, Mareki

JSPS (Japan Society for the Promotion of Science) Foreign Research Fellows

Name	Program	Period	Host Researcher
None			

VII Graduate Course Education

1. Department of Astronomical Science, School of Physical Sciences, SOKENDAI (The Graduate University for Advanced Studies)

SOKENDAI (The Graduate University for Advanced Studies) was established in 1988 as an independent graduate university without undergraduate courses via partnerships with inter-university research institutes for the sake of advancing graduate education.

There used to be four schools – Cultural and Social Studies, Mathematical and Physical Sciences, Life Science, and Advanced Sciences before the reorganization of the School of Mathematical and Physical Sciences into the schools of Physical Sciences, High Energy Accelerator Science, and Multidisciplinary Sciences in April 2004. Now the total of six schools are offering doctoral education and research opportunities.

NAOJ has been accepting three-year doctoral-course students since FY 1992 and five-year students since FY 2006 for the Department of Astronomical Science at the School of Physical Sciences. (The School of Mathematical and Physical Sciences was reorganized into the School of Physical Sciences in April 2004.)

(1) Objective of the Department of Astronomical Science

The Department of Astronomical Science aims to train students, through observational, theoretical, or instrument development research in astronomy or in related fields, in an environment with the most advanced observational instruments and supercomputers, as researchers who work at the forefront of world-class research; experts who carry out development of advanced technology; and specialists who endeavor in education and public outreach activities equipped with advanced and specialized knowledge.

Numbers of students to be admitted:
Two (per year in the five-year doctoral course)
Three (per year in the three-year doctoral course)
Degree: Doctor of Philosophy

(2) Admission Policy

The Department of Astronomical Sciences seeks students with a strong interest in astronomy and the Universe; a passion for unraveling scientific questions through theoretical, observational, and instrument development research; and students who have not only basic academic skills, but also theoretical and creative aptitude required for advanced research.

(3) Department Details (Course Offerings)

Optical and Near Infrared Astronomy
[Educational and Research Guidance Field]
Ground-based astronomy / Optical and infrared telescope system / Planets / Sun, stars and interstellar matter / Galaxies and cosmology

Radio Astronomy
[Educational and Research Guidance Field]
Ground-based astronomy / Radio telescope system / Sun, stars and interstellar matter / Galaxies

General Astronomy and Astrophysics
[Educational and Research Guidance Field]
High-precision astronomical measurement / Astronomy from space / Data analysis and numerical simulation / Earth and planets / Sun, stars and interstellar matter / Galaxies and cosmology

(4) Course-by-Course Education Program to Cultivate Researchers in Physical Sciences with Broad Perspectives

The School of Physical Sciences began its "Course-by-Course Education Program to Develop Student Research Capability and Aptitude" in FY 2009 as a part of MEXT's Program for "Enhancing Systematic Education in Graduate Schools". Currently the School is carrying out its succeeding program, "Course-by-Course Education Program to Cultivate Researchers in Physical Sciences with Broad Perspectives" since FY 2012, offering four specific courses to the students: the Basic Course, the Advanced Research Course, the Project Research Course, and the Development Research Course. In FY 2015, the Department of Astronomical Science accepted five students in the Basic Course and two students in the Advanced Research Course. The Department also offered the e-learning class "Introduction to Observational Astronomy II" as a school-wide common basic subject, as well as the "Exercise in Scientific English" class, in order to provide a good foundation for students at the graduate school.

In order to better prepare students for the international stage, the Department hosted the Asia Winter School during January 26 to 28, 2016, as well as the 2015 Summer Student program at Mitaka, Mizusawa and Okayama campuses to allow undergraduate students a chance to experience research at the Department of Astronomical Science. In addition to the existing Research Assistant system, the Department also provided Associate Researcher positions for the students of the Department of Astronomical Science.

(5) Number of Affiliated Staff (2016/3/31)

Chair of the Department of Astronomical Science	1
Optical and Near Infrared Astronomy Course	
Professors	9
Associate Professors	13
Lecturer	1
Assistant Professors	14
Radio Astronomy Course	
Professors	8
Associate Professors	9
Assistant Professors	16
General Astronomy and Astrophysics Course	
Professors	7
Associate Professors	13
Assistant Professors	14
Total	105

(6) Graduate Students (32 students)

1st year (5 students)

Name	Principal Supervisor	Supervisor	Research Theme
Ando, Misaki	Iono, Daisuke	Saito, Masao Espada, Daniel	Observing Colliding Galaxies Using ALMA
Kambara, Nagaaki	Sekii, Takashi	Watanabe, Tetsuya	Local helioseismology
Kikuta, Satoshi	Imanishi, Masatoshi	Kodama, Tadayuki	Observational study of the formation and evolution of galaxies and supermassive blackholes
Matsuno, Tadafumi	Aoki, Wako	Arimoto, Nobuo	Observational study of metal-poor stars to reveal the history of the near-field Universe
Yoshida, Masaki	Suematsu, Yoshinori	Hara, Hirohisa	On the Structure and Heating Mechanism of Solar Chromosphere and Corona

2nd year (2 students)

Name	Principal Supervisor	Supervisor	Research Theme
Michiyama, Tomonari	Iono, Daisuke	Kodama, Tadayuki Nakanishi, Koichiro	Observing Starburst Galaxies Using ALMA
Yamamoto, Moegi	Kodama, Tadayuki	Iwata, Ikuru	Searching for distant clusters with Subaru/HSC

3rd year (7 students)

Name	Principal Supervisor	Supervisor	Research Theme
Okutomi, Koki	Aso, Yoichi	Flaminio, Raffael	Development of laser interferometer module torwards DECIGO
Onoue, Masafusa	Kashikawa, Nobunari	Miyazaki, Satoshi	Studies on High-z quasars by wide-field imaging observation
Nagasawa, Ryosuke	Hanada, Hideo	Matsumoto, Koji	Development of software for precise LLR data analysis and study of Lunar rotation
Baba, Haruka	Aoki, Wako	Usuda, Tomonori	Development of infrared instruments and observational research for the search of earth-like planets
Ryu, Tsuguru	Hayashi, Saeko	Usuda, Tomonori	Direct-imaging for intermediate mass giants with RV trends
Uchiyama, Hisakazu	Kashikawa, Nobunari	Matsuda, Yuichi	The study of large-scale structures based on wide-imaging observations of Subaru telescope
Taniguchi, Kotomi	Saito, Masao	Oishi, Masatoshi	Establishment of new chemistry for carbon-chain molecules in star-forming regions

4th year (10 students)

Name	Principal Supervisor	Supervisor	Research Theme
Yang, Yi	Hayashi, Saeko	Usuda, Tomonori	Observation and Research on Circumbinary Planets
Ishikawa, Shogo	Kashikawa, Nobunari	Kodama, Tadayuki	Measurement of dark halo mass by clustering analysis of star-forming galaxies
Onishi, Kyoko	Iguchi, Satoru	Iono, Daisuke	Observational study towards black-hole mass: resolving the coevolution process of black hole and galaxy
Onitsuka, Masahiro	Usuda, Tomonori	Takato, Naruhisa	The observational study of the atmospheres of the exoplanets and the brown dwarfs
Sakurai, Junya	Miyazaki, Satoshi	Kobayashi, Yukiyasu	Study of large scale structures in the universe through wide field imaging
Shimakawa, Rizumu	Kodama, Tadayuki	Arimoto, Nobuo	Physical conditions of star-forming galaxies at the epoch of galaxy assembly and their environmental dependence
Suzuki, Taiki	Oishi, Masatoshi	Saito, Masao	Research on Organic Molecules in the Universe
Pathak, Prashant	Takami, Hideki	Minowa, Yosuke	Development of Adaptive Optics system and Coronagraph for Subaru Telescope, and observational study of extrasolar planets
Kobayashi, Hiroshi	Osuga, Ken	Tomisaka, Kohji	Radiation Hydrodynamics Simulations of Clumpy Outflows from Black-hole Accretion disks
Suzuki, Tomoko	Kodama, Tadayuki	Iono, Daisuke	Star formation activities at the epoch just before the peak epoch of galaxy formation probed by [OIII] emitters

5th year (8 students)

Name	Principal Supervisor	Supervisor	Research Theme
Aoki, Sumire	Arimoto, Nobuo	Kodama, Tadayuki Takada, Tadafumi	The origin of the morphology of elliptical galaxy
Saito, Yuriko	Imanishi, Masatoshi	Kashikawa, Nobunari Hayashi, Saeko	Investigating the supermassive black hole to spheroidal stellar mass ratio at z~3
Matsuzawa, Ayumu	Iguchi, Satoru	Saito, Masao	Research of pointing performance verification method of ALMA at sab mm wavelength and absorbing plasma around SMBH
Oh, Daehyeon	Aoki, Wako	Takami, Hideki	Observational Research on formation of exoplanets and brown dwarfs
Min, Cheul Hong	Honma, Mareki	Shibata, Katsunori	Research for a symbiotic star using VERA
Giono, Gabriel	Suematsu, Yoshinori	Hara, Hirohisa	Study of Optical Tests in Ly-α for CLASP Instrumentation
Shino, Nagisa	Honma, Mareki	Shibata, Katsunori	Testing the formation scenario of massive stars by CH_3OH maser
Sukom, Amnart	Tomisaka, Kohji	Hayashi, Saeko	Study of star and planetary formation process and the exoplanets based on infrared observations

Research Student (4 student)

Name	Supervisor	Research Theme
Yang, Yongzhang	Hanada, Hideo	Research of the interior of the moon and the planet based on an application of rotation theory
Cheng, Chen	Nakamura, Fumitaka	Observational Research of Nearby Star-Forming Regions
De Leon, Jerome Pitogo	Usuda, Tomonori	Near-Infrared Observations of Protoplanetary Disks and Exo-Planets
Chida, Hikaru	Honma, Mareki	Probing very Early Stage of Radio Source Evolution in 3C 84 with VERA

2. Education and Research Collaboration with Graduate Schools

Name	Affiliated Institute	Supervisor	Thesis
Kurose, Ippei	The University of Tokyo	Ohashi, Nagayoshi	Observational Study of Star Forming Regions
Sakai, Iori	The University of Tokyo	Kobayashi, Yukiyasu	Development of equipment and data analysis related to JASMINE
Sasaki, Hirokazu	The University of Tokyo	Kajino, Toshitaka	Neutrino oscillation in super novas
Tatsuuma, Misako	The University of Tokyo	Kokubo, Eiichiro	Theoretical Study of Formation and Evolution of Planetary Systems
Fujii, Yoshinori	The University of Tokyo	Flaminio, Raffaele	Development of the vibration isolation system for the KAmioka GRavitational-wave Antenna
Fujita, Ayato	The University of Tokyo	Gouda, Naoteru	Dynamical Structure and its Evolution of the Milky Way
Isoe, Mari	The University of Tokyo	Kokubo, Eiichiro	Theoretical Study of Formation and Evolution of Planetary Systems
Ito, Yuta	The University of Tokyo	Gouda, Naoteru	The dynamical structure of the Galaxy
Kimura, Yasuhisa	The University of Tokyo	Hara, Hirohisa	Study of Sub-arcsec Transition-Region Structures at the Footpoints of Active-Region Loops
Kuramochi, Kazuki	The University of Tokyo	Kobayashi, Hideyuki	A test of in-beam phase referencing with VERA
Kuwahara, Sho	The University of Tokyo	Mizuno, Norikazu	Triggered star formation of the young massive clusters by the cloud-cloud collisions
Kato, Yuta	The University of Tokyo	Mizuno, Norikazu	Star forming activity in the z=2–3 proto-clusters with Infrared Space telescope
Sakai, Daisuke	The University of Tokyo	Kobayashi, Hideyuki	Dynamical study of the Galactic center region with VLBI observations
Hirai, Yutaka	The University of Tokyo	Kajino, Toshitaka	Origin of the r-process elements in galactic chemodynamical evolution model
Lee, Minju	The University of Tokyo	Kawabe, Ryohei	Environmental effects on galaxy evolution in protoclusters
Marchio, Manuel	The University of Tokyo	Flaminio, Raffaele	Development, characterization and improvement of the mirrors for the KAGRA gravitational wave detector
Shu, Shibo	The University of Tokyo	Sekimoto, Yutaro	Development of MKID camera
Aso, Yusuke	The University of Tokyo	Ohashi, Nagayoshi	Environmental effects on star and disk formation
Ohashi, Satoshi	The University of Tokyo	Mizuno, Norikazu	Chemical evolution of the star-forming cores in the giant molecular clouds
Saito, Toshiki	The University of Tokyo	Kawabe, Ryohei	Star Formation and SMBH Activities in Merging Galaxies from High –density Molecular Gas Tracers
Shibagaki, Shota	The University of Tokyo	Kajino, Toshitaka	Revealing the origin of r-process elements with astrophysical simulations
Shibata, Takashi	The University of Tokyo	Kokubo, Eiichiro	Theoretical Study of Formation and Evolution of Planetary Systems
Sekiguchi, Sigeyuki	The University of Tokyo	Sekimoto, Yutaro	Development of broadband polarization MKID camera for Cosmic Microwave Background B-mode observations
Tagawa, Hiromichi	The University of Tokyo	Gouda, Naoteru	Early cosmic merger of multiple black holes
Koyamatsu, Shin	The University of Tokyo	Ohashi, Nagayoshi	Formation and Evolution of Protoplanetary Disks
Sekine, Masakazu	The University of Tokyo	Sekimoto, Yutaro	Development of superconducting device for wideband observation of CMB B-mode polarization
Hara, Takuji	The University of Tokyo	Gouda, Naoteru	Construction of the galaxy model with phase space distribution
Hara, Chihomi	The University of Tokyo	Kawabe, Ryohei	Structures and Kinematics of Dense gas and Molecular Outflow in YSOs.
Fujii, Kosuke	The University of Tokyo	Mizuno, Norikazu	Observational Study of the triggered star formation in the Large Magellanic Cloud
Kiyokane, Kazuhiro	The University of Tokyo	Mizuno, Norikazu	Observational Study of Star Formation process with radio observations

3. Commissioned Graduate Students

Doctoral Course	Affiliated Institute	Period	Supervisor	Thesis
Silva, Andrea	Department of Physics and Astronomy, Tufts University	2015/4/1~ 2016/3/31	Iono, Daisuke	ALMA Observations of Starburst Galaxies
Matsuo, Mitsuhiro	Kagoshima University	2015/4/1~ 2016/3/31	Saito, Masao	Observations of molecular clouds in the outer galaxy with a wideband digital spectrometer
Ui, Takahiro	Hiroshima University	2015/4/1~ 2016/3/31	Yamashita, Takuya	Observational study of the young planet 2MASSJ0525+0125
Oya, Masahito	Nihon University	2015/4/1~ 2016/3/31	Watanabe, Junichi	Development of precise adaptive optics for direct observation of extrasolar planets
Sekiguchi, Takanori	The University of Tokyo	2015/4/1~ 2015/9/30	Flaminio, Raffaele	Development of Vibration Isolation System for KAGRA

Master's Course	Affiliated Institute	Period	Supervisor	Thesis
Mori, Takahiro	Tokyo University of Agriculture and Technology	2015/4/1~ 2016/3/31	Watanabe, Junichi	Wideband Laser frequency comb for IR Doppler observation
Aoki, Misa	International Christian University	2015/4/1~ 2015/9/30	Aoki, Wako	Study of Galactic chemical evolution based on abundance analysis of metal-poor stars
Kozuki, Yuto	Osaka Prefecture University	2015/4/1~ 2016/3/31	Noguchi, Takashi	100 GHz SIS Mixer with wide RF and IF bandwidth
Sunaga, Naoki	Shizuoka University	2015/4/1~ 2015/9/30	Kajino, Toshitaka	Primordial nucleosynthesis in the early universe
Tsuchiya, Chie	The Open University of Japan	2015/4/1~ 2016/3/31	Watanabe, Junichi	Effect of Earth's motion to expansion of radiant points in meteor showers
Fukagawa, Nao	International Christian University	2015/10/1~ 2016/3/31	Kodama, Tadayuki	Inflow and Outflow of Gas in Galaxies and Its Mass Dependence

4. Degrees Achieved with NAOJ Facilities

Name	Degree	Thesis
Oh, Daehyeon	Doctor of Philosophy, SOKENDAI	Direct Imaging Analysis of the Circumstellar Disks and Planetary-mass Companions on Wide Orbit Around a Disk-host Star
Giono, Gabriel	Doctor of Philosophy, SOKENDAI	Novel Instrumentation to Reach the 0.1 % Polarization Accuracy for the Chromospheric Lyman-Alpha Spectro-Polarimeter
Nagasawa, Ryosuke	Master of Science, SOKENDAI	Development of software for precise LLR data analysis and study of Lunar rotation

VIII Public Access to Facilities

1. Mitaka Campus

[Open year-round]
Dates: April to March, 10:00–17:00
Every day except for New Year's season (December 28–January 4)
Visitors: 19,729
Open Facilities: 65-cm Telescope Dome (Observatory History Museum), 20-cm Telescope Dome, Solar Tower Telescope, Exhibit Room, Repsold Transit Instrument Building (Transit Instrument Museum), Astronomical Instruments Museum, Gautier Meridian Circle, Old Library

[Regular Star Gazing Party]
Dates: Friday before second Saturday; fourth Saturday
Visitors: 4,717 (23 events)
Open Facility: 50-cm Telescope for Public Outreach

[4D2U Theater Showings]
Dates: Friday before second Saturday; third and fourth Saturdays
Visitors: 4,446 (35 events)
Open facility: 4D2U Theater

[Special Open-House Event] Mitaka Open House Day
Dates: October 23 (Fri), 2015, 14:00–19:00
October 24 (Sat), 2015, 10:00–19:00
Topic: The Challenges Awaiting Astrobiology
Visitors: 5,036

This event is jointly sponsored by NAOJ, the University of Tokyo School of Science Institute of Astronomy, the SOKENDAI Department of Astronomical Science, and the newly established NINS Astrobiology Center. It has been held for 2 days each year, starting from 2010. The perennially popular lectures related to this year's theme were hosted by the Institute of Astronomy, University of Tokyo ("The Long Road: 13.8 Billion Years from the Start of the Universe to Us" Masuo Tanaka, Associate Professor, University of Tokyo) and NAOJ ("Astrobiology, Opening 'New Worlds' in the Universe" Motohide Tamura, Professor, University of Tokyo, NAOJ, Astrobiology Center; and "Astrobiology, Approaching the Origins of Life" Akihiko Yamagishi, Professor, Tokyo Univsersity of Pharmacy and Life Science).

* Guided tours corresponding to group tours (Dantai Kengaku) were also held. In addition the "Information Space of Science and Astronomy" was opened in 2015 near the south entrance of Mitaka Station to distribute information.

2. Mizusawa Campus

[Open year-round]
Dates: April to March (except for the New Year's season), 9:00–17:00 daily
Visitors: 17,415
Open Facilities: Kimura Hisashi Memorial Museum, VERA 20-m antenna, 10-m VLBI antenna

The campus is opened to the public in cooperation with the Oshu Space & Astronomy Museum (OSAM: Yugakukan) located in the campus.

[Special Open Day] Held as part of Iwate Galaxy Festival 2015 (Festival Hours: 10:00-21:00)
Date: August 22 (Sat.), 2015, 10:00–16:30
Visitors: Approximately 660

Same as last year, the Open Day was co-hosted with Ihatov Space Action Center / the Oshu Space & Astronomy Museum (OSAM: Yugakukan) and the city of Oshu.

Although a performance by a marching band from a local elementary school and tours of the 20-m parabolic antenna were canceled due to rain, NAOJ offered a chance to experience operating the 20-m parabolic antenna; a commemorative photo booth; plastic bottle rocket launching; a quiz game; tours of the supercomputer "Aterui"; a science cafe; and exhibitions of the research highlights of the VERA, RISE, and CfCA projects.

As a new event for this year, a special guided tour of the Kimura Hisashi Memorial Museum, the Array Operations Center (AOC), and the VLBI correlator was carried out, and was well received.

A special lecture was given by Tomoaki Ishiyama, Associate Professor at Chiba University, entitled "Approaching the dark side of the Universe with the power of a supercomputer — dark matter structure formation—". He covered studies on the formation and evolution of the structure of the Universe using supercomputers. His talk was easy to understand for the audience.

OSAM (Yugakukan) offered various experiments in the science stalls, workshops, etc., which were carried out by the students on internships. The Special Open Day was a great success, strengthening ties with the local people.

Iriki: VERA Iriki Station

[Open year-round]
Dates: April to March (except for the New Year's season)
Visitors: Approximately 1,551

[Special Open Day]
Date: August 8 (Sun.), 2015, 12:00–20:00

Since a typhoon hit the VERA Iriki station and the public

open event was canceled last year, in 2015 the event was held for the first time in two years. This special open event was held in conjunction with "Yaeyama Highland Star Festival 2015" hosted by the executive committee primarily formed by members of Satsuma-Sendai city hall and Kagoshima University.

At the NAOJ VERA 20-m radio telescope and the Kagoshima University 1-m optical/infrared telescope facilities, guided tours of telescopes and observation building were held dozens of times. An astronomical 3D movie was presented by the 4D2U project team for the first time at Iriki station. As the special lecture for the year, Dr. Yoshiaki Tamura from Mizusawa VLBI Observatory gave a talk about "the Great Eastern Japan Earthquake" from the perspective of a geophysicist. At night, a public stellar observation was held under the starlit sky. All visitors had fun and were satisfied the with many scientific programs offered in this festival.

Ogasawara: VERA Ogasawara Station

[Open year-round]

Dates: April to March (except for the New Year's season)
Visitors: 8,540

[Special Open Day]

Date: February 14 (Sun.), 2016, 10:00–16:30
Visitors: 222

A special open house event was held this year again under the name "Star Island 15." Same as last year, the free shuttle buses were appreciated by the visitors. The number of visitors was 222, which was more than last year. Because the number of the residents on the island is about 2,000, more than 10 % of the islanders visited this event.

NAOJ offered such attractions as exhibits about the research results of VERA, RISE, and TMT; science experiments; quiz games; and short lectures.

On February 13, a stargazing party was held by the local Ogasawara astronomy club, and NAOJ members also participated. Thanks to good weather, the number of visitors reached about 50.

In addition, Space Lectures were also given by Nobuyuki Sakai of the Mizusawa VLBI Observatory and Hiroki Harakawa of TMT-Japan at the Ogasawara Visitor Center on the night of February 14.

Ishigaki-jima: VERA Ishigaki-jima Station

[Open year-round]

Dates: April to March (except for the New Year's season); premises are open to the public 24 hours/day, and the observation rooms are open during the hours of 10:00–16:30
Visitors: 2,713

[Special Open day]

Date: August 16 (Sun.), 2015, 10:00-17:00
Visitors: 238

The Special Open Day was held as a part of the Southern Island Star Festival.

Same as previous years, attractions like antenna tours, photo booth stickers, merchandise, commemorative lectures, and exhibits were offered.

Ishigaki-jima: Ishigaki-jima Astronomical Observatory

[Open year-round]

Dates: April to March
Open Hours: Wednesdays through Sundays (Except for the New Year's season; when Monday/Tuesday is a national holiday, it is opened and closed on the next day.), 10:00–17:00
Stargazing sessions: Evenings on Saturdays, Sundays, Holidays, and Star Festival week days (19:00–22:00), two 30-minute sessions per evening (four in August)
4D2U screenings: from 15:00 to 15:30 every day when the Observatory is open
Visitors: 13,906 (1,032 during the Southern Island Star Festival)
Open facilities: Murikabushi 105-cm optical/infrared telescope, Hoshizora Manabi no Heya (Room of Learning the Starlit Sky) (featuring the 4D2U "Four Dimensional Digital Universe"), interior of the observation dome (including exhibits of astronomical images)

The "Hoshizora Manabi no Heya" (Room of Learning the Starlit Sky), constructed adjacent to the Observatory in 2013 by the city of Ishigaki, was very popular, welcoming 3,925 guests.

[Southern Island Star Festival 2015]

Dates: August 15 (Sat.) to August 23 (Sun.), 2015
Visitors: 10,930

This year is the 14th anniversary of both the completion of VERA Ishigaki-jima Station and the Southern Island Star Festival. Approximately 9,000 visitors attended the light-down stargazing event blessed with better weather than ever before.

In addition, because this was the 70th anniversary of the end of World War II, a film named "Vega shining over the battlefield" produced by the Yamanashi Prefectural Science Museum was screened every day during the period, and these became memorial screenings. The annual planetarium screening was attended by 435.

The activities at Ishigaki-jima Astronomical Observatory help regional development through school education, lifelong learning, and sightseeing. The cooperation agreement between NAOJ and the Tourism Association of the city of Ishigaki has been finalized. And it is widely recognized that the starry sky can be used as a tourism resource. Considering this situation, we will continue to strengthen our ties with other associations.

3. Nobeyama Campus

[Open year-round]
Open Time: 8:30–17:00 (every day except the New Year's season (Dec. 29 to Jan. 3), open until 18:00 during the summer (Jul. 20 to Aug. 31))
Visitors: 50,185
Open facilities: Nobeyama 45-m Radio Telescope, Nobeyama Millimeter Array, Nobeyama Radioheliograph, etc. (viewing only)

[Open House Day]
Date: August 22 (Sat.), 2015, 9:30–16:00
Visitors: 2,429

The Nobeyama branch was crowded with 2,429 visitors on the 2015 Open House Day. The theme of the Open House Day was "Searching for the Origin of Life in the Universe." We had two lectures on the theme, which attract large audiences every year. One was "The Search for Life in the Universe" by the former Director, Prof. Miyama, Shoken . The other was "Biotic Species in the Universe 2 –Life is linked with the Universe" by Dr. Ohishi, Masatoshi (NAOJ). We had some established hands-on events such as touch the main reflector panel of the Nobeyama 45-m Radio Telescope, the antenna handicrafts, solar radio wave detector handicrafts, and the antenna origami. In addition, some short lectures and the Q&A corner were carried out. These events were held by 119 staff members, including NRO alumni, other project staff members, and volunteers. Also with NRO character, Dr.Nobeyama and Nagano Pref. PR character, ARUKUMA. NRO was more festive on that day.

[Jimoto Kansha Day (Thanks Day for the locals)]
Date: October 10 (Sat.), 2015, 13:30–19:00
Visitors: 76

The local people have difficulty participating in the Open House Day during the farming season. They have said that they do not know much about what we, not only NRO but also Tsukuba and Shinshu Universities, study in Nobeyama. In order to respond to these comments, we established this event in cooperation with Tsukuba University, Agricultural and Forestry Research Center, Yatsugatake Forest and Shinshu University, Faculty of Agriculture, Education and Research Center of Alpine Field Science. As an event, we had the forest and trees rally for walking around 4 points in Tsukuba University Meguminomori (the Mercy Forest), which had its opening ceremony on the same day. It was very popular among the visitors. We also had an introduction from each institute about its research activities.

4. Okayama Campus

Okayama Astrophysical Observatory
[Open year-round]
Dates: 9:00–16:30 daily
Visitors: 11,126
Open Facilities: Window view of Okayama 188-cm Reflector Telescope

[Special Open House]
Date: August 29 (Sat.), 2015, 9:30–16:30
Visitors: 366

We had two Exoplanet Naming commemorative lectures at the 188-cm reflector telescope in the dome.

The first lecture, by Associate Professor Bun-ei Sato of Tokyo Institute of Technology, was "Exoplanets found on Okayama." The second lecture, by Professor Norio Narita of the AstroBiology Center/NINS, was "Exploring exoplanets with the new observation instrument MuSCAT on the 188-cm telescope." The both 90 minute lectures attracted nearly 110 audience members. The special open house event was co-hosted with Asakuchi City and the Asakuchi City Board of Education, with support from the Yakage Town Board of Education. In particular, the Observatory would like to thank the members of Asakuchi City and the Asakuchi City Board of Education for their considerable assistance in arranging complimentary shuttle bus service between the Observatory and temporary parking at Kamogata Station on the JR San'yo Main Line.

[Special Stargazing Party]
Date: April 11 (Sat.), 2015, 18:30–22:45
Visitors: 112
186 applications for 544 applicants were received. Castor of Gemini and Jupiter were viewed.

Date: November 3 (Tue., Culture Day), 2015, 17:00–21:15
Visitors: 103
76 applications for 192 applicants were received. Vega of Lyra and globular cluster M15 were viewed.

Special stargazing parties co-hosted with the Okayama Astronomical Museum were held twice over the course of the year, in spring and fall. Maximum participation for each special session was 100. As applications exceeded capacity for both sessions, participants were selected by lottery, with 120 winners being selected to allow for cancellations.

5. Subaru Telescope

[Summit Facility Tour]

Dates open for public tour: 77 (these dates are listed in the public tour program page at the Subaru Telescope's web site; the tour was cancelled during the summer due to the road closure, 16 days were affected; no tours scheduled during the winter months of December to March)

Public tour visitors: 421 (due to the road closure, etc., more than 100 people were not able to visit)

Special tour visitors: 131 visits, 538 visitors

As some special tours were conducted during public tour programs, the total number of actual visitors was 923.

*Special note: During the summer from late June to mid-August, the tours were cancelled due to the closure of the Maunakea access road and Visitor Information Station. The period corresponds to summer vacation in Japan, the U.S.A., and many other places, so it had a large impact on the tour program.

[Base Facility Tour]

Special tour visitors: 67 visits, 393 visitors

[Public information]

Primary means of public information announcement is posting it on the official website http://subarutelescope.org

- Science results from the Subaru Telescope – 14 Japanese and 17 English articles
- Depictions of special activities, or announcements about Calls for Proposals and recruitment – 14 Japanese and 24 English articles
- Web postings are supplemented by social media via official accounts

• Twitter accounts – SubaruTelescope (for Japanese), SubaruTel_Eng (for English)
• Facebook pages – 国立天文台 (for Japanese), National Astronomical Observatory of Japan (for English, started February 2015)
• YouTube channels – SubaruTelescopeNAOJ (for Japanese), SubaruTelescopeNAOJe (for English)

[Outreach]

1. Lectures at Subaru Telescope's Hilo Base Facility

2015

July 13: Subaru Telescope staff gave a lecture at Subaru Telescope's Hilo Base Facility to the Upward Bound Summer Workshop for local high school students.

July 24: Subaru Telescope staff gave a lecture at Subaru Telescope's Hilo Base Facility to the PAES (Pacific Astronomy & Engineering Summer Summit) for high school students from 5 countries.

August 5: Subaru Telescope staff gave a lecture at Subaru Telescope's Hilo Base Facility for the junior high School students from Nago City in Okinawa.

August 18: Subaru Telescope staff gave a lecture at Subaru Telescope's Hilo Base Facility for the Fukushima Kenjin Kai members.

August 19: Subaru Telescope staff gave a lecture at Subaru Telescope's Hilo Base Facility for the Kanto Gakuin High School students from Kanagawa.

August 19: Subaru Telescope staff gave a lecture at Subaru Telescope's Hilo Base Facility for the junior high school students from Fukushima.

August 20: Subaru Telescope staff gave a lecture at Subaru Telescope's Hilo Base Facility for the Waseda Koto Gakuin High School students from Tokyo.

August 24: Subaru Telescope staff gave a lecture at Subaru Telescope's Hilo Base Facility for the Kawagoe High School students from Saitama.

August 26: Subaru Telescope staff gave a lecture at Subaru Telescope's Hilo Base Facility for the Hibiya High School students from Tokyo.

September 23: Subaru Telescope staff gave a lecture at Subaru Telescope's Hilo Base Facility for the Japanese Group (astronomy supporters from Japan).

September 28: Subaru Telescope staff gave a lecture at Subaru Telescope's Hilo Base Facility for the University of the Ryukyus students.

October 15: Subaru Telescope staff gave a lecture at Subaru Telescope's Hilo Base Facility for the Namiki Secondary School students from Ibaraki.

November 18: Subaru Telescope staff gave a lecture at Subaru Telescope's Hilo Base Facility for the Osaka Kokusai Science Club members.

November 20: Subaru Telescope staff gave a lecture at Subaru Telescope's Hilo Base Facility for the selected high school students from Okinawa.

December 7: Subaru Telescope staff gave a lecture at Subaru Telescope's Hilo Base Facility for the Ryugasaki Daiichi High School students from Ibaraki.

December 8: Subaru Telescope staff gave a lecture at Subaru Telescope's Hilo Base Facility for the Senri High School students from Osaka.

2016

January 8: Subaru Telescope staff gave a lecture at Subaru Telescope's Hilo Base Facility for the Seisho High School students from Nara.

January 26: Subaru Telescope staff gave a lecture at Subaru Telescope's Hilo Base Facility for the Sanbonmatsu High School students from Kagawa.

March 2: Subaru Telescope staff gave a lecture at Subaru Telescope's Hilo Base Facility for the Nagaoka High School students from Niigata.

March 15: Subaru Telescope staff gave a lecture at Subaru Telescope's Hilo Base Facility for the Ritsumeikan Uji High School students from Kyoto.

March 17: Subaru Telescope staff gave a lecture at Subaru Telescope's Hilo Base Facility for the Masuda High School students from Shimane.

March 23: Subaru Telescope staff gave a lecture at Subaru Telescope's Hilo Base Facility for the Kanagawa University High School students.

2. Remote Presentation

2015

April 25: Subaru Telescope staff gave a presentation via remote conferencing system from Subaru Telescope's Hilo Base Facility to Science Museum in Tokyo.

June 6: Subaru Telescope staff gave a presentation via remote conferencing system from Subaru Telescope's Hilo Base Facility to Science Museum in Tokyo.

June 8: Subaru Telescope staff gave a presentation via remote conferencing system from Subaru Telescope's Hilo Base Facility to Izumo High School in Shimane.

July 2: Subaru Telescope staff gave a presentation via remote conferencing system from Subaru Telescope's Hilo Base Facility to Masuda City in Shimane for its Science Town event.

July 14: Subaru Telescope staff gave a presentation via remote conferencing system from Subaru Telescope's Hilo Base Facility to the University of the Ryukyus in Okinawa.

July 17: Subaru Telescope staff gave a presentation via remote conferencing system from Subaru Telescope's Hilo Base Facility to Tokyo Mirai University in Tokyo.

October 31: Subaru Telescope staff gave a presentation via remote conferencing system from Subaru Telescope's Hilo Base Facility to Science Museum in Tokyo.

November 9: Subaru Telescope staff gave a presentation via remote conferencing system from Subaru Telescope's Hilo Base Facility to Masuda High School in Shimane.

November 16: Subaru Telescope staff gave a presentation via remote conferencing system from Subaru Telescope's Hilo Base Facility to Masuda High School in Shimane.

November 27: Subaru Telescope staff gave a presentation via remote conferencing system from Subaru Telescope's Hilo Base Facility to the Galaxity in Adachi Ward of Tokyo.

December 2: Subaru Telescope staff gave a presentation via remote conferencing system from Subaru Telescope's Hilo Base Facility to Matsubara Junior High School in Shiga.

December 11: Subaru Telescope staff gave a presentation via remote conferencing system from Subaru Telescope's Hilo Base Facility to Arakawa 3rd Junior High School in Tokyo.

December 18: Subaru Telescope staff gave a presentation via remote conferencing system from Subaru Telescope's Hilo Base Facility to Inagawa Town in Hyogo.

2016

February 12: Subaru Telescope staff gave a presentation via remote conferencing system from Subaru Telescope's Hilo Base Facility to Wakayama Shin-Ai High School.

March 5: Subaru Telescope staff gave a presentation via remote conferencing system from Subaru Telescope's Hilo Base Facility to Science Museum in Tokyo.

3. Lectures, Demonstrations, Workshops, etc. in the Vicinity

2015

April 17: Subaru Telescope staff gave a lecture and panel discussion for the Journey master educators workshop, career panel discussion at the 'Imiloa Astronomy Center in Hilo.

May 3: Subaru Telescope staff gave a lecture at the Honpa Hongwanji Betsuin in Hilo.

July 13: Subaru Telescope staff gave a lecture at the Lyman Museum in Hilo.

July 21: Subaru Telescope staff gave a lecture for the PAES (Pacific Astronomy & Engineering Summer Summit) program at the University of Hawai`i at Hilo.

August 18: Subaru Telescope staff gave a lecture for the high school students from China at the University of Hawai`i at Hilo.

August 21: Subaru Telescope staff gave a lecture for the high school students from Sumoto City, Hyogo and the local high school students at the Kilauea Military Camp.

Sepember 10–13: Subaru Telescope staff gave three lectures at HawaiiCon.

October 16: Subaru Telescope staff gave a lecture at the ‘Imiloa Astronomy Center in Hilo.

November 17: Subaru Telescope staff gave a lecture for the Chiba Meitoku High School students at the University of Hawai`i at Hilo.

2016

January 2: Subaru Telescope staff gave a lecture at the Visitor Information Station, Maunakea.

January 10: Subaru Telescope staff gave a lecture for the Seisa Junior High School students from Kanagawa at the Kilauea Military Camp.

January 30: Subaru Telescope staff provided four astronomy workshops during Onizuka Science Day at the University of Hawai`i at Hilo.

March 7–11: For the Journey through the Universe program, Subaru Telescope staff went to 55 classes in local public schools and delivered presentations, hands-on experiences, and other demonstrations.

4. Lectures in Japan

2015

April 5: Subaru Telescope staff gave a lecture at Science Museum in Tokyo.

October 5 & 7: Subaru Telescope staff gave a lecture at the Nanbu Medical Center and Nanbu Child Medical Center in Okinawa.

October 6: Subaru Telescope staff gave a lecture for Okinawa Shogaku High School and Junior High School students in Okinawa.

October 8: Subaru Telescope staff gave a lecture at the Ishigaki City Hall in Okinawa.

November 2: Subaru Telescope staff gave a lecture at the International Science Fair at Ritsumeikan High School in Kyoto.

November 4: Subaru Telescope staff gave two lectures for Ritsumeikan High School students in Kyoto.

November 6: Subaru Telescope staff gave a lecture at Niwakubo Junior High School in Osaka (as part of the Fureai “Friendly” Astronomy Program).

5. Others

2015

May 2: Subaru Telescope staff provided a booth with many hands-on activities about the Subaru Telescope at the AstroDay event in Hilo and interacted with hundreds of families in the local community.

August 2: Subaru Telescope staff provided a booth at the Aloha Art Festival in 'Imiloa Astronomy Center, Hilo.

August 3–14: Subaru Telescope staff provided a booth and gave demonstrations at the IAU General Assembly in Honolulu.

2016

January 27: Subaru Telescope staff provided a booth and gave demonstrations at a special event at 'Imiloa Astronomy Center in Hilo.

January 30: Subaru Telescope staff made presentations about the Subaru Telescope at the Onizuka Science Day event at the University of Hawai`i at Hilo and interacted with hundreds of families in the local community.

February 18: Subaru Telescope staff provided a booth at the Career Expo and gave demonstrations for local Junior High School and High School students in Hilo.

February 21: Subaru Telescope staff provided an exhibition with many hands-on activities about the Subaru Telescope at the ‘Imiloa Astronomy Center’s open house and interacted with a wide range of age groups in the local community.

March 26: Subaru Telescope staff provided an exhibition with other observatories and interacted with the local community.

6. Media Coverage

Japanese 14, English 8

IX Overseas Travel

Research and Academic Staff Overseas Travel

(Including employees on annual salary system)

category / country/area	Business Trip	Training	Total
South Korea	47	0	47
China	19	0	19
Thailand	9	0	9
Taiwan	22	0	22
Hong Kong	1	0	1
Singapore	4	0	4
Indonesia	1	0	1
Philippines	0	0	0
Other areas in Asia	6	0	6
Hawai`i	83	0	83
U.S.A.	89	0	89
Australia	9	0	9
Italy	11	0	11
U.K.	22	0	22
France	25	0	25
Canada	4	0	4
Guam, Saipan	0	0	0
Germany	17	0	17
Other areas in Europe and Oceania	56	0	56
Mexico	0	0	0
Brazil	0	0	0
Africa	3	0	3
Other areas in South and Central America *	35	0	35
Total	463	0	463

* Most travelers to South and Central America went to Chile.

X Award Winners

Award Recipients	Affiliated Division	Job Title	Award	Date
Miyazaki, Satoshi; Komiyama, Yutaka; Kawanomoto, Satoshi	Advanced Technology Center/Subaru Telescope/ Subaru Telescope	Associate Professor/Assistant Professor/Research Expert	The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology Prizes for Science and Technology (Research Category) 2015	2015/4/15
PARTY/National Astronomical Observatory of Japan			D&AD Digital Design Wood Pencil	2015/5/21
Hinode Extreme Ultraviolet Imaging Spectrometer (EIS) team	Hinode Science Center		Royal Astronomical Society 2015 Group Achievement Award in geophysics	2015/7/2
Suematsu, Yoshinori	Hinode Science Center	Associate Professor	The Second ISAS Award	2016/2/6
Chiba,Kurazo; Kawashima, Susumu: Kikuchi, Kenichi	NAOJ Chile Observatory	Specially Appointed Senior Specialist/ Chief Research Engineer/Chief Research Engineer	2015 NAOJ Director General Prize	2016/3/4
Tatsuzawa, Kaichi; Okayasu, Rikako; Saito,Yasufumi	Division of Radio Astronomy/Division of Radio Astronomy/Advanced Technology Center	Research Expert/ Research Supporter/Research Expert	2015 Director General Prize	2016/3/4
Miyazaki, Satoshi	Advanced Technology Center	Associate Professor	20th Chushiro Hayashi Prize	2016/3/15
Tanaka, Masaomi	Division of Theoretical Astronomy	Assistant Professor	27th Japan Astronomical Society Research Award	2016/3/16
Iye, Masanori	TMT-J Project Office	RCUH/Professor emeritus	The International Society for Optical Engineering, SPIE Senior Fellow	—

XI Library, Publications

1. Library

Number of books in each library (2016/3/31)

	Japanese Books	Foreign Books	Total
Mitaka	17,277	45,487	62,764
Okayama	220	3,344	3,564
Nobeyama	1,225	6,279	7,504
Mizusawa	4,957	18,074	23,031
Hawaii	1,568	4,259	5,827
Total	25,247	77,443	102,690

Number of journal titles in each library (2016/3/31)

	Japanese Journals	Foreign Journals	Total
Mitaka	637	773	1,410
Okayama	4	18	22
Nobeyama	16	82	98
Mizusawa	659	828	1,487
Hawaii	18	18	36
Total	1,334	1,719	3,053

2. Publication

Here we list continuing publications produced by NAOJ in FY 2015.
The data is based on publications delivered to the libraries.

Mitaka

01) Report of the National Astronomical Observatory of Japan, Vol. 17: 1 issue
02) Annual Report of the National Astronomical Observatory of Japan (in Japanese), no. 27, Fiscal Year 2014: 1 issue
03) Annual Report of the National Astronomical Observatory of Japan (in English), vol. 17, Fiscal Year 2014: 1 issue
04) National Astronomical Observatory Reprint, No. 2651–2748; 98 issues
05) Calendar and Ephemeris, 2016; 1 issue
06) NAOJ News, No. 261–272; 12 issues
07) Guide to the National Astronomical Observatory of Japan pamphlet (Japanese); 1 issue
08) Guide to the National Astronomical Observatory of Japan pamphlet (English); 1 issue
09) Rikanenpyo (Chronological Scientific Tables), 2016; 1 issue
10) National Astronomical Observatory of Japan 2015 External Review Report; 1 issue

XII Important Dates

April 1, 2015 – March 31, 2016

2015	
April 2	Accompanying the reopening of the 4D2U Dome Theater, a private showing was held for the press, with 26 guests in attendance.
April 11	Spring 2015 Special Stargazing Party held at Okayama Astrophysical Observatory, with 112 visitors in attendance (out of 544 applicants).
April 19	Sixth Open Observatory event held at the Ibaraki University Center for Astronomy and the NAOJ Mizusawa VLBI Observatory Ibaraki Station, with approximately 230 visitors in attendance.
April 23	The Joint ALMA Observatory issued the ALMA Cycle 4 call for proposals for early scientific observations which starts from October 2015 and received by the deadline a total of 1,582 observation proposals from astronomers around the world, which exceeded the number of proposals for Cycle 2 that counted 1,382. A total of 3,608 astronomers are engaged in the submitted proposals for Cycle 3 as either principal investigators or co-investigators.
May 2	Subaru Telescope staff provided a booth with many hands-on activities about the Subaru Telescope at the AstroDay event in Hilo and interacted with hundreds of families in the local community.
May 7~8	Mr. Kosaburo Nishime, State Minister for Internal Affairs and Communications and his party visited the Operations Support Facility (OSF) and Array Operations Site (AOS) of ALMA for a study tour.
May 25~28	"Artists in Residence in NAOJ Nobeyama" was held in Nobeyama Radio Observatory by Siga-Kogen Roman Museum (Yamanouchi-machi, Nagano). There were 5 participants who were artists related with Nagano Prefecture.
June 1~5	Observation training of Radio Astronomy at Nobeyama Radio Observatory for Undergraduate Students was performed; there were 12 participants.
June 23~24	"Summer Break Junior Astronomical Classes + You are Galileo!" held in the Mitaka area.
July 4	The Star Festival held using the 6-m antenna at the NAOJ Mizusawa VLBI Observatory Kagoshima station in Kagoshima city Kinko Bay Park, co-hosted with Kagoshima city and Kagoshima University, with approximately 100 visitors in attendance.
July 7	NAOJ Chile Observatory staff members gave a lecture as a Tanabata event at the Japanese School in Santiago.
July 21	Subaru Telescope staff gave a lecture for the PAES (Pacific Astronomy & Engineering Summer Summit) program at the University of Hawaii at Hilo.
July 21~24, July 27	Facility Guide Week for Educational Organization was carried out at Nobeyama Radio Observatory.
July 27	The National Astronomical Observatory of Japan (NAOJ) and the Academia Sinica Institute of Astronomy and Astrophysics (ASIAA) in Taiwan signed an agreement concerning ALMA, following the conclusion of a prior agreement concerning the operations and development of ALMA which was entered into as of July 21 between the National Institutes of Natural Sciences of Japan (NINS) and Academia Sinica (AS) in Taiwan. These agreements will further strengthen cooperation between Japan and Taiwan for the operations of ALMA.
August 1~3	Ninth Z-star Research Team event held for high school students in the six Tohoku prefectures, with 11 participants attending. The participants were divided into two groups and searched new water vapor masers using VERA Mizusawa 20m radio telescope. One team found 3 maser candidates from variable stars and the other team found 3 maser candidates from star forming regions.
August 1~3	The VLBI experiment was successfully carried out connecting ALMA's antennas and six VLBA's antennas of the National Radio Astronomy Observatory.
August 1 ~September 30	Sixth International Festival of Scientific Visualization — International Year of Light 2015 — held with over 1 million visitors attending during the festival period.
August 8	Special Open House of VERA Iriki station held jointly with the Yaeyama Highland Star Festival 2015, with approximately 4,000 visitors in attendance.
August 12~14	Chura-boshi Research Team workshop for the local Yaeyama high school in Ishigaki-jima held at VERA Ishigaki-jima Station and Ishigaki-jima Astronomical Observatory, with 18 participants in attendance. One team using radio-waves discovered 1 maser. A second team using visible light observations with the Murikabushi telescope discovered 3 asteroids.

August15~23	The Southern Island of Star Festival 2015 held together with a special open house event at the VERA Ishigaki-jima Station and Ishigaki-jima Astronomical Observatory with approximately 10,930 visitors to the whole Star Festival. Events included an astronomical observation party at the Ishigaki-jima Astronomical Observatory, attended by 257 visitors; and a special public opening of the VERA Station attended by 238 visitors.
August 22	Iwate Galaxy Festival 2015, a special open house day of Mizusawa Campus, held with 660 visitors in attendance.
August 22	Open House day of Nobeyama Radio Observatory. There were 2,429 visitors for this event.
August 29	Special Open House event held at Okayama Astrophysical Observatory, with 366 visitors in attendance.
September 26 ~October 25	"Information Space of Science and Astronomy" (Mitaka Station, South Exit, Chuo Street) opened. Special exhibit "Commemorating the International Year of Light, Cosmic Light" opened with 5,482 guests in attendance. * Established as a joint establishment with the Mitaka City Planning Board in cooperation with Mitaka City and Mitaka Network University, this space distributes information about astronomy and the Universe. In the half-a-year before the end of the fiscal year, it welcomed 9,981 guests.
September 27 ~September 29	"International Symposium on the NAOJ Museum" held with 96 guests attending from 9 countries; 7 guests participated via internet relay from Japan and other countries.
October 10	"Jimoto Kansha Day (Thanks Day for the Locals)" was held at Tsukuba Univ. Forest. It was carried out by 3 Nobeyama Institutes (Tsukuba and Shinshu Universities and Nobeyama Radio Observatory). There were 76 participants.
October 14	The Joint ALMA Office (JAO) welcomed 30 students of the Japanese School in Santiago including those at the third grade or higher and gave a tour for their out-of-school activity.
October 18	The third "three selections of Japanese starry sky summit" was held in Minamimaki-mura by the executive committee consisting of Minamimaki tourist association, Minamimaki-mura, and Nobeyama Radio Observatory. This summit also cooperated with Ishigaki and Bisei astronomical observatory.
October 23 ~October 24	Mitaka Open House Day held, with 5,036 visitors in attendance.
November 3	Fall 2015 Special Stargazing Party held at Okayama Astrophysical Observatory, with 103 visitors in attendance (out of 192 applicants).
November 24	22th Astronomy Lecture for Science Reporters "In what does Rikanenpyo tell us now?" held, with 39 participants in attendance.
November 25	A ceremony for FY 2015 continuous service recognition held. 5 staff members were recognized: Takashi Ito, Tomoyuki Onishi, Ikuko Yoshikawa, Hiroko Kikkawa, Yukiko Kamata.
December 3~4	As part of the reconstruction support for the children in the areas affected by the Great East Japan Earthquake, the NAOJ Chile Observatory provided distance learning connecting ALMA Operations Support Facility (OSF) with a junior high school in Fukushima Prefecture and an elementary school in Miyagi Prefecture.
December 12	ALMA public lecture/Osaka Science Museum Special Night "Exploring with ALMA" held, with 200 guests in attendance.
December 13	NAOJ lecture meeting "The challenge which exceeded space-time: General Relativity's 100th Anniversary and Gravitational Wave Astronomy" held at Hitotsubashi Hall, Hitotsubashi University with 400 guests in attendance.
December15	The National Institutes of Natural Sciences of Japan (NINS), the European Southern Observatory (ESO), and the National Science Foundation (NSF) signed an agreement concerning the operations of ALMA in Tokyo.

2016

January 7 ~February 21	Photo exhibit "Observatory Landscapes" opened at "Information Space of Science and Astronomy" with 1,404 guests in attendance.
January 28	The NAOJ Chile Observatory gave talks at a summer camp for students from the first to fourth grades of the Japanese School in Santiago.
January 30	Subaru Telescope staff made presentation about the Subaru Telescope at the Onizuka Science Day event at the University of Hawai'i at Hilo and interacted with hundreds of families in the local community.
February 14	Star Island 15 open house event of VERA Ogasawara Station held, with 222 visitors in attendance (more than the average year).
March 7~11	For the Journey through the Universe program, Subaru Telescope staff went to 55 classes in local public schools and delivered presentations, hands-on experiences, and other demonstrations.
March 30	A ceremony for FY 2015 continuous service recognition for retiring staff members held. 4 staff members were recognized: Takashi Sakurai, Goro Sasaki, Yasuo Torii, Yoshizo Iizuka.

XIII Publications, Presentations

1. Refereed Publications

Aasi, J., et al. including **Fujimoto, M.-K.**, **Hayama, K.**, **Kawamura, S.**, **Mori, T.**, **Nishida, E.**, **Nishizawa, A.**: 2015, Characterization of the LIGO detectors during their sixth science run, *Classical Quantum Gravity*, **32**, 115012.

Abbott, B. P., et al. including **Flaminio, R.**, LIGO Scientific Collaboration, Virgo Collaboration: 2016, Astrophysical Implications of the Binary Black Hole Merger GW150914, *ApJ*, **818**, L22.

Abbott, B. P., et al. including **Flaminio, R.**, LIGO Scientific Collaboration, Virgo Collaboration: 2016, Observation of Gravitational Waves from a Binary Black Hole Merger, *Phys. Rev. Lett.*, **116**, 061102.

Abbott, B. P., et al. including **Flaminio, R.**, LIGO Scientific Collaboration, Virgo Collaboration: 2016, GW150914: Implications for the Stochastic Gravitational-Wave Background from Binary Black Holes, *Phys. Rev. Lett.*, **116**, 131102.

Abbott, B. P., et al. including **Flaminio, R.**, LIGO Scientific Collaboration, Virgo Collaboration: 2016, GW150914: The Advanced LIGO Detectors in the Era of First Discoveries, *Phys. Rev. Lett.*, **116**, 131103.

Akiyama, E., et al. including **Kusakabe, N.**, **Kataoka, A.**, **Hashimoto, J.**, **Kwon, J.**, **Kudo, T.**, **Kandori, R.**, **Currie, T.**, **Ohashi, N.**, **Egner, S.**, **Guyon, O.**, **Hayano, Y.**, **Hayashi, M.**, **Hayashi, S.**, **Ishi, M.**, **Iye, M.**, **Miyama, S.**, **Morino, J.-I.**, **Nishimura, T.**, **Pyo, T.-S.**, **Suenaga, T.**, **Suto, H.**, **Suzuki, R.**, **Takahashi, Y. H.**, **Takato, N.**, **Terada, H.**, **Tomono, D.**, **Takami, H.**, **Usuda, T.**, **Tamura, M.**: 2015, Discovery of a Disk Gap Candidate at 20 AU in TW Hydrae, *ApJ*, **802**, L17.

Akiyama, E., **Hasegawa, Y.**, **Hayashi, M.**, **Iguchi, S.**: 2016, Planetary System Formation in the Protoplanetary Disk around HL Tauri, *ApJ*, **818**, 158.

Akiyama, K., et al. including **Hada, K.**, **Nagai, H.**, **Honma, M.**: 2015, 230 GHz VLBI Observations of M87: Event-horizon-scale Structure during an Enhanced Very-high-energy γ-Ray State in 2012, *ApJ*, **807**, 150.

Akiyama, M., et al. including **Furusawa, H.**, **Takata, T.**, **Takato, N.**, **Sekiguchi, K.**: 2015, The Subaru-XMM-Newton Deep Survey (SXDS). VIII. Multi-wavelength identification, optical/NIR spectroscopic properties, and photometric redshifts of X-ray sources, *PASJ*, **67**, 82.

ALMA Partnership, et al. including **Asaki, Y.**, **Hirota, A.**, **Nakanishi, K.**, **Espada, D.**, **Kameno, S.**, **Nagai, H.**, **Sawada, T.**, **Takahashi, S.**, **Tatematsu, K.**, **Kurono, Y.**, **Iguchi, S.**, **Hasegawa, T.**, **Saito, M.**, **Inatani, J.**, **Mizuno, N.**, **Asayama, S.**, **Kosugi, G.**, **Morita, K.-I.**, **Chiba, K.**, **Kawashima, S.**, **Ohashi, N.**, **Ogasawara, R.**, **Sakamoto, S.**, **Noguchi, T.**, **Chikada, Y.**, **Hiramatsu, M.**, **Iono, D.**, **Shimojo, M.**, **Komugi, S.**, **Muller, E.**, **Herrera, C.**, **Miura, R. E.**, **Ueda, J.**, **Chibueze, J.**, **Kiuchi, H.**, **Ukita, N.**, **Sugimoto, M.**, **Kawabe, R.**, **Hayashi, M.**, **Kaifu, N.**, **Ishiguro, M.**: 2015, The 2014 ALMA Long Baseline Campaign: An Overview, *ApJ*, **808**, L1.

ALMA Partnership, et al. including **Asaki, Y.**, **Hirota, A.**, **Nakanishi, K.**, **Espada, D.**, **Kameno, S.**, **Sawada, T.**, **Takahashi, S.**, **Akiyama, E.**, **Kawamura, A.**, **Nguyen Luong, Q.**, **Sanhueza, P.**, **Kurono, Y.**: 2015, The 2014 ALMA Long Baseline Campaign: First Results from High Angular Resolution Observations toward the HL Tau Region, *ApJ*, **808**, L3.

ALMA Partnership, et al. including **Asaki, Y.**, **Hirota, A.**, **Nakanishi, K.**, **Espada, D.**, **Kameno, S.**, **Sawada, T.**, **Takahashi, S.**, **Ao, Y.**, **Hatsukade, B.**, **Matsuda, Y.**, **Iono, D.**, **Kurono, Y.**: 2015, The 2014 ALMA Long Baseline Campaign: Observations of the Strongly Lensed Submillimeter Galaxy HATLAS J090311.6+003906 at z = 3.042, *ApJ*, **808**, L4.

ALMA Partnership, et al. including **Asaki, Y.**, **Hirota, A.**, **Nakanishi, K.**, **Espada, D.**, **Kameno, S.**, **Sawada, T.**, **Takahashi, S.**, **Kurono, Y.**, **Tatematsu, K.**: 2015, The 2014 ALMA Long Baseline Campaign: Observations of Asteroid 3 Juno at 60 Kilometer Resolution, *ApJ*, **808**, L2.

Alonso-Herrero, A., et al. including **Imanishi, M.**: 2016, A mid-infrared spectroscopic atlas of local active galactic nuclei on sub-arcsecond resolution using GTC/CanariCam, *MNRAS*, **455**, 563-583.

Ando, R., Kohno, K., Tamura, Y., Izumi, T., Umehata, H., **Nagai, H.**: 2016, New detections of Galactic molecular absorption systems toward ALMA calibrator sources, *PASJ*, **68**, 6.

Antolin, P., Okamoto, T. J., De Pontieu, B., Uitenbroek, H., Van Doorsselaere, T., Yokoyama, T.: 2015, Resonant Absorption of Transverse Oscillations and Associated Heating in a Solar Prominence. II. Numerical Aspects, *ApJ*, **809**, 72.

Antolin, P., Vissers, G., Pereira, T. M. D., van der Voort, L. R., Scullion, E.: 2015, The Multithermal and Multi-stranded Nature of Coronal Rain, *ApJ*, **806**, 81.

Ao, Y., **Matsuda, Y.**, Beelen, A., Henkel, C., Cen, R., De Breuck, C., Francis, P. J., Kovács, A., Lagache, G., Lehnert, M., Mao, M. Y., Menten, K. M., Norris, R. P., Omont, A., **Tatemastu, K.**, Weiß, A., Zheng, Z.: 2015, What powers Lyα blobs?, *A&A*, **581**, A132.

Aoki, W.: 2015, Molecular Line Formation in the Extremely Metal-poor Star BD+44 493, *ApJ*, **811**, 64.

Arai, T., Matsuura, S., Bock, J., Cooray, A., Kim, M.-G., Lanz, A., Lee, D.-H., Smidt, J., Matsumoto, T., Nakagawa, T., Onishi, Y., Korngut, P., **Shirahata, M.**, Tsumura, K., Xemcov, M.: 2015, Measurements of the Mean Diffuse Galactic Light Spectrum in the 0.95 μm to 1.65 μm Band from CIBER, *ApJ*, **806**, 69.

Argudo-Fernandez, M., Verley, S., Bergond, G., Puertas, S. D., Carmona, E. R., Sabater, J., Lorenzo, M. F., **Espada, D.**, Sulentic, J., Ruiz, J. E., Leon, S.: 2015, Catalogues of isolated galaxies, isolated pairs, and isolated triplets in the local Universe, *A&A*, **578**, A110.

Arrigoni, B. F., Yang, Y., Hennawi, J. F., Prochaska, J. X., **Matsuda, Y.**, Yamada, T., Hayashino, T.: 2015, A Deep Narrowband Imaging Search for C IV and He II Emission from Lyα Blobs, *ApJ*, **804**, 26.

Arunbabu, K. P., Antia, H. M., Dugad, S. R., Gupta, S. K., Hayashi, Y., Kawakami, S., Mohanty, P. K., **Oshima, A.**, Subramanian, P.: 2015, How are Forbush decreases related to interplanetary magnetic field enhancements?, *A&A*, **580**, A40.

Asayama, S., Hasegawa, Y., Mizuno, A., Ogawa, H., Onishi, T.: 2015, A Novel Compact Low Loss Waveguide Image Rejection Filter Based

on a Backward Coupler with Band Pass Filters for 100 GHz Band, *J. Infrared, Millim. Terahertz Waves*, **36**, 445-454.

Aso, Y., **Ohashi, N.**, **Saigo, K.**, Koyamatsu, S., Aikawa, Y., **Hayashi, M.**, Machida, M. N., **Saito, M.**, Takakuwa, S., Tomida, K., **Tomisaka, K.**, Yen, H., 2015, ALMA Observations of the Transition from Infall Motion to Keplerian Rotation around the Late-phase Protostar TMC-1A, *ApJ*, **812**, 27.

Baba, J., **Morokuma-Matsui, K.**, **Egusa, F.**: 2015, Radial distributions of arm-gas offsets as an observational test of spiral theories, *PASJ*, **67**, L4.

Bachelet, E., et al. including **Fukui, A.**: 2015, Red Noise Versus Planetary Interpretations in the Microlensing Event Ogle-2013-BLG-446, *ApJ*, **812**, 136.

Balogh, M. L., et al. including **Tanaka, M.**: 2016, Evidence for a change in the dominant satellite galaxy quenching mechanism at $z = 1$, *MNRAS*, **456**, 4364-4376.

Barnes, P. J., **Muller, E.**, Indermuehle, B., O'Dougherty, S. N., Lowe, V., Cunningham, M., Hernandez, A. K., Fuller, G. A.: 2015, The Three-mm Ultimate Mopra Milky Way Survey. I. Survey Overview, Initial Data Releases, and First Results, *ApJ*, **812**, 6.

Batista, V., Beaulieu, J.-P., Bennett, D. P., Gould, A., Marquette, J.-B., **Fukui, A.**, Bhattacharya, A.: 2015, Confirmation of the OGLE-2005-BLG-169 Planet Signature and Its Characteristics with Lens-Source Proper Motion Detection, *ApJ*, **808**, 170.

Bekki, K., Hirashita, H., **Tsujimoto, T.**: 2015, The Origin of Dust Extinction Curves with or without the 2175 A Bump in Galaxies: the Case of the Magellanic Clouds, *ApJ*, **810**, 39.

Benedettini, M., et al. including **Nguyen-Luong, Q.**: 2015, Filaments in the Lupus molecular clouds, *MNRAS*, **453**, 2036-2049.

Berney, S., et al. including **Ichikawa, K.**: 2015, BAT AGN spectroscopic survey-II. X-ray emission and high-ionization optical emission lines, *MNRAS*, **454**, 3622-3634.

Bihr, S., et al. including **Nguyen-Luong, Q.**: 2015, THOR: The H I, OH, Recombination line survey of the Milky Way. The pilot study: H I observations of the giant molecular cloud W43, *A&A*, **580**, A112.

Blair, D., et al. including **Flaminio, R.**: 2015, Gravitational wave astronomy: the current status, *Sci. China Phys. Mech. Astron.*, **58**, 120402.

Bowler, R. A. A., Dunlop, J. S., McLure, R. J., McCracken, H. J., Milvang-Jensen, B., **Furusawa, H.**, Taniguchi, Y., Le Fèvre, O., Fynbo, J. P. U., Jarvis, M. J., Häußler, B.: 2015, The galaxy luminosity function at $z \simeq 6$ and evidence for rapid evolution in the bright end from $z \simeq 7$ to 5, *MNRAS*, **452**, 1817-1840.

Bozza, V., et al. including **Fukui, A.**: 2016, Spitzer Observations of OGLE-2015-BLG-1212 Reveal a New Path toward Breaking Strong Microlens Degeneracies, *ApJ*, **820**, 79.

Buitink, S., et al. including **Kuniyoshi, M.**: 2016, A large light-mass component of cosmic rays at 10(17)-10(17.5) electronvolts from radio observations, *Nature*, **531**, 70-73.

Burns, R. A., Handa, T., **Hirota, T.**, **Motogi, K.**, Imai, H., Omodaka, T.: 2016, Molecular Jet Emission and a Spectroscopic Survey of S235AB, *A&A*, **586**, A34.

Burns, R. A., Imai, H., Handa, T., Omodaka, T., Nakagawa, A., **Nagayama, T.**, **Ueno, Y.**: 2015, A 'water spout' maser jet in S235AB-MIR, *MNRAS*, **453**, 3163-3173.

Carrasco-González, C., Torrelles, J. M., Cantó, J., Curiel, S., Surcis, G., Vlemmings, W. H. T., van Langevelde, H. J., Goddi, C., Anglada, G., Kim, S.-W., **Kim, J.-S.**, Gómez, J. F.: 2015, Observing the onset of outflow collimation in a massive protostar, *Science*, **348,** 114-117.

Chen, Y. G., **Fujimoto, K.**, Xiao, C. J., Ji, H. T.: 2015, Plasma waves around separatrix in collisionless magnetic reconnection with weak guide field, *J. Geophys. Res. A: Space Phys.*, **120**, 6309-6319.

Chibueze, J. O., Miyahara, T., Omodaka, T., Ohta, T., Fujii, T., Tanaka, M., Motohara, K., **Miyoshi, M.**: 2016, Near-Infrared Observations of SiO Maser-Emitting Asymptotic Giant Branch (AGB) Stars, *ApJ*, **817**, 115.

Christian, D. J., Jess, D. B., **Antolin, P.**, Mathioudakis, M.: 2015, Hα and EUV Observations of a Partial CME, *ApJ*, **804**, 147.

Coccato, L., **Fabricius, M.**, Morelli, L., Corsini, E. M., Pizzella, A., Erwin, P., Dalla Bontà, E., Saglia, R., Bender, R., Williams, M.: 2015, Properties and formation mechanism of the stellar counter-rotating components in NGC 4191, *A&A*, **581**, A65.

Contreras, Y., Garay, G., Rathborne, J. M., **Sanhueza, P.**: 2016, Fragmentation in filamentary molecular clouds, *MNRAS*, **456**, 2041-2051.

Csengeri, T., Leurini, S., Wyrowski, F., Urquhart, J. S., Menten, K. M., Walmsley, M., Bontemps, S., Wienen, M., Beuther, H., Motte, F., **Nguyen-Luong, Q.**, Schilke, P., Schuller, F., Zavagno, A., Sanna, C.: 2016, ATLASGAL-selected massive clumps in the inner Galaxy. II. Characterisation of different evolutionary stages and their SiO emission, *A&A*, **586**, A149.

Darnley, M. J., et al. including **Maehara, H.**: 2015, A remarkable recurrent nova in M31: Discovery and optical/UV observations of the predicted 2014 eruption, *A&A*, **580**, A45.

Das, M., **Saito, T.**, **Iono, D.**, Honey, M., Ramya, S.: 2015, Detection of Molecular Gas in Void Galaxies: Implications for Star Formation in Isolated Environments, *ApJ*, **815**, 40.

Davidge, T. J., Andersen, D. R., Lardière, O., Bradley, C., Blain, C., **Oya, S.**, Akiyama, M., Ono, Y. H.: 2015, Raven and the Center of Maffei 1: Multi-object Adaptive Optics Observations of the Center of a Nearby Elliptical Galaxy and the Detection of an Intermediate Age Population, *ApJ*, **811**, 133.

de Leon, J., et al. including **Hashimoto, J.**, **Kudo, T.**, **Kusakabe, N.**, **Akiyama, E.**, **Usuda, T.**, **Guyon, O.**, **Hayano, Y.**, **Hayashi, M.**, **Hayashi, S.**, **Ishii, M.**, **Iye, M.**, **Kandori, R.**, **Morino, J.-I.**, **Nishimura, T.**, **Pyo, T.-S.**, **Suto, H.**, **Suzuki, R.**, **Takahashi, Y.**, **Takato, N.**, **Terada, H.**, **Tomono, D.**, **Takami, H.**, **Tamura, M.**: 2015, Near-IR High-resolution Imaging Polarimetry of the SU Aur Disk: Clues for Tidal Tails?, *ApJ*, **806**, L10.

Díaz, C. G., Ryan-Weber, E. V., Cooke, J., **Koyama, Y.**, Ouchi, M.: 2015, Large-scale environment of $z \sim 5.7$ C IV absorption systems -II. Spectroscopy of Lyman α emitters, *MNRAS*, **448**, 1240-1270.

Didelon, P., et al. including **Nguyen-Luong, Q.**: 2015, From forced collapse to H II region expansion in Mon R2: Envelope density structure and age determination with Herschel, *A&A*, **584**, A4.

Doi, Y., et al. including **Komugi, S.**: 2015, The AKARI far-infrared all-sky survey maps, *PASJ*, **67**, 50.

Dominjon, A., **Sekine, M.**, **Karatsu, K.**, Noguchi, T., Sekimoto, Y., Shu, S., Sekiguchi, S., Nitta, T.: 2016, Study of superconducting bi-layer for Microwave Kinetic Inductance Detectors for astrophysics, *IEEE Trans. Appl. Supercond.*, **26**, 2400206.

Doyle, P. M., Jogo, K., Nagashima, K., Krot, A. N., **Wakita, S.**, Ciesla, F. J., Hutcheon, I. D.: 2015, Early aqueous activity on the ordinary

and carbonaceous chondrite parent bodies recorded by fayalite, *Nat. Commun.*, **6**, 7444.

Eda, K., **Shoda, A.**, Kuwahara, Y., Itoh, Y., **Ando, M.**: 2016, All-sky coherent search for continuous gravitational waves in 6–7 Hz band with a torsion-bar antenna, *Progr. Theor. Experimental Phys.*, 011F01.

Escapa, A., **Fukushima, T.**: 2015, Revisiting the Slichter mode of Mercury in the context of differentiated models, *A&A*, **583**, A139.

Fathi, K., Izumi, T., Romeo, A. B., Martín, S., **Imanishi, M.**, Hatziminaoglou, E., Aalto, S., **Espada, D.**, Kohno, K., Krips, M., Matsushita, S., Meier, D. S., Nakai, N., Terashima, Y.: 2015, Local Instability Signatures in ALMA Observations of Dense Gas in NGC 7469, *ApJ*, **806**, L34.

Ferré-Mateu, A., Trujillo, I., Mezcua, M., Balcells, van den Bosch, R.: 2015, Massive Relic Galaxies Challenge the Co-evolution of Supermassive Black Holes and Their Host Galaxies, *ApJ*, **808**, 79.

Finet, F., Elyiv, A., Melnyk, O., Wertz, O., Horellou, C., Surdej, J.: 2015, Predicted multiply imaged X-ray AGNs in the XXL survey, *MNRAS*, **452**, 1480-1492.

Finoguenov, A., et al. including **Tanaka, M.**: 2015, Ultra-deep catalog of X-ray groups in the Extended Chandra Deep Field South, *A&A*, **576**, A130.

Fujii, M. S., Zwart, S. P.: 2016, The Formation and Dynamical Evolution of Young Star Clusters, *ApJ*, **817**, 4.

Fujii, M. S., Portegies Zwart, S.: 2015, The initial mass function of star clusters that form in turbulent molecular clouds, *MNRAS*, **449**, 726-740.

Fujii, M. S.: 2015, Formation of young massive clusters from turbulent molecular clouds, *PASJ*, **67**, 59.

Fujimoto, K., Takamoto, M.: 2016, Ion and electron dynamics generating the Hall current in the exhaust far downstream of the reconnection x-line, *Phys. Plasmas*, **23**, 012903.

Fujimoto, S., Ouchi, M., Ono, Y., Shibuya, T., Ishigaki, M., **Nagai, H.**, **Momose, R.**: 2016, ALMA Census of Faint 1.2 mm Sources Down to ~ 0.02 mJy: Extragalactic Background Light and Dust-poor, High-z Galaxies, *ApJS*, **222**, 1.

Fukue, K., Matsunaga, N., Yamamoto, R., Kondo, S., Kobayashi, N., Ikeda, Y., Hamano, S., Yasui, C., Arasaki, T., **Tsujimoto, T.**, Bono, G., Inno, L.: 2015, Line-depth Ratios in H-band Spectra to Determine Effective Temperatures of G- and K-type Giants and Supergiants, *ApJ*, **812**, 64.

Fukui, A., et al.: 2015, OGLE-2012-BLG-0563Lb: A Saturn-mass Planet around an M Dwarf with the Mass Constrained by Subaru AO Imaging, *ApJ*, **809**, 74.

Fukui, A., **Narita, N.**, Kawashima, Y., **Kusakabe, N.**, **Onitsuka, M.**, **Ryu, T.**, Ikoma, M., **Yanagisawa, K.**, **Izumiura, H.**: 2016, Demonstrating High-precision, Multiband Transit Photometry with MuSCAT: A Case for HAT-P-14b, *ApJ*, **819**, 27.

Fukui, Y., et al. including **Kawamura, A.**, **Saigo, K.**, **Minamidani, T.**, **Inoue, T.**: 2015, High-mass Star Formation Triggered by Collision between CO Filaments in N159 West in the Large Magellanic Cloud, *ApJ*, **807**, L4.

Fukui, Y., Torii, K., Ohama, A., Hasegawa, K., Hattori, Y., Sano, H., Ohashi, S., Fujii, K., Kuwahara, S., **Mizuno, N.**, Dawson, J. R., Yamamoto, H., Tachihara, K., **Okuda, T.**, Onishi, T., Mizuno, A.: 2016, The Two Molecular Clouds in RCW38: Evidence for the Formation of the Youngest Super Star Cluster in the Milky Way Triggered by Cloud-Cloud Collision, *ApJ*, **820**, 26.

Fukushima, T.: 2015, Precise and fast computation of generalized Fermi-Dirac integral by parameter polynomial approximation, *Appl. Math. Comp.*, **270**, 802-807.

Fukushima, T.: 2016, Numerical computation of gravitational field of infinitely thin axisymmetric disc with arbitrary surface mass density profile and its application to preliminary study of rotation curve of M33, *MNRAS*, **456**, 3702-3714.

Furusawa, S., Takahiro, S., Yamada, S.: 2016, Hydrodynamical Study on the Conversion of Baryonic Matter to Quark Matter: I. Shock-Induced Conversion, *Phys. Rev. D*, **93**, 043018.

Furusawa, S., Takahiro, S., Yamada, S.: 2016, Hydrodynamical Study on the Conversion of Baryonic Matter to Quark Matter: II. Diffusion-Induced Conversion, *Phys. Rev. D*, **93**, 043019.

Gallagher, A. J., Ludwig, H.-G., Ryan, S. G., **Aoki, W.**: 2015, A three-dimensional hydrodynamical line profile analysis of iron lines and barium isotopes in HD 140283, *A&A*, **579**, A94.

Genda, H., Kobayashi, H., **Kokubo, E.**: 2015, Warm Debris Disks Produced by Giant Impacts during Terrestrial Planet Formation, *ApJ*, **810**, 136.

Getling, A. V., **Ishikawa, R.**, Buchnev, A. A.: 2016, Development of Active Regions: Flows, Magnetic-Field Patterns and Bordering Effect, *Solar Phys.*, **291**, 371-382.

Ginsburg, A., et al. including **Ao, Y.**: 2016, Dense gas in the Galactic central molecular zone is warm and heated by turbulence, *A&A*, **586**, A50.

Gonzalez, A., **Fujii, Y.**, **Kojima, T.**, **Asayama, S.**: 2016, Reconfigurable near-field beam pattern measurement system from 0.03 to 1.6 THz, *IEEE Trans. Terahertz Sci. Technol.*, **6**, 300-305.

Gonzalez, A.: 2015, Frqeuency independent LO injection in quasi-optical heterodyne systems, *IEEE Trans. Terahertz Sci. Technol.*, **5**, 546-550.

Gonzalez, A.: 2015, Frequency independent design of quasi-optical systems, *J. Infrared, Millim. Terahertz Waves*, **37**, 147-159.

Gonzalez, L. X., Valdes-Galicia, J. F., Sanchez, F., Muraki, Y., Tsako, T., **Watanabe, K.**, Matsubara, Y., Nagai, Y., Shibata, S., Sakai, T., Musalem, O., Hurtado, A.: 2015, Re-evaluation of the Neutron Emission from the Solar Flare of 2005 September 7, Detected by the Solar Neutron Telescope at Sierra Negra, *ApJ*, **814**, 136.

Gošić, M., Bellot Rubio, L. R., del Toro Iniesta, J. C., Orozco Suárez, D., **Katsukawa, Y.**: 2016, The Solar Internetwork. II. Flux Appearance and Disappearance Rates, *ApJ*, **820**, 35.

Goswami, A., **Aoki, W.**, Karinkuzhi, D.: 2016, Subaru/HDS study of CH stars: elemental abundances for stellar neutron-capture process studies, *MNRAS*, **455**, 402-422.

Goto, M., Geballe, T. R., **Usuda, T.**: 2015, Infrared Absorption Lines Toward NGC 7538 IRS 1: Abundances of H_2, H_3^+, and CO, *ApJ*, **806**, 57.

Granata, M., Balzarini, L., Degallaix, J., Dolique, V., **Flaminio, R.**, Forest, D., Hofman, D., Michel, C., Pedurand, R., Pinard, L.: 2015, Internal friction and Young modulus measurements on SiO_2 and Ta_2O_5 films done with an ultra-high Q silicon wafer suspension, *Arch. Metall. Mater.*, **60**, 365-370.

Granata, M., Saracco, E., Morgado, N., Cajgfinger, A., Cagnoli, G., Degallaix, J., Dolique, V., Forest, D., Franc, J., Michel, C., Pinard, L., **Flaminio, R.**: 2016, Mechanical loss in state-of-the-art amorphous optical coatings, *Phys. Rev. D*, **93**, 012007.

Guzmán, A. E., **Sanhueza, P.**, Contreras, Y., Smith, H. A., Jackson, J. M., Hoq, S., Rathborne, J. M.: 2015, Far-infrared Dust Temperatures and Column Densities of the MALT90 Molecular Clump Sample, *ApJ*, **815**, 130.

Hada, K., Kino, M., Doi, A., **Nagai, H.**, **Honma, M.**, **Akiyama, K.**, **Tazaki, F.**, Loco, R., Giroletti, M., Giovannini, G., Orienti, M., **Hagiwara, Y.**: 2016, High-sensitivity 86 GHz (3.5 mm) VLBI Observations of M87: Deep Imaging of the Jet Base at a Resolution of 10 Schwarzschild Radii, *ApJ*, **817**, 131.

Haga, T., Doi, A., Murata, Y., Sudou, H., **Kameno, S.**, **Hada, K.**: 2015, Determination of Central Engine Position and Accretion Disk Structure in NGC 4261 by Core Shift Measurements, *ApJ*, **807**, 15.

Hagino, K., Sagawa, H.: 2016, Are There Good Probes for the Di-Neutron Correlation in Light Neutron-Rich Nuclei?, *Few-Body Syst.*, **57**, 185-193.

Hagino, K., Sagawa, H.: 2016, Decay dynamics of the unbound O-25 and O-26 nuclei, *Phys. Rev. C*, **93**, 034330.

Hagino, K., Scamps, G.: 2015, Enhancement factor for two-neutron transfer reactions with a schematic coupled-channels model, *Phys. Rev. C*, **92**, 064602.

Hagino, K., Yao, J. M.: 2015, Semimicroscopic modeling of heavy-ion fusion reactions with multireference covariant density functional theory, *Phys. Rev. C*, **91**, 064606.

Hamana, T., **Sakurai, J.**, **Koike, M.**, Miller, L.: 2015, Cosmological constraints from Subaru weak lensing cluster counts, *PASJ*, **67**, 34.

Hanawa, T., **Tomisaka, K.**: 2015, Structure and Stability of Filamentary Clouds Supported by Lateral Magnetic Field, *ApJ*, **801**, 11.

Harakawa, H., Sato, B., **Omiya, M.**, Fischer, D. A., Hori, Y., Ida, S., **Kambe, E.**, Yoshida, M., **Izumiura, H.**, **Koyano, H.**, **Nagayama, S.**, **Shimizu, Y.**, **Okada, N.**, **Okita, K.**, **Sakamoto, A.**, Yamamuro, T.: 2015, Five New Exoplanets Orbiting Three Metal-rich, Massive Stars: Two-planet Systems Including Long-period Planets and an Eccentric Planet, *ApJ*, **806**, 5.

Harra, L., Baker, D., Edwards, S. J., **Hara, H.**, Howe, R., van Driel-Gesztelyi, L.: 2015, A Study of the Coronal Non-thermal Velocity in Polar Regions During the Rise from Solar Minimum to Solar Maximum in Cycle 24, *Solar Phys.*, **290**, 3203-3220.

Hasegawa, A., Kashiwagi, K., Tanaka, Y., **Kurokawa, T.**: 2015, Temporal imaging of optical asymmetric waveform pulses with a time lens, *IEEE Photonics J.*, **7**, 6802711.

Hasegawa, Y., **Takeuchi, T.**: 2015, Viscous Instability Triggered by Layered Accretion in Protoplanetary Disks, *ApJ*, **815**, 99.

Hasegawa, Y., Turner, N. J., Masiero, J., **Wakita, S.**, **Matsumoto, Y.**, **Oshino, S.**: 2016, Forming Chondrites in a Solar Nebula with Magnetically Induced Turbulence, *ApJ*, **820**, L12.

Hasegawa, Y., **Wakita, S.**, **Matsumoto, Y.**, **Oshino, S.**: 2015, Chondrule formation via impact jetting triggered by planetary accretion, *ApJ*, **816**, 8.

Hashimoto, T., Perley, D. A., Ohta, K., **Aoki, K.**, **Tanaka, I.**, Niino, Y., **Yabe, K.**, Kawai, N.: 2015, The Star Formation Rate and Metallicity of the Host Galaxy of the Dark GRB 080325 at $z = 1.78$, *ApJ*, **806**, 250.

Hashizume, K., **Ohsuga, K.**, Kawashima, T., Tanaka, M.: 2015, Radiation hydrodynamics simulations of wide-angle outflows from super-critical accretion disks around black holes, *PASJ*, **67**, 58.

Hatsukade, B., Ohta, K., **Yabe, K.**, Seko, A., Makiya, R., Akiyama, M.: 2015, Optical-Infrared Properties of Faint 1.3 mm Sources Detected with ALMA, *ApJ*, **810**, 91.

Hatsukade, B., Tamura, Y., **Iono, D.**, **Matsuda, Y.**, **Hayashi, M.**, Oguri, M.: 2015, High-resolution ALMA observations of SDP.81. II. Molecular clump properties of a lensed submillimeter galaxy at $z = 3.042$, *PASJ*, **67**, 93.

Hayama, K., Kuroda, T., **Kotake, K.**, **Takiwaki, T.**: 2015, Coherent network analysis of gravitational waves from three-dimensional core-collapse supernova models, *Phys. Rev. D*, **92**, 122001.

Heald, G. H., et al. including **Kuniyoshi, M.**: 2015, The LOFAR Multifrequency Snapshot Sky Survey (MSSS) I. Survey description and first results, *A&A*, **582**, A123.

Helminiak, K. G., **Ukita, N.**, **Kambe, E.**, Konacki, M.: 2015, Absolute Stellar Parameters of KIC 09246715: A Double-giant Eclipsing System with a Solar-like Oscillator, *ApJ*, **813**, L25.

Hesse, M., Aunai, N., Birn, J., Cassak, P., Denton, R., Drake, J. F., Gombosi, T., Hoshino, M., Matthaeus, W., Sibeck, D., **Zenitani, S.**: 2016, Theory and Modeling for the Magnetospheric Multiscale Mission, *Space Sci. Rev.*, **199**, 577-630.

Hibi, Y., **Matsuo, H.**, Ikeda, H., Fujiwara, M., Kang, L., Chen, J., Wu, P.: 2016, Cryogenic ultra-low power dissipation operational amplifiers with GaAs JFETs, *Cryogenics*, **73**, 8-13.

Higuchi, A. E., **Hasegawa, T.**, Saigo, K., **Sanhueza, P.**, Chibueze, J.: 2015, Sgr B2(N): A Bipolar Outflow and Rotating Hot Core Revealed by ALMA, *ApJ*, **815**, 106.

Higuchi, A., **Kokubo, E.**: 2015, Effect of Stellar Encounters on Comet Cloud Formation, *AJ*, **150**, 26.

Hine, N. K., Geach, J. E., Alexander, D. M., Lehmer, B. D., Chapman, S. C., **Matsuda, Y.**: 2016, An enhanced merger fraction within the galaxy population of the SSA22 protocluster at $z = 3.1$, *MNRAS*, **455**, 2363-2370.

Hirai, Y., Ishimaru, Y., Saitoh, T. R., Fujii, M. S., Hidaka, J., **Kajino, T.**: 2015, Enrichment of r-process Elements in Dwarf Spheroidal Galaxies in Chemo-dynamical Evolution Model, *ApJ*, **814**, 41.

Hirano, T., **Fukui, A.**, Mann, A. W., Sanchis-Ojeda, R., Gaidos, E., **Narita, N.**, Dai, F., Van Eylen, V., **Lee, C.-H.**, Onozato, H., **Ryu, T.**, **Kusakabe, N.**, Ito, A., Kuzuhara, M., **Onitsuka, M.**, **Tatsuuma, M.**, Nowak, G., Pallè, E., Ribas, I., **Tamura, M.**, Yu, L.: 2016, The *K2*-ESPRINT Project III: A Close-in Super-Earth around a Metal-rich Mid-M Dwarf, *ApJ*, **820**, 41.

Hirashita, H., et al. including **Takahashi, S.**: 2016, First-generation science case for ground-based terahertz telescopes, *PASJ*, **68**, R1.

Hirashita, H., **Nozawa, T.**, Villaume, A., Srinivasan, S.: 2015, Dust processing in elliptical galaxies, *MNRAS*, **454**, 1620-1633.

Hirota, T., Kim, M. K., **Honma, M.**: 2016, ALMA Observation of the 658 GHz Vibrationally Excited H_2O Maser in Orion KL Source I, *ApJ*, **817**, 168.

Honda, M., Maaskant, K., Okamoto, Y. K., Kataza, H., **Yamashita, T.**, Miyata, T., Sako, S., **Fujiyoshi, T.**, Sakon, I., **Fujiwara, H.**, Kamizuka, T., Mulders, G. D., Lopez-Rodriguez, E., Packham, C., Onaka, T.: 2015, High-resolution 25 μm Imaging of the Disks around Herbig Ae/Be Stars, *ApJ*, **804**, 143.

Honda, S., Notsu, Y., **Maehara, H.**, Notsu, S., Shibayama, T., Nogami, D., Shibata, K.: 2015, High dispersion spectroscopy of solar-type superflare stars. III. Lithium abundances, *PASJ*, **67**, 85.

Honma, M., **Nagayama, T.**, **Sakai, N.**: 2015, Determining dynamical parameters of the Milky Way Galaxy based on high-accuracy radio

astrometry, *PASJ*, **67**, 70.

Hunt, L. K., et al. including **Koda, J.**: 2015, Cool dust heating and temperature mixing in nearby star-forming galaxies, *A&A*, **576**, A33.

Ichikawa, K., Packham, C., Ramos Almeida, C., Asensio Ramos, A., Alonso-Herrero, A., Gonzalez-Martin, O., Lopez-Rodriguez, E., Ueda, Y., Diaz-Santos, T., Elitzur, M., Honig, S. F., **Imanishi, M.**, Levenson, N. A., Mason, R. E., Perlman, E. S., Alsip, C. D.: 2015, The Differences in the Torus Geometry between Hidden and Non-hidden Broad Line Active Galactic Nuclei, *ApJ*, **803**, 57.

Ichikawa, K., **Ueda, J.**, Shidatsu, M., Matsuoka, K., Kawamuro, T.: 2016, Signs of active galactic nucleus quenching in a merger remnant with radio jets, *PASJ*, **68**, 9.

Ikarashi, S., Ivison, R. J., Caputi, K. I., Aretxaga, I., Dunlop, J. S., **Hatsukade, B.**, Hughes, D. H., **Iono, D.**, Izumi, T., **Kawabe, R.**, Kohno, K., Lagos, C. D. P., Motohara, K., **Nakanishi, K.**, Ohta, K., Tamura, Y., Umehata, H., Wilson, G. W., Yabe, K., Yun, M. S.: 2015, Compact Starbursts in $z \sim 3$–6 Submillimeter Galaxies Revealed by ALMA, *ApJ*, **810**, 133.

Imada, S., Murakami, I., **Watanabe, T.**: 2015, Observation and numerical modeling of chromospheric evaporation during the impulsive phase of a solar flare, *Phys. Plasmas*, **22**, 101206.

Ishiguro, M., Sarugaku, Y., **Kuroda, D.**, **Hanayama, H.**, Kim, Y., Kwon, Y. G., **Maehara, H.**, Takahashi, J., **Terai, T.**, Usui, F., Vaubaillon, J. J., Morokuma, T., Kobayashi, N., **Watanabe, J.**: 2016, Detection of Remnant Dust Cloud Associated with the 2007 Outburst of 17P/Holmes, *ApJ*, **817**, 77.

Ishii, S., Seta, M., Nagai, M., **Miyamoto, Y.**, Nakai, N., Nagasaki, T., **Arai, H.**, Imada, H., Miyagawa, N., Maezawa, H., Maehashi, H., Fronfman, L., Finger, R.: 2016, Large-Scale CO (J=4–3) Mapping toward the Orion-A Giant Molecular Cloud, *PASJ*, **68**, 10.

Ishikawa, S., **Kashikawa, N.**, **Toshikawa, J.**, **Onoue, M.**: 2015, The very wide-field gzK galaxy survey - I. Details of the clustering properties of star-forming galaxies at $z \sim 2$, *MNRAS*, **454**, 205-217.

Ishikawa, S., Shimizu, T., **Kano, R.**, **Bando, T.**, **Ishikawa, R.**, **Giono, G.**, Tsuneta, S., Nakayama, S., Tajima, T.: 2015, Development of a Precise Polarization Modulator for UV Spectropolarimetry, *Solar Phys.*, **290**, 3081-3088.

Itoh, Y., **Fukagawa, M.**, Shibai, H., Sumi, T., Yamamoto, K.: 2015, Study of infrared excess from circumstellar disks in binaries with Spitzer/IRAC, *PASJ*, **67**, 88.

Iwai, K., Koshiishi, H., **Shibasaki, K.**, Nozawa, S., Miyawaki, S., Yoneya, T.: 2016, Chromospheric Sunspots in Millimeter Range as Observed by Nobeyama Radioheliograph, *ApJ*, **816**, 91.

Iwai, K., **Shimojo, M.**: 2015, Observation of the Chromospheric Sunspot at Millimeter Range with the Nobeyama 45 m Telescope, *ApJ*, **804**, 48.

Izumi, T., et al. including **Espada, D.**, **Hatsukade, B.**, **Hattori, T.**, **Imanishi, M.**, **Iono, D.**, **Ishizuki, S.**, **Nagai, H.**, **Nakanishi, K.**: 2015, ALMA Observations of the Submillimeter Dense Molecular Gas Tracers in the Luminous Type-1 Active Nucleus of NGC 7469, *ApJ*, **811**, 39.

Izumi, T., Kohno, K., Aalto, S., **Espada, D.**, Fathi, K., Harada, N., **Hatsukade, B.**, Hsieh, P.-Y., Imanishi, M., Krips, M., Martín, S., Matsushita, S., Meier, D. S., Nakai, N., **Nakanishi, K.**, Schinnerer, E., Sheth, K., Terashima, Y., Turner, J. L.: 2015, Submillimeter-HCN Diagram for Energy Diagnostics in the Centers of Galaxies, *ApJ*, **818**, 42.

Jeong, J., et al. including **Fukui, A.**: 2015, Reanalyses of Anomalous Gravitational Microlensing Events in the OGLE-III Early Warning System Database with Combined Data, *ApJ*, **804**, 38.

Jiang, L., Finlator, K., Cohen, S. H., Egami, E., Windhorst, R. A., Fan, X., Davé, R., **Kashikawa, N.**, Mechtley, M., Ouchi, M., Shimasaku, K., Clément, B.: 2016, Physical Properties of Spectroscopically Confirmed Galaxies at $z \geq 6$. III. Stellar Populations from SED Modeling with Secure Lyα Emission and Redshifts, *ApJ*, **816**, 16.

Jiao, C.-L., Mineshige, S., Takeuchi, S., **Ohsuga, K.**: 2015, Comparison between Radiation-Hydrodynamic Simulation of Supercritical Accretion Flows and a Steady Model with Outflows, *ApJ*, **806**, 93.

Johnson, M. D., et al. including **Akiyama, K.**, **Honma, M.**: 2015, Resolved magnetic-field structure and variability near the event horizon of Sagittarius A(star), *Science*, **350**, 1242-1245.

Jovanovic, N., et al. including **Guyon, O.**, **Clergeon, C.**, **Singh, G.**, **Kudo, T.**, **Doughty, D.**, **Lozi, J.**, **Minowa, Y.**, **Hayano, Y.**, **Takato, N.**, **Morino, J.**, **Nishikawa, J.**, **Tamura, M.**, **Kotani, T.**: 2015, The Subaru Coronagraphic Extreme Adaptive Optics System: Enabling High-Contrast Imaging on Solar-System Scales, *PASP*, **127**, 890-910.

Jovanovic, N., **Guyon, O.**, Martinache, F., **Pathak, P.**, Hagelberg, J., **Kudo, T.**: 2015, Artificial Incoherent Speckles Enable Precision Astrometry and Photometry in High-contrast Imaging, *ApJ*, **813**, L24.

Jun, H. D., Im, M., Lee, H. M., Ohyama, Y., Woo, J.-H., Fan, X., Goto, T., Kim, D., **Kim, J. H.**, Kim, M., Lee, M. G., Nakagawa, T., Pearson, C., Serjeant, S.: 2015, Rest-frame Optical Spectra and Black Hole Masses of $3<z<6$ Quasars, *ApJ*, **806**, 109.

Kalas, P. G., et al. including **Bulger, J.**: 2015, Direct Imaging of an Asymmetric Debris Disk in the HD 106906 Planetary System, *ApJ*, **814**, 32.

Kamata, S., Sugita, S., Abe, Y., Ishihara, Y., Harada, Y., Morota, T., **Namiki, N.**, **Iwata, T.**, **Hanada, H.**, **Araki, H.**, **Matsumoto, K.**, Tajika, E., Kuramoto, K., Nimmo, F.: 2015, The relative timing of Lunar Magma Ocean solidification and the Late Heavy Bombardment inferred from highly degraded impact basin structures, *Icarus*, **250**, 492-503.

Kanagawa, K. D., Muto, T., Tanaka, H., Tanigawa, T., Takeuchi, T., Tsukagoshi, T., **Momose, M.**: 2015, Mass Estimates of a Giant Planet in a Protoplanetary Disk from the Gap Structures, *ApJ*, **806**, L15.

Kang, M., Choi, M., Stutz, A. M., **Tatematsu, K.**: 2015, Measurement of HDCO/H_2CO Ratios in the Envelopes of Extremely Cold Protostars in Orion, *ApJ*, **814**, 31.

Kataoka, A., Muto, T., **Momose, M.**, Tsukagoshi, T., Dullemond, C. P.: 2016, Grain Size Constraints on HL TAU with Polarization Signature, *ApJ*, **820**, 54.

Kataoka, A., Muto, T., **Momose, M.**, Tsukagoshi, T., **Fukagawa, M.**, Shibai, H., Hanawa, T., Murakawa, K., Dullemond, C. P.: 2015, Millimeter-wave Polarization of Protoplanetary Disks due to Dust Scattering, *ApJ*, **809**, 78.

Kato, T., et al. including **Maehara, H.**: 2015, Survey of period variations of superhumps in SU UMa-type dwarf novae. VII. The seventh year (2014-2015), *PASJ*, **67**, 105.

Katsuda, S., Mori, K., Maeda, K., **Tanaka, M.**, Koyama, K., Tsunemi, H., Nakajima, H., Maeda, Y., Ozaki, M., Petre, R.: 2015, Kepler's Supernova: An Overluminous Type Ia Event Interacting with a Massive Circumstellar Medium at a Very Late Phase, *ApJ*, **808**, 49.

Katsuda, S., et al. including **Aoki, W.**: 2016, Spatially Resolved

Spectroscopy of a Balmer-dominated Shock in the Cygnus Loop: An Extremely Thin Cosmic-Ray Precursor?, *ApJ*, **819**, L32.

Kaur, G., Behera, B. R., Jhingan, A., Sugathan, P., **Hagino, K.**: 2015, Influence of vibrational excitation on surface diffuseness of the internuclear potential: Study through heavy-ion quasielastic scattering at deep sub-barrier energies, *Phys. Rev. C*, **92**, 044609.

Keane, E. F., et al. including **Honma, M.**, **Furusawa, H.**, **Hattori, T.**, **Niino, Y.**, **Terai, T.**: 2015, The host galaxy of a fast radio burst, *Nature*, **530**, 453-456.

Kettula, K., et al. including **Tanaka, M.**: 2015, CFHTLenS: weak lensing calibrated scaling relations for low-mass clusters of galaxies, *MNRAS*, **451**, 1460-1481.

Kim, J., Jeong, W.-S., Pak, S., Park, W.-K., **Tamura, M.**: 2016, Near-Infrared Polarization Source Catalog of the Northeastern Regions of the Large Magellanic Cloud, *ApJS*, **222**, 2.

Kim, Y., Im, M., Jeon, Y., Kim, M., Choi, C., Hong, J., Hyun, M., Jun, H. D., Karouzos, M., Kim, D., Kim, D., Kim, J.-W., **Kim, J. H.**, Lee, S.-K., Pak, S., Park, W.-K., Taak, Y. C., Yoon, Y.: 2015, Discovery of a Faint Quasar at $z \sim 6$ and Implications for Cosmic Reionization, *ApJ*, **813**, L35.

Kino, M., Ito, H., Kawakatu, N., Orienti, M., **Nagai, H.**, Wajima, K., Itoh, R.: 2016, Fossil shell emission in dying radio loud AGNs, *Astron. Nachr.*, **337**, 47-51.

Kino, M., Takahara, F., **Hada, K.**, Akiyama, K., **Nagai, H.**, Sohn, B. W.: 2015, Magnetization Degree at the Jet Base of M87 Derived from the Event Horizon Telescope Data: Testing the Magnetically Driven Jet Paradigm, *ApJ*, **803**, 30.

Kitagawa, N., **Hara, H.**, Yokoyama, T.: 2016, Doppler Shift of the Quiet Region Measured by Meridional Scans with the EUV Imaging Spectrometer on board Hinode, *ApJ*, **816**, 14.

Kiuchi, H., **Okada, T.**, **Karatsu, K.**, **Sekimoto, Y.**: 2015, A frequency sweeping readout system for kinetic inductance detectors based on submillimeter Radio Astronomy, *IEEE Trans. Terahertz Sci. Technol.*, **5**, 456-463.

Kobayashi, K., Sakai, Y., Tsunekawa, S., Miyamoto, T., Fujitake, M., Ohashi, N.: 2016, Reanalysis of the ground and three torsional excited states of trans-ethyl methyl ether by using an IAM-like tunneling matrix formalism, *J. Mol. Spectrosc.*, **321**, 63-77.

Koda, J., **Yagi, M.**, **Komiyama, Y.**, Boissier, S., Boselli, A., Bouquin, A. Y. K., Mayer, J. D., Gil de Paz, A., **Imanishi, M.**, Madore, B. F., Thilker, D. A.: 2015, Discovery of New Dwarf Galaxy Near the Isolated Spiral Galaxy NGC 6503, *ApJ*, **802**, L24.

Koda, J., **Yagi, M.**, **Yamanoi, H.**, **Komiyama, Y.**: 2015, Approximately a Thousand Ultra-diffuse Galaxies in the Coma Cluster, *ApJ*, **807**, L2.

Kojima, H., Antia, H. M., Dugad, S. R., Gupta, S. K., Hayashi, Y., Jagadeesan, P., Jain, A., Kawakami, S., Mohanty, P. K., Nonaka, T., **Oshima, A.**, Rao, B. S., Shibata, S., The GRAPES-3 Collaboration: 2015, Dependence of cosmic ray intensity on variation of solar wind velocity measured by the GRAPES-3 experiment for space weather studies, *Phys. Rev. D*, **91**, 121303(R).

Kojima, T., Kuroiwa, K., **Takahashi, T.**, **Fujii, Y.**, **Uzawa, Y.**, **Asayama, S.**, **Noguchi, T.**: 2015, Design and performance of mass-produced sideband separating SIS mixers for ALMA band 4 receivers, *Supercond. Sci. Technol.*, **28**, 094001.

Kondratiev, V. I. et al. including **Kuniyoshi, M.**: 2016, A LOFAR census of millisecond pulsars, *A&A*, **585**, A128.

Könyves, V., et al. including **Nguyen-Luong, Q.**: 2015, A census of dense cores in the Aquila cloud complex: SPIRE/PACS observations from the Herschel Gould Belt survey, *A&A*, **584**, A91.

Koyama, S., Kino, M., Doi, A., Niinuma, K., **Hada, K.**, **Nagai, H.**, **Honma, M.**, Akiyama, K., Giroletti, M., Giovannini, G., Orienti, M., Isobe, N., Kataoka, J., Paneque, D., Kobayashi, H., Asada, K.: 2015, Probing the precise location of the radio core in the TeV blazar Mrk 501 with VERA at 43 GHz, *PASJ*, **67**, 67.

Koyama, S., Kino, M., Giroletti, M., Doi, A., Giovannini, G., Orienti, M., **Hada, K.**, Ros, E., Niinuma, K., **Nagai, H.**, Savolainen, T., Krichbaum, T. P., Perez-Torres, M. A.: 2016, Discovery of off-axis jet structure of TeV blazar Mrk 501 with mm-VLBI, *A&A*, **586**, A113.

Koyama, Y., **Kodama, T.**, **Hayashi, M.**, **Shimakawa, R.**, Yamamura, I., **Egusa, F.**, Oi, N., Tanaka, I., Tadaki, K.-i., Takita, S., Makiuti, S.: 2015, Predicting dust extinction properties of star-forming galaxies from H-alpha/UV ratio, *MNRAS*, **453**, 879-892.

Kubo, M., Yamada, T., Ichikawa, T., Kajisawa, M., **Matsuda, Y.**, **Tanaka, I.**, Umehata, H.: 2016, An extremely dense group of massive galaxies at the centre of the protocluster at $z = 3.09$ in the SSA22 field, *MNRAS*, **455**, 3333-3344.

Kuniyoshi, M., Verbiest, J. P. W., Lee, K. J., Adebahr, B., Kramer, M., Noutsos, A.: 2015, Low-frequency spectral turn-overs in millisecond pulsars studied from imaging observations, *MNRAS*, **453**, 828-836.

Kuroda, D., et al. including **Takagi, Y.**, **Hanayama, H.**, **Sekiguchi, K.**, **Watanabe, J.**: 2015, Optical and Near-infrared Polarimetry for a Highly Dormant Comet 209P/LINEAR, *ApJ*, **814**, 156.

Kuroda, T., **Takiwaki, T.**, **Kotake, K.**: 2016, A New Multi-energy Neutrino Radiation-Hydrodynamics Code in Full General Relativity and Its Application to the Gravitational Collapse of Massive Stars, *ApJS*, **222**, 20.

Kwon, J., **Tamura, M.**, Hough, J. H., Nakajima, Y., Nishiyama, S., **Kusakabe, N.**, Nagata, T., Kandori, R.: 2015, Wide-field Infrared Polarimetry of the ρ Ophiuchi Cloud Core, *ApJS*, **220**, 17.

Kwon, Y. G., Ishiguro, M., **Hanayama, H.**, **Kuroda, D.**, Honda, S., Takahashi, J., Kim, Y., Lee, M. G., Choi, Y.-J., Kim, M.-J., Vaubaillon, J. J., **Miyaji, T.**, **Yanagisawa, K.**, Yoshida, M., Ohta, K., Kawai, N., **Fukushima, H.**, **Watanabe, J.**: 2016, Monitoring Observations of the Jupiter-Family Comet 17P/Holmes during its 2014 Perihelion Passage, *ApJ*, **818**, 67.

Lee, C.-H.: 2015, Properties of eclipsing binaries from all-sky surveys - I. Detached eclipsing binaries in ASAS, NSVS, and LINEAR, *MNRAS*, **453**, 3474-3482.

Lee, C.-H.: 2015, Properties of eclipsing binaries from all-sky surveys - II. Detached eclipsing binaries in Catalina Sky Surveys, *MNRAS*, **454**, 2946-2953.

Li, W.-X., Grumer, J., Yang, Y., Brage, T., Yao, K., Chen, C.-Y., **Watanabe, T.**, Jonsson, P., Lundstedt, H., Hutton, R., Zou, Y.-M.: 2015, A Novel Method to Determine Magnetic Fields in Low-density Plasma Facilitated through Accidental Degeneracy of Quantum States in Fe^{9+}, *ApJ*, **807**, 69.

Li, H.-N., **Aoki, W.**, Honda, S., Zhao, G., Christlieb, N., Suda, T.: 2015, Discovery of a strongly *r*-process enhanced extremely metal-poor star LAMOST J110901.22+075441.8, *Res. Astron. Astrophys.*, **15**, 1264-1274.

Li, H.-N., **Aoki, W.**, Zhao, G., Honda, S., Christlieb, N., Suda, T.: 2015, High-resolution spectroscopic studies of ultra metal-poor stars found

in the LAMOST survey, *PASJ*, **67**, 84.

Lidman, C., et al. including **Finet, F.**: 2016, The XXL Survey XIV. AAOmega Redshifts for the Southern XXL Field, *PASA* , **33**, e001.

Lin, H. W., **Yoshida, F.**, Chen, Y. T., Ip, W. H., Chang, C. K.: 2015, A search for subkilometer-sized ordinary chondrite like asteroids in the main-belt, *Icarus*, **254**, 202-212.

Liu, H. B., Galvan-Madrid, R., Vorobyov, E. I., Kospal, A., Rodriguez, L. F., Dunham, M. M., Hirano, N., Henning, T., Takami, M., Dong, R., **Hashimoto, J.**, **Hasegawa, Y.**, Carrasco-Gonzalez, C.: 2016, Absence of Significant Cold Disks in Young Stellar Objects Exhibiting Repetitive Optical Outbursrs, *ApJ*, **816**, L29.

Liu, H. B., Takami, M., **Kudo, T.**, **Hashimoto, J.**, Dong, R., Vorobyov, E. I., **Pyo, T.-S.**, Fukagawa, M., **Tamura, M.**, Henning, T., Dunham, M. M., Karr, J. L., **Kusakabe, N.**, Tsuribe, T.: 2016, Circumstellar disks of the most vigorously accreting young stars, *Sci. Adv.*, **2**, e1500875.

Liu, S.-F., **Hori, Y.**, Lin, D. N. C., Asphaug, E.: 2015, Giant Impact: An Efficient Mechanism for the Devolatilization of Super-Earths, *ApJ*, **812**, 164.

Liu, T., et al. including **Tatematsu, K.**, **Sanhueza, P.**, **Nguyen-Luong, Q., Hirota, T.**: 2016, Planck Cold Clumps in the λ Orionis Complex. I. Discovery of an Extremely Young Class 0 Protostellar Object and a Proto-brown Dwarf Candidate in the Bright-rimmed Clump PGCC G192.32-11.88, *ApJS*, **222**, 7.

Liu, T., Kim, K. T., Wu, Y. F., Li, D., Lee, C. W., De Pree, C. G., Qin, S. L., Wang, K., **Tatematsu, K.**, Zhang, Q. Z., Mardones, D., Liu, S. Y., Cho, S. H.: 2015, Extremely Energetic Outflow and Decelerated Expansion in W49N, *ApJ*, **810**, 147.

Liu, W., De Pontieu, B., Vial, J.-C., Title, A. M., Carlsson, M., Uitenbroek, H., Okamoto, T. J., Berger, T. E., **Antolin, P.**: 2015, First High-resolution Spectroscopic Observations of an Erupting Prominence Within a Coronal Mass Ejection by the Interface Region Imaging Spectrograph (IRIS), *ApJ,* **803**, 85.

Lodieu, N., Alonso, R., González Hernández, J. I., Sanchis-Ojeda, R., **Narita, N.**, Kawashima, Y., Kawauchi, K., Suárez Mascareño, A., Deeg, H., Prieto Arranz, J., Rebolo, R., Pallé, E., Béjar, V. J. S., Ferragamo, A., Rubiño-Martín, J. A.: 2015, An eclipsing double-line spectroscopic binary at the stellar/substellar boundary in the Upper Scorpius OB association, *A&A*, **584**, A128.

Lorusso, G., et al. including **Kajino, T.**: 2015, β-Decay Half-Lives of 110 Neutron-Rich Nuclei across the N=82 Shell Gap: Implications for the Mechanism and Universality of the Astrophysical *r*-Process, *Phys. Rev. Lett.*, **114**, 192501.

Ma, C.-J., Smail, I., Swinbank, A. M., Simpson, J. M., Thomson, A. P., Chen, C.-C., Danielson, A. L. R., Hilton, M., Tadaki, K., Stott, J. P., **Kodama, T.**: 2015, Dusty Starbursts and the Formation of Elliptical Galaxies: A SCUBA-2 Survey of a z = 1.46 Cluster, *ApJ*, **806**, 257.

Macintosh, B., et al. including **Bulger, J.**: 2015, Discovery and spectroscopy of the young jovian planet 51 Eri b with the Gemini Planet Imager, *Science*, **350**, 64-67.

Maeda, K., et al. including **Hattori, T.**, **Tanaka, M.**, **Kim, J. H.**, **Tajitsu, A.**, **Iye, M.**: 2015, Type IIb Supernova 2013df Entering into an Interaction Phase: A Link between the Progenitor and the Mass Loss, *ApJ*, **807**, 35.

Maeda, K., et al. including **Tajitsu, A.**, **Tanaka, M.**, **Aoki, W.**, **Harakawa, H.**, **Arimoto, N.**: 2015, Sodium Absorption Systems toward SN Ia 2014J Originate on Interstellar Scales, *ApJ*, **816**, 57.

Maeda, K., **Nozawa, T.**, Nagao, T., Motohara, K.: 2015, Constraining the amount of circumstellar matter and dust around Type Ia supernovae through near-infrared echoes, *MNRAS*, **452**, 3281-3292.

Maehara, H., Shibayama, T., Notsu, Y., Notsu, S., Honda, S., Nogami, D., Shibata, K.: 2015, Statistical properties of superflares on solar-type stars based on 1-min cadence data, *Earth, Planets and Space*, **67**, 59.

Makise, K., Odou, T., **Ezaki, S.**, Asano, T., Shinozaki, B.: 2015, Superconductor–insulator transition in two-dimensional NbN/MgO and NbN/AlN/MgO films, *Mater. Res. Express*, **2**, 106001.

Makise, K., Terai, H., **Uzawa, Y.**: 2016, NbN/AlN/NbN/TiN Tunnel Junctions on Si (100) Substrate for Superconducting Devices, *IEEE Trans. Appl. Supercond.*, **26**, 1100403.

Marcote, B., et al. including **Kuniyoshi, M.**: 2016, Orbital and superorbital variability of LS I+61 303 at low radio frequencies with GMRT and LOFAR, *MNRAS*, **456**, 1791-1802.

Martinez-Paredes, M., Alonso-Herrero, A., Aretxaga, I., Ramos Almeida, C., Hernan-Caballero, A., Gonzalez-Martin, O., Pereira-Santaella, M., Packham, C., Asensio Ramos, A., Diaz-Santos, T., Elitzur, M., Esquej, P., Garcia-Bernete, I., **Imanishi, M.**, Levenson, N. A., Rodriguez Espinosa, J. M.: 2015, A deep look at the nuclear region of UGC 5101 through high angular resolution mid-IR data with GTC/CanariCam, *MNRAS*, **454**, 3577-3589.

Martín-Navarro, I., La Barbera, F., Vazdekis, A., **Ferré-Mateu, A.**, Trujillo, I., Beasley, M. A.: 2015, The initial mass function of a massive relic galaxy, *MNRAS*, **451**, 1081-1089.

Maruyama, T., Cheoun, M. K., **Kajino, T.**, Kwon, Y., Mathews, G. J., Ryu, C. Y.: 2015, Quantum field theoretic treatment of pion production via proton synchrotron radiation in strong magnetic fields: Effects of Landau levels, *Phys. Rev. D*, **91**, 123007.

Mathews, G. J., Gangopadhyay, M. R., Garnavich, P., Rose, B., Ichiki, K., **Kajino, T.**, Yamazaki, D.: 2015, Constraints on the birth of the universe and origin of cosmic dark flow, *Int. J. Mod. Phys. A*, **30**, 1545022.

Mathews, G. J., Gangopadhyay, M. R., Ichiki, K., **Kajino, T.**: 2015, Possible evidence for Planck-scale resonant particle production during inflation from the CMB power spectrum, *Phys. Rev. D*, **92**, 123519.

Mathews, G. J., Suh, I. S., Lan, N. Q., **Kajino, T.**: 2015, Constraints on preinflation fluctuations in a nearly flat open ACDM cosmology, *Phys. Rev. D*, **92**, 123514.

Matsuda, Y., Nagao, T., **Iono, D.**, **Hatsukade, B.**, Kohno, K., Tamura, Y., Yamaguchi, Y., Shimizu, I.: 2015, The ALMA Patchy Deep Survey: a blind search for [CII] emitters at $z \sim 4.5$, *MNRAS*, **451**, 1141-1145.

Matsumoto, K., **Yamada, R.**, **Kikuchi, F.**, Kamata, S., Ishihara, Y., Iwata, T., **Hanada, H.**, Sasaki, S.: 2015, Internal structure of the Moon inferred from Apollo seismic data and selenodetic data from GRAIL and LLR, *Geophys. Res. Lett.*, **42**, 7351-7358.

Matsumoto, N., Komori, K., Michimura, Y., Hayase, G., **Aso, Y.**, Tsubono, K.: 2015, 5-mg suspended mirror driven by measurement-induced backaction, *Phys. Rev. A*, **92**, 033825.

Matsumoto, T., **Onishi, T.**, Tokuda, K., Inutsuka, S.: 2015, An origin of arc structures deeply embedded in dense molecular cloud cores, *MNRAS*, **449**, L123-L127.

Matsumoto, Y., Nagasawa, M., Ida, S.: 2015, Eccentricity evolution through accretion of protoplanets, *ApJ*, **810**, 106.

Matsuoka, Y., Strauss, M. A., Shen, Y., Brandt, W. N., Greene, J. E.,

Ho, L. C., Schneider, D. P., Sun, M., Trump, J. R.: 2015, The Sloan Digital Sky Survey Reverberation Mapping Project: Post-Starburst Signatures in Quasar Host Galaxies at $z < 1$, *ApJ*, **811**, 91.

Mawatari, K., Inoue, A. K., Kousai, K., Hayashino, T., Cooke, R., Prochaska, J. X., Yamada, T., **Matsuda, Y.**: 2016, Discovery of a Damped Lyα Absorber at $z = 3.3$ along a Galaxy Sight-line in the SSA22 Field, *ApJ*, **817**, 161.

Mei, H., **Hagino, K.**, Yao, J. M.: 2016, Generator coordinate method for hypernuclear spectroscopy with a covariant density functional, *Phys. Rev. C*, **93**, 011301(R).

Michikoshi, S., Fujii, A., **Kokubo, E.**, Salo, H.: 2015, Dynamics of Self-gravity Wakes in Dense Planetary Rings. I. Pitch Angle, *ApJ*, **812**, 151.

Miyazaki, S., Oguri, M., **Hamana, T.**, **Tanaka, M.**, Miller, L., Utsumi, Y., **Komiyama, Y.**, **Furusawa, H.**, **Sakurai, J.**, **Kawanomoto, S.**, **Nakata, F.**, **Uraguchi, F.**, **Koike, M.**, **Tomono, D.**, Lupton, R., Gunn, J. E., Karoji, H., Aihara, H., Murayama, H., Takada, M.: 2015, Properties of Weak Lensing Clusters Detected on Hyper Suprime-Cam's 2.3 $\deg^2$ field, *ApJ*, **807**, 22.

Momose, M., et al. including **Kudo, T.**, **Akiyama, E.**, **Currie, T.**, **Kusakabe, N.**, **Guyon, O.**, **Hayashi, M.**, **Hayashi, S. S.**, **Ishii, M.**, **Iye, M.**, **Kandori, R.**, **Morino, J.**, **Nishimura, T.**, **Pyo, T.**, **Suenaga, T.**, **Suto, H.**, **Suzuki, R.**, **Takahashi, Y. H.**, **Takato, N.**, **Terada, H.**, **Tomono, D.**, **Takami, H.**, **Usuda, T.**, **Tamura, M.**: 2015, Detailed structure of the outer disk around HD 169142 with polarized light in H-band, *PASJ*, **67**, 83.

Moore, T. J. T., et al. including **Nguyen-Luong, Q.**: 2015, The JCMT Plane Survey: early results from the $\ell = 30°$ field, *MNRAS*, **453**, 4264-4277.

Morokuma-Matsui, K., Baba, J., Sorai, K., Kuno, N.: 2015, CO emissions from optically selected galaxies at $z \sim 0.1$–0.2: Tight anti-correlation between molecular gas fraction and 4000 Å break strength, *PASJ*, **67**, 36.

Morokuma-Matsui, K., Baba, J.: 2015, Redshift evolution of stellar mass versus gas fraction relation in $0 < z < 2$ regime: observational constraint for galaxy formation models, *MNRAS*, **454**, 3792-3804.

Mullaly, F., et al. including **Hełminiak, K. G.**: 2015, Planetary Candidates Observed by Kepler. VI. Planet Sample from Q1-Q16 (47 Months), *ApJS*, **217**, 31.

Muranushi, T., **Akiyama, E.**, Inutsuka, S., Nomura, H., Okuzumi, S.: 2015, Development of a Method for the Observation of Lightning in Protoplanetary Disks Using Ion Lines, *ApJ*, **815,** 84.

Murata, K., **Koyama, Y.**, **Tanaka, M.**, Matsuhara, H., **Kodama, T.**: 2015, Environmental dependence of polycyclic aromatic hydrocarbon emission at $z \sim 0.8$. Investigation by observing RX J0152.7-1357 with AKARI, *A&A*, **581**, A114.

Muto, T., Tsukagoshi, T., Momose, M., Hanawa, T., Nomura, H., **Fukagawa, M.**, Saigo, K., **Kataoka, A.**, Kitamura, Y., Takahashi, S. Z., Inutsuka, S., Takeuchi, T., Kobayashi, H., **Akiyama, E.**, Honda, M., Fujiwara, H., Shibai, H.: 2015, Significant gas-to-dust ratio asymmetry and variation in the disk of HD 142527 and the indication of gas depletion, *PASJ*, **67**, 122.

Nagai, H., **Chida, H.**, Kino, M., Orienti, M., D'Ammando, F., Gionannini, G., Hiura, K.: 2016, Nature of radio feature formed by re-started jet activity in 3C 84 and its relation with γ-ray emissions, *Astron. Nachr.*, **337**, 69-72.

Nagai, T., Shinohara, I., **Zenitani, S.**: 2015, The dawn-dusk length of the X line in the near-Earth magnetotail: Geotail survey in 1994-2014, *J. Geophys. Res. A: Space Phys.*, **120**, 8762-8773.

Nagayama, T., **Kobayashi, H.**, Omodaka, T., Murata, Y., Burns, R. A., **Honma, M.**, Kurayama, T., Nakagawa, A., **Oyama, T.**, **Tamura, Y.**, Sato, K.: 2015, Astrometry of Galactic star-forming regions G48.99-0.30 and G49.19-0.34 with VERA: Astrometric accuracy verification of VERA, *PASJ*, **67**, 65.

Nagayama, T., Omodaka, T., Handa, T., Burns, R. A., **Chibueze, J. O.**, **Kobayashi, H.**, **Sato, K.**, **Ueno, Y.**, **Shizugami, M.**: 2015, Astrometry of Galactic star-forming region IRAS 20126+4104 with VERA, *PASJ*, **67**, 66.

Nakajima, T., Tsuji, T., **Takeda, Y.**: 2105, Physical Properties of Gliese 229B Based on Newly Determined Carbon and Oxygen Abundances of Gliese 229A, *AJ*, **150**, 53.

Nakamura, F., et al. including **Kameno, S.**, **Shinnaga, H.**, **Takano, S.**, **Kawabe, R.**, **Iono, D.**, **Momose, M.**: 2015, Z45: A new 45-GHz band dual-polarization HEMT receiver for the NRO 45-m radio telescope, *PASJ*, **67**, 117.

Nakamura, K., **Kajino, T.**, Mathews, G. J., Sato, S., Harikae, S.: 2015, *r*-process nucleosynthesis in the MHD plus neutrino-heated collapsar jet, *A&A*, **582**, A34.

Nakamura, K., **Takiwaki, T.**, Kuroda, T., **Kotake, K.**: 2015, Systematic features of axisymmetric neutrino-driven core-collapse supernova models in multiple progenitors, *PASJ*, **67**, 107.

Nakanishi, H., **Sakai, N.**, Kurayama, T., Matsuo, M., Imai, H., Burns, R. A., Ozawa, T., **Honma, M.**, **Shibata, K. M.**, **Kawaguchi, N.**: 2015, Outer rotation curve of the Galaxy with VERA. II. Annual parallax and proper motion of the star-forming region IRAS21379+5106, *PASJ*, **67**, 68.

Nakashima, J., Sobolev, A. M., Salii, S. V., Zhang, Y., Yung, B. H. K., **Deguchi, S.**: 2015, Methanol Observations of IRAS 19312+1950: A Possible New Type of Class I Methanol Masers, *PASJ*, **67**, 95.

Narita, N., Enomoto, T., Masaoka, S., **Kusakabe, N.**: 2015, Titania may produce abiotic oxygen atmospheres on habitable exoplanets, *Nature Scientific Report*, **5**, 13977.

Narita, N., **Fukui, A.**, **Kusakabe, N.**, **Onitsuka, M.**, **Ryu, T.**, **Yanagisawa, K.**, **Izumiura, H.**, **Tamura, M.**, Yamamuro, T.: 2015, MuSCAT: a multicolor simultaneous camera for studying atmospheres of transiting exoplanets, *J. Astron. Telesc. Instrum. Syst.*, **1**, 045001.

Narita, N., Hirano, T., **Fukui, A.**, **Hori, Y.**, Sanchis-Ojeda, R., Winn, J. N., Ryu, T., **Kusakabe, N.**, **Kudo, T.**, **Onitsuka, M.**, Delrez, L., Gillon, M., Jehin, E., McCormac, J., Holman, M., **Izumiura, H.**, **Takeda, Y.**, **Tamura, M.**, **Yanagisawa, K.**: 2015, Characterization of the K2-19 Multiple-transiting Planetary System via High-dispersion Spectroscopy, AO Imaging, and Transit Timing Variations, *ApJ*, **815**, 47.

Naruse, M., **Nitta, T.**, **Karatsu, K.**, Sekine, M., Sekiguchi, S., **Sekimoto, Y.**, **Noguchi, T.**, Taino, T., Myoren, H.: 2016, Dual-double slot antennas fabricated with single superconducting film for millimeter wave camera, *J. Infrared, Millim. Terahertz Waves*, **37**, 128-136.

Nelles, A., et al. including **Kuniyoshi, M.**: 2015, Calibrating the absolute amplitude scale for air showers measured at LOFAR, *J. Instrum.*, **10**, P11005.

Nguyen, H., Nguyen-Luong, Q., Martin, P. G., Barnes, P. J., **Muller, E.**, Lowe, V., Lo, N., Cunningham, M., Motte, F., Indermuhle, B.,

O'Dougherty, S. N., Hernandez, A. K., Fuller, G. A.: 2015, The Three-mm Ultimate Mopra Milky Way Survey. II. Cloud and Star Formation near the Filamentary Ministarburst RCW 106, *ApJ*, **812**, 7.

Niinuma, K., Kino, M., Doi, A., **Hada, K.**, **Nagai, H.**, Koyama, S.: 2015, Discovery of a Wandering Radio Jet Base after a Large X-Ray Flare in the Blazar Markarian 421, *ApJ*, **807**, L14.

Ninan, J. P., Ojha, D. K., Baug, T., Bhatt, B. C., Mohan, V., Ghosh, S. K., Men'shchikov, A., Anupama, G. C., **Tamura, M.**, Henning, Th.: 2015, V899 Mon: An Outbursting Protostar with a Peculiar Light Curve, and Its Transition Phases, *ApJ*, **815**, 4.

Nishimura, Y., Shimonishi, T., Watanabe, Y., Sakai, N., Aikawa, Y., **Kawamura, A.**, Yamamoto, S.: 2016, Spectral Line Survey toward Molecular Clouds in the Large Magellanic Cloud, *ApJ*, **818**, 161.

Nishimura, N., **Takiwaki, T.**, Thielemann, F.-K.: 2015, The r-process Nucleosynthesis in the Various Jet-like Explosions of Magnetorotational Core-collapse Supernovae, *ApJ*, **810**, 109.

Nomura, H., Tsukagoshi, T., **Kawabe, R.**, Ishimoto, D., Okuzumi, S., Muto, T., Kanagawa, K. D., Ida, S., Walsh, C., Millar, T. J., Bai, X.-N.: 2015, ALMA Observations of a Gap and a Ring in the Protoplanetary Disk around TW Hya, *ApJ*, **819**, L7.

Nomura, M., **Ohsuga, K.**, **Takahashi, H. R.**, Wada, K., **Yoshida, T.**: 2016, Radiation hydrodynamic simulations of line-driven disk winds for ultra-fast outflows, *PASJ*, **68**, 16.

Notsu, Y., Honda, S., **Maehara, H.**, Notsu, S., Shibayama, T., Nogami, D., Shibata, K.: 2015, High dispersion spectroscopy of solar-type superflare stars. I. Temperature, surface gravity, metallicity, and $v \sin i$, *PASJ*, **67**, 32.

Notsu, Y., Honda, S., **Maehara, H.**, Notsu, S., Shibayama, T., Nogami, D., Shibata, K.: 2015, High dispersion spectroscopy of solar-type superflare stars. II. Stellar rotation, starspots, and chromospheric activities, *PASJ*, **67**, 33.

Nozawa, T., **Wakita, S.**, **Hasegawa, Y.**, Kozasa, T.: 2015, Probing the Physical Conditions of Supernova Ejecta with the Measured Sizes of Presolar Al_2O_3 Grains, *ApJ*, **811**, L39.

Ohashi, S., **Tatematsu, K.**, Fujii, K., **Sanhueza, P.**, **Nguyen-Luong, Q.**, Choi, M., **Hirota, T.**, **Mizuno, N.**: 2016, Chemical evolution of the HC_3N and N_2H^+ molecules in dense cores of the Vela C giant molecular cloud complex, *PASJ*, **68**, 3.

Ohsuga, K., **Takahashi, H. R.**: 2016, A Numerical Scheme for Special Relativistic Radiation Magnetohydrodynamics Based on Solving the Time-dependent Radiative Transfer Equation, *ApJ*, **818**, 162.

Okabe, N., Akamatsu, H., Kakuwa, J., Fujita, Y., Zhang, Y., **Tanaka, M.**, Umetsu, K.: 2015, Radio relics tracing the projected mass distribution in CIZA J2242.8+5301, *PASJ*, **67**, 114.

Okamoto, S., **Arimoto, N.**, Ferguson, A. M. N., Bernard, E. J., Irwin, M. J., **Yamada, Y.**, Utsumi, Y.: 2015, A Hyper Suprime-Cam View of the Interacting Galaxies of the M81 Group, *ApJ*, **809**, L1.

Okamoto, T. J., **Antolin, P.**, De Pontieu, B., Uitenbroek, H., Van Doorsselaere, T., Yokoyama, T.: 2015, Resonant Absorption of Transverse Oscillations and Associated Heating in a Solar Prominence. I. Observational Aspects, *ApJ*, **809**, 71.

Okamoto, T., **Isoe, M.**, Habe, A.: 2015, Cosmic evolution of bars in simulations of galaxy formation, *PASJ*, **67**, 63.

Onishi, K., **Iguchi, S.**, Sheth, K., Kohno, K.: 2015, A Measurement of the Black Hole Mass in NGC 1097 Using ALMA, *ApJ*, **806**, 39.

Onodera, M., Carollo, C. M., Renzini, A., Cappellari, M., Mancini, C., **Arimoto, N.**, Daddi, E., Gobat, R., Strazzullo, V., Tacchella, S., **Yamada, Y.**: 2015, The Ages, Metallicities, and Element Abundance Ratios of Massive Quenched Galaxies at $z \simeq 1.6$, *ApJ*, **808**, 161.

Onozato, H., Ita, Y., Ono, K., **Fukagawa, M.**, **Yanagisawa, K.**, **Izumiura, H.**, Nakada, Y., Matsunaga, N.: 2015, A study on the mid-infrared sources that dramatically brightened, *PASJ*, **67**, 39.

Orru, E., et al. including **Kuniyoshi, M.**: 2015, Wide-field LOFAR imaging of the field around the double-double radio galaxy B1834+620 A fresh view on a restarted AGN and doubeltjes, *A&A*, **584**, A112.

Oshigami, S., Yamaguchi, Y., Mitsuishi, M., Momose, A., Yajima, T.: 2015, An advanced method for mineral mapping applicable to hyperspectral images: The composite MSAM, *Remote Sensing Letters*, **6**, 499-508.

Otsuka, M., Hyng, S., **Tajitsu, A.**: 2015, Chemical Abundances and Dust in the Halo Planetary Nebula K648 in M15: Its Origin and Evolution Based on an Analysis of Multiwavelength Data, *ApJS*, **217**, 22.

Oya, M., **Nishikawa, J.**, Horie, M., Sato, K., Murakami, N., **Kotani, T.**, Kumagai, S., **Tamura, M.**, Tanaka, Y., **Kurokawa, T.**: 2015, Coronagraph experiment on dark-hole control by speckle area nulling method, *Opt. Rev.*, **22**, 736-740.

Pagnotta, A., Schaefer, B. E., Clem, J. L., Landolt, A. U., Handler, G., Page, K. L., Osborne, J. P., Schlegel, E. M., Hoffman, D. I., Kiyota, S., **Maehara, H.**: 2015, The 2010 Eruption of the Recurrent Nova U Scorpii: The Multi-wavelength Light Curve, *ApJ*, **811**, 32.

Pan, H.-A., Kuno, N., **Koda, J.**, **Hirota, A.**, Sorai, K., Kaneko, H.: 2015, Molecular Gas and Star-formation Properties in the Central and Bar Regions of NGC 6946, *ApJ*, **815**, 59.

Peña Arellano, F. E., **Sekiguchi, T.**, **Fujii, Y.**, **Takahashi, R.**, **Barton, M.**, **Hirata, N.**, **Shoda, A.**, Heijningen, Y. v., **Flaminio, R.**, DeSalvo, R., **Okutumi, K.**, **Akutsu, T.**, **Aso, Y.**, **Ishizaki, H.**, **Ohishi, N.**, Yamamoto, K., Uchiyama, T., Miyakawa, O., Kamiizumi, M., Takamori, A., Majorana, E., Agatsuma, K., Hennes, E., Brand, Y. v. d., Bertolini, A.: 2016, Characterization of the room temperature payload prototype for the cryogenic interferometric gravitational wave detector KAGRA, *Rev. Sci. Instrum.*, **87**, 034501.

Pereira-Santaella, M., Colina, L., Alonso-Herrero, A., Usero, A., Diaz-Santos, T., Garcia-Burillo, S., Alberdi, A., Gonzalez-Martin, O., Herrero-Illana, R., **Imanishi, M.**, Levenson, N. A., Perez-Torres, M. A., Ramos Almeida, C.: 2015, Sub-arcsec mid-IR observations of NGC 1614: Nuclear star formation or an intrinsically X-ray weak AGN?, *MNRAS*, **454**, 3679-3687.

Pilia, M., et al. including **Kuniyoshi, M.**: 2016, Wide-band, low-frequency pulse profiles of 100 radio pulsars with LOFAR, *A&A*, **586**, A92.

Placco, V. M., Beers, T. C., Ivans, I. I., Filler, D., Imig, J. A., Roederer, I. U., Abate, C., Hansen, T., Cowan, J. J., Frebel, A., Lawler, J. E., Schatz, H., Sneden, C., Sobeck, J. S., **Aoki, W.**, Smith, V. V., Bolte, M.: 2015, Hubble Space Telescope Near-Ultraviolet Spectroscopy of Bright CEMP-s Stars, *ApJ*, **812**, 109.

Ranc, C., et al. including **Fukui, A.**: 2015, MOA-2007-BLG-197: Exploring the brown dwarf desert, *A&A*, **580**, A125.

Rapson, V. A., Kastner, J. H., Andrews, S. M., Hines, D. C., Macintosh, B., Millar-Blanchaer, M., **Tamura, M.**: 2015, Scattered Light from Dust in the Cavity of the V4046 Sgr Transition Disk, *ApJ*, **803**, L10.

Rattenbury, N. J., et al. including **Fukui, A.**: 2015, MOA-2010-BLG-353Lb: a possible Saturn revealed, *MNRAS*, **454**, 946-951.

Rebolledo, D., Wong, T., Xue, R., Leroy, A., **Koda, J.**, Meyer, J. D.: 2015, Scaling Relations of the Properties for CO Resolved Structures in Nearby Spiral Galaxies, *ApJ*, **808**, 99.

Ricci, C., Bauer, F. E., Treister, E., Romero-Canizales, C., Arevalo, P., Iwasawa, K., Privon, G. C., Sanders, D. B., Schawinski, K., Stern, D., **Imanishi, M.**: 2016, NuSTAR Unveils a Heavily Obscured Low-luminosity Active Galactic Nucleus in the Luminous Infrared Galaxy NGC 6286, *ApJ*, **819**, 4.

Rich, E. A., et al. including **Hashimoto, J.**, **Kudo, T.**, **Kusakabe, N.**, **Akiyama, E.**, **Currie, T.**, **Egner, S.**, **Guyon, O.**, **Hayano, Y.**, **Hayashi, M.**, **Hayashi, S. S.**, **Ishii, M.**, **Iye, M.**, **Kandori, R.**, **Morino, J.**, **Nishimura, T.**, **Pyo, T.**, **Suto, H.**, **Suzuki, R.**, **Takahashi, Y. H.**, **Takato, N.**, **Terada, H.**, **Tomono, D.**, **Takami, H.**, **Usuda, T.**, **Tamura, M.**: 2015, Near-IR Polarized Scattered Light Imagery of the DoAr 28 Transitional Disk, *AJ*, **150**, 86.

Rivera-Ingraham, A., et al. including **Nguyen-Luong, Q.**: 2015, Herschel Observations of the W3 GMC (II): Clues to the Formation of Clusters of High-mass Stars, *ApJ*, **809**, 81.

Roh, S., Inutsuka, S., **Inoue, T.**: 2016, Diffusion of cosmic rays in a multiphase interstellar medium swept-up by a supernova remnant blast wave, *Astropart. Phys.*, **73**, 1-7.

Rowley, N., **Hagino, K.**: 2015, Examination of fusion cross sections and fusion oscillations with a generalized Wong formula, *Phys. Rev. C*, **91**, 044617.

Saez, C., Lehmer, B. D., Bauer, F. E., Stern, D., Gonzales, A., Rreza, I., Alexander, D. M., **Matsuda, Y.**, Geach, J. E., Harrison, F. A., Hayashino, T.: 2015, An extragalactic spectroscopic survey of the SSA22 field, *MNRAS*, **450**, 2615-2630.

Sagawa, H., **Hagino, K.**: 2015, Theoretical models for exotic nuclei, *Eur. Phys. J. A*, **51**, 102.

Sai, S., Itoh, Y., **Fukagawa, M.**, Shibai, H., Sumi, T.: 2015, Near-infrared image of the debris disk around HD 15115, *PASJ*, **67**, 20.

Saito, T., **Iono, D.**, Yun, M. S., **Ueda, J.**, **Nakanishi, K.**, Sugai, H., **Espada, D.**, **Imanishi, M.**, Motohara, K., Hagiwara, Y., Tateuchi, K., Lee, M., **Kawabe, R.**: 2015, ALMA Multi-line Observations of the IR-bright Merger VV 114, *ApJ*, **803**, 60.

Saito, Y., **Imanishi, M.**, **Minowa, Y.**, Morokuma, T., Kawaguchi, T., Sameshima, H., Minezaki, T., Oi, N., Nagao, T., Kawatatu, N., Matsuoka, K.: 2016, Near-infrared spectroscopy of quasars at $z \sim 3$ and estimates of their supermassive black hole masses, *PASJ*, **68**, 1.

Sakai, N., Nakanishi, H., Matsuo, M., Koide, N., Tezuka, D., Kurayama, T., **Shibata, K. M.**, **Ueno, Y.**, **Honma, M.**: 2015, Outer rotation curve of the Galaxy with VERA. III. Astrometry of IRAS 07427-2400 and test of the density-wave theory, *PASJ*, **67**, 69.

Sakai, T., Sakai, N., Furuya, K., Aikawa, Y., Hirota, T., Foster, J. B., **Sanhueza, P.**, Jackson, J. M., Yamamoto, S.: 2015, ALMA Observations of the IRDC Clump G34.43+00.24 MM3: DNC/HNC Ratio, *ApJ*, **803**, 70.

Sakai, Y., **Kobayashi, K.**, **Hirota, T.**: 2015, An ALMA imaging study of methyl formate ($HCOOCH_3$) in torsionally excited states toward Orion KL, *ApJ*, **803**, 97.

Sakakibara, Y., Kimura, N., **Akutsu, T.**, Suzuki, T., Kuroda, K.: 2015, Performance test of pipe-shaped radiation shields for cryogenic interferometric gravitational wave detectors, *Classical Quantum Gravity*, **32**, 155011.

Sakon, I., Sako, S., Onaka, T., **Nozawa, T.**, Kimura, Y., Fujiyoshi, T., Shimonishi, T., Usui, F., Takahashi, H., Ohsawa, R., Arai, A., Uemura, M., Nagayama, T., Koo, B. C., Kozasa, T.: 2016, Concurrent Formation of Carbon and Silicate Dust in Nova V1280 SCO, *ApJ*, **817**, 145.

Samal, M. R., Ojha, D. K., Jose, J., Zavagno, A., **Takahashi, S.**, Neichel, B., Kim, J. S., Chauhan, N., Pandey, A. K., Zinchenko, I., **Tamura, M.**, Ghosh, S. K.: 2015, Star formation in the filament of S254-S258 OB complex: a cluster in the process of being created, *A&A*, **581**, A5.

Sanchis-Ojeda, R., et al. including **Fukui, A.**, **Narita, N.**, **Onitsuka, M.**: 2015, The K2-ESPRINT Project I: Discovery of the Disintegrating Rocky Planet K2-22b with a Cometary Head and Leading Tail, *ApJ*, **812**, 112.

Sano, H., et al. including **Inoue, T.**: 2015, A Detailed Study of Non-thermal X-ray Properties and Interstellar Gas Toward the γ-ray Supernova Remnant RX J1713.7-3946, *ApJ*, **799**, 175.

Sano, K., Kawara, K., Matsuura, S., Kataza, H., Arai, T., **Matsuoka, Y.**: 2015, Derivation of a Large Isotopic Diffuse Sky Emission Component at 1.25 and 2.2 μm from the COBE/DIRBE Data, *ApJ*, **811**, 77.

Sano, K., Kawara, K., Matsuura, S., Kataza, H., Arai, T., **Matsuoka, Y.**: 2016, Measurements of Diffuse Sky Emission Components in High Galactic Latitudes at 3.5 and 4.9 μm Using Dirbe and WISE Data, *ApJ*, **818**, 72.

Sato, B., Wang, L., Liu, Y.-J., Zhao, G., **Omiya, M.**, **Harakawa, H.**, Nagasawa, M., Wittenmyer, R. A., Butler, P., Song, N., He, W., Zhao, F., **Kambe, E.**, **Noguchi, K.**, **Ando, H.**, **Izumiura, H.**, **Okada, N.**, Yoshida, M., **Takeda, Y.**, Itoh, Y., **Kokubo, E.**, Ida, S.: 2016, A Pair of Giant Planets around the Evolved Intermediate-mass Star HD 47366: Multiple Circular Orbits or a Mutually Retrograde Configuration, *ApJ*, **819**, 59.

Scamps, G., **Hagino, K.**: 2015, Coupled-channels description of multinucleon transfer and fusion reactions at energies near and far below the Coulomb barrier, *Phys. Rev. C*, **92**, 054614.

Schellart, P., et al. including **Kuniyoshi, M.**: 2015, Probing Atmospheric Electric Fields in Thunderstorms through Radio Emission from Cosmic-Ray-Induced Air Showers, **Phys. Rev. Lett.**, **114**, 165001.

Sekii, T., Appourchaux, T., Fleck, B., Turck-Chieze, S.: 2015, Future Mission Concepts for Helioseismology, *Space Sci. Rev.*, **196**, 285-302.

Seko, A., Ohta, K., **Yabe, K.**, **Hatsukade, B.**, Akiyama, M., Iwamuro, F., Tamura, N., Dalton, G.: 2016, Properties of the Interstellar Medium in Star-Forming Galaxies at $z \sim 1.4$ Revealed with ALMA, *ApJ*, **819**, 82.

Shashkova, I., Shkursky, B., Frolov, P., Bezymyannikova, Y., Kiselev, A., **Nishikwa, J.**, Tavrov, A.: 2015, Extremely unbalanced interferometer for precise wavefront control in stellar coronagraphy, *J. Astron. Telesc. Instrum. Syst.*, **2**, 011011.

Shibagaki, S., **Kajino, T.**, Mathews, G. J., Chiba, S., Nishimura, S., Lorusso, G.: 2016, Relative Contributions of the Weak, Main, and Fission-recycling *r*-Process, *ApJ*, **816**, 79.

Shimajiri, Y., Kitamura, Y., **Nakamura, F.**, **Momose, M.**, **Saito, M.**, Tsukagoshi, T., Hiramatsu, M., Shimoikura, T., Dobashi, K., Hara, C., **Kawabe, R.**: 2015, Catalog of Dense Cores in the Orion A Giant Molecular Cloud, *ApJS*, **217**, 7.

Shimajiri, Y., Sakai, T., Kitamura, Y., Tsukagoshi, T., **Saito, M.**, **Nakamura, F.**, **Momose, M.**, Takakuwa, S., Yamaguchi, T., Sakai, N.,

Yamamoto, S., **Kawabe, R.**: 2015, Spectral-line Survey at Millimeter and Submillimeter Wavelengths toward an Outflow-shocked Region, OMC 2-FIR 4, *ApJS*, **221**, 31.

Shimakawa, R., **Kodama, T.**, Steidel, C. C., Tadaki, K., **Tanaka, I.**, Strom, A. L., **Hayashi, M.**, **Koyama, Y.**, **Suzuki, T. L.**, **Yamamoto, M.**: 2015, Correlation between star formation activity and electron density of ionized gas at $z = 2.5$, *MNRAS*, **451**, 1284-1289.

Shimoikura, T., Dobashi, K., **Nakamura, F.**, **Hara, C.**, Tanaka, T., Shimajiri, Y., Sugitani, K., **Kawabe, R.**: 2015, Dense Clumps and Candidates for Molecular Outflows in W40, *ApJ*, **806**, 201.

Shin, J., **Sakurai, T.**: 2015, Vignetting Effect in the Soft X-Ray Telescope Onboard Yohkoh: I. Numerical Simulation, *Solar Phys.*, **290**, 1531-1546.

Shin, J., **Sakurai, T.**: 2016, Vignetting Effect in the Soft X-Ray Telescope Onboard Yohkoh: II. Pre-Launch Data Analysis, *Solar Phys.*, **291**, 705-725.

Shirasaki, M., Horiuchi, S., Yoshida, N.: 2015, Cross-correlation of the extragalactic gamma-ray background with luminous red galaxies, *Phys. Rev. D*, **92**, 123540.

Shirasaki, M., Hamana, T., Yoshida, N.: 2015, Probing cosmology with weak lensing selected clusters - I. Halo approach and all-sky simulations, *MNRAS*, **453**, 3043-3067.

Shulevski, A., et al. including **Kuniyoshi, M.**: 2015, The peculiar radio galaxy 4C 35.06: a case for recurrent AGN activity?, *A&A*, **579**, A27.

Silva, A., Sajina, A., Lonsdale, C., Lacy, M.: 2015, ALMA Detected Overdensity of Sub-millimeter Sources Around WISE/NVSS-selected $z \sim 2$ Dusty Quasars, *ApJ*, **806**, L25.

Silverman, J. D., et al. including **Arimoto, N.**: 2015, A Higher Efficiency of Converting Gas to Stars Pushes Galaxies at $z \sim 1.6$ Well Above the Star-forming Main Sequence, *ApJ*, **812**, L23.

Silverman, J. D., et al. including **Arimoto, N.**: 2015, The FMOS-COSMOS Survey of Star-forming Galaxies at $z \sim 1.6$. III. Survey Design, Performance, and Sample Characteristics, *ApJS*, **220**, 12.

Singh, G., **Lozi, J.**, **Guyon, O.**, Baudoz, P., **Jovanovic, N.**, Martinache, F., **Kudo, T.**, Serabyn, E., Kuhn, J.: 2015, On-Sky Demonstration of Low-Order Wavefront Sensing and Control with Focal Plane Phase Mask Coronagraphs, *PASP*, **127**, 857-869.

Skidmore, W., et al. including **Kodama, T.**, **Narita, N.**, **Tanaka, M.**, **Aoki, W.**, **Currie, T.**, **Iye, M.**, **Kashikawa, N.**, **Tanaka, M.**: 2015, Thirty Meter Telescope Detailed Science Case: 2015, *Res. Astron. Astrophys.*, **15**, 1945-2140.

Skowron, J., et al. including **Fukui, A.**: 2015, OGLE-2011-BLG-0265Lb: A Jovian Microlensing Planet Orbiting an M Dwarf, *ApJ*, **804**, 33.

Skowron, J., et al. including **Fukui, A.**: 2016, MOA-2011-BLG-028Lb: A Neptune-mass Microlensing Planet in the Galactic Bulge, *ApJ*, **820**, 4.

Soam, A., **Kwon, J.**, Maheswar, G., **Tamura, M.**, Lee, C. W.: 2015, First Optical and Near-infrared Polarimetry of a Molecular Cloud Forming a Proto-brown Dwarf Candidate, *ApJ*, **803**, L20.

Sotani, H., Iida, K., Oyamatsu, K.: 2016, Possible identifications of newly observed magnetar quasi-periodic oscillations as crustal shear modes, *New Astron.*, **43**, 80-86.

Sotani, H., Miyamoto, U.: 2015, Strong gravitational lensing by an electrically charged black hole in Eddington-inspired Born-Infeld gravity, *Phys. Rev. D*, **92**, 044052.

Sotani, H.: 2015, Magnetized relativistic stellar models in Eddington-inspired Born-Infeld gravity, *Phys. Rev. D*, **91**, 084020.

Sotani, H.: 2015, Torsional oscillations of neutron stars with highly tangled magnetic fields, *Phys. Rev. D*, **92**, 104024.

Sotani, H.: 2016, Empirical formula of crustal torsional oscillations, *Phys. Rev. D*, **93**, 044059.

SSALMON Grp., et al. including **Antolin, P.**: 2015, SSALMON - The Solar Simulations for the Atacama Large Millimeter Observatory Network, *Adv. Space Res.*, **56**, 2679-2692.

Straniero, N., Degallaix, J., **Flaminio, R.**, Pinard, L., Cagnoli, G.: 2015, Realistic loss estimation due to mirror surfaces in a 10 meters-long high finesse Fabry-Perot filter-cavity, *Opt. Express*, **23**, 21455-21476.

Strazzullo, V., et al. including **Arimoto, N.**: 2015, Passive galaxies as tracers of cluster environments at $z \sim 2$, *A&A*, **576**, L6.

Street, R., et al. including **Fukui, A.**: 2016, Spitzer Parallax of OGLE-2015-BLG-0966: A Cold Neptune in the Galactic Disk, *ApJ*, **819**, 93.

Suwa, Y., Yamada, S., **Takiwaki, T.**, **Kotake, K.**: 2016, The Criterion of Supernova Explosion Revisited: The Mass Accretion History, *ApJ*, **816**, 43.

Suzuki, T. L., **Kodama, T.**, Tadaki, K., **Hayashi, M.**, Koyama, Y., **Tanaka, I.**, **Minowa, Y.**, **Shimakawa, R.**, **Yamamoto, M.**: 2015, Galaxy Formation at $z > 3$ Revealed by Narrowband-selected [OIII] Emission Line Galaxies, *ApJ*, **806**, 208.

Tadaki, K., et al. including **Kodama, T.**, **Hatsukade, B.**, **Hayashi, M.**, **Koyama, Y.**, **Matsuda, Y.**, **Nakanishi, K.**: 2015, SXDF-ALMA 1.5 arcmin2 Deep Survey: A Compact Dusty Star-forming Galaxy at $z = 2.5$, *ApJ*, **811**, L3.

Tagawa, H., Umemura, M., **Gouda, N.**, **Yano, T.**, Yamai, Y.: 2015, Early cosmic merger of multiple black holes, *MNRAS*, **451**, 2174-2184.

Tajitsu, A., Sadakane, K., Naito, H., Arai, A., Kawakita, H., **Aoki, W.**: 2016, The ^{7}Be II Resonance Lines in Two Classical Novae V5668 Sgr and V2944 Oph, *ApJ*, **818**, 191.

Takahashi, H. R., **Ohsuga, K.**: 2015, Radiation drag effects in black hole outflows from super-critical accretion disks via special relativistic radiation magnetohydrodynamics simulations, *PASJ*, **67**, 60.

Takakuwa, S., **Kiyokane, K.**, Saigo, K., **Saito, M.**: 2015, Dispersing Envelope around the Keplerian Circumbinary Disk in L1551 NE and Its Implications for Binary Growth, *ApJ*, **814**, 160.

Takamoto, M., **Inoue, T.**, Lazarian, A.: 2015, Turbulent Reconnection in Relativistic Plasmas and Effects of Compressibility, *ApJ*, **815**, 16.

Takeda, Y., Honda, S.: 2015, On the oxygen abundances of M 67 stars from the turn-off point through the red giant branch, *PASJ*, **67**, 25.

Takeda, Y., Sato, B., **Omiya, M.**, **Harakawa, H.**: 2015, Can surface oxygen abundances of red giants be explained by the canonical mixing theory?, *PASJ*, **67**, 24.

Takeda, Y., **Tajitsu, A.**: 2015, Spectroscopic study of red giants in the Kepler field with asteroseismologically established evolutionary status and stellar parameters, *MNRAS*, **450**, 397-413.

Takita, S., Doi, Y., Ootsubo, T., Arimatsu, K., Ikeda, N., Kawada, M., Kitamura, Y., Matsuura, S., Nakagawa, T., Hattori, M., Morishima, T., Tanaka, M., **Komugi, S.**: 2015, Calibration of the AKARI far-infrared all-sky survey maps, *PASJ*, **67**, 51.

Tamura, T., **Noguchi, T.**, **Sekimoto Y.**, **Shan, W.**, **Sato, N.**, **Iizuka, Y.**, **Kumagai, K.**, **Niizeki, Y.**, **Iwakuni, M.**, **Ito, T.**: 2015, Performance and Uniformity of the Mass-produced SIS Mixers for the ALMA Band8 Receiver Cartridges, *IEEE Tran. Appl. Supercond.*, **25**, 2400305.

Tamura, Y., et al. including **Kawabe, R.**, **Shimajiri, Y.**, **Hatsukade, B.**, **Ezawa, H.**, **Hayashi, M.**, **Hiramatsu, M.**, **Ogasawara, R.**, **Ohashi,**

N., **Oshima, T.**: 2015, Extremely Bright Submillimeter Galaxies beyond the Lupus-I Star-forming Region, *ApJ*, **808**, 121.

Tamura, Y., Oguri, M., **Iono, D.**, **Hatsukade, B.**, **Matsuda, Y.**, **Hayashi, M.**: 2015, High-resolution ALMA observations of SDP.81. I. The innermost mass profile of the lensing elliptical galaxy probed by 30 milli-arcsecond images, *PASJ*, **67**, 72.

Tan, L. M., Thu, N. N., Ha, T. Q., **Nguyen-Luong, Q.**: 2015, Seasonal variations of nighttime D-region ionosphere in 2013 solar maximum observed from a low-latitude station, *Earth, Planets and Space*, **67**, 163.

Tanaka, M., Tominaga, N., Morokuma, T., Yasuda, N., **Furusawa, H.**, Baklanov, P. V., Blinnikov, S. I., Moriya, T. J., Doi, M., Jiang, J., Kato, T., Kikuchi, Y., Kuncarayakti, H., Nagao, T., Nomoto, K., Taniguchi, Y.: 2016, Rapidly Rising Transients from the Subaru Hyper Suprime-Cam Transient Survey, *ApJ*, **819**, 5.

Tanaka, Y., Tominaka, S., **Kurokawa, T.**: 2015, Precision distance measurement using a two-photon absorption process in a silicon avalanche photodiode with saw-tooth phase modulation, *Appl. Opt.*, **54**, E35-E40.

Taniguchi, K., Ozeki, H., **Saito, M.**, Sakai, N., **Nakamura, F.**, **Kameno, S.**, **Takano, S.**, Yamamoto, S.: 2016, Implication of Formation Mechanisms of HC_5N in TMC-1 as Studied by ^{13}C Isotopic Fractionation, *ApJ*, **817**, 147.

Taniguchi, Y., et al. including **Miyazaki, S.**, **Komiyama, Y.**, **Arimoto, N.**: 2015, The Subaru COSMOS 20: Subaru optical imaging of the HST COSMOS field with 20 filters, *PASJ*, **67**, 104.

Tanikawa, K., Mikkola, S.: 2015, Symbol sequences and orbits of the free-fall three-body problem, *PASJ*, **67**, 115.

Tanimura, Y., **Hagino, K.**, Liang, H. Z.: 2015, 3D mesh calculations for covariant density functional theory, *Progr. Theor. Experimental Phys.*, 073D01.

Tateuchi, K., et al. including **Komugi, S.**, **Koshida, S.**, **Nakashima, A.**: 2015, Ground-based Paα Narrow-band Imaging of Local Luminous Infrared Galaxies. I. Star Formation Rates and Surface Densities, *ApJS*, **217**, 1.

Teixeira, P. S., **Takahashi, S.**, Zapata, L. A., Ho, P. T. P.: 2016, Two-level hierarchical fragmentation in the norhtern filament of the Orion Molecular Cloud 1, *A&A*, **587**, A47.

The JEM-EUSO Collaboration, et al. including **Kajino, T.**, **Mizumoto, Y.**, **Watanabe, J.**: 2015, Erratum to: Performances of JEM-EUSO: angular reconstruction, *Exp. Astron.*, **40**, 179-181.

The JEM-EUSO Collaboration, et al. including **Kajino, T.**, **Mizumoto, Y.**, **Takami, H.**, **Watanabe, J.**: 2015, JEM-EUSO observational technique and exposure, *Exp. Astron.*, **40**, 117-134.

The JEM-EUSO Collaboration, et al. including **Kajino, T.**, **Mizumoto, Y.**, **Takami, H.**, **Watanabe, J.**: 2015, The JEM-EUSO observation in cloudy conditions, *Exp. Astron.*, **40**, 135-152.

The JEM-EUSO Collaboration, et al. including **Kajino, T.**, **Mizumoto, Y.**, **Takami, H.**, **Watanabe, J.**: 2015, Performances of JEM-EUSO: angular reconstruction. The JEM-EUSO Collaboration, *Exp. Astron.*, **40**, 153-177.

The JEM-EUSO Collaboration, et al. including **Kajino, T.**, **Mizumoto, Y.**, **Takami, H.**, **Watanabe, J.**: 2015, Performances of JEM-EUSO: energy and X max reconstruction, *Exp. Astron.*, **40**, 183-214.

The JEM-EUSO Collaboration, et al. including **Kajino, T.**, **Mizumoto, Y.**, **Takami, H.**, **Watanabe, J.**: 2015, The JEM-EUSO instrument, *Exp. Astron.*, **40**, 19-44.

The JEM-EUSO Collaboration, et al. including **Kajino, T.**, **Mizumoto, Y.**, **Takami, H.**, **Watanabe, J.**: 2015, Ultra high energy photons and neutrinos with JEM-EUSO, *Exp. Astron.*, **40**, 215-233.

The JEM-EUSO Collaboration, et al. including **Kajino, T.**, **Mizumoto, Y.**, **Takami, H.**, **Watanabe, J.**: 2015, Science of atmospheric phenomena with JEM-EUSO, *Exp. Astron.*, **40**, 239-251.

The JEM-EUSO Collaboration, et al. including **Kajino, T.**, **Mizumoto, Y.**, **Takami, H.**, **Watanabe, J.**: 2015, JEM-EUSO: Meteor and nuclearite observations, *Exp. Astron.*, **40**, 253-279.

The JEM-EUSO Collaboration, et al. including **Kajino, T.**, **Mizumoto, Y.**, **Takami, H.**, **Watanabe, J.**: 2015, The EUSO-Balloon pathfinder, *Exp. Astron.*, **40**, 281-299.

The JEM-EUSO Collaboration, et al. including **Kajino, T.**, **Mizumoto, Y.**, **Takami, H.**, **Watanabe, J.**: 2015, Ground-based tests of JEM-EUSO components at the Telescope Array site, "EUSO-TA", *Exp. Astron.*, **40**, 301-314.

The JEM-EUSO Collaboration, et al. including **Kajino, T.**, **Mizumoto, Y.**, **Takami, H.**, **Watanabe, J.**: 2015, Space experiment TUS on board the Lomonosov satellite as pathfinder of JEM-EUSO, *Exp. Astron.*, **40**, 315-326.

The JEM-EUSO Collaboration, et al. including **Kajino, T.**, **Mizumoto, Y.**, **Takami, H.**, **Watanabe, J.**: 2015, The JEM-EUSO mission: An introduction, *Exp. Astron.*, **40**, 3-17.

The JEM-EUSO Collaboration, et al. including **Kajino, T.**, **Mizumoto, Y.**, **Takami, H.**, **Watanabe, J.**: 2015, The atmospheric monitoring system of the JEM-EUSO instrument, *Exp. Astron.*, **40**, 45-60.

The JEM-EUSO Collaboration, et al. including **Kajino, T.**, **Mizumoto, Y.**, **Takami, H.**, **Watanabe, J.**: 2015, The infrared camera onboard JEM-EUSO, *Exp. Astron.*, **40**, 61-89.

The JEM-EUSO Collaboration, et al. including **Kajino, T.**, **Mizumoto, Y.**, **Takami, H.**, **Watanabe, J.**: 2015, Calibration aspects of the JEM-EUSO mission, *Exp. Astron.*, **40**, 91-116.

The JEM-EUSO Collaboration, et al. including **Kajino, T.**, **Mizumoto, Y.**, **Takami, H.**, **Watanabe, J.**: 2015, Erratum to: Ultra high energy photons and neutrinos with JEM-EUSO, *Exp. Astron.*, **40**, 235-237.

Toba, Y., et al. including **Aoki, K.**, **Imanishi, M.**, **Doi, Y.**, **Komiyama, Y.**, **Matsuoka, Y.**, **Miyazaki, S.**, **Nakata, F.**, **Onoue, M.**, **Tait, P. J.**, **Takata, T.**, **Tanaka, M. M.**, **Terai, T.**, **Usuda, T.**, **Yamada, Y.**: 2015, Hyper-luminous dust-obscured galaxies discovered by the Hyper Suprime-Cam on Subaru and WISE, *PASJ*, **67**, 86.

Tonegawa, M., et al. including **Takato, N.**: 2015, The Subaru FMOS galaxy redshift survey (FastSound). I. Overview of the survey targeting Hα emitters at $z \sim 1.4$, *PASJ*, **67**, 81.

Torii, K., Hasegawa, K., Hattori, Y., Sano, H., Ohama, A., Yamamoto, H., Tachihara, K., Soga, S., Shimizu, S., **Okuda, T.**, **Mizuno, N.**, Onishi, T., Mizuno, A., Fukui, Y.: 2015, Cloud-Cloud Collision as a Trigger of the High-mass Star Formation: A Molecular Line Study in RCW 120, *ApJ*, **806**, 7.

Toriumi, S., Cheung, M. C. M., **Katsukawa, Y.**: 2015, Light Bridge in a Developing Active Region. II. Numerical Simulation of Flux Emergence and Light Bridge Formation, *ApJ*, **811**, 138.

Toriumi, S., **Katsukawa, Y.**, Cheung, M. C. M.: 2015, Light Bridge in a Developing Active Region. I. Observation of Light Bridge and its Dynamic Activity Phenomena, *ApJ*, **811**, 137.

Totani, T., **Aoki, K.**, **Hattori, T.**, Kawai, N.: 2016, High-precision analyses of Lyα damping wing of gamma-ray bursts in the

reionization era: On the controversial results from GRB 130606A at z = 5.91, *PASJ*, **68**, 15.

Tregloan-Reed, J., et al. including **Finet, F.**: 2015, Transits and starspots in the WASP-6 planetary system, *MNRAS*, **450**, 1760-1769.

Tsuji, T., *Nakajima, T.*, **Takeda, Y.**: 2015, Near-infrared spectroscopy of M dwarfs. II. H_2O molecule as an abundance indicator of oxygen, *PASJ*, **67**, 26.

Tsuji, T., **Nakajima, T.**: 2016, Near-infrared spectroscopy of M dwarfs. III. Carbon and oxygen abundances in late M dwarfs, including the dusty rapid rotator 2MASSI J1835379+325954, *PASJ*, **68**, 13.

Tsujimoto, T., Ishigaki, M. N., Shigeyama, T., **Aoki, W.**: 2015, Chemical feature of Eu abundance in the Draco dwarf spheroidal galaxy, *PASJ*, **67**, L3.

Tsujimoto, T., Nishimura, N.: 2015, The *r*-process in Magnetorotational Supernovae, *ApJ*, **811**, L10.

Turek, Y., Kobayashi, H., **Akutsu, T.**, Sun, C. P., Shikano, Y.: 2015, Post-selected von Neumann measurement with Hermite-Gaussian and Laguerre-Gaussian pointer states, *New J. Phys.*, **17**, 083029.

Ueda, Y., Hashimoto, Y., **Ichikawa, K.**, Ishino, Y., Kniazev, Y., Vaisanen, P., Ricci, C., Berny, S., Gandhi, P., Koss, M., Mushotzky, R., Terashima, Y., Trakhtenbrot, B., Crenshaw, M.: 2015, [OIII] λ5007 and X-Ray Properties of a Complete Sample of Hard X-Ray Selected AGNs in the Local Universe, *ApJ*, **815**, 1.

Umehata, H., Tamura, Y., Kohno, K., Ivison, R. J., Alexander, D. M., Geach, J. E., **Hatsukade, B.**, Hughes, D. H., Ikarashi, S., **Kato, Y.**, Izumi, T., **Kawabe, R.**, Kubo, M., **Lee, M.**, Lehmer, B., Makiya, R., **Matsuda, Y.**, **Nakanishi, K.**, **Saito, T.**, Smail, I., Yamada, T., Yamaguchi, Y., Yun, M.: 2015, ALMA Deep Field in SSA22: A Concentration of Dusty Starbursts in a z = 3.09 Protocluster Core, *ApJ*, **815**, L8.

Uzawa, Y., **Fujii, Y.**, **Gonzalez, A.**, **Kaneko, K.**, **Kroug, M.**, **Kojima, T.**, Miyachi, A., Makise, K., Saito, S., Terai, H., Wang Z.: 2015, Tuning Circuit Material for Mass-Produced Terahertz SIS Receivers, *IEEE Tran. Appl. Supercond.*, **25**, 2401005.

van der Plas, G., Ménard, F., Ward-Duong, K., **Bulger, J.**, Harvey, P. M., Pinte, C., Patience, J., Hales, A., Casassus, S.: 2016, Dust Masses of Disks around 8 Brown Dwarfs and Very Low-mass Stars in Upper Sco OB1 and Ophiuchus, *ApJ*, **819**, 102.

Van Eylen, V., et al. including **Narita, N.**: 2016, The K2-ESPRINT Project II: Spectroscopic follow-up of three exoplanet systems from Campaign 1 of K2, *ApJ*, **820**, 56.

Walsh, A. J., et al. including **Nguyen-Luong, Q.**: 2016, A survey for hydroxyl in the THOR pilot region around W43, *MNRAS*, **455**, 3494-3510.

Wang, Y.-P., He, W., Yamada, T., **Tanaka, I.**, **Iye, M.**, Ji, T.: 2015, High resolution deep imaging of a bright radio quiet QSO at $z \sim 3$, *Res. Astron. Astrophys.*, **15**, 673-686.

Watanabe, Y., Sakai, N., Lopez-Sepulcre, A., Furuya, R., Sakai, T., **Hirota, T.**, Liu, S.-Y., Su, Y.-N., Yamamoto, S.: 2015, Spectral Line Survey toward Young Massive Protostar NGC 2264 CMM3 in the 4 mm, 3 mm, and 0.8 mm Bands, *ApJ*, **809**, 162.

Watanabe, Y., Sakai, N., Sorai, K., **Ueda, J.**, Yamamoto, S.: 2016, Molecular Distribution in the Spiral Arm of M51, *ApJ*, **819**, 144.

Wisnioski, E., et al. including **Fabricius, M.**: 2015, The KMOS3D Survey: Design, First Results, and the Evolution of Galaxy Kinematics from $0.7 \leq z \leq 2.7$, *ApJ*, **799**, 209.

Yabe, K., Ohta, K., Akiyama, M., Bunker, A., Dalton, G., Ellis, R., Glazebrook, K., Goto, T., **Imanishi, M.**, Iwamuro, F., Okada, H., Shimizu, I., **Takato, N.**, Tamura, N., Tonegawa, M., Totani, T.: 2015, The Subaru FMOS Galaxy Redshift Survey (FastSound). III. The mass-metallicity relation and the fundamental metallicity relation at $z \sim 1.4$, *PASJ*, **67**, 102.

Yamada, R., Nébut, T., Shiraishi, H., Lognonné, P., Kobayashi, N., Tanaka, S.: 2015, Frequency band enlargement of the penetrator seismometer and its application to moonquake observation, *Adv. Space Res.*, **56**, 341-354.

Yamanaka, M., et al. including **Tanaka, M.**, **Kuroda, D.**, **Yanagisawa, K.**, **Fukui, A.**, **Isogai, M.**, **Hattori, T.**, **Hanayama, H.**, **Izumiura, H.**, **Sekiguchi, K.**: 2015, OISTER Optical and Near-Infrared Observations of Type Iax Supernova 2012Z, *ApJ*, **806**, 191.

Yasui, C., Kobayashi, N., Hamano, S., Kondo, S., Izumi, N., **Saito, M.**, Tokunaga, A. T.: 2016, Herbig Ae/Be Candidate Stars in the Innermost Galactic Disk: Quartet Cluster, *ApJ*, **817**, 181.

Yasui, C., Kobayashi, N., Tokunaga, A. T., **Saito, M.**, Izumi, N.: 2016, Low-Metallicity Young Clusters in the Outer Galaxy I. Sh 2-207, *AJ*, **151**, 50.

Yasui, K., Nishiyama, S., Yoshikawa, T., Nagatomo, S., Uchiyama, H., Tsuru, T. G., Koyama, K., **Tamura, M.**, Kwon, J., Sugitani, K., Schodel, R., Nagata, T.: 2015, Number density distribution of near-infrared sources on a sub-degree scale in the Galactic center: Comparison with the Fe XXV Kα line at 6.7 keV, *PASJ*, **67**, 123.

Yatsu, Y., et al. including **Sekiguchi, K.**, **Kuroda, D.**, **Yanagisawa, K.**, **Hanayama, H.**, **Isogai, M.**: 2015, Multi-wavelength Observations of the Black Widow Pulsar 2FGL J2339.6-0532 with OISTER and Suzaku, *ApJ*, **802**, 84.

Yeh, S. C. C., Seaquist, E. R., Matzner, C. D., Pellegrini, E. W.: 2015, Molecular and Ionized Hydrogen in 30 Doradus. I. Imaging Observations, *ApJ*, **807**, 117.

Yen, H.-W., Takakuwa, S., Koch, P. M., Aso, Y., Koyamatsu, S., Krasnopolsky, R., **Ohashi, N.**: 2015, No Keplerian Disk >10 AU Around the Protostar B335: Magnetic Braking or Young Age?, *ApJ*, **812**, 129.

Yoshida, K., Sakai, N., Tokudome, T., Lopez-Sepulcre, A., Watanabe, Y., **Takano, S.**, Lefloch, B., Ceccarelli, C., Bachiller, R., Caux, E., Vastel, C., Yamamoto, S.: 2015, Abundance Anomaly of the ^{13}C Isotopics of c-C_3H_2 in the Low-Mass Star Formation Region L1527, *ApJ*, **807**, 66.

Yoshida, M., **Yagi, M.**, Ohyama, Y., **Komiyama, Y.**, **Kashikawa, N.**, Tanaka, H., Okamura, S.: 2015, Giant Hα Nebula Surrounding the Starburst Merger NGC 6240, *ApJ*, **820**, 48.

Yoshiura, S., Shimabukuro, H., Takahashi, K., **Momose, R.**, Nakanishi, H., Imai, H.: 2015, Sensitivity for 21 cm bispectrum from Epoch of Reionization, *MNRAS*, **451**, 266-274.

Yuan, D., Van Doorsselaere, T., Banerjee, D., **Antolin, P.**: 2015, Forward Modeling of Standing Slow Modes in Flaring Coronal Loops, *ApJ*, **807**, 98.

Yun, M., et al. including **Iono, D.**: 2015, Early Science with the Large Millimeter Telescope: CO and [CII] Emission in the z = 4.3 AzTEC J095942.9+022938 (COSMOS AzTEC-1), *MNRAS*, **454**, 3485-3499.

Zenitani, S.: 2015, Loading relativistic Maxwell distributions in particle simulations, *Phys. Plasmas*, **22**, 042116.

Zhu, W., et al. including **Fukui, A.**: 2015, Planet Sensitivity from Combined Ground- and Space-based Microlensing Observations, *ApJ*, **814**, 129.

2. Publications of the National Astronomical Observatory of Japan

Not Published.

3. Report of the National Astronomical Observatory of Japan (in Japanese)

Ozawa, T., **Noda, S.**, **Furusawa, J.**, **Yoshida, T.**, **Higuchi, Y.**, **Ichikawa, S.-i.**: 2015, Development of the SkyMonitor Imaging Data Service System, *Rep. Nat. Astron. Obs. Japan*, **17**, 1-17.

Kuroda, D., **Izumiura, H.**, **Yanagisawa, K.**, **Kambe, E.**, **Koyano, H.**, **Fukui, A.**, **Tsutsui, H.**, **Ukita, N.**, **Okita, K.**, **Toda, H.**, **Sakamoto, A.**, **Imada, A.**, **Shimizu, Y.**: 2015, Performance Upgrade of the 188-cm Telescope at Okayama Astrophysical Observatory, *Rep. Nat. Astron. Obs. Japan*, **17**, 19-39.

4. Conference Proceedings

Agata, H.: 2016, Opening Talk -The Need for Museum-like Activities-, Proc. Int. Symp. on the NAOJ Museum, Eds. K. Usuda-Sato, S. Nemoto, H. Agata, 3-5.

Agata, H.: 2016, Closing Talk -Toward the Next Step-, Proc. Int. Symp. on the NAOJ Museum, Eds. K. Usuda-Sato, S. Nemoto, H. Agata, 195.

Akiyama, E., Chapillion, E., **Espada, D.**, **Takahashi, S.**, Kitamura, Y., de Gregorio-Monsalvo, I., Klaassen, P., Rawlings, M., Mathews, G., Hales, A., **Saito, M.**: 2015, The Radial Distribution of the Surface Density of a Protoplanetary Disk Around HD 163296: Evidence for the Viscous Evolution of the Disk, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 291-292.

Akutsu, T., the KAGRA collaboration: 2015, Large-scale cryogenic gravitational-wave telescope in Japan: KAGRA, *J. Phys.: Conf. Ser.*, **610**, 012016.

Algaba, J. C., Zhao, G. Y., Lee, S. S., Byun, D. Y., Kang, S. C., Kim, D. W., Kim, J. Y., **Kim, J. S.**, Kim, S. W., Kino, M., Miyazaki, A., Park, J. H., Trippe, S., Wajima, K.: 2015, Interferometric Monitoring of Gamma-ray Bright Active Galactic Nuclei II: Frequency Phase Transfer, *J. Korean Astron. Soc.*, **48**, 237-255.

Ali, S., Shimizu, E., Sakaue, H. A., Kato, D., Murakami, I., Yamamoto, N., **Hara, H.**, **Watanabe, T.**, Nakamura, N.: 2015, Intensity ratio measurements for density sensitive lines of highly charged Fe ions, *Hyperfine Interactions*, **235**, 45-49.

Arai, A., Naito, H., Watanabe, F., Nakajima, K., Sano, Y., Watanabe, M., Kiyota, S., **Maehara, H.**, **Kuroda, D.**, Kawai, N., Henze, M., Darnley, M. J., Shafter, A. W., Kato, M.: 2015, Optical Photometric Observations of M31N 2008-12a: Pre- and Post-maximum of the 2015 Eruption, The Astronomer's Telegram, 7979.

Aso, Y., **Ohashi, N.**, **Saigo, K.**, Takakuwa, S., Yen, H.-W., Koyamatsu, S., Aikawa, Y., Machida, M. N., **Saito, M.**, Tomida, K., **Tomoda, K.**: 2015, Keplerian and Infall Motions Around the Large-Phase Protostar TMC-1A, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 285-286.

Baba, N., Murakami, N., Miura, N., **Tamura, M.**: 2015, Numerically designed phase-mask for stellar coronagraph, Proc. SPIE 9605, Ed. S. Shaklan, 96051V.

Baba, Y., **Ishikawa, T.**: 2016, Nearly 120 Years of Science History in Danger: The Collections in the National Astronomical Observatory of Japan, Mizusawa, Proc. of the "Astronomy museums and related activities", Eds. K. Usuda-Sato, S. Nemoto, H. Agata, 73-76.

Belikov, R., Bendek, E., Thomas, S., Males, J., **Lozi, J.**: 2015, How to directly image a habitable planet around Alpha Centauri with a ~30–45 cm space telescope, Proc. SPIE 9605, Ed. S. Shaklan, 960517.

Bendek, E. A., Belikov, R., **Lozi, J.**, Thomas, S., Males, J., Weston, S., McElwain, M.: 2015, Space telescope design to directly image the habitable Zone of Alpha Centauri, Proc. SPIE 9605, Ed. S. Shaklan, 960516.

Canas, L., **Cheung, S. L.**: 2016, International Astronomical Union (IAU) Directory for World Astronomy Network, Proc. of the "Astronomy museums and related activities", Eds. K. Usuda-Sato, S. Nemoto, H. Agata, 158-160.

Carlhoff, P., Schilke, P., Motte, F., **Nguyen-Luong, Q.**: 2015, Molecular cloud structure and star formation in the W43 complex, XXVIIIth General Assembly - Highlights of Astronomy 16, Eds. T. Montmerle, 592-592.

Cheoun, M.-K., Ha, E., Yang, G.-S., Kim, K., **Kajino, T.**: 2015, Neutrino-induced Reactions and Neutrino Scattering with Nuclear Targets, EPJ Web of Conf., 109, Eds. W.-P. Liu, Z.-H. Li, Y.-B. Wang, B. Guo, Y.-P. Shen, 05002.

Cheung, S. L.: 2016, Science Center, Planetariums, Public Observatories and the OAO, Proc. of the "Astronomy museums and related activities", Eds. K. Usuda-Sato, S. Nemoto, H. Agata, 126-127.

Dooley, K. L., **Akutsu, T.**, Dwyer, S., Puppo, P.: 2015, Status of advanced ground-based laser interferometers for gravitational-wave detection, J. Phys.: Conf. Ser., 610, 012012.

Eguchi, S., **Shirasaki, Y.**, **Zapart, C.**, **Ohishi, M.**, **Mizumoto, Y.**, **Kawasaki, W.**, **Kobayashi, T.**, **Kosugi, G.**: 2015, Blade Runner -What kind objects are there in the JVO ALMA Archive?-, Proc. of the Astronomical Data Analysis Software and Systems Conf. XXV.

Egusa, F., **Hirota, A.**, Baba, J., Muraoka, K.: 2015, Molecular Gas Properties in M83 from PDFs, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 149-150.

Ferré-Mateu, A.: 2015, Massive relic galaxies from the Early Universe challenge the co-evolution of SMBHs and their host galaxies, IAU General Assembly, Meeting #29, 2256764.

Fujii, K., **Minamidani, T.**, **Mizuno, N.**, **Onishi, T.**, **Kawamura, A.**, **Muller, E.**, Dawson, J., Fukui, Y.: 2015, Dense Molecular Clumps Associated with the LMC Supergiant Shell LMC 4 and LMC 5, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 255-256.

Furusawa, S., Nagakura, H., Sumiyoshi, K., Yamada, S.: 2016, Inelastic Neutrino Reactions with Light Nuclei and Standing Accretion Shock Instability in Core-Collapse Supernovae, *J. Phys.: Conf. Ser.*, **665**, 012070.

Groff, T. D., Kasdin, N. J., Limbach, M.-A., Galvin, M., Carr, M. A., Knapp, G., Brandt, T., Loomis, C., Jarosik, N., Mede, K., McElwain, M. W., Leviton, D. B., Miller, K. H., Quijada, M. A., **Guyon, O.**, **Jovanovic, N.**, **Takato, N.**, **Hayashi, M.**: 2015, The CHARIS IFS for high contrast imaging at Subaru, Proc. SPIE 9605, Ed. S. Shaklan, 96051C.

Gusev, A., **Hanada, H.**, Petrova, N., Ping, J.: 2015, Physical librations and free nutations of the three-layer Moon for ChangE-3/4, Luna-Glob-Resource, SELENE-2 missions, SPACEKAZAN- IAPS-2015, 153-155.

Gusev, A., **Hanada, H.**, Petrova, N.: 2015, Physical librations and the internal structure of a multilayer resonant moons in the Solar System, SPACEKAZAN- IAPS-2015, 73-85.

Hagiwara, Y., Horiuchi, S., Doi, A., **Miyoshi, M.**: 2015, Extragalactic Sub-millimeter H_2O Maser - Detection of a 321 GHz Water Maser in Circinus Galaxy, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 131-132.

Hanada, H., **Tsuruta, S.**, **Asari, K.**, **Araki, H.**, **Noda, H.**, Kashima, S., Funazaki, K., Satoh, A., Taniguchi, H., Kato, H., Kikuchi, M., Sasaki, H., Shinke, S., Petrova, N., Gusev, A.: 2015, Ground experiments of a small telescope like PZT for observations on the Moon, SPACEKAZAN- IAPS-2015, 61-64.

Hanaoka, Y., **Sakurai, T.**, **IRMag Group**: 2015, Solar Full-Disk Polarization Measurement with the FeI 15648 Angstrom Line, Proc. IAU Symp. 305: Polarimetry: The Sun to Stars and Stellar Environments, Eds. K. N. Nagendra, S. Bagnulo, R. Centeno, M. J.

Martinez Gonzalez, 92-96.

Hatsukade, B., Ohta, K., Endo, A., **Nakanishi, K.**, Tamura, Y., **Hashimoto, T.**, Kohno, K.: 2015, Gamma-ray Bursts from Dusty Regions with Little Molecular Gas, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 47-50.

Hayatsu, N., Yoshida, N., **Matsuda, Y.**, Shimizu, I.: 2015, Detectability and Statistical Properties of the [C II] Emitter in Cosmological Hydrodynamic Simulations, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 79-80.

Helminiak, K. G., Konacki, M., Ratajczak, M., Jordán, A., Espinoza, N., Brahm, R., **Kambe, E.**, **Ukita, N.**: 2015, Multiples Among Detached Eclipsing Binaries from the ASAS Catalog, ASP Conf. Ser., 496, Eds. S. M. Rucinski, T. Guillermo, Z. Miloslav, 76-81.

Hidaka, J., Mathews, G. J., **Kajino, T.**, Suzuki, J.: 2015, Equation of State of Proto-Neutron Star and Failed Supernova Neutrino, JPS Conf. Proc. 6 (Int. Conf. on Advances in Radioactive Isotope Science), Eds. T. Otsuka, H. Enyo, et al., 30137.

Hirai, Y., Ishimaru, Y., Saitoh, T. R., Fujii, M. S., Hidaka, J., **Kajino, T.**: 2016, Astrophysical site(s) of r-process elements in galactic chemodynamical evolution model, EPJ Web of Conf., 109, Eds. W.-P. Liu, Z.-H. Li, Y.-B. Wang, B. Guo, Y.-P. Shen, 02001.

Hirota, T., Kim, M. K., **Kurono, Y.**, **Honma, M.**: 2015, Detection of a Hot Molecular Disk Around a Massive Protostar Candidate Orion KL Source I, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 225-228.

Ide, H., **Kinugasa, K.**, **Nishioka, M.**, **Mikoshiba, H.**, **Miyazawa, K.**, **Shinohara, N.**, **Saito, M.**, **Naito, S.**, Suzuki, Y., Ohnishi, K.: 2016, Artist in Residence in Nobeyama Radio Observatory, Proc. of the "Astronomy museums and related activities", Eds. K. Usuda-Sato, S. Nemoto, H. Agata, 146-153.

Jenniskens, P., Borovicka, J., **Watanabe, J.**, Consolmagno, G., Jopek, T., Vaubaillon, J., Abe, S., Janches, D., Ryabova, G., Ishiguro, M., Zhu, J.: 2015, Division III: Commission 22: Meteors, Meteorites and Interplanetary Dust, Transactions IAU, Vol. 10, Issue T28, 120-123.

Jike, T., **Tamura, Y.**, **Shizugami, M.**: 2015, VERA 2014 Geodetic Activities, IVS 2014 Annual Report, Eds. K. D. Baver, D. Behrend, K. L. Armstrong, 87-89.

Jung, T., Dodson, R., Han, S. T., Rioja, M. J., Byun, D. Y., **Honma, M.**, Stevens, J., de Vicente, P., Sohn, B. W.: 2015, Measureing the Core Shift Effect in AGN Jets with the Extended Korean VLBI Network, J. Korean Astron. Soc., 48, 277-284.

Kameya, O., **Funayama, H.**: 2016, Kimura Hisashi Memorial Museum in NAOJ Mizusawa Campus, Proc. of the "Astronomy museums and related activities", Eds. K. Usuda-Sato, S. Nemoto, H. Agata, 154-157.

Kameya, O., **Funayama, H.**: 2016, Collaboration of Kimura Hisashi Memorial Museum and Oshu Space and Astronomy Museum in NAOJ Mizusawa Campus, Proc. of the "Astronomy museums and related activities", Eds. K. Usuda-Sato, S. Nemoto, H. Agata, 71-72.

Kameya, O., Tsuboi, M., **Asaki, Y.**, Yonekura, Y., Miyamoto, Y., Kaneko, H., Seta, M., Nakai, N., **Miyoshi, M.**, Takaba, H., Wakamatsu, K., Fukuzaki, Y., Morimitsu, T., Sekido, M.: 2015, 22 GHz Monitoring of SGR A* During the G2 Peri-center Passing with the Japanese VLBI Network, Publ. Korean Astron. Soc., 30, 649-650.

Kataoka, A., Muto, T., Momose, M., Tsukagoshi, T., **Fukagawa, M.**, Shibai, H., Hanawa, T., Murakawa, K.: 2015, Expected Polarization at Sub-mm Wavelengths from Lopsided Protoplanetary Disks, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 279-280.

Kato, Y., **Matsuda, Y.**, Smail, I., Swinbank, M., Alexander, D., Geach, J., Lehmer, B., Tamura, Y., Umehata, H., Kohno, K., Kubo, M., Yamada, T., Hayashino, T., Erb, D., Steidel, C.: 2015, Protocluster Survey at z = 2.23: from Herschel to ALMA, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 25-26.

Kinugasa, K., **Nishioka, M.**, **Mikoshiba, H.**, **Miyazawa, K.**, **Shinohara, N.**, **Ide, H.**, **Saito, M.**: 2016, The Record 3 Million Visitors and the NINS PR Center in the NAOJ Nobeyama Campus, Proc. of the "Astronomy museums and related activities", Eds. K. Usuda-Sato, S. Nemoto, H. Agata, 65-70.

Kitazato, K., Iwata, T., Abe, M., Ohtake, M., Tsumura, K., Ishikawa, T., **Takato, N.**, Nakauchi, Y., Arai, T., Senshu, H., Hirata, N., Takagi, Y., Hayabusa2 NIRS3 Team: 2016, Near-Infrared Spectroscopy of the Earth and Moon During the Hayabusa2 Earth Swing-By, 47th Lunar and Planetary Sci. Conf., 2158.

Kojima, H., Antia, H. M., Dugad, S. R., Gupta, S. K., Hayashi, Y., Jagadeesan, P., Jain, A., Kawakami, S., Mohanty, P. K., Nonaka, T., **Oshima, A.**, Rao, B. S., Shibata, S., The GRAPES-3 Collaboration: 2015, Rigidity dependence of the intensity variations of galactic cosmic rays, 34th Int. Cosmic Ray Conf., 163.

Kojima, H., Antia, H.M., Dugad, S. R., Gupta, S.K., Hayashi, Y., Jagadeesan, P., Jain, A., Kawakami, S., Mohanty, P. K., Nonaka, T., **Oshima, A.**, Rao, B. S., Shibata, S., The GRAPES-3 Collaboration: 2015, An estimation of the diffusion coefficient of galactic cosmic rays in the heliosphere near the Earth, 34th Int. Cosmic Ray Conf., 160.

Komatsubara, T., Yuasa, T., Onishi, T., Saito, Y., Okada, S., Sasa, K., Ozawa, A., Hayakawa, T., Shizuma, T., **Kajino, T.**, Kubono, S.: 2015, Study for Big Bang Nucleosynthesis Concerning Lithium Isotopes, JPS Conf. Proc. 6 (Int. Conf. on Advances in Radioactive Isotope Science), Eds. T. Otsuka, H. Enyo, et al., 13055.

Kuncarayakti, H., Aldering, G., Anderson, J. P., **Arimoto, N.**, Doi, M., Galbany, L., Hamuy, M., Hashiba, Y., Kruehler, T., Maeda, K., Morokuma, T., **Usuda, T.**: 2015, Constraining Supernova Progenitors: AN Integral Field Spectroscopic Survey of the Explosion Sites, Publ. Korean Astron. Soc., 30, 139.

Kurahashi, T., **Iono, D.**, **Hatsukade, B.**, **Matsuda, Y.**, **Ueda, J.**, Saito, T., Kato, Y., **Michiyama, T.**, High-z Legacy Team: 2015, Nobeyama Molecular Gas Observations of Distant Bright Galaxies, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 65-66.

Kuroda, D., **Hanayama, H.**, **Miyaji, T.**, **Watanabe, J.**, **Yanagisawa, K.**, **Nagayama, S.**, Yoshida, M., Ohta, K., Kawai, N.: 2015, GRB 150818A: MITSuME Ishigakijima upper limits, *GRB Coordinates Network, Circular Service*, **18174**, 1.

Kuroda, D., **Hanayama, H.**, **Miyaji, T.**, **Watanabe, J.**, **Yanagisawa, K.**, **Nagayama, S.**, Yoshida, M., Ohta, K., Kawai, N.: 2015, GRB 150910A: MITSuME Ishigakijima Optical Observation, *GRB Coordinates Network, Circular Service*, **18276**, 1.

Kuroda, D., **Hanayama, H.**, **Miyaji, T.**, **Watanabe, J.**, **Yanagisawa, K.**, **Nagayama, S.**, Yoshida, M., Ohta, K., Kawai, N.: 2015, GRB 150910A: MITSuME Ishigakijima Optical Observation after 1 day, *GRB Coordinates Network, Circular Service*, **18288**, 1.

Kuroda, D., **Hanayama, H.**, **Miyaji, T.**, **Watanabe, J.**, **Yanagisawa, K.**, **Nagayama, S.**, Yoshida, M., Ohta, K., Kawai, N.: 2015, GRB

150910A: MITSuME Ishigakijima Optical Observation after 2 days, *GRB Coordinates Network, Circular Service*, **18301**, 1.

Kuroda, D., **Hanayama, H.**, **Miyaji, T.**, **Watanabe, J.**, **Yanagisawa, K.**, **Nagayama, S.**, Yoshida, M., Ohta, K., Kawai, N.: 2015, GRB 150912A: MITSuME Ishigakijima upper limits, *GRB Coordinates Network, Circular Service*, **18304**, 1.

Kuroda, D., **Hanayama, H.**, **Miyaji, T.**, **Watanabe, J.**, **Yanagisawa, K.**, **Nagayama, S.**, Yoshida, M., Ohta, K., Kawai, N.: 2015, GRB 151029A: MITSuME Ishigakijima upper limits, *GRB Coordinates Network, Circular Service*, **18534**, 1 .

Kuroda, D., **Hanayama, H.**, **Miyaji, T.**, **Watanabe, J.**, **Yanagisawa, K.**, **Nagayama, S.**, Yoshida, M., Ohta, K., Kawai, N.: 2015, GRB 151029A: MITSuME Ishigakijima upper limits, *GRB Coordinates Network, Circular Service*, **18534**, 1.

Kuroda, D., **Hanayama, H.**, **Miyaji, T.**, **Watanabe, J.**, **Yanagisawa, K.**, **Nagayama, S.**, Yoshida, M., Ohta, K., Kawai, N.: 2016, GRB 160131A: MITSuME Ishigakijima Optical Observation, *GRB Coordinates Network, Circular Service*, **18968**, 1.

Kuroda, D., **Hanayama, H.**, **Miyaji, T.**, **Watanabe, J.**, **Yanagisawa, K.**, **Nagayama, S.**, Yoshida, M., Ohta, K., Kawai, N.: 2016, GRB 160131A: MITSuME Ishigakijima Optical Observation, *GRB Coordinates Network, Circular Service*, **18968**, 1.

Kuroda, D., **Yanagisawa, K.**, **Shimizu, Y.**, **Toda, H.**, **Nagayama, S.**, Yoshida, M., Ohta, K., Kawai, N.: 2015, GRB 150423A: MITSuME Okayama upper limits, *GRB Coordinates Network, Circular Service*, **17742**, 1.

Kuroda, D., **Yanagisawa, K.**, **Shimizu, Y.**, **Toda, H.**, **Nagayama, S.**, Yoshida, M., Ohta, K., Kawai, N.: 2015, GRB 150527A: MITSuME Okayama upper limits, *GRB Coordinates Network, Circular Service*, **17883**, 1.

Kuroda, D., **Yanagisawa, K.**, **Shimizu, Y.**, **Toda, H.**, **Nagayama, S.**, Yoshida, M., Ohta, K., Kawai, N.: 2015, GRB 150910A: MITSuME Okayama Optical Observation, *GRB Coordinates Network, Circular Service*, **18267**, 1.

Kuroda, D., **Yanagisawa, K.**, **Shimizu, Y.**, **Toda, H.**, **Nagayama, S.**, Yoshida, M., Ohta, K., Kawai, N.: 2015, GRB 150911A: MITSuME Okayama upper limits, *GRB Coordinates Network, Circular Service*, **18286**, 1.

Kuroda, D., **Yanagisawa, K.**, **Shimizu, Y.**, **Toda, H.**, **Nagayama, S.**, Yoshida, M., Ohta, K., Kawai, N.: 2015, GRB 151006A: MITSuME Okayama upper limits, *GRB Coordinates Network, Circular Service*, **18402**, 1.

Kuroda, D., **Yanagisawa, K.**, **Shimizu, Y.**, **Toda, H.**, **Nagayama, S.**, Yoshida, M., Ohta, K., Kawai, N.: 2015, GRB 151021A: MITSuME Okayama upper limits, *GRB Coordinates Network, Circular Service*, **18431**, 1.

Kuroda, D., **Yanagisawa, K.**, **Shimizu, Y.**, **Toda, H.**, **Nagayama, S.**, Yoshida, M., Ohta, K., Kawai, N.: 2015, GRB 151022A: MITSuME Okayama upper limits, *GRB Coordinates Network, Circular Service*, **18447**, 1.

Kuroda, D., **Yanagisawa, K.**, **Shimizu, Y.**, **Toda, H.**, **Nagayama, S.**, Yoshida, M., Ohta, K., Kawai, N.: 2015, GRB 151031A, *GRB Coordinates Network, Circular Service*, **18547**, 1.

Kuroda, D., **Yanagisawa, K.**, **Shimizu, Y.**, **Toda, H.**, **Nagayama, S.**, Yoshida, M., Ohta, K., Kawai, N.: 2015, GRB 151229A: MITSuME Okayama upper limits, *GRB Coordinates Network, Circular Service*, **18761**, 1.

Kuroda, D., **Yanagisawa, K.**, **Shimizu, Y.**, **Toda, H.**, **Nagayama, S.**, Yoshida, M., Ohta, K., Kawai, N.: 2016, GRB 160104A: MITSuME Okayama upper limits, *GRB Coordinates Network, Circular Service*, **18825**, 1.

Kuzuhara, M., **Tamura, M.**, **Helminiak, K. G.**, Mede, K., Brandt, T., Janson, M., **Kandori, R.**, **Kudo, T.**, Kusakabe, N., Hashimoto, J.: 2015, The SEEDS High-Contrast Imaging Survey: Exoplanet and Brown Dwarf Survey for Nearby Young Stars Dated with Gyrochronology and Activity Age Indicators, Extreme Solar Systems III, 104.04.

Lee, M., Suzuki, K., Kohno, K., Tamura, Y., **Iono, D.**, **Hatsukade, B.**, **Nakanishi, K.**, **Tanaka, I.**, **Kodama, T.**, Tadaki, K., Ikarashi, S., **Ueda, J.**, **Umehata, H.**, **Saito, T.**, **Kawabe, R.**: 2015, Dusty, Intensively Star Forming Hα Emitters (HAEs) in Protocluster 4C23.56, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 27-28.

Lee, M., Suzuki, K., Kohno, K., Tamura, Y., **Iono, D.**, **Hatsukade, B.**, **Nakanishi, K.**, **Tanaka, I.**, **Kodama, T.**, Tadaki, K., Ikarashi, S., **Ueda, J.**, **Umehata, H.**, **Saito, T.**, **Kawabe, R.**: 2015, Deep JVLA and ALMA observations of dusty star forming galaxies in protocluster 4C23.56 at z = 2.5, IAU General Assembly, Meeting #29, 2254344.

Lee, S. S., Oh, C. S., Roh, D. G., Oh, S. J., Kim, J., Yeom, J. H., Kim, H. R., Jung, D. G., Byun, D. Y., Jung, T., Kawaguchi, N., **Shibata, K. M.**, Wajima, K.: 2015, A New Hardware Correlator in Korea: Performance Evaluation Using KVN Observations, *J. Korean Astron. Soc.*, **48**, 125-137.

Lin, S.-J., Shimajiri, Y., Hara, C., Lai, S.-P., **Nakamura, F.**, Sugitani, K., **Kawabe, R.**, Kitamura, Y., Yoshida, A., Tatei, H., Akashi, T., Tsukagoshi, T.: 2015, Influence of Interstellar FUV Radiation on the Abundance Ratio of ^{13}CO to C^{18}O in L 1551, IAU General Assembly, Meeting #29, 2256988.

Liu, H. B., Takami, M., **Kudo, T.**, **Hashimoto, J.**, Dong, R., Vorobyov, E. I., **Pyo, T.-S.**, **Fukagawa, M.**, **Tamura, M.**, Henning, T., Dunham, M. M., Karr, J. L., **Kusakabe, N.**, Tsuribe, T.: 2016, Circumstellar disks of the most vigorously accreting young stars, *Sci. Adv.*, **2**, e1500875.

Liuzzo, E., **Nagai, H.**, Giovannini, G., Mignano, A.: 2015, The Jet of the BL Lac Object PKS 0521-365 in the mm-Band: ALMA Observations, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 129-130.

Maehara, H., Ayani, K., Itoh, R., Takata, K., Kawabata, K. S.: 2015, Spectroscopic identification of ASASSN-15qi as an FU Ori-like object, *The Astronomer's Telegram*, 8147.

Maehara, H., Fujii, M., Arai, A.: 2015, Spectroscopic identification of ASASSN-15qd (= PNV J19215012+1509248) as a classical nova, *The Astronomer's Telegram*, 8127.

Maehara, H.: 2016, Pre-discovery observations of MASTER OT J004514.13+420007.2, *The Astronomer's Telegram*, 8606.

Maruyama, T., Cheoun, M.-K., **Kajino, T.**, Mathews, G. J.: 2015, Pion Production from Proton Synchrotron Radiation under Strong Magnetic Field in Relativistic Quantum Approach, EPJ Web of Conf., 109, Eds. W.-P. Liu, Z.-H. Li, Y.-B. Wang, B. Guo, Y.-P. Shen, 05006.

Maruyama, T., Hidaka, J., **Kajino, T.**, Yasutake, N., Kuroda, T., Cheoun, M.-K., Ryu, C.-Y., Mathews, G. J.: 2015, Asymmetric Neutrino Emission Process in Rapid Spin-Deceleration of Magnetized Proto-Neutron Stars, JPS Conf. Proc. 6 (Int. Conf. on Advances in Radioactive Isotope Science), Eds. T. Otsuka, H. Enyo, et al., 13042.

Maruyama, T., **Kajino, T.**, Hidaka, J., Takiwaki, T., Yasutake, N., Kuroda, T., Cheoun, M.-K., Ryu, C.-Y., Mathews, G. J.: 2015, Nuclear Equation of State and Asymmetric Neutrino Emission from Proto-Neutron Stars, JPS Conf. Proc. 6 (Int. Conf. on Advances in Radioactive Isotope Science), Eds. T. Otsuka, H. Enyo, et al., 30061.

Matsuda, Y., APDS Team: 2015, The ALMA Patchy Deep Survey: A Blind Search for [CII] Emitters at $z \sim 4.5$, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 77-78.

Matsumoto, K., **Yamada, R.**, **Kikuchi, F.**, Kamata, S., Ishihara, Y., **Iwata, T.**, **Hanada, H.**, Sasaki, S.: 2015, Internal Structure of the Moon Inferred from Apollo Seismic Data and Selenodetic Data from GRAIL and LLR, SPACEKAZAN- IAPS-2015, 86-88.

Mendillo, C. B., Brown, J., Martel, J., Howe, G. A., Hewasawam, K., Finn, S. C., Cook, T. A., Chakrabarti, S., Douglas, E. S., Mawet, D., **Guyon, O.**, **Singh, G.**, Lozi, J., Cahoy, K. L., Marinan, A. D.: 2015, The low-order wavefront sensor for the PICTURE-C mission, Proc. SPIE 9605, Ed. S. Shaklan, 960519.

Meyer, J. D., Mason, B., Impellizzeri, V., **Kameno, S.**, Fomalont, E., **Chibueze, J.**, **Takahashi, S.**, Remijan, A., Wilson, C., ALMA Science Team: 2015, ALMA High Frequency Techniques, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 361-362.

Michiyama, T., **Iono, D.**, **Ueda, J.**, Saito, T.: 2015, CO(3–2)/CO(1–0) Ratio of Molecular Gas Outflow in NGC 3256, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 139-140.

Momose, M., Muto, T., Hanawa, T., **Fukagawa, M.**, Tsukagoshi, T., Saigo, K., Kataoka, A., Nomura, H., Takeuchi, T., **Akiyama, E.**, **Ohashi, N.**, **Fujiwara, H.**, Shibai, H., Kitamura, Y., Inutsuka, S., Kobayashi, H., Honda, M., Aso, Y., Takahashi, S. Z.: 2015, Gas and Dust Structures of the Protoplanetary Disk around HD 142527, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 277-278.

Morokuma-Matsui, K., Baba, J., Sorai, K., Kuno, N.: 2015, CO Emissions from Optically Selected Galaxies at $z \sim 0.1$–0.2: Tight Anti-Correlation Between Molecular Gas Fraction and 4000 Angstrom Break Strength, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 157-158.

Muller, E., Kempen, T., **Mizuno, N.**, **Kawamura, A.**, **Minamidani, T.**: 2015, Candidate Filament Collision in the SMC; Energy Distribution within the SFR N66/NGC346, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 251-252.

Nagai, H., **Nakanishi, K.**, Paladino, R., Moellenbrock, G., Fomalont, E., Amigano, A., Vahakis, C., Remijan, A., ALMA Polarization Team: 2015, ALMA Polarization Science Verification: 3C 286, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 357-358.

Nakajima, T., **Takano, S.**, Kohno, K., Harada, N., Herbest, E., Tamura, Y., Izumi, T., Taniguchi, A., Tosaki, T.: 2015, High-Resolution Imaging in 3-mm and 0.8-mm Bands and Abundances of Shock/Dust Related Molecular Toward the Seyfert Galaxy NGC 1068 Observed with ALMA, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 109-110.

Nakamura, F., et al. including **Kawabe, R.**, **Nishitani, H.**, **Kameno, S.**, **Hirota, T.**, **Takano, S.**, **Iono, D.**: 2015, Cluster Formation Triggered by Filament Collisions in Serpens South, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 239-240.

Nakanishi, K., **Nagai, H.**, Fomalont, E., Cortes, P., Remijan, A., Vlahakis, C., Corder, S., Moellenbrock, G., Tang, Y.-W., Hills, R., ALMA Science Team: 2015, ALMA Polarization: Current Status and Extension of Capability, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 359-360.

Nakanishi, K., Sorai, K., Nakai, N., Kuno, N., Matsubayashi, K., Sugai, H., **Takano, S.**, Kohno, K., Nakajima, T.: 2015, Ionizes Gas Observation Toward a Nearby Starburst Galaxy NGC 253, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 117-120.

Nakano, S., Itagaki, K., Kazarovets, E., Samus, N., Shappee, B. J., **Maehara, H.**, Kojima, T., Hirosawa, K., Noguchi, T., Fujii, M.: 2015, V1831 Aql = N Aql 2015 = PNV J19215012+1509248, IAU Circ. 9278, #4, Ed. D. W. E. Green.

Nakano, S., Itagaki, K., Shappee, B. J., **Maehara, H.**, Kojima, T., Hirosawa, K., Noguchi, T., Fujii, M.: 2015, Nova Aquilae 2015 = PNV J19215012+1509248, Central Bureau Electronic Telegrams, Ed. D.W.E. Green, 4147.

Narita, N., Onitsuka, M., **Fukui, A.**, PEaCH Team.: 2015, Long-term transit observations for a hot Jupiter around a T-Tauri star, IAU General Assembly, Meeting #29, 2254942.

Narukage, N., **Kubo, M.**, **Ishikawa, R.**, **Katsukawa, Y.**, Ishikawa, S., **Kobiki, T.**, **Giono, G.**, **Kano R.**, **Bando, T.**, Tsuneta, S.: 2015, Evaluation of the VUV Coating Performed on the Flight Mirrors of the CLASP Sounding Rocket, UVSOR Activity Report 2015, 42.

Nemoto, S., **Usuda-Sato, K.**, **Matsuda, K.**, **Sasaki, G.**, **Nakagiri, M.**, **Agata, H.**, **Funayama, H.**, **Kameya, O.**, **Kinugasa, K.**, **Toda, H.**, **Yanagisawa, K.**, Baba, Y.: 2016, Historical Intems Database of the NAOJ Museum, Proc. of the "Astronomy museums and related activities", Eds. K. Usuda-Sato, S. Nemoto, H. Agata, 136-139.

Nishimura, A., **Umemoto, T.**, **Minamidani, T.**, Kuno, N., Tosaki, T., Fujita, S., Matsuo, M., Tsuda, Y., Ohashi, S.: 2015, Nobeyama 45m CO Galactic Plane Survey: Filament Properties and Star Formation in M17, IAU General Assembly, Meeting #29, 2247474.

Nishimura, Y., Shimonishi, T., Watanabe, Y., Sakai, N., Aikawa, Y., **Kawamura, A.**, Yamamoto, S.: 2015, Spectral Line Survey Toward Quiescent Giant Molecular Clouds in the Large Magellanic Cloud, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 165-166.

Nishioka, M., **Kinugasa, K.**, **Mikoshiba, H.**, **Miyazawa, K.**, **Shinohara, N.**, **Ide, H.**, **Saito, M.**: 2016, Making Brochure and Original Goods in the NAOJ Nobeyama Campus, Proc. of the "Astronomy museums and related activities", Eds. K. Usuda-Sato, S. Nemoto, H. Agata, 140-145.

Nishiyama, K., Kabashima, F., Kojima, T., Nakano S., Fujikawa, S., **Soma, M.**, Masi, G., O'Connor, S., Waagen, E.O., Kiyota, S., Yusa, T., Ayani, K., Fujii, M.: 2015, V2949 OPHIUCHI = NOVA OPH 2015 No. 2 = TCP J17344775-2409042, Central Bureau Electronic Telegrams, Ed. D.W.E. Green, 4150.

Oh, H., **Pyo, T.-S.**, Yuk, I.-S., Park, B.-G.: 2015, Long-Slit Spectroscopy of Parsec-Scale Jets from DG Tauri, *J. Korean Astron. Soc.*, **48**, 113-123.

Ohashi, S., **Tatematsu, K.**, Choi, M., Kang, M., **Umemoto, T.**, Lee, J.-E., **Hirota, T.**, Yamamoto, S., **Mizuno, N.**: 2015, The Chemical Variation in the Orion A Cloud Cores, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 191-192.

Oka, T., Mizuno, R., Miura, K., Takekawa, S., Tanaka, K.: 2015, Spectral Line Survey and Mapping Observations toward the HVCC CO–0.40–0.22, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 175-176.

Onishi, K., **Iguchi, S.**, Sheth, K., Kohno, K.: 2015, Measurement of the Black-Hole Mass in NGC 1097 using ALMA, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 161-162.

Onishi, T., **Nishimura, A.**, Tokuda, K., Harada, R., Dobashi, K., Shimoikura, T., Kitamura, Y., Ogawa, H.: 2015, Large-Scale Molecular Gas Survey in ^{12}CO, ^{13}CO and C^{18}O (J=2–1) with the Osaka 1.85 m mm-submm Telescope, IAU General Assembly, Meeting #29, 2252707.

Onishi, T., Tokuda, K., Saigo, K., **Kawamura, A.**, Fukui, Y., Matsumoto, T., Inutsuka, S.-i., Machida, M., Tomida, K., Tachihara, K.: 2015, ALMA Observations of a High-density Core in Taurus: Dynamical Gas Interaction at the Possible Site of a Multiple Star Formation, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 211-214.

Pyo, T.-S., Hayashi, M., Beck, T., Davis, C. J., Takami, M.: 2015, Unveiling Complex Outflow Structure of UY Aur, *Publ. Korean Astron. Soc.*, **30**, 109-112.

Ratajczak, M., **Hełminiak, K. G.**, Konacki, M.: 2015, Studies of Long Period Eclipsing Binaries, ASP Conf. Ser., 496, Eds. S. M. Rucinski, T. Guillermo, Z. Miloslav, 311.

Saito, M., de Gregorio, I., Team SOLA: 2015, The Soul of Lupus with ALMA (SOLA) Project Overview, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 215-216.

Saito, T., **Iono, D.**, **Ueda, J.**, **Nakanishi, K.**, **Imanishi, M.**, **Hagiwara, Y.**, Yun, M. S., **Kaneko, H.**, **Komugi, S.**, **Espada, D.**, Sugai, H., Motohara, K., Lee, M., **Kawabe, R.**, Yamashita, T.: 2015, Molecular Gas Excitation and Chemistry in Nearby LIRGs with ALMA, IAU General Assembly, Meeting #29, 2254284.

Saito, T., **Iono, D.**, **Ueda, J.**, Yun, M. S., **Nakanishi, K.**, **Imanishi, M.**, Hagiwara, Y., **Kaneko, H.**, **Komugi, S.**, **Espada, D.**, Motohara, K., Sugai, H., Yamashita, T., Tateuchi, K., Lee, M., **Michiyama, T.**, **Kawabe, R.**: 2015, Diffuse and Dense Gas in Nearby Luminous Merging Galaxies, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 133-135.

Sakao, T., Matsuyama, S., Kime, A., Goto, T., Nishihara, A., Nakamori, H., Yamauchi, K., Kohmura, Y., Miyake, A., Hashizume, H., Maezawa, T., **Suematsu, Y.**, **Narukage, N.**: 2015, Development of precision Wolter mirrors for future solar x-ray observations, Proc. SPIE 9603, Eds. S. L. O'Dell, G. Pareschi, 96030U.

Sanhueza, P., Jackson, J. M., Zhang, Q., Foster, J., Guzmán, A.: 2015, A Massive, Prestellar Clump Hosting no High-Mass Cores, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 245-246.

Sano, H., Fukui, Y., Yoshiike, S., Fukuda, T., Tachihara, K., Inutsuka, S., **Kawamura, A.**, Fujii, K., **Mizuno, N.**, **Inoue, T.**, **Onishi, T.**, Acero, F., Vink, J.: 2015, Revealing the Large-Scale Structures of Interstellar Gas Associated with the Magellanic SNR N132D, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 257-260.

Sawada, T., **Hasegawa, T.**, **Koda, J.**: 2015, ALMA Reveals Internal Structure of Molecular Clouds in the LMC, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 253-254.

Sawada-Satoh, S., Akiyama, K., Niinuma, K., **Nagai, H.**, Kino, M., D'Ammando, F., Koyama, S., **Hada, K.**, Orienti, M., **Honma, M.**, **Shibata, K. M.**: 2015, Apparent Inward Motion of the Parsec-Scale Jet in the BL Lac Object OJ287 during the 2011-2012 γ-ray Flares, Publ. Korean Astron. Soc., 30, 429-432.

Sekiguchi, K., **Yoshida, F.**: 2015, NAOJ's activities on Astronomy for Development : Aiding Astronomy Education in Developing Nations. in Highlights of Astronomy, XXVIIIth General Assembly - Highlights of Astronomy 16, Eds. T. Montmerle, 553.

Sekimoto, Y., **Dominjon, A.**, **Noguchi, T.**, **Okada, N.**, **Mitsui, K.**, **Obuchi, Y.**, Sekine, M., Sekiguchi, S., Shu, S., Nitta, T., Naruse, M.: 2015, Design of MKID focal plane array for LiteBIRD, Proceedings of ESA antenna conference, Eds. E. Saenz, K. Klooster, B. Shortt, L. Duvet.

Seko, A., Ohta, K., **Hatsukade, B.**, **Yabe, K.**: 2015, Properties of Molecular Gas in Star-Forming Galaxies at $z \sim 1.4$ with ALMA, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 43-46.

Shibagaki, S., **Kajino, T.**, Mathews, G. J., Chiba, S.: 2015, Impact of the nuclear fission on r-process nucleosynthesis and the origin of solar r-process elements, AIP Conf. Proc. 1645 (Carpathian Summer School of Physics 2014), Eds. C. Spitaleri, et al., 402-405.

Shibagaki, S., **Kajino, T.**, Mathews, G. J., Chiba, S.: 2015, R-Process in Neutron Star Merger with a New Fission Model, JPS Conf. Proc. 6 (Int. Conf. on Advances in Radioactive Isotope Science), Eds. T. Otsuka, H. Enyo, et al., 20030.

Shimakawa, R., **Kodama, T.**, **Hayashi, M.**, Tadaki, K., **Suzuki, T. L.**, **Koyama, Y.**, **Tanaka, I.**, **Yamamoto, M.**: 2015, Toward unveiling internal properties of HII regions and their connections at the cosmic noon era, IAU General Assembly, Meeting #29, 2235631.

Shimizu, E., Ali, S., Sakaue, H. A., Kato, D., Murakami, I., **Hara, H.**, **Watanabe, T.**, Nakamura, N.: 2015, Intensity ratio in EUV spectra of highly charged Fe ions: Experimental evaluation of astrophysical plasma model, *J. Phys.: Conf. Ser.*, **635**, 052061.

Shinnaga, H., Humphreys, E., Indebetouw, R., Villard, E., Kern, J., Davis, L., **Miura, R. E.**, **Nakazato, T.**, **Sugimoto, K.**, **Kosugi, G.**, **Akiyama, E.**, Muders, D., Wyrowski, F., Williams, S., Lightfoot, J., Kent, B., Momjian, E., Hunter, T., ALMA Pipeline Team: 2015, ALMA Pipeline: Current Status, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 355-356.

Shinohara, I., Fujimoto, M., Nagai, T., **Zenitani, S.**, Kojima H.: 2016, Low-frequency Waves in the Tail Reconnection Region, AGU Geophysical Monograph 216, Eds. A. Keiling, D.-H. Lee, V. Nakariakov, 181-191,

Shirasaki, Y., Komiya, Y., **Ohishi, M.**, **Mizumoto, Y.**: 2015, Properties of galaxies around the most massive SMBHs, IAU General Assembly, Meeting #29, 2252576.

Sirbu, D., Thomas, S. J., Belikov, R., Lozi, J., Bendek, E., Pluzhnik, E., Lynch, D. H., Hix, T., Zell, P., Schneider, G., **Guyon, O.**: 2015, EXCEDE technology development IV: demonstration of polychromatic contrast in vacuum at 1.2 λ/D, Proc. SPIE 9605, Ed. S. Shaklan, 96050J.

Sliwa, K., Wilson, C. D., **Iono, D.**, Peck, A. B., Matsushita, S.: 2015, Around the Ring We Go: The Cold, Dense Ring of Molecular Gas in NGC 1614, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 141-142.

Soam, A., Kwon, J., Maheswar, G., **Tamura, M.**, Lee, C. W.: 2015, Optical and NIR Polarimetry of a Core L328 with Proto-Brown Dwarf, Revolution in Astronomy with ALMA: The Third Year. Proc. a Conf., Eds. D. Iono, K.-I. Tatematsu, A. Wootten, L. Testi, 293.

Soma, M., Tanikawa K.: 2015, Reliability of Eclipse Records in Japanese Ancient Periods, Intensive Workshop on Ancient and Medieval Eclipse Data: Compilation of Eclipse Data and Examination of their **Reliability, Eds. M. Soma, K. Tanikawa, 49-52.**

Soma, M., Tanikawa, K.: 2015, Determination of ΔT and Lunar Tidal Acceleration from Ancient Eclipses and Occultations, New Insights From Recent Studies in Historical Astronomy: Following in the Footsteps of F. Richard Stephenson, Eds. W. Orchiston, D. Green, R. Strom, 11-23.

Soma, M.: 2015, Observations of the Annular Eclipse on 2012 May 21 by the General Public in Japan, APRIM 2014: Proc. 12th Asian-Pacific Regional IAU Meeting, Eds. Y. C. Minh H. Kim, 753-755.

Soma, M.: 2015, Observations of the Annular Eclipse on 2012 may 21 BY the General Public in Japan, *Publ. Korean Astron. Soc.*, **30**, 753.

Stoehr, F., Grothkopf, U., Meakins, S., Bishop, M., **Uchida, A.**, Testi, L., **Iono, D.**, **Tatematsu, K.**, Wootten, A.: 2015, ALMA Cycle 0 Publication Statistics, *The Messenger*, **162**, 30-35.

Sugai, H., et al. including **Takato, N.**, **Ueda, A.**: 2015, Prime Focus Spectrograph for the Subaru telescope: massively multiplexed optical and near-infrared fiber spectrograph, *J. Astron. Telescopes Systems*, **1**, 035001.

Sugiyama, K., Fujisawa, K., Hachisuka, K., Yonekura, Y., **Motogi, K.**, Sawada-Satoh, S., **Matsumoto, N.**, Saito, Y., Hirano, D., Hayashi, K., Shen, Z. Q., **Honma, M.**, **Hirota, T.**, Murata, Y., Doi, A., Niinuma, K., Dodson, R., Rioja, M., Ellingsen, S., Chen, X., Kim, K. T., Ogawa, H.: 2015, The VLBI Monitoring Project for 6.7 GHz Methanol Masers Using the JVN/EAVN, *Publ. Korean Astron. Soc.*, **30**, 645-647.

Sugiyama, K., Yonekura, Y., Motogi, K., Saito, Y., Fujisawa, K., Ishii, S., **Momose, M.**, **Honma, M.**, **Tazaki, F.**, Tanaka, K. E. I., Hosokawa, T., Uchiyama, M., Inayoshi, K.: 2015, Flux Monitoring of 6.7 GHz Methanol Maser to Systematically Research Periodic Variations Using the Hitachi 32-m, *Publ. Korean Astron. Soc.*, **30**, 129-131.

Suzuki, T., Honma, M., Otsuka, T., **Kajino, T.**: 2015, Electron-Capture Rates for Exotic Nuclei at Stellar Environments, JPS Conf. Proc. 6 (Int. Conf. on Advances in Radioactive Isotope Science), Eds. T. Otsuka, H. Enyo, et al., 30029.

Suzuki, T., **Kajino, T.**, Honma, M., Toki, H., Otsuka, T.: 2015, Roles of Nuclear Weak Processes in Stars, Exotic Nuclei (IASEN-2013) - Proc. of the First Int. African Symp. on Exotic Nuclei, Eds. Y. E. Penionzhkevich, et al., 129-139.

Suzuki, T., Yoshida, T., Wanajo, S., **Kajino, T.**, Otsuka, T.: 2015, Beta-Decay Rates for Exotic Nuclei and R-Process Nucleosynthesis, JPS Conf. Proc. 6 (Int. Conf. on Advances in Radioactive Isotope Science), Eds. T. Otsuka, H. Enyo, et al., 30063.

Takakuwa, S., **Saito, M.**, **Saigo, K.**, Matsumoto, T., Lim, J., Hanawa, T., Ho, P. T. P.: 2015, Spiral Arms and Mass Accretion in the Circumbinary Disk around the Protostellar Binary System L1551 NE Revealed with ALMA, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 287-288.

Takeda, T., **Kato, T.**, **Narazaki, Y.**, **Nakayama, H.**, **Fukushi, H.**, **Agata, H.**, **Kokubo, E.**: 2016, Four-Dimensional Digital Universe Project, Proc. of the "Astronomy museums and related activities", Eds. K. Usuda-Sato, S. Nemoto, H. Agata, 131-135.

Takekawa, S., **Oka, T.**, Tanaka, K., Matsumura, S., Miura, K., Sakai, D.: 2015, Millimeter-wave Spectral Line Surveys Toward the Galactic Circumnuclear Disk and Sgr A*, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 173-174.

Takekawa, S., **Oka, T.**, Tanaka, K.: 2015, Deep Mapping Observations of the Galactic Circumnuclear Disk with Two Single-dish Telescopes, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 171-172.

Tamura, M.: 2016, SEEDS - Strategic explorations of exoplanets and disks with the Subaru Telescope -, Proc. Japan Academy, Ser. B: Physical and Biological Sciences, 92, 45-55.

Taniguchi, A., Kohno, K., Tamura, Y., Izumi, T., **Takano, S.**, Nakajima, T., Tosaki, T.: 2015, Spatial Distribution of CO Isotopologue Abundance Ratios in the Center of NGC 1068, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 107-108.

Tanikawa K., **Soma, M.**: 2015, Historical Astronomy and Eclipses, Intensive Workshop on Ancient and Medieval Eclipse Data: Compilation of Eclipse Data and Examination of their Reliability, Eds. M. Soma, K. Tanikawa, 1-15.

Tatematsu, K., **Hirota, T.**, Ohashi, S., Choi, M., Lee, J. E., Yamamoto, S., **Umemoto, T.**, Kandori, R., Kang, M., **Mizuno, N.**: 2015, Thermal Starless Ammonia Core Surrounded by CCS in the Orion A Cloud, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 189-190.

Terazono, J., **Sakamoto, S.**, Yoshikawa, M., Wakabayashi, N., **Watanabe, J.**: 2016, Japanese Lunar and Planetary Exploration Outreach — 17 Years' History of "The Moon Station" —, Proc. of the "Astronomy museums and related activities", Eds. K. Usuda-Sato, S. Nemoto, H. Agata, 161-167.

Tokuda, K., Osaki, S., Maezawa, H., Onishi, T., Saigo, K., **Kawamura, A.**, Fukui, Y., Tachihara, K.: 2015, Extensive Surveys of Dense Cores in Taurus in High Density Molecular Tracers, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 193-194.

Ueda, J., **Iono, D.**, Yun, M. S., Crocker, A. F., Narayanan, D., Komugi, S., **Espada, D.**, **Hatsukade, B.**, **Kaneko, H.**, **Matsuda, Y.**, Tamura, Y., Wilner, D., **Kawabe, R.**, Pan, H.-A.: 2015, Investigating Nuclear and Extended Molecular Gas in the Final Stages of Mergers, IAU General Assembly, Meeting #29, 2256394.

Umehata, H., Kohno, K., Tamura, Y., **Iono, D.**, **Nakanishi, K.**, **Hatsukade, B.**, Ikarashi, S., Izumi, T., **Matsuda, Y.**, Ivison, R., Yun, M., Wilson, G., Hughes, D.: 2015, Dusty Starbursts within a $z=3$ Large Scale Structure, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 29-30.

Urata, Y., Huang, K., **Takahashi, S.**: 2015, Gamma-Ray Burst Afterglows with ALMA, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 339-340.

Usuda-Sato, K., Museum Project Office Members: 2016, Introduction of the NAOJ Museum Plan, Proc. of the "Astronomy museums and related activities", Eds. K. Usuda-Sato, S. Nemoto, H. Agata, 19-26.

Usuda-Sato, K., Tomita, A.: 2015, Astronomy for Development; Approaches in Asia, APRIM 2014: Proc. 12th Asian-Pacific Regional IAU Meeting, Eds. Y. C. Minh H. Kim, 731-733.

Uzawa, Y., Makise, K., **Kojima, T.**, Saito, S., **Kroug, M.**, **Fujii, Y.**, **Gonzalez, A.**, **Kaneko, K.**, Terai, H., Wang, Z.: 2015, Characterization of NbTiN Films for Superconducting Terahertz Circuitry, 15th Int. Superconductive Electronics Conf. 2015 (ISEC2015), Eds. N. Yoshikawa, Y. Hatsukade, A. Saito, T. Taino, Y. Yamanashi, T. Yamashita, MF-P11.

Wedemeyer, S., Bastian, T., Braja, R., Barta, M., **Shimojo, M.**, Hales, A., Yagoubov, P., Hudson, H.: 2015, Solar ALMA Observations - A New View of Our Host Star, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 345-346.

Wedemeyer, S., Bastian, T., Braja, R., Barta, M., **Shimojo, M.**: 2015,

Solar Simulations for the Atacama Large Millimeter Observatory Network, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 341-342.

Yamada, M., Yoo, J., **Zenitani, S.**: 2016, Energy conversion and inventory of a prototypical magnetic reconnection layer, Astrophysics and Space Science Library, 427, Eds. W. Gonzalez, E. Parker, 143-179.

Yamada, R., Shiraishi, H., Nebut, T., Lognonne P., **Asari, K.**, Tanaka, S.: 2015, Seismic observation using the broadband seismometers targeted for moonquake, 5th Int. Symp. on Technology for Sustainability (ISTS2015), K-20.

Yamaguchi, Y., Kohno, K., Tamura, Y., **Matsuda, Y.**: 2015, Constraints on the CO Luminosity Function at $z \sim 1$ Using ALMA Archival Data, ASP Conf. Ser., 499, Eds. D. Iono, K. Tatematsu, A. Wootten, L. Testi, 61-62.

Yamaoka, H., **Maehara, H.**, Kaneko, S., Noguchi, T., Kiyota, S., Yusa, T.: 2015, Probable New Dwarf Nova in Orion = TCP J05002724+1334199, Central Bureau Electronic Telegrams, Ed. D.W.E. Green, 4207.

Yanagisawa, K., **Kuroda, D.**, **Shimizu, Y.**, **Izumiura, H.**, Yoshida, M., Ohta, K., Kawai, N.: 2015, GRB 150910A: MITSuME Okayama Ks-band Observation, *GRB Coordinates Network, Circular Service*, **18278**, 1.

Yanagisawa, K., **Kuroda, D.**, **Shimizu, Y.**, **Izumiura, H.**, Yoshida, M., Ohta, K., Kawai, N.: 2015, GRB150911A MITSuME Okayama Ks-band upper-limit, *GRB Coordinates Network, Circular Service*, **18282**, 1.

Yanagisawa, K., **Kuroda, D.**, **Shimizu, Y.**, **Izumiura, H.**, Yoshida, M., Ohta, K., Kawai, N.: 2015, GRB 151006A: MITSuME Okayama Ks-band upper-limit, *GRB Coordinates Network, Circular Service*, **18408**, 1.

Yanagisawa, K., **Kuroda, D.**, **Shimizu, Y.**, **Izumiura, H.**, Yoshida, M., Ohta, K., Kawai, N.: 2015, GRB 151021A: MITSuME Okayama Ks-band upper-limit, *GRB Coordinates Network, Circular Service*, **18435**, 1.

Yanagisawa, K., **Kuroda, D.**, **Shimizu, Y.**, **Izumiura, H.**, Yoshida, M., Ohta, K., Kawai, N.: 2015, GRB 151022A: MITSuME Okayama Ks-band upper-limit, *GRB Coordinates Network, Circular Service*, **18440**, 1.

Yanagisawa, K., **Kuroda, D.**, **Shimizu, Y.**, **Izumiura, H.**, Yoshida, M., Ohta, K., Kawai, N.: 2016, GRB 160104A: MITSuME Okayama Ks-band upper-limit, *GRB Coordinates Network, Circular Service*, **18819**, 1.

Yeh, S. C. C., **Tsai, C.-W.**, **Geballe, T. R.**, **Herrera, C. N.**: 2015, Mid-infrared [NeII] Imaging of Young Massive Star Clusters Near Galactic Nuclei, IAU General Assembly, Meeting #29, A. Nota, C. Charbonnel, 2246331.

Yilmaz, M., Selam, S. O., **Izumiura, H.**, Bikmaev, I., Sato, B., Keskin, V., **Kambe, E.**: 2015, RTT150 Planet Search Program at TUG: Results from Seven Years of Observation, ASP Conf. Ser., 496, Eds. S. M. Rucinski, T. Guillermo, Z. Miloslav, 378-379.

Yoshii, T., Kawai, N., **Hanayama, H.**, Saito, Y., Yatsu, Y.: 2015, X-ray and optical observations of a compact black hole binary MAXI J1910-057: implication for the companion and evidence for the jet turn-on, IAU General Assembly, Meeting #29, 2257355.

Yoshikoshi, T., Clay, R. W., Matsubara, Y., Miyo, K., Mori, M., Naito, T. Nishijima, K. Ohishi, M. Okuda, T., **Oshima, A.**, Rowell, G. P., Saito, T., Sako, T., Tajima, H., Terasawa, T., Yamamoto, T.: 2015, A 3-Meter Atmospheric Cherenkov Telescope as a Test Bench for Very High Energy Gamma-Ray Astrophysics Projects, 34th Int. Cosmic Ray Conf., 1300.

5. Publications in English

Canas, L., et al.: 2016, Inspired by Light: Reflections from the International Year of Light 2015, SPIE, EPS, ICTP, USA.

Edited by **Usuda-Sato, K.**, **Nemoto, S.**, **Agata, H.**: 2016, Astronomy Museums and Related Activities: Proceedings of the International Symposium on the NAOJ Museum, NAOJ, Tokyo.

Iono, D., **Tatematsu, K.**, Wootten, A., Testi, L.: 2015, Proceedings of the International Conference "Revolution in Astronomy with ALMA: The Third Year", ASP, San Francisco.

Soma, M., Tanikawa, K.: 2015, Proceedings of Intensive Workshop on Ancient and Medieval Eclipse Data: Compilation of Eclipse Data and Examination of their Reliability, NAOJ, Tokyo.

6. Conference Presentations

Agata, H., **Furusho, R.**: 2015, Makalii and Subaru Telescope Images, Global Hands-On Universe Conference 2015, (Honolulu, HI, USA, Aug. 4-5, 2015).

Akiyama, E., et al. including **Kusakabe. N.**, **Tamura, M.**: 2015, Multiple gap structure of TW Hydrae, Protoplanetary Disk Dynamics and Planet Formation, (Kanagawa, Japan, Sep. 29-Oct. 2, 2015).

Akiyama, E., **Kusakabe. N.**, Muto, T., **Kataoka, A.**, Tamura, M., SEEDS/HiCIAO/AO188 Team: 2015, Discovery of a disk gap candidate at 20 AU in TW Hydrae, Disc Dynamics & Planet Formation, (Lancashire, UK, Jun. 29-Jul. 3, 2015).

Akiyama, E.: 2015, ALMA Capabilities and Science Review of HL Tau, 3rd DTA Symposium: The Origins of Planetary Systems: From the Current View to New Horizons, (Tokyo, Japan, Jun. 1-4, 2015).

Akiyama, E.: 2015, Planet Formation in the Protoplanetary Disk around HL Tauri, East Asian ALMA Science Workshop 2015, (Osaka, Japan, Dec. 8-11, 2015).

Akiyama, E.: , ALMA Single Dish Pipeline and ALMA Quality Assurance (AQUA) System, NRO-ALMA Science/Development Workshop 2015, (Nagano, Japan, Jul. 28-30, 2015).

Akiyama, K.: 2015, 230 GHz (1.3 mm) VLBI observations of M87 with the Event Horizon Telescope, 8th East Asia VLBI Workshop, (Sapporo, Japan, Jul. 8-10, 2015).

Akutsu, T., for the KAGRA collaboration: 2016, Status of KAGRA, LSC-Virgo March 2016 meeting, (Pasadena, CA, USA, Mar. 14-18, 2016).

Ando, M.: 2015, The Physical Condition of the Gas in the Luminous Galaxy NGC 1614, East Asian ALMA Science Workshop 2015, (Osaka, Japan, Dec. 8-11, 2015).

Anthes Rich, E., Wisniewski, J. P., **Hashimoto, J.**, Brandt, T., Kuzuhara, M., **Tamura, M.**: 2015, Discovery of Low Mass Binary with Super Jupiter Companion, American Astronomical Society, ESS meeting #3, (Hawaii, USA, Nov. 29-Dec. 4, 2015).

Ao, Y.: 2015, Submm observations towards LABs, East Asian ALMA Science Workshop 2015, (Osaka, Japan, Dec. 8-11, 2015).

Aoki, W.: 2015, Very Low Mass Stars with Extremely Low Metallicity in the Milky Way's Halo, IAU Symp. 317: The General Assembly of Galaxy Halos Structure, Origin and Evolution, (Honolulu, HI, USA, Aug. 3-7, 2015).

Aoki, W.: 2015, Metal-poor stars in the Galactic halo and dwarf galaxies, First stars, galaxies, and black holes: Now and Then, (Groningen, Netherland, June 15-19, 2015).

Aoki, W.: 2015, Observational constraints on *r*-process, Quarks to Universe in Computational Science, (Nara, Japan, Nov. 4-8, 2015).

Asai, A., Isobe, H., Ueno, S., Shinbori, A., Kitai, R., Shiota, D., **Morita, S.**: 2016, Solar Ultraviolet Radiation estimated from Solar Images, Int. Symp. PSTEP-1: Toward the Solar-Terrestrial Environment Prediction as Science and Social Infrastructure, (Nagoya, Japan, Jan. 13-14, 2016).

Asayama, A., Saini, K., Yagoubov, P., Whyborn, N., Siringo, G.: 2015, ALMA Front End and Its Performances, 36th ESA Antenna Workshop, (Noordwijk, the Netherlands, Oct. 6-9, 2015).

Baba, Y., **Ishikawa, T.**: 2015, Nearly 120 Years of Science History in Danger: The Collections in the National Astronomical Observatory of Japan, Mizusawa, Int. Symp. on the NAOJ Museum, (Tokyo, Japan,

Sep. 27-29, 2015).

Barkin Y., **Hanada, H.**, Barkin, M.: 2015, Precession, nutation, pole motion and variations of LOD of the Earth and the Moon, Japan Geoscience Union Meeting 2015, (Chiba, Japan, May 24-28, 2015).

Barnes, P., **Muller, E.**, **Nguyen-Luong, Q.**, Nguyen, H.: 2015, The Three-mm Ultimate Mopra Milky Way Survey (ThrUMMS): A New View of the Molecular Milky Way, IAU XXIX General Assembly, (Honolulu, HI, USA. Aug. 3-14, 2015).

Bastian, T. S., Barta, M., Brajsa, R., Chen, B., De Pontieu, B., Fleishman, G., Gary, D., Hales, A., Hills, R., Hudson, H., Iwai, K., **Shimojo, M.**, White, S., Wedemeyer, S., Yan, Y.: 2015, The Atacama Large Millimeter/Submillimeter Array: a New Asset for Solar and Heliospheric Physics, IAU XXIX General Assembly, (Honolulu, HI, USA. Aug. 3-14, 2015).

Belikov, R., Bendek, E., Thomas, S., Males, J., **Lozi, J.**: 2015, How to directly image a habitable planet around Alpha Centauri with a ~30–45 cm space telescope, SPIE Optics + Photonics, (San Diego, CA, USA, Aug. 9-13, 2015).

Bellot Rubio, L., Gosic, M., del Toro Iniesta, J. C., **Katsukawa, Y.**: 2015, The origin and fate of internetwork magnetic elements, 9th Hinode Science Meeting, (Belfast, UK, Sep. 14-17, 2015).

Bendek, E. A., Belikov, R., **Lozi, J.**, Thomas, S., Males, J., Weston, S., McElwain, M.: 2015, Space telescope design to directly image the habitable Zone of Alpha Centauri, SPIE Optics + Photonics, (San Diego, CA, USA, Aug. 9-13, 2015).

Canas, L., **Cheung, S. L.**: 2015, International Astronomical Union (IAU) Directory for World Astronomy Network, Int. Symp. on the NAOJ Museum, (Tokyo, Japan, Sep. 27-29, 2015).

Canas, L., **Cheung, S. L.**: 2015, International Astronomical Union (IAU) Directory for World Astronomy Network, IAU XXIX General Assembly, (Honolulu, HI, USA, Jul. 30-Aug. 15, 2015).

Canas, L., Ortiz-Gil, A.: 2015, Astronomy for Inclusion, UNAWE workshop 2015, (Leiden, Netherlands, Oc. 5-10, 2015).

Capocasa, E., Barsuglia, M., Degallaix, J., Pinard, L., Straniero, N., Schnabel, R., Somiya, K., **Aso, Y.**, **Tatsumi, D.**, **Flaminio, R.**: 2015, Losses estimation in a 300-m filter cavity and quantum noise reduction in KAGRA, 4th ELiTES general meeting, (Tokyo, Japan, Dec. 2-3, 2015).

Cheung, S. L.: 2015, IAU Office for Astronomy Outreach, IAU XXIX General Assembly, (Honolulu, HI, USA. Aug. 3-14, 2015).

Cheung, S. L.: 2015, Science Center, Planetariums, Public Observatories and OAO, Int. Symp. on the NAOJ Museum, (Tokyo, Japan, Sep. 27-29, 2015).

Cheung, S. L.: 2015, IAU Outreach Initatives and Projects, dotAstronomy 7, (Sydney, Australia, Nov. 3-6, 2015).

Cheung, S. L.: 2015, OAO-SEAAN partnership and the Total Solar Eclipse 2016, South East Asian Astronomer Network Meeting 2015, (Krabi, Thailand, Nov. 30-Dec. 1, 2015).

Cheung, S. L.: 2015, Planetarium and OAO, Int. Symp. on the NAOJ Museum, (Tokyo, Japan, Sep. 27-29, 2015).

Cheung, S. L., Pun, J. C. S., So, C. W., **Shibata, Y.**, Walker, C., **Agata, H.**: 2015, Globe at Night - Sky Brightness Monitoring Network, IAU XXIX General Assembly, (Honolulu, HI, USA. Aug. 3-14, 2015).

Chiba, M., Tanaka, M., **Komiyama, Y.**: 2015, Subaru Hyper Suprime Cam Survey of the Andromeda Halo, IAU XXIX General Assembly, (Honolulu, HI, USA. Aug. 3-14, 2015).

Dominjon, A., **Noguchi, T.**, Sekine, M., **Karatsu, K.**, **Sekimoto, Y.**, Okada, T., Shibo, S., Sekiguchi, S., Nitta, T.: 2015, Microwave Kinetic Inductance Detectors with Superconductor Bilayer, The 16th Workshop on Submm Wave Receiver Technologies in Eastern Asia, (Nanjing, China, Nov. 22-25, 2015).

Egusa, F.: 2015, CO(1-0) Mapping Survey of ~100 Nearby Spiral Galaxies with ALMA, ALMA Workshop for Large Proposals on Nearby Galaxies, (Tokyo, Japan, Aug. 25-26, 2015).

Egusa, F.: 2015, CO survey of ~100 nearby spiral galaxies with ALMA, ALMA/45m/ASTE/Mopra Users Meeting 2015, (Tokyo, Japan, Oct. 20-22, 2015).

Egusa, F.: 2015, Large Proposal Plans for Nearby Galaxies, East Asian ALMA Science Workshop 2015, (Osaka, Japan, Dec. 8-11, 2015).

Egusa, F.: 2015, Review of recent observations of nearby galaxies with NRO45m and ALMA, NRO-ALMA Science/Development Workshop 2015, (Nagano, Japan, Jul. 28-30, 2015).

Espada, D.: 2015, Galaxies and AGN studies with ALMA, East Asian ALMA Science Workshop 2015, (Osaka, Japan, Dec. 8-11, 2015).

Ferré-Mateu, A., Mezcua, M., Trujillo, I., Balcells, M., van den Bosch, R.: 2015, Witnessing a different (co-)evolution for relic massive galaxies and their Übermassive black holes, EWASS 2015, (La Laguna, Spain, Jun. 22-26, 2015).

Flaminio, R.: 2015, The case of a cryogenic interferometer: KAGRA, The Next Detectors for Gravitational Wave Astronomy, (Beijing, China, Apr. 6-May 8, 2015).

Flaminio, R.: 2015, The cryogenic challenge: status of the KAGRA project, The 11th Edoardo Amaldi Conference on Gravitational Waves, (Gwangju, Korea, June 21-26, 2015).

Flaminio, R.: 2015, Frequency dependent squeezing experiment at TAMA, KAGRA F2F Meeting, (Toyama, Japan, Aug. 25-28, 2015).

Fujii, M.: 2015, Formation of intermediate-mass black holes in star clusters, Max's 4 questions in X-ray astronomy to be addressed with ASTRO-H, (Tokyo, Japan, Jul. 31, 2015).

Fujii, M.: 2015, The Origin of the Mass Function of Star Clusters, XXIX IAU General Assembly FM18: Scale-free processes in the universe, (Honolulu, HI, USA, Aug. 12-14, 2015).

Fujii, M.: 2015, The formation and dynamical evolution of young star clusters, MODEST-15S, (Kobe, Japan, Dec. 7-11, 2015).

Fujii, M.: 2015, The origin of the variety of star clusters, Star Formation Workshop 2015, (Mitaka, Japan, June 29-Jul. 1, 2015).

Fujii, M., Portegies Zwart, S.: 2015, Formation of young massive clusters from turbulent molecular clouds, IAU Symp. 316: Formation, evolution, and survival of massive star clusters, (Honolulu, HI, USA, Aug. 11-14, 2015).

Fujii, Y., **Sekiguchi, T.**, **Takahashi, R.**, **Aso, Y.**, **Barton, M.**, **Peña Arellano, F. E.**, **Shoda, A.**, **Akutsu, T.**, **Ishizaki, H.**, **Tatsumi, D.**, **Hirata, N.**, **Hayama, K.**, **Okutomi, K.**, **Miyamoto, T.**, **Ishizuka, H.**, **Flaminio, R.**: 2015, Status of KAGRA vibration isolation system, The 11th Edoardo Amaldi Conference on Gravitational Waves, (Gwangju, Korea, June 21-26, 2015).

Fujita, C., Ozeki, H., **Kobayashi, K.**: 2015, The Microwave Spectroscopy of Aminoacetonitrile in the Vibrational Excited State, Int. Symp. on Molecular Spectroscopy, 70th meeting, (Urbana-Champagne, IL, USA, Jun. 22-26, 2015).

Fujiwara, H.: 2015, Observational Research with Subaru Telescope, SEAYAC 2015, (Krabi, Thailand, Dec. 3-4, 2015).

Fujiwara, H.: 2015, Infrared Observation of Warm Debris Disks, Exoplanets in Lund 2015, (Lund, Sweden, May 6-8, 2015).

Fukagawa, M., Grady, C. A., Wisniewski, J. P., Ohta, Y., **Momose, M.**, Matura, Y., **Kotani, T.**, Okamoto, Y., Hashimoto, J., Muto, T., Sitko, M., Follette, K., Bonnefoy, M., **Kusakabe, N.**, **Tamura, M.**, SEEDS/HiCIAO/IRCS/AO188 Collaboration: 2015, Non-axisymmetric structure in million-year-old discs around intermediate-mass stars, Disc Dynamics & Planet Formation, (Lancashire, UK, Jun. 29-Jul. 3, 2015).

Fukagawa, M.: 2015, A review of recent observations of protoplanetary disks, Protoplanetary Disk Dynamics and Planet Formation, (Kanagawa, Japan, Sep. 29–Oct. 2, 2015).

Fukagawa, M.: 2015, Recent advances in understanding planet formation, NRO-ALMA Science/Development Workshop 2015, (Nagano, Japan, Jul. 28-30, 2015).

Fukui, A.: 2015, Characterization of microlensing planetary systems by AO imaging, From super-earths to brown dwarfs: who's who?, (Paris, France, Jun. 29-Jul. 3, 2015).

Fukui, A.: 2016, Toward the Metallicity Measurements of Microlensing Planetary Host Stars, 20th Microlensing Workshop, (Paris, France, Jan. 13-15, 2016).

Furusawa, H.: 2015, Software and database: A review of S15A workarounds, Understanding Evolution of Quasars: Collaboration between Theoretical Models and Initial HSC Survey, (Kagoshima, Japan, Dec. 1-3, 2015).

Furusawa, H.: 2015, Status of SSP data release production, HSC Collaboration Meeting, (Princeton, NJ, USA, Jul. 27-19, 2015).

Furusawa, H.: 2016, Status of Data Release Preparation, HSC Collaboration Meeting, (Taipei, Taiwan, Jan. 13-15, 2016).

Furusawa, H.: 2015, Equations of state at sub-nuclear densities and weak interactions in Supernovae, Physics and Astronomy of Neutron Stars and Supernovae, (Tokyo, Japan, Jun. 21-22, 2015).

Furusawa, S.: 2015, Equation of State of Supernova Matter with Ensembles of Nuclei, International Numazu Workshop on Challenges of Modeling Supernovae with Nuclear Data, (Shizuoka, Japan, Sep. 1-4, 2015).

Furusawa, S.: 2015, Equation of state including full nuclear ensemble in supernova simulations, Quarks to Universe in Computational Science, (Nara, Japan, Nov. 4-8, 2015).

Geballe, T. R., Oka, T., Lambrides, E., **Yeh, S. C. C.**, Schlegelmilch, B., Goto, M., Westrick, C. W.: 2015, New Background Infrared Sources For Studying the Galactic Center's Interstellar Gas, Int. Symp. on Molecular Spectroscopy, 70th meeting, (Urbana-Champagne, IL, USA, Jun. 22-26, 2015).

Giono, G., **Ishikawa, R.**, **Narukage, N.**, **Kano, R.**, **Katsukawa, Y.**, **Kubo, M.**, Ishikawa, S., **Bando, T.**, **Hara, H.**, **Suematsu, Y.**, Winebarger, A., Kobayashi, K., Auchère, F., Trujillo Bueno, J.: 2015, CLASP: reaching below the 0.1 % polarization sensitivity, 9th Hinode Science Meeting, (Belfast, UK, Sep. 14-17, 2015).

Gonzalez, A.: 2015, Optical design considerations for a large dish antenna in ALMA, NRO-ALMA Science/Development Workshop 2015, (Nagano, Japan, Jul. 28-30, 2015).

Gonzalez, A.: 2015, Design of optics for ALMA receivers at NAOJ, 36th ESA Antenna Workshop, (Noordwijk, the Netherlands, Oct. 6-9, 2015).

Gonzalez, A., Tapia, V., Finger, R., **Asayama, S.**, Huang, T.: 2015, Alternative Optics Design for the ALMA Band 1 Receiver (35-52GHz), 9th European conference on Antennas and Propagation, (Lisbon, Portugal, Apr. 12-17, 2015).

Gouda, N.: 2015, Infrared Space Astrometry missions: JASMINE, Division A meeting at the XXIX General Assembly of IAU, (Honolulu, USA, Aug. 7-10, 2015).

Grady, C. A., et al. including **Tamura, M.**: 2015, Decoding Debris System Substructures: Imprints of Planets/Planetesimals and Signatures of Extrinsic Influences on Material in Ring-Like Disks, AAS Meeting #227, (Kissimmee, FL, USA, Jan. 4-8, 2016).

Gusev, A., **Hanada, H.**, Petrova, N., Ping, J.: 2015, Physical librations and free nutations of the three-layer Moon for ChangE-3/4, Luna-Glob-Resource, SELENE-2 missions, 2nd IAPS Scientific Assembly, (Kazan, Russia, Jun. 1-4, 2015).

Gusev, A., **Hanada, H.**, Petrova, N.: 2015, Physical librations and the internal structure of a multilayer resonant moons in the Solar System, 2nd IAPS Scientific Assembly, (Kazan, Russia, Jun. 1-4, 2015).

Guyon, O., **Jovanovic, N.**, **Lozi, J.**: 2015, Direct imaging and spectroscopic characterization of habitable planets with ELTs, Extreme Solar Systems III, (Waikoloa, HI, USA, Nov. 29-Dec. 4, 2015).

Hada, K.: 2015, Deep imaging and monitoring of the collimation and acceleration region of the M87 jet, 8th East Asia VLBI Workshop, (Sapporo, Japan, Jul. 8-10, 2015).

Hada, K.: 2016, (Lecture) AGN, NARIT-UST-GUAS Radio Astronomy Winter School 2016, (Chiang Mai, Thailand, Feb.15-19, 2016).

Hada, L.: 2016, M87 monitor project with KaVA: current status, The 10th NARIT-KaVA Joint Science WG meeting, (Krabi, Thailand, Feb. 22-24, 2016).

Hagino, M., Ichimoto, K., Ueno, S., Kimura, G., **Otsuji, K.**, Kitai, R., Zhong, L., Xu, Z., **Shinoda, K.**, **Hara, H.**, **Suematsu, Y.**, Shimizu, T.: 2015, Development of the Universal Tunable Filter and High-resolution Imaging Observation with the Fuxian Solar Observatory, Coimbra Solar Physics Meeting: Ground-based Solar Observations in the Space Instrumentation Era, (Coimbra, Portugal, Oct. 5-9, 2015).

Hamana, T.: 2015, Cosmological constraints from Subaru weak lensing cluster counts, Theoretical and Observational Progress on Large-scale Structure of the Universe, (Garching, Germany, Jul. 20-24, 2015).

Hanada, H., **Tsuruta, S.**, **Asari, K.**, **Araki, H.**, **Noda, H.**, **Kashima, S.**, Funazaki, K., Satoh, A., Taniguchi, H., Kato, H., Kikuchi, M., Sasaki, H., Shinke, S., Petrova, N., Gusev, A.: 2015, Ground experiments of a small telescope like PZT for observations on the Moon, 2nd IAPS Scientific Assembly, (Kazan, Russia, Jun. 1-4, 2015).

Hanada, H., **Tsuruta, S.**, **Asari, K.**, **Araki, H.**, **Noda, H.**, **Kashima, S.**, Funazaki, K., Satoh, A., Taniguchi, H., Kato, H., Kikuchi, M., Yokokawa, R., Shinke, S.: 2015, Summary of the development of a small telescope for lunar rotation and the experiments on the ground, Japan Geoscience Union Meeting 2015, (Chiba, Japan, May 24-28, 2015).

Hanada, H.: 2015, International Cooperation in NAOJ Mizusawa : Result of Kaguya, and possibility in the future, Japan Geoscience Union Meeting 2015, (Chiba, Japan, May 24-28, 2015).

Hanaoka, Y., **the Solar Observatory of NAOJ**: 2015, Past and Present of the Synoptic Observations of the Sun at the National Astronomical Observatory of Japan, Coimbra Solar Physics Meeting: Ground-based Solar Observations in the Space Instrumentation Era, (Coimbra, Portugal, Oct. 5-9, 2015).

Hara, H., Glesener, L.: 2015, Coronal Velocity Fields near an Impulsive

Hard X-ray Source Located above Soft X-ray Flare Loops, 9th Hinode Science Meeting, (Belfast, UK, Sep. 14-17, 2015).

Hara, H.: 2015, Unresolved Plasma Motions in Coronal Loops, Coronal Loop Workshop VII, (Cambridge, UK, Jul. 21-23, 2015).

Hara, H.: 2015, The SOLAR-C Mission, 3rd Asia-Pacific Solar Physics Meeting (APSPM 2015), (Soule, South Korea, Nov. 3-6, 2015).

Hara, H.: 2016, Reconnection-associated Dynamic Structures from EUV Observations in Solar Flares, 2016 US-Japan Workshop on Magnetic Reconnection (MR2016), (Napa, CA, USA, Mar. 7-11, 2016).

Hara, H.: 2016, The SOLAR-C Mission, ISEE Workshop 2015, (Nagoya, Japan, Mar. 22-25, 2016).

Harada, R., Onishi, T., Hughes, A., Meixner, M., Sewilo, M., Indebetouw, R., Nayak, O., Tokuda, K., Morioka, Y., Fukui, Y., **Kawamura, A.**, Wong, T., Bernard, J.-P.: 2015, Investigating formation of isolated intermediate/massive YSOs in the LMC, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Harada, Y., Goossens, S., **Matsumoto, K.**, Yan, J., Ping, J., **Noda, H.**, Haruyama, J.: 2015, Strong tidal heating inside an ultralow-viscosity zone over the lunar core-mantle boundary, Japan Geoscience Union Meeting 2015, (Chiba, Japan, May 24-28, 2015).

Harakawa, H., Sato, B., **Omiya, M.**, Fischer, D. A., Hori, Y., Ida, S., **HIDES-F team**: 2015, Search for Exoplanets around Metal-Rich FGK Stars, Exoplanets and Disks: Their Formation and Diversity III, (Ishigaki, Japan, Feb. 21-24, 2016).

Harra, L. K., Baker, D. Sterling, A., Edwards, S., **Hara, H.**, Howe, R. van Driel-Gesztelyi, L.: 2015, Exploring polar regions and corona hole boundaries through coronal spectroscopy, 9th Hinode Science Meeting, (Belfast, UK, Sep. 14-17, 2015).

Hasegawa, T.: 2015, SgrB2(N): A bipolar outflow and rotating hot core revealed by ALMA, East Asian ALMA Science Workshop 2015, (Osaka, Japan, Dec. 8-11, 2015).

Hatsukade, B., Ohta, K., Endo, A., **Nakanishi, K.**, Tamura, Y., **Hashimoto, T.**, Kohno, K.: 2015, Gamma-ray bursts from dusty regions with little molecular gas, Gas, Dust, and Star-Formation in Galaxies from the Local to Far Universe, (Plantanias-Chania, Crete, Greece, Apr. 25-29, 2015).

Hatsukade, B.: 2015, High-resolution ALMA observations of SDP.81. II. Molecular clump properties of a lensed submillimeter galaxy at z=3.042, ALMA/45m/ASTE/Mopra Users Meeting 2015, (Tokyo, Japan, Oct. 20-22, 2015).

Hatsukade, B.: 2015, High-resolution ALMA observations of SDP.81: Molecular clump properties of a lensed submillimeter galaxy at z = 3.042, East Asian ALMA Science Workshop 2015, (Osaka, Japan, Dec. 8-11, 2015).

Hatsukade, B.: 2015, Gamma-ray bursts from dusty regions with little molecular gas, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Hatsukade, B.: , Recent studies of distant galaxies with NRO 45m and ALMA, NRO-ALMA Science/Development Workshop 2015, (Nagano, Japan, Jul. 28-30, 2015).

Hayano, Y.: 2016, Adaptive optics in astronomy and the future perspective, Symposium on Super adaptive optics with wave field correction: Toward perfect imaging of the universe and live organisms, (Mitaka, Japan, Mar. 23, 2016).

Hayano, Y., Chun, M., Honda, M.: 2015, Development and on-sky experiment of narrow band filter for daytime AO observation using laser guide star in mid-infrared wavelength, AO4ELT4, (Lake Arrowhead, CA, USA, Oct. 26-30, 2015).

Hayashi, M.: 2015, NAOJ Projects and E/PO Activities, Int. Symp. on the NAOJ Museum, (Tokyo, Japan, Sep. 27-29, 2015).

Herrera, C. N., Boulanger, F., Falgarone, E. G., des Forets, G. P., Garcia-Burillo, S., **Iono, D.**, Guillard, P.: 2015, The ALMA view of the Antennae galaxy collision, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Herrera, C. N., Boulanger, F.: 2015, Stellar feedback from a massive Super Star Cluster in the Antennae merger, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Hirai, Y., Ishimaru, Y., Saitoh, T. R., Fujii, M. S., Hidaka, J., **Kajino, T.**: 2015, Astrophysical site(s) of r-process elements in galactic chemo-dynamical evolution model, The 13th International Symposium on Origin of Matter and Evolution of Galaxies (OMEG2015), (Beijing, China, Jun. 24-27, 2015).

Hirai, Y., Ishimaru, Y., Saitoh, T. R., Fujii, M. S., Hidaka, J., **Kajino, T.**: 2015, Chemo-dynamical evolution model: Enrichment of r-process elements in the Local Group dwarf galaxies, IAU Symp. 317: The General Assembly of Galaxy Halos Structure, Origin and Evolution, (Honolulu, HI, USA, Aug. 3-7, 2015).

Hiramatsu, M.: 2015, ALMA Public Outreach, ALMA/45m/ASTE/Mopra Users Meeting 2015, (Tokyo, Japan, Oct. 20-22, 2015).

Hirano, T., Sato, B., Masuda, K., Benomar, O., Takeda, Y., **Omiya, M.**, **Harakawa, H.**: 2015, Search for Close-in Planets around Evoloved Stars with Phase-curve variations and Radial Velocity Measurements, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Hirota, A.: 2015, Giant Molecular Clouds and Star Formation in Nearby Galaxy M83, East Asian ALMA Science Workshop 2015, (Osaka, Japan, Dec. 8-11, 2015).

Hirota, T., **Matsumoto, N.**, **Hada, K.**, Sawada-Satoh, S.: 2016, AIPS tutorial, NARIT-UST-GUAS Radio Astronomy Winter School 2016, (Chiang Mai, Thailand, Feb.15-19, 2016).

Hirota, T.: 2015, Observational study of (sub)millimeter maser lines in star-forming regions, High Mass Star Formation Workshop, (Tokyo, Japan, Jul. 22, 2015).

Hirota, T.: 2015, CASA Users Committee Report, ALMA/45m/ASTE/Mopra Users Meeting 2015, (Tokyo, Japan, Oct. 20-22, 2015).

Hirota, T.: 2016, Hot water disk around Orion Source I, Workshop on Astrochemistry in Star and Planet Formation, (Wako, Japan, Feb. 16, 2016).

Hirota, T.: 2016, Status report of SFRs sub-WG, The 10th NARIT-KaVA Joint Science WG meeting, (Krabi, Thailand, Feb. 22-24, 2016).

Hirota, T.: 2016, Proposal of new science cases for SFRs studies with KaVA, The 10th NARIT-KaVA Joint Science WG meeting, (Krabi, Thailand, Feb. 22-24, 2016).

Honma, M.: 2015, Current status of EHT and related activities in Japan, 8th East Asia VLBI Workshop, (Sapporo, Japan, Jul. 8-10, 2015).

Honma, M.: 2016, (Lecture) VERA, NARIT-UST-GUAS Radio Astronomy Winter School 2016, (Chiang Mai, Thailand, Feb.15-19, 2016).

Honma, M.: 2016, EAVN and SKA, Australia-Japan School on Low Frequency Astrometry in the SKA Era, (Kagoshima, Japan, Mar. 28-31, 2016).

Hori, Y.: 2015, Can ExoEarths be Habitable?: Origin and Evolution of Planetary Atmospheres, Astrobiology: A Japanese-German

Colloquium, (Kiel, Germany, Dec. 8-10, 2015).

Hori, Y.: 2015, Recent Developments in Planetary Interiors under High Pressure, International Workshop on Warm Dense Matter 2015, (Kurashiki, Okayama, Japan, Aug. 8-13, 2015).

Hori, Y.: 2015, The Interior Structure of Jupiter Towards Future Missions of the Jovian System, 48th ISAS Lunar and Planetary Symp., (Sagamihara, Kanagawa, Japan, Jul. 29-31, 2015).

Hori, Y.: 2015, Peer into a Nutshell: The Interior of Jupiter, Science Workshop for the Giant Planet System, (Ookayama, Tokyo, Japan, Apr. 14, 2015) .

Hori, Y.: 2016, The Atmospheres and Water on Our Terrestrial Planets and Other Planets, Symposium on Hierarchy and Holism in Natural Sciences, (Mitaka, Tokyo, Japan, Feb. 5-6, 2016).

Hori, Y., Liu, S-F., Lin, D. N. C., Asphaug, E.: 2015, A Collisional Origin for the Coexistence of Volatile-poor Super-Earths and Mini-Neptunes in the Proximity of Their Host Stars, Extreme Solar Systems III, (Waikoloa, HI, USA, Nov. 29-Dec. 4, 2015).

Hori, Y., Liu, S-F., Lin, D. N. C., Asphaug, E.: 2015, A Collisional Origin for the Coexistence of Volatile-poor Super-Earths and Mini-Neptunes in the Proximity of Stars, Exoplanetary Atmospheres and Habitability: Thermodynamics, Disequilibrium, and Evolution Focus Group, (Nice, France, Oct. 12-16, 2015).

Hori, Y., Liu, S-F., Lin, D. N. C., Asphaug, E.: 2016, Deep Impact on a Super-Earth in the Vicinity of a Central Star, Exoplanets and Disks: Their Formation and Diversity III, (Ishigaki, Japan, Feb. 21-24, 2016).

Ichikawa, K.: 2015, Outflow/inflow study of buried AGN through 4.7 μm CO absorption line, TMT Thermal infrared science & instrument workshop, (Tokyo, Japan, Jun. 12, 2015).

Ichikawa, K.: 2015, On the torus structure and the detection of polarized broad emission lines in AGN, East Asia AGN workshop 2015, (Changchun, China, Jul. 14-16, 2015).

Ichikawa, K.: 2015, Determining the dust torus covering factor using clumpy torus models in IR, Prospects, challenges and evolution of AGN modeling in the Astro-H Era, (Tokyo, Japan, Oct. 21-22, 2015).

Ide, H., **Kinugasa, K.**, **Suzuki, Y.**, **Nishioka, M.**, **Mikoshiba, H.**, **Miyazawa, K.**, **Shinohara, N.**, **Saito, M.**, Ohnishi, K.: 2015, Artist in Residence at the Nobeyama Radio Observatory, NAOJ, Int. Symp. on the NAOJ Museum, (Tokyo, Japan, Sep. 27-29, 2015).

Iguchi, S.: 2015, ALMA project report, ALMA/45m/ASTE/Mopra Users Meeting 2015, (Tokyo, Japan, Oct. 20-22, 2015).

Iguchi, S.: 2015, Compact Array vs Large Single Dish Telescope - which is more cost-effective -, NRO-ALMA Science/Development Workshop 2015, (Nagano, Japan, Jul. 28-30, 2015).

Ikeya, M., **Kojima, T.**, Sakai, T., **Noguchi, T.**: 2015, Reduction of Leakage Current of Nb SIS Junctions by Adding an Extra Al Layer, 15th Int. Superconductive Electronics Conf. 2015 (ISEC2015), (Nagoya, Japan, Jul. 6-9, 2015).

Ikeya, M., **Kojima, T.**, Sakai, T., **Noguchi, T.**: 2015, Evaluation and Analysis of Nb/Al/AlOx/Al/Nb Junctions, 16th Workshop on Submillimeter-Wave Receiver Technologies in Eastern Asia , (Nanjing, China, Nov. 22-25, 2015).

Imanishi, M.: 2015, ALMA observations of molecular gas in the close vicinity of AGNs, Torus 2015 The unification scheme after 30 years, (Winchester, UK, Sep. 14-17, 2015).

Imanishi, M.: 2015, Optically-elusive buried dual AGN population in infrared-luminous gas/dust-rich galaxy mergers and implication for feedback to galaxies, Demographics and environment of AGN from multi-wavelength surveys, (Chania, Greece, Sep. 21-24, 2015).

Inoue, A., Shimizu, I., Okamoto, T., Yoshida, N., **Matsuo, H.**, Tamura, Y.: 2015, Prediction of emission line fluxes of gravitationally lensed very high-z galaxies, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Inoue, T.: 2015, MHD Simulations of Massive Star Formation Triggered by Cloud Collision, Star Formation Workshop 2015, (Mitaka, Japan, June 29-Jul. 1, 2015).

Inoue, T.: 2015, Magnetohydrodynamic Simulation of Supernova Shock Wave in Realistic Interstellar Medium, The 1st Conference on Laser Energetics, (Yokohama, Japan, Apr. 22-24, 2015).

Iono, D.: 2015, Mopra report, ALMA/45m/ASTE/Mopra Users Meeting 2015, (Tokyo, Japan, Oct. 20-22, 2015).

Iono, D.: 2015, ALMA Workshops and Large Proposals, ALMA/45m/ASTE/Mopra Users Meeting 2015, (Tokyo, Japan, Oct. 20-22, 2015).

Iono, D.: 2015, ALMA Future Development, ALMA/45m/ASTE/Mopra Users Meeting 2015, (Tokyo, Japan, Oct. 20-22, 2015).

Iono, D.: 2015, ALMA Future Development, NRO-ALMA Science/Development Workshop 2015, (Nagano, Japan, Jul. 28-30, 2015).

Ishigaki, M. N., **Tsujimoto, T.**, Shigeyama, T., **Aoki, W.**: 2015, Chemical evolution of *r*-process elements in Draco dwarf spheroidal galaxies, "IAU Symp. 317: The General Assembly of Galaxy Halos Structure, Origin and Evolution", (Honolulu, HI, USA, Aug. 3-7, 2015).

Ishiguro, M., **Kuroda, D.**, Kim, Y., Kwon, Y., **Hanayama, H.**, **Miyaji, T.**, Honda, S., Takahashi, J., **Watanabe, J.-I.**: 2015, Multiple Outbursts of a Short-Periodic Comet 15P/Finlay, Korean Astronomical Society 2015 Spring Meeting, (Seoul National University, South Korea, Apr. 15-17, 2015).

Ishikawa, R., et al. including **Kano, R.**, **Bando, T.**, **Narukage, N.**, **Katsukawa, Y.**, **Kubo, M.**, **Giono, G.**, **Hara, H.**, **Suematsu, Y.**: 2015, CLASP: a UV spectropolarimeter on a sounding rocket for probing the chromosphere-corona transition region, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Ishikawa, R., et al. including **Kano, R.**, **Bando, T.**, **Narukage, N.**, **Katsukawa, Y.**, **Kubo, M.**, **Giono, G.**, **Hara, H.**, **Suematsu, Y.**: 2015, Initial Results of Chromospheric Lyman-Alpha Spectro-Polarimeter (CLASP), 3rd Asia-Pacific Solar Physics Meeting (APSPM 2015), (Soule, South Korea, Nov. 3-6, 2015).

Iye, M.: 2015, Subaru Telescope, Adaptive Optics, and Thirty Meter Telescope, The 1st International Conference on Advanced Imaging, (Tokyo, Japan, Jun. 17-19, 2015).

Iye, M.: 2015, The Thirty Meter Telescope Project, Camera and Photo Imaging Show 2016, (Yokohama, Japan, Feb. 28, 2016).

Izumiura, H.: 2015, The Future of the Okayama Astrophysical Observatory, The 9th Workshop on Astronomy with Precise Radial Velocity, (Lijiang, YN, China, Oct. 27-29, 2015).

Jike, T.: 2015, Current status and future view of VERA Geodesy, 1st Asia-Oceania-VLBI Meeting, (Tasmania Univ. Hobart, Austraria, Nov. 19, 2015).

Jike, T.: 2016, VERA K-band Geodetic VLBI Experiment Using Newly Developed High Speed Sampler and Recorder, 9th IVS General Meeting, (Johanesburg, South Africa, Mar. 15, 2016).

Kajino, T.: 2015, Explosive nucleosynthesis: A Probe of Cosmic and Supernova Neutrinos, The 13th International Symposium on Origin

of Matter and Evolution of Galaxies (OMEG2015), (Beijing, China, Jun. 24-27, 2015).

Kajino, T.: 2015, Supernova Neutrinos and Nucleosynthesis, The 5th International Symposium on Neutrinos and Dark Matter, (Jyuaskyla, Finland, Jun. 1-5, 2015).

Kajino, T.: 2015, Quest for Nuclear Physics and the Origin of R-Process, The 3rd International Conference on Nuclear Structure and Dynamics, (Portoroz, Slovenia, Jun. 15-19, 2015).

Kajino, T.: 2015, Galactic Evolution of the R-Process Elements and the Universality, International Numazu Workshop on Challenges of Modeling Supernovae with Nuclear Data, (Shizuoka, Japan, Sep. 1-4, 2015).

Kajino, T.: 2015, Solving Coalescence Time Scale Problem of GRB R-Process in Galactic Chemo-Dynamics, Gamma-Ray Burst Workshop, (Wako, Saitama, Japan, Aug. 31-Sep. 2, 2015).

Kajino, T.: 2015, Neutrino Physics in Astrophysics, and the Origin of R-Process, The 8th European Summer School on Experimental Nuclear Astrophysics, (St. Tecla, Catania, Italy, Sep. 13-20, 2015).

Kajino, T.: 2015, Origin of R-Process Elements in Galactic Evolution and Relic Supernova Neutrinos, Korean Physical Society 2015 Fall Meeting, (Gyeonju, Korea, Oct. 21-23, 2015).

Kajino, T.: 2015, Galactic Evolution of Supernova and Merger R-Process, Quarks to Universe in Computational Science, (Nara, Japan, Nov. 4-8, 2015).

Kajino, T.: 2016, Neutrino Astrophysics in Supernovae, KIAS/KNRC School on Neutrino Physics, (KIAS, Seoul, Korea, Feb. 15-17, 2016).

Kambe, E.: 2015, Recent status and updates of HIDES/OAO, The 9th Workshop on Astronomy with Precise Radial Velocity, (Lijiang, YN, China, Oct. 27-29, 2015).

Kameya, O., **Funayama, H.**: 2015, Collaboration of Kimura Hisashi Memorial Museum and Oshu Space and Astronomy Museum in NAOJ Mizusawa Campus, Int. Symp. on the NAOJ Museum, (Tokyo, Japan, Sep. 27-29, 2015).

Kameya, O., **Funayama, H.**: 2015, Kimura Memorial Museum in NAOJ Mizusawa Campus, Int. Symp. on the NAOJ Museum, (Tokyo, Japan, Sep. 27-29, 2015).

Kameya, O.: 2015, Current Status of the Mizusawa 10m Radio telescope, 8th East Asia VLBI Workshop, (Sapporo, Japan, Jul. 8-10, 2015).

Kaneko, H.: 2015, Large Massive Molecular Gas Cloud at the Collision Front of the Interacting Galaxies in Early Stage, Gas, Dust, and Star-Formation in Galaxies from the Local to Far Universe, (Plantanias-Chania, Crete, Greece, Apr. 25-29, 2015).

Kaneko, H.: 2015, COMING-TAO Collaboration "COMING-PLUS", TAO/SWIMS Sceince Workshop 2015, (Mitaka, Japan, Sep. 17-18, 2015).

Kaneko, H.: 2015, Molecular Collision Front in Interacting Galaxies, East Asian ALMA Science Workshop 2015, (Osaka, Japan, Dec. 8-11, 2015).

Kaneko, H.: 2016, Effects of Galaxy Interactions on Molecular Gas Properties, From Stellar Evolution to Galaxy Formation, (Nobeyama, Japan, Mar. 7-9, 2016).

Kang, M., Choi, M., Stutz, A. M., **Tatematsu, K.**: 2015, [HDCO]/[H_2CO] ratios toward extremely cold protostars in Orion, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Kano, R., et al. including **Narukage, N.**, **Ishikawa, R.**, **Bando, T.**, **Katsukawa, Y.**, **Kubo, M.**, **Giono, G.**, **Hara, H.**, **Suematsu, Y.**: 2015, Chromospheric Lyman-Alpha Spectro-Polarimeter (CLASP), 9th Hinode Science Meeting, (Belfast, UK, Sep. 14-17, 2015).

Kashiwagi, K., **Kurokawa, T.**: 2015, Photonic Arbitrary Waveform Generation Using Optical Pulse Synthesizer and Its Applications, PIERS 2015, (Prague, Czech Republic, Jul. 6-9, 2015).

Kato, C., Nakajima, T., Akiyama, N., Ito, M., Urushihara, K., Koga, M., Yamamoto, H., Mizuno, A., **Kojima, T.**, **Fujii, Y.**, **Asayama, S.**, **Noguchi, T.**, **Kozuki, Y.**, Hasegawa, Y., Ogawa, H.: 2015, Development of superconducting device for millimeter-wave atmospheric radiometer, Founding Symposium for the Institute for Space-Earth Environmental Research, (Nagoya, Japan, Nov. 4-5, 2015).

Kato, C., Nakajima, T., Akiyama, N., Ito, M., Urushihara, K., Koga, M., Yamamoto, H., Mizuno, A., **Kojima, T.**, **Fujii, Y.**, **Asayama, S.**, **Noguchi, T.**, **Kozuki, Y.**, Hasegawa, Y., Ogawa, H.: 2015, Progress of the development of series junction SIS device in 100 and 200GHz band, NRO-ALMA Science/Development Workshop 2015, (Nagano, Japan, Jul. 28-30, 2015).

Katsukawa, Y., Kimura, Y., Okamoto, T. J., Tarbell, T.: 2015, HINODE-IRIS observation of penumbral microjets in the chromosphere and their transition region counterpart, 9th Hinode Science Meeting, (Belfast, UK, Sep. 14-17, 2015).

Katsukawa, Y., Kimura, Y., Okamoto, T. J., Tarbell, T.: 2015, IRIS Observation of Penumbral Microjets in the Chromosphere and their Transition Region Counterpart, IRIS-4 Workshop, (Boulder, CO, USA, May. 18-22, 2015).

Kawabe, R.: 2015, LST, NRO-ALMA Science/Development Workshop 2015, (Nagano, Japan, Jul. 28-30, 2015).

Kawamura, A., Onishi, T., Harada, R., Morioka, Y., Tokuda, K., Meixner, M., Indebetouw, R., Sewilo, M., Nayak, O., Saigo, K., Fukui, Y.: 2015, Giant molecular clouds in the Large Magellanic Cloud seen in sub-parsec scales by ALMA, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Kawamura, A.: 2015, Development of our study with 45m and ALMA: Molecules in the active galaxy NGC 1068, ALMA/45m/ASTE/Mopra Users Meeting 2015, (Tokyo, Japan, Oct. 20-22, 2015).

Kawamura, A.: 2015, Tracing an evolution of giant molecular clouds in the LMC, East Asian ALMA Science Workshop 2015, (Osaka, Japan, Dec. 8-11, 2015).

Kawashima, T., Matsumoto, Y., Matsumoto, R.: 2015, Time evolution of the Sgr A* accretion flow interacting with the G2 cloud, QUCS 2015, (Nara, Japan, Nov. 4-8, 2015).

Kawashima, T., Matsumoto, Y., Matsumoto, R.: 2015, On the time evolution of the Sgr A* accretion flow interacting with the G2 cloud, 8th East Asia VLBI Workshop, (Sapporo, Japan, Jul. 8-10, 2015).

Kawashima, T., Matsumoto, Y., Matsumoto, R.: 2015, Time evolution of the Sgr A* accretion flow interacting with a gas cloud, Black Hole Accretion and AGN Feedback, (Shanghai, China, Jun. 1-5, 2015).

Kawashima, T., **Ohsuga, K.**, **Takahashi, H.**, Mineshige, S., **Yoshida, T.**, Matsumoto, R.: 2015, Photon Spectra of Super-critical Black Hole Accretion Flows, Prospects, challenges and evolution of AGN modeling in the Astro-H Era, (Tokyo, Japan, Oct. 21-22, 2015).

Kim, J. S.: 2016, Recent Water Maser distribution for Massive Star Formation Region in Cepheus A, The 10th NARIT-KaVA Joint Science WG meeting, (Krabi, Thailand, Feb. 22-24, 2016).

Kimura, Y., **Hara, H.**: 2015, Properties of the sub-arcsecond structure

observed in Transition region under Coronal loop, Japan Geoscience Union Meeting 2015, (Chiba, Japan, May. 24-28, 2015).

Kinugasa, K., **Nishioka, M.**, **Mikoshiba, H.**, **Miyazawa, K.**, **Shinohara, N.**, **Ide, H.**, **Saito, M.**: 2015, The Record of 3 Million Visitors and the NINS PR Center in the NAOJ Nobeyama Campus, Int. Symp. on the NAOJ Museum, (Tokyo, Japan, Sep. 27-29, 2015).

Kitazato, K., Iwata, T., Abe, M., Ohtake, M., Tsumura, K., Ishikawa, T., **Takato, N.**, Nakauchi, Y., Arai, T., Senshu, H., Hirata, N., Takagi, Y., Hayabusa2 NIRS3 Team: 2016, Near-Infrared Spectroscopy of the Earth and Moon During the Hayabusa2 Earth Swing-By, 47th Lunar and Planetary Sci. Conf., (The Woodlands, TX, USA, Mar. 21-25, 2016).

Kiuchi, H.: 2015, MKID readout: Frequency sweeping scheme readout system, B-mode from space, (Chiba, Japan, Dec. 10-16, 2015).

Kobayashi, H.: 2015, EAVN status and future, 8th East Asia VLBI Workshop, (Sapporo, Japan, Jul. 8-10, 2015).

Kobayashi, K., Tsunekawa, S.: 2015, Development of a Room Temperature Chirped Pulse Fourier Transform Microwave Spectrometer, Symposium on Advanced Molecular Spectroscopy, (Tokyo, Japan, Jul. 18-19, 2015).

Koda, J.: 2015, ALMA is not sensitive enough, ALMA Workshop for Large Proposals on Nearby Galaxies, (Tokyo, Japan, Aug. 25-26, 2015).

Koda, J.: 2015, Subaru Deep Imaging of Diffuse (Parts of) Galaxies, Caltech Infrared Processing and Analysis Center Science Talk, (Pasadena, CA, USA, Oct. 21, 2015).

Koda, J.: 2015, Evolution of the ISM in the Milky Way and Nearby Galaxies, Caltech Colloqouim, (Pasadena, CA, USA, Nov. 18, 2015).

Koda, J.: 2015, Linking galactic and extragalactic gas and dust surveys, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Koda, J.: 2015, Evolution of the interstellar medium in the Milky Way and nearby galaxies, NRAO Socoro Colloquium, (Socoro, NM, USA, Sep. 18, 2015).

Kodama, T., **Hayashi, M.**, Tadaki, K., **Shimakawa, R.**, **Suzuki, T.**, **Yamamoto, M.**, **Tanaka, I.**: 2015, Proto-clusters and the early environmental effects, Galaxy clusters and galaxy formaiton, (Yonsei Univ., Korea, Oct. 19-23, 2015).

Kodama, T., **Hayashi, M.**, Tadaki, K., **Shimakawa, R.**, **Suzuki, T.**, **Yamamoto, M.**, **Tanaka, I.**: 2015, Early environmental effects in proto-clusters at the cosmic high noon, RSAA Colloquia, (ANU, Australia, Oct. 12, 2015).

Kodama, T., **Hayashi, M.**, Tadaki, K., **Shimakawa, R.**, **Suzuki, T.**, **Yamamoto, M.**, **Tanaka, I.**: 2015, Early environmental effects in proto-clusters at the cosmic high noon, AAO Colloquium, (AAO, Australia, Oct. 15, 2015).

Kodama, T., **Hayashi, M.**, Tadaki, K., **Shimakawa, R.**, **Suzuki, T.**, **Yamamoto, M.**, **Tanaka, I.**: 2015, Galaxy ecology: How does environmewnt matter?, Department colloquium, (Yonsei Univ., Korea, Oct. 23, 2015).

Kodama, T., **Hayashi, M.**, Tadaki, K., **Shimakawa, R.**, **Suzuki, T.**, **Yamamoto, M.**, **Tanaka, I.**: 2015, Proto-clusters as the site of early environmental effects on galaxy formation explored by Mahalo and up-coming surveys on Subaru, ALMA, and TAO, In the footsteps of galaxies: Tracing the evolution of environmental effects, (Soverato, Italy, Sep. 7-11, 2015).

Kodama, T., **Hayashi, M.**, Tadaki, K., **Shimakawa, R.**, **Suzuki, T.**, **Yamamoto, M.**, **Tanaka, I.**: 2016, From galaxy evolution to cluster formation, From stellar-evolution to galaxy formation, (Yatsugatake, Japan, Mar. 7-9, 2016).

Kodama, T., Mahalo-Subaru Team, Gracias-ALMA Team, HSC-HSC Team: 2015, Physical states of galaxies across various environments, PFS-SSP galaxy survey workshop, (Kashiwa, Japan, Nov. 13, 2015).

Kodama, T., Mahalo-Subaru Team, SWIMS-18 Team: 2015, Nature of star forming galaxies at the peak epoch of galaxy formation, Suabru-Keck synergy workshop, (Sendai, Miyagi, Japan, Sep. 1-2, 2015).

Kodama, T., Motohara, K., Mahalo-Subaru Team, SWIMS-18 Team: 2015, Super multi-colour, wide-field, NIR imaging survey with Subaru and TAO, Galaxies of Many Colours, (Marstrand, Sweden, Jun. 1-5, 2015).

Kodama, T., ULTIMATE-Subaru Team: 2015, ULTIMATE-K imaging survey, ULTIMATE Science workshop, (AAO, Australia, Oct. 16, 2015).

Kohno, K., et al. including **Kodama, T.**, **Hatsukade, B.**, **Yobe, K.**, **Hayashi, M.**, **Iono, D.**, **Matsuda, Y.**, **Nakanishi, K.**, **Kawabe, R.**: 2015, SXDF-UDS-CANDELS-ALMA 1.5 arcmin^2 deep survey, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Kokubo, E.: 2015, Formation of Close-in Terrestrial Planets by Giant Impacts: The Basic Scaling Laws, Extreme Solar Systems III, (Waikoloa, HI, USA, Nov. 29-Dec. 4, 2015).

Kokubo, E.: 2016, Orbital Structure of Planetary Systems Formed by Giant Impacts, Exoplanets and Disks: Their Formation and Diversity III, (Ishigaki, Japan, Feb. 21-24, 2016).

Komiyama, Y.: 2016, Outskirts of Local Group Dwarf Galaxies Revealed by Subaru Hyper Suprime-Cam, IAU Symp. 321: Fornation and evolution of galaxy outskirts, (Toledo, Spain, Mar. 14-18, 2016).

Kono, S., Yokoyama, T., **Toriumi, S.**, **Katsukawa, Y.**: 2015, One-dimensional numerical simulations and observations of MHD wave propagation in the solar chromospheric regions with strong magnetic fields, IRIS-4 Workshop, (Boulder, CO, USA, May. 18-22, 2015).

Koshida, S.: 2015, Reverberation Measurements of the Inner Radius of the Dust Torus in 17 Seyfert Galaxies, Torus 2015 The unification scheme after 30 years, (Winchester, UK, Sep. 14-17, 2015).

Koyama,Y.: 2015, Galaxy anatomy with Subaru: our new challenge beyond MAHALO-Subaru, MPE Infrared Group Retreat, (Bavaria, Germany , Dec. 9-12, 2015).

Koyama,Y.: 2015, A systematic study of the geometry of stars and dust within distant star- forming galaxies with PFS, PFS-SSP galaxy survey workshop, (Kashiwa, Japan, Nov. 13, 2015).

Koyama,Y.: 2016, ULTIMATE-Subaru current status, Subaru Users Meeting FY2015, (Atami, Japan, Jan. 19-21, 2016).

Kroug, M.: 2015, SIS Mixers for Ultra-Wide RF Bandwidth Operation, 16th Workshop on Submillimeter-Wave Receiver Technologies in Eastern Asia , (Nanjing, China, Nov. 22-25, 2015).

Kumamoto, A., Yamaguchi, Y., Yamaji, A., Kobayashi, T., **Oshigami, S.**, Ishiyama, K., Nakamura, N., Goto, Y.: 2015, Studies based on global subsurface radar sounding of the Moon by SELENE (Kaguya) Lunar Radar Sounder (LRS): A summary, AGU Fall meeting 2015, (San Francisco, CA, USA, Dec. 14-18, 2015).

Kuzuhara, M., **Tamura, M.**, **Helminiak, K. G.**, Mede, K., Brandt, T., Janson, M., **Kandori, R.**, **Kudo, T.**, Kusakabe, N., Hashimoto, J.: 2015, The SEEDS High-Contrast Imaging Survey: Exoplanet and Brown Dwarf Survey for Nearby Young Stars Dated with

Gyrochronology and Activity Age Indicators, Extreme Solar Systems III, (Waikoloa, HI, USA, Nov. 29-Dec. 4, 2015).

Kwon, Y., Ishiguro, M., **Hanayama, H.**, **Kuroda, D.**, Honda, S., Takahashi, J., Sarugaku, Y., Kim, Y., Vaubaillon, J. J., **Miyaji, T.**, **Yanagisawa, K.**, Yoshida, M., Ohta, K., Kawai, N., Fukushima, H., **Watanabe, J.-I.**: 2015, A Monitoring Observation of Comet 17P/Holmes during 2014 Apparition, Korean Astronomical Society 2015 Spring Meeting, (Seoul National University, South Korea, Apr. 15-17, 2015).

Lee, M., Suzuki, K., Kohno, K., Tamura, Y., **Iono, D.**, **Hatsukade, B.**, **Nakanishi, K.**, **Tanaka, I.**, **Kodama, T.**, Tadaki, K., Ikarashi, S., **Ueda, J.**, Umehata, H., Saito, T., **Kawabe, R.**: 2015, Deep JVLA and ALMA observations of dusty star forming galaxies in protocluster 4C23.56 at z = 2.5, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Lin, S.-J., Shimajiri, Y., Hara, C., Lai, S.-P., **Nakamura, F.**, Sugitani, K., **Kawabe, R.**, Kitamura, Y., Yoshida, A., Tatei, H., Akashi, T., Tsukagushi, T.: 2015, Influence of Interstellar FUV Radiation on the Abundance Ratio of ^{13}CO to $C^{18}O$ in L 1551, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Louvet, F., **Nguyen-Luong, Q.**: , The origin of massive clusters: from hyper-massive clouds to mini-bursts of star formation, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Lozi, J., **Guyon, O.**, **Jovanovic, N.**, **Singh, G.**, **Doughty, D.**, **Pathak, P.**, **Goebel, S.**, **Kudo, T.**: 2015, SCExAO: the most complete instrument to characterize exoplanets and stellar environments, Extreme Solar Systems III, (Waikoloa, HI, USA, Nov. 29-Dec. 4, 2015).

Lundock, R.: 2015, Mad Science Crash Course, HawaiiCon, (Kohala Coast, HI, USA, Sept. 10-13, 2015).

Maehara, H.: 2015, Superflares on G-type stars discovered with Kepler mission, VarSITI SCOSTEP conference "Superflares and the Sun in the cycle formation epoch", (Tel Aviv, Israel, Apr. 28-May 1, 2015).

Maehara, H.: 2015, Statistical properties of superflares on solar-type stars, The first K2 Science Conference, (Santa Barbara, USA, Nov. 2-5, 2015).

Maehara, H.: 2016, Superflares and starspot activity on solar-type stars, Superflare Workshop 2016 "Superflares on Solar-type Stars and Solar Flares, and Their Impacts on Exoplanets and the Earth", (Kyoto, Japan, Mar. 1-4, 2015).

Maehara, H., Shibayama, T., Notsu, Y., Notsu, S., Honda, S., Nogami, D., Shibata, K.: 2015, Statistical properties of superflares on solar-type stars based on the Kepler 1-min cadence data, IAU Symp. 320: Solar and Stelar Flares and Thire Effects on Planets, (Honolulu, HI, USA, Aug. 3-14, 2015).

Makise, K., Terai, H., **Uzawa, Y.**: 2015, NbN/AlN/NbN/TiN tunnel junctions on Si (100) substrate for superconducting devices, 12th European Conference on Applied Superconductivity (EUCAS2015), (Lyon, France, Sep. 6-10, 2015).

Makise, K., Terai, H., **Uzawa, Y.**: 2015, Growth of (100)-oriented NbN thin films on Silicon substrate using TiN buffer layer, 15th Int. Superconductive Electronics Conf. 2015 (ISEC2015), (Nagoya, Japan, Jul. 6-9, 2015).

Marchio, M., Cella, G.: 2015, Bayesian approach to the locking problem for high finesse suspended optical cavities, GWADW2015, (Alaska, USA, May. 17-22, 2015).

Marchio, M., **Tatsumi, D.**, **Flaminio, R.**: 2015, Mirror absorption bench setup and commissioning, KAGRA F2F Meeting, (Toyama, Japan, Aug. 25-28, 2015).

Matsuda, Y.: 2015, ALMA 860um continuum observations of 100kpc-scale Ly-alpha Blobs at z=3.1, East Asian ALMA Science Workshop 2015, (Osaka, Japan, Dec. 8-11, 2015).

Matsuda, Y.: 2015, Lyman-alpha blobs, MIAPP 2015 Workshop, (Garching, Germany, Jul. 27-Aug. 21, 2015).

Matsumoto, K., Ikeda, H.: 2016, Inhomogeneous Two-Layer Internal Structure and Moments of Inertia of Phobos, 47th Lunar and Planetary Sci. Conf., (The Woodlands, TX, USA, Mar. 21-25, 2016).

Matsumoto, K., **Yamada, R.**, **Kikuchi, F.**, Kamata, S., Ishihara, Y., **Iwata, T.**, **Hanada, H.**, Sasaki, S.: 2015, Internal Structure of the Moon Inferred from Apollo Seismic Data and Selenodetic Data from GRAIL and LLR, 2nd IAPS Scientific Assembly, (Kazan, Russia, Jun. 1-4, 2015).

Matsumoto, K., **Yamada, R.**, **Kikuchi, F.**, Kamata, S., Ishihara, Y., **Iwata, T.**, **Hanada, H.**, Sasaki, S.: 2015, On low-velocity zone at the bottom of the lunar mantle, Japan Geoscience Union Meeting 2015, (Chiba, Japan, May 24-28, 2015).

Matsumoto, N.: 2015, Fringe check observations of SiO maser sources toward the Galactic center and antennanodding mode with KaVA, 8th East Asia VLBI Workshop, (Sapporo, Japan, Jul. 8-10, 2015).

Matsumoto, N.: 2015, VLBI imaging of 44 GHz methanol maser with KaVA, High Mass Star Formation Workshop, (Tokyo, Japan, Jul. 22, 2015).

Matsumoto, N.: 2016, (Lecture) Star forming region: VLBI observation, NARIT-UST-GUAS Radio Astronomy Winter School 2016, (Chiang Mai, Thailand, Feb.15-19, 2016).

Matsumoto, N.: 2016, KaVA PET activity, The 10th NARIT-KaVA Joint Science WG meeting, (Krabi, Thailand, Feb. 22-24, 2016).

Matsumoto, N.: 2016, KaVA SFR science sub-WG: JVN follow-up observations for G10.32-0.26 and G18.34-1.78, The 10th NARIT-KaVA Joint Science WG meeting, (Krabi, Thailand, Feb. 22-24, 2016).

Matsumoto, Y., **Kokubo, E.**: 2015, Formation of Close-in Super-Earths by Giant Impacts: Effects of Initial Eccentricities and Inclinations of Protoplanets, Extreme Solar Systems III, (Waikoloa, HI, USA, Nov. 29-Dec. 4, 2015).

Matsumoto, Y., **Kokubo, E.**: 2015, The eccentricities and inclinations of planets formed through in situ accretion of protoplanets, 3rd DTA Symposium: The Origins of Planetary Systems: From the Current View to New Horizons, (Tokyo, Japan, Jun. 1-4, 2015).

Matsumoto, Y., **Kokubo, E.**: 2016, In Situ Accretion of Close-in Super-Earths: Effects of Initial Eccentricities and Inclination of Protoplanets, Exoplanets and Disks: Their Formation and Diversity III, (Ishigaki, Japan, Feb. 21-24, 2016).

Matsuo, H.: 2015, Terahertz Interferometry with Milli-Arcsecond Angular Resolution, Bringing Far Infrared Interferometry Into Vision, (London, UK, Dec. 15-17, 2015).

Matsuo, H., **Ezawa, H.**, **Kojima, T.**, Kawamura, Y., Sakurai, D.: 2015, Readout electronics for THz photon counter, The 16th Workshop on Submm Wave Receiver Technologies in Eastern Asia, (Nanjing, China, Nov. 22-25, 2015).

Matsuoka, Y.: 2015, Search for z > 6 quasars, Understanding Evolution of Quasars: Collaboration between Theoretical Models and Initial HSC Survey, (Kagoshima, Japan, Dec. 1-3, 2015).

Matsuoka, Y.: 2015, AGN observations in the coming PFS-SSP survey,

PFS-SSP galaxy survey workshop, (Kashiwa, Japan, Nov. 13, 2015).

Matsuoka, Y.: 2015, Search for distant ($z > 6$) quasars with SWIMS + Subaru/HSC, TAO/SWIMS Sceince Workshop 2015, (Mitaka, Japan, Sep. 17-18, 2015).

Matsuoka, Y.: 2015, AGN observations with Subaru/PFS, Subaru Prime Focus Spectrograph science workshop, (Mitaka, Japan, Jul. 9, 2015).

Matsuoka, Y.: 2015, HSC high-z quasar survey project, Subaru/HSC SSP survey collaboration meeting, (Princeton, USA, Jul. 27-29, 2015).

Matsuoka, Y.: 2016, Subaru high-z exploration of low-luminosity quasars, Subaru Users Meeting FY2015, (Atami, Japan, Jan. 19-21, 2016).

Matsuzawa, A.: , Optical Seeing Properties on the Pointing Verification for ALMA Antenna, NRO-ALMA Science/Development Workshop 2015, (Nagano, Japan, Jul. 28-30, 2015).

Mendillo, C. B., Brown, J., Martel, J., Howe, G. A., Hewasawam, K., Finn, S. C., Cook, T. A., Chakrabarti, S., Douglas, E. S., Mawet, D., **Guyon, O.**, **Singh, G.**, **Lozi, J.**, Cahoy, K. L., Marinan, A. D.: 2015, The low-order wavefront sensor for the PICTURE-C mission, SPIE Optics + Photonics, (San Diego, CA, USA, Aug. 9-13, 2015).

Michiyama, T.: 2015, Star Forming Molecular Gas in Merging Galaxies ~ASTE observation~, East Asian ALMA Science Workshop 2015, (Osaka, Japan, Dec. 8-11, 2015).

Minamidani, T.: 2015, NRO Future Development, NRO-ALMA Science/Development Workshop 2015, (Nagano, Japan, Jul. 28-30, 2015).

Miura, R.: 2015, High Velocity Compact Clouds in Nearby Young Starburst Galaxy NGC 5253, East Asian ALMA Science Workshop 2015, (Osaka, Japan, Dec. 8-11, 2015).

Miyamoto, Y., Nakai, N., Seta, M., Salak, D., Nagai, M., Ishii, S., **Yamauchi, A.**: 2015, Hot gas in the center of the Seyfert galaxy NGC 3079, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Miyoshi, M.: 2015, Caravan-submm and a mm/sub-mm VLBI network in East Asia, NRO-ALMA Science/Development Workshop 2015, (Nagano, Japan, Jul. 28-30, 2015).

Momose, M.: 2015, Long Baseline Observations with ALMA~Impact by the image of HL Tau~, ALMA/45m/ASTE/Mopra Users Meeting 2015, (Tokyo, Japan, Oct. 20-22, 2015).

Momose, M. 2015, Udenkon report, ALMA/45m/ASTE/Mopra Users Meeting 2015, (Tokyo, Japan, Oct. 20-22, 2015).

Momose, M.: 2015, Follow-up studies related to the high-resolution imaging of HL Tau, East Asian ALMA Science Workshop 2015, (Osaka, Japan, Dec. 8-11, 2015).

Momose, M.: 2016, Observations of Protoplanetary disks with ALMA, Exoplanets and Disks: Their Formation and Diversity III, (Ishigaki, Japan, Feb. 21-24, 2016).

Morokuma, K.: 2015, Search for molecular gas in XUV disk of M83, ALMA/45m/ASTE/Mopra Users Meeting 2015, (Tokyo, Japan, Oct. 20-22, 2015).

Morokuma, K.: 2015, Tight anti-correlation between Dn4000 and molecular gas mass fraction of galaxies, NRO-ALMA Science/Development Workshop 2015, (Nagano, Japan, Jul. 28-30, 2015).

Morokuma-Matsui, K., Baba, J., Sorai, K., Kuno, N.: 2015, Tight anti-correlation between molecular gas fraction and 4000 Å break strength, Gas, Dust, and Star-Formation in Galaxies from the Local to Far Universe, (Plantanias-Chania, Crete, Greece, Apr. 25-29, 2015).

Morokuma-Matsui, K., **Koda, J.**, **Takekoshi, T.**, **Saito, M.**, Nakanishi, H., Boissier, S., Madore, B. F., Boselli, A., Gil de Paz, A., Thilker, D., **Yagi, M.**, Sorai, K., Kuno, N.: 2016, Search for molecular gas in XUV disk of M83, IAU Symp. 321: Fornation and evolution of galaxy outskirts, (Toledo, Spain, Mar. 14-18, 2016).

Morokuma-Matsui, K.: 2015, Redshift evolution of gas fraction of galaxies in $0<z<2$, East Asian ALMA Science Workshop 2015, (Osaka, Japan, Dec. 8-11, 2015).

Motogi, K.: 2015, Multi-scale view of the face-on accretion system around G353.273+0.641, High Mass Star Formation Workshop, (Tokyo, Japan, Jul. 22, 2015).

Motte, F., Bontemps, S., **Nguyen-Luong, Q.**: 2015, HOBYS and W43, two more steps towards a Galaxy-wide understanding of star formation, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Muller, E.: 2015, Complete survey of the Galactic fourth quadrant in 4 lines, ALMA/45m/ASTE/Mopra Users Meeting 2015, (Tokyo, Japan, Oct. 20-22, 2015).

Muraki, Y., et al. including **Watanabe, K.**: 2015, Simultaneous Observation of Solar Neutrons from the ISS and High Mountain Observatories in association with a flare on July 8, 34th International Cosmic Ray Conference, (The Hague, Jul. 30-Aug. 6, 2015).

Nagai, H.: 2015, Long-term Radio and Gamma-ray Properties of 3C 84, 5th Workshop on Compact Steep Spectrum and GHz-Peaked Spectrum Radio Sources, (Rimini, Italy, May 27-29, 2015).

Nagai, H.: 2015, Millimeter Spectrum of Blazars and Its Connection with High Energy Emission, East Asian ALMA Science Workshop 2015, (Osaka, Japan, Dec. 8-11, 2015).

Nagai, H.: 2015, ALMA Polarization Commissioning and Implication for Future Projects (II), NRO-ALMA Science/Development Workshop 2015, (Nagano, Japan, Jul. 28-30, 2015).

Nagasawa, R., Otsubo, T., Sekido, M., **Hanada, H.**: 2015, Software development for precise LLR data analysis and initial results of parameter estimation for lunar motion, Japan Geoscience Union Meeting 2015, (Chiba, Japan, May 24-28, 2015).

Nakajima, T., Kato, C., Ito, M., Akiyama, N., Fujii, Y., Yamamoto, H., Mizuno, A., **Kojima, T.**, **Fujii, Y.**, **Noguchi, T.**, **Asayama, S.**, **Kozuki, Y.**, Ogawa, H., Sakai, T.: 2015, Development of the Series Junction Superconducting Device in 100 and 200 GHz Band, ALMA/45m/ASTE/Mopra Users Meeting 2015, (Tokyo, Japan, Oct. 20-22, 2015).

Nakamura, F.: 2015, ALMA Observations toward the nearest cluster-forming region, East Asian ALMA Science Workshop 2015, (Osaka, Japan, Dec. 8-11, 2015).

Nakamura, F.: 2015, Cluster Formation Triggered by Filament Collisions in Serpens South, IAU Symp. 315, (Honolulu, HI, USA, Aug. 3-14, 2015).

Nakamura, F.: 2015, Stellar Feedback in Clustered Star Formation, 6th Zermatt ISM meeting Conditions and Impact of Star Formation: From Lab to Space, (Zermatt, Switherland, Sep. 7-11, 2015).

Nakamura, F.: 2016, ALMA View of Nearest Cluster-forming Region, Rho Ophiuchus Cloud, Astronomy at Taj, (India, Feb. 15-19).

Nakamura, F., Kameno, S., Dobashi, K., Shimoikura, T., Taniguchi, K.: 2015, CCS Zeeman Observations toward TMC-1, Star Formation 2015: From Clouds to Cores, (Mitaka, Japan, June 25-27, 2015).

Nakanishi, K., **Nagai, H.**: 2015, ALMA Polarization Commissioning and Implication for Future Projects (I) & (II), NRO-ALMA Science/Development Workshop 2015, (Nagano, Japan, Jul. 28-30, 2015).

Nakanishi, K., Sorai, K., Nakai, N., Kuno, N., Matsubayashi, K., Sugai, H., Takano, S., Kohno, K., Nakajima, T.: 2015, Millimeter/Sub-millimeter Hydrogen Recombination Line in the Center of NGC 253, East Asian ALMA Science Workshop 2015, (Osaka, Japan, Dec. 8-11, 2015).

Nakanishi, K.: 2015, ALMA Archive, ALMA/45m/ASTE/Mopra Users Meeting 2015, (Tokyo, Japan, Oct. 20-22, 2015).

Nakanishi, K.: 2015, ALMA Polarization Commissioning and Implication for Future Projects (I), NRO-ALMA Science/Development Workshop 2015, (Nagano, Japan, Jul. 28-30, 2015).

Namiki, N., Enya, K., Kobayashi, M., Kimura, J., **Araki, H.**, **Noda, H.**, **Kashima, S.**, Utsunomiya, S., Ishibashi K., **Oshigami, S.**, Kobayashi, S., Fujii, M., Hussmann, H., Lingenauber, Oberst, K.: 2015, Development of JUICE/Ganymede Laser Altimeter (GALA), Japan Geoscience Union Meeting 2015, (Chiba, Japan, May 24-28, 2015).

Narita, N.: 2015, Future Missions of Transit Surveys and Characterizations, 3rd DTA Symposium: The Origins of Planetary Systems: From the Current View to New Horizons, (Tokyo, Japan, Jun. 1-4, 2015).

Narita, N.: 2015, Exoplanet ISDT Activity Report: TMT's Prospects for Exoplanets, TMT Science Forum 2015, (Washington D.C., USA, Jun. 23-25, 2015).

Narita, N.: 2015, Possible Contribution of the Subaru telescope to TESS follow-up, Suabru-Keck synergy workshop, (Sendai, Miyagi, Japan, Sep. 1-2, 2015).

Narita, N.: 2015, Introduction of Japanese Facilities for K2 Follow-up Observations and Latest Results, The first K2 Science Conference, (Santa Barbara, USA, Nov. 2-5, 2015).

Narita, N.: 2016, Possible Subaru-TESS Synergy Campaign, Subaru Users Meeting FY2015, (Atami, Japan, Jan. 19-21, 2016).

Narita, N.: 2016, Toward detections of habitable terrestrial planets around the Solar neighborhood, Symposium on Hierarchy and Holism in Natural Sciences, (Mitaka, Tokyo, Japan, Feb. 5-6, 2016).

Narita, N., Enomoto, T., Masaoka, S., **Kusakabe, N.**: 2016, Titania may produce abiotic oxygen atmospheres on habitable exoplanets, Extreme Solar Systems III, (Waikoloa, HI, USA, Nov. 29-Dec. 4, 2015).

Narukage, N., **Shimojo, M.**, Sakao, T.: 2015, Evidence of Electron Acceleration around the Reconnection X-point in a Solar Flare, 9th Hinode Science Meeting, (Belfast, UK, Sep. 14-17, 2015).

Nemoto, S., **Usuda-Sato, K.**, **Matsuda, K.**, **Sasaki, G.**, **Nakagiri, M.**, **Agata, H.**, **Funayama, H.**, **Kameya, O.**, **Kinugasa, K.**, **Toda, H.**, **Yanagisawa, K.**, Baba, Y.: 2015, Historical Items Database of the NAOJ Museum, Int. Symp. on the NAOJ Museum, (Tokyo, Japan, Sep. 27-29, 2015).

Nguyen-Luong, Q., Motte, F., Nguyen, H., Schneider, N., Louvet, F.: , COnnecting LOcal to GLObal star formation via MIni-starburst, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Nguyen-Luong, Q.: 2015, Searching for the densest massive dense cores, East Asian ALMA Science Workshop 2015, (Osaka, Japan, Dec. 8-11, 2015).

Nguyen-Luong, Q.: 2015, Connecting local to global star formation via ministarburst, NRO-ALMA Science/Development Workshop 2015, (Nagano, Japan, Jul. 28-30, 2015).

Nishikawa, J., Oya, M., Murakami, N., **Tamura, M.**, **Kurokawa, T.**, Tanaka, K.: 2015, Imperfect Pre-coronagraph for contrast enhancement with speckle area nulling control, In the spirit of Bernard Lyot, (Montréal, USA, Jun. 22-26, 2015).

Nishikawa, J., Oya, M., Murakami, N., **Tamura, M.**, **Kurokawa, T.**, Tanaka, K.: 2015, Imperfect Pre-coronagraph for additional contrast, Pathways 2015: Pathways Towards Habitable Planets, (Bern, Schweizerische, Jul. 13-17, 2015).

Nishikawa, J., Oya, M., Murakami, N., **Tamura, M.**, **Kurokawa, T.**: 2015, Contrast enhancement with pre-coronagraph and dark-hole, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Nishimura, A., **Umemoto, T.**, **Minamidani, T.**, Kuno, N., Tosaki, T., Fujita, S., Matsuo, M., Tsuda, Y., Ohashi, S.: 2015, Nobeyama 45 m CO Galactic Plane Survey: Filament properties and star formation in M17, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Nishioka, M., **Kinugasa, K.**, **Mikoshiba, H.**, **Miyazawa, K.**, **Shinohara, N.**, **Ide, H.**, **Saito, M.**: 2015, Making Brochure and Original Goods in the NAOJ Nobeyama Campus, Int. Symp. on the NAOJ Museum, (Tokyo, Japan, Sep. 27-29, 2015).

Noda, H., Mizuno, T., Kunimori, H., Takeuchi, H., Senshu, H., Ogawa, N., Saiki, T., Yamaguchi, T., Pollard, A., Moore, C., **Namiki, N.**, Tsuda, Y.: 2016, Establishment of laser link between ground station and Hayabusa2 LIDAR, 47th Lunar and Planetary Sci. Conf., (The Woodlands, TX, USA, Mar. 21-25, 2016).

Notsu, Y., Honda, S., **Maehara, H.**, Notsu, S., Shibayama, T., Nogami, D., Shibata, K.: 2015, High dispersion spectroscopy of solar-type superflare stars with Subaru/HDS, IAU Symp. 320: Solar and Stelar Flares and Thire Effects on Planets, (Honolulu, HI, USA, Aug. 3-14, 2015).

Nozawa, T.: 2015, Dust Production Factories in the Early Unvierse, Frascati Workshop 2015: Multifrequency Behavior of High Energy Cosmic Sources, (Palermo, Italy, May 25-31, 2015).

Nozawa, T.: 2015, On the Reddening Law Observed for Type Ia Supernovae, Cosmic Dust VIII, (Tokyo, Japan, Aug. 17-21, 2015).

Ohashi, N.: 2016, ALMA Observations of Formation and Evolution of Disks around Protostars, Astrochemistry with ALMA cycle 4, (Bordeaux, France, Jan. 12-13, 2016).

Ohashi, N.: 2016, Compact SO emission around protostars: Possible rings due to accretion shocks?, From clouds to protoplanetary disks: the astrochemical link, (Belrin, German, Oct. 5-8, 2015).

Ohsuga, K.: 2015, Radiation magnetohydrodynamics simulations of accretion flows and outflows around black holes, "Quarks to Universe in Computational Science", (Nara, Japan, Nov. 4-8, 2015).

Ohsuga, K.: 2015, Radiation-magnetohydrodynamics simulations of black hole accretion flows and outflows, Prospects, challenges and evolution of AGN modeling in the Astro-H Era, (Tokyo, Japan, Oct. 21-22, 2015).

Ohsuga, K.: 2015, Theory of black hole accretion flows and outflows, Max's 4 questions in X-ray astronomy to be addressed with ASTRO-H, (Tokyo, Japan, Jul. 31, 2015).

Ohsuga, K.: 2015, Radiation-MHD simulations of black-hole accretion flows and outflows, Black Hole Accretion and AGN Feedback, (Shanghai, China, Jun. 1-5, 2015).

Oka, T.: , The Galactic Center - Recent Progress and Future Perspectives -, NRO-ALMA Science/Development Workshop 2015, (Nagano, Japan, Jul. 28-30, 2015).

Okuda, T.: 2015, Long term plan for ASTE, ALMA/45m/ASTE/Mopra Users Meeting 2015, (Tokyo, Japan, Oct. 20-22, 2015).

Onishi, K.: 2015, Black-Hole Mass Estimation using Molecular Gas

Dynamics, East Asian ALMA Science Workshop 2015, (Osaka, Japan, Dec. 8-11, 2015).

Onishi, T.: 2015, High-mass star formation in the LMC as seen by ALMA, East Asian ALMA Science Workshop 2015, (Osaka, Japan, Dec. 8-11, 2015).

Onishi, T.: 2015, Star Formation in the Large Magellanic Cloud: Tracing an Evolution of Giant Molecular Clouds, NRO-ALMA Science/Development Workshop 2015, (Nagano, Japan, Jul. 28-30, 2015).

Onodera, M., Carollo, C. M., Lilly, S., Tacchella, S., Renzini, A., **Arimoto, N.**, Capak, P., Scoville, N., Daddi, E., **Tatehora, S.**, Zamorani, G.: 2016, ISM excitation and metallicity of star-forming galaxies at z~3.3 from near-IR spectroscopy, From stellar-evolution to galaxy formation, (Yatsugatake, Japan, Mar. 7-9, 2016).

Oshigami, S., Watanabe, S., Yamaguchi, Y., Yamaji, A., Kobayashi, T., Kumamoto, A., Ishiyama, K., Ono, T.: 2015, Mare volcanism: Reinterpretation based on Kaguya Lunar Radar Sounder data, JSEDI Symposium 2015, (Tokyo, Japan, Sep. 24-26, 2015).

Oshima, A.: 2015, An estimation of the diffusion coefficient of galactic cosmic rays in the heliosphere near the Earth, 34th International Cosmic Ray Conference, (The Hague, Jul. 30-Aug. 6, 2015).

Oshino, S., **Matsumoto, Y.**, **Kokubo, E.**: 2015, Terrestrial Planet Formation around Low-Mass Stars: Effect of the Mass of Central Stars, American Astronomical Society, ESS meeting #3, (Hawaii, USA, Nov. 29-Dec. 4, 2015).

Oshino, S., **Matsumoto, Y.**, **Kokubo, E.**: 2016, Terrestrial Planet Formation around Low-Mass Stars: Effect of the Mass of Central Stars, Exoplanets and Disks: Their Formation and Diversity III, (Ishigaki, Japan, Feb. 21-24, 2016).

Otsuji, K., **Sakurai, T.**, Kuzanyan, K., **Hagino, M.**: 2015, Current Helicity and Twist of Solar Magnetic Fields from Hinode/SOT SP and Ground Based Telescopes Data, 9th Hinode Science Meeting, (Belfast, UK, Sep. 14-17, 2015).

Oya, M., **Nishikawa, J.**, Murakami, N., **Tamura, M.**, **Kurokawa, T.**, Tanaka, K.: 2015, A new dark-hole control of speckle area nulling (SAN) method, Pathways 2015: Pathways Towards Habitable Planets, (Bern, Schweizerische, Jul. 13-17, 2015).

Oyama, T.: 2015, A progress report on the development and performance of OCTAVE-DAS and Correlator System, 8th East Asia VLBI Workshop, (Sapporo, Japan, Jul. 8-10, 2015).

Oyama, T.: 2016, Results of test broad band vlbi observations with VERA+Yonsei21m using OCTAD and OCTADISK2, The 10th NARIT-KaVA Joint Science WG meeting, (Krabi, Thailand, Feb. 22-24, 2016).

Sagawa, H.: 2015, New frontier of the Solar system observations with ALMA, ALMA/45m/ASTE/Mopra Users Meeting 2015, (Tokyo, Japan, Oct. 20-22, 2015).

Saito, M.: 2015, Status and Plans for Nobeyama 45m, NRO-ALMA Science/Development Workshop 2015, (Nagano, Japan, Jul. 28-30, 2015).

Saito, M.: 2015, Performance of Atacama Compact Array Antennas for ALMA, 36th ESA Antenna Workshop, (Noordwijk, the Netherlands, Oct. 6-9, 2015).

Saito, M.: 2015, Future (Sub)Millimeter Development in Japan, U.S. Radio/Millimeter/Submillimeter Science Futures in the 2020s, (Chicago, USA, Dec.15-17, 2015).

Saito, T., **Iono, D.**, **Ueda, J.**, **Nakanishi, K.**, **Imanishi, M.**, **Hagiwara, Y.**, Yun, M. S., Kaneko, H., **Komugi, S.**, **Espada, D.**, Sugai, H., Motohara, K., Lee, M., **Kawabe, R.**, Yamashita, T.: 2015, Molecular Gas Excitation and Chemistry in Nearby LIRGs with ALMA, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Sakai, N.: 2015, Test of the density-wave theory based on VLBI astrometry results, 8th East Asia VLBI Workshop, (Sapporo, Japan, Jul. 8-10, 2015).

Sakai, N.: 2016, Progress report from KaVA Galactic Astrometry sub-WG, The 10th NARIT-KaVA Joint Science WG meeting, (Krabi, Thailand, Feb. 22-24, 2016).

Sakai, N.: 2016, Test of the density-wave theory using VLBI astrometry results, The 10th NARIT-KaVA Joint Science WG meeting, (Krabi, Thailand, Feb. 22-24, 2016).

Sakai, N.: 2016, Galactic astrometry science, Australia-Japan School on Low Frequency Astrometry in the SKA Era, (Kagoshima, Japan, Mar. 28-31, 2016).

Sanhueza, P.: 2015, A Massive, Prestellar Clump hosting no High-Mass Prestellar Cores, East Asian ALMA Science Workshop 2015, (Osaka, Japan, Dec. 8-11, 2015).

Sasai, Y., et al. including **Watanabe, K.**: 2015, Upgrade of a data acquisition system for SciBar Cosmic Ray Telescope (SciCRT) at Mt. Sierra Negra, Mexico, 34th International Cosmic Ray Conference, (The Hague, Jul. 30-Aug. 6, 2015).

Sasaki, H.: 2016, Collective neutrino flavor oscillations and application to supernova nucleosynthesis, 13th Russbach School on Nuclear Astrophysics, (Russbach, Austria, Mar. 6-12, 2016).

Sekimoto, Y.: 2015, Broadband and wide-field focal plane with MKID, The 16th Workshop on Submm Wave Receiver Technologies in Eastern Asia, (Nanjing, China, Nov. 22-25, 2015).

Sekimoto, Y.: 2015, MKID focal plan array for LiteBIRD, B-mode from space, (Chiba, Japan, Dec. 10-16, 2015).

Seko, A., Ohta, K., **Hatsukade, B.**, **Yabe, K.**: 2015, Properties of Interstellar Medium in Star-Forming Galaxies at z~1.4 revealed with ALMA, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Shibagaki, S., **Kajino, T.**, Chiba, S., Mathews, G. J.: 2015, Relative Contributions of the *r*-Process in Supernova and Neutron Star Merger, The 13th International Symposium on Origin of Matter and Evolution of Galaxies (OMEG2015), (Beijing, China, Jun. 24-27, 2015).

Shibagaki, S., **Kajino, T.**, Chiba, S., Mathews, G. J.: 2015, The role of fission in the *r*-process in dynamical ejecta from neutron star mergers, Workshop on Microphysics In Computational Relativistic Astrophysics (MICRA2015), (Stockholm, Sweden, Aug. 17-21, 2015).

Shibagaki, S., **Kajino, T.**, Chiba, S., Mathews, G. J.: 2015, Roles of fission in the r-process, The 5th International Workshop on Compound-Nuclear Reactions and Related Topics (CNR*15), (Tokyo, Japan, Oct. 19-23, 2015).

Shibata, Y., **Cheung, S. L.**, Pun, J., So, C., Walker, C., **Agata, H.**: 2015, Early Performance and Results from the Globe at Night - Sky Brightness Monitoring Network, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Shimojo, M., ALMA Solar Development Team: 2015, Solar Observations with ALMA, 3rd Asia-Pacific Solar Physics Meeting (APSPM 2015), (Soule, South Korea, Nov. 3-6, 2015).

Shimojo, M., ALMA Solar Development Team: 2015, Solar Observations with ALMA, Hinode 9, (Belfast, UK, Sep. 14-17, 2015).

Shimojo, M., ALMA Solar Development Team: 2016, Performance of Solar mm-wave Observations with ALMA, ALMA-IRIS-DKIST Workshop 'The Sun's Chromosphere in the Era of ALMA, IRIS, and DKIST', (Boulder, CO, USA, Mar. 15-18, 2015).

Shimojo, M., Bastian, T., White, S., Iwai, K., Wedemeyer, S., Hudson, H., Brajsa, R., Barta, M., Hales, A., Hirota, A. Remijan, A., Solar Development Team of EA/NA/EU-ARC: 2015, Solar Observations with ALMA, 9th Hinode Science Meeting, (Belfast, UK, Sep. 14-17, 2015).

Shimojo, M., Iwai, K., Asai, A., Nozawa, S., **Minamidani, T.**, **Saito, M.**: 2015, Variation of Solar Microwave Spectrum in the Last Half Century, 3rd Asia-Pacific Solar Physics Meeting (APSPM 2015), (Soule, South Korea, Nov. 3-6, 2015).

Shimojo, M., Iwai, K., Asai, A., Nozawa, S., **Minamidani, T.**, **Saito, M.**: 2015, Variation of Solar Microwave Spectrum in the Last Half Century, 9th Hinode Science Meeting, (Belfast, UK, Sep. 14-17, 2015).

Shino, N.: 2015, Investigating methanol maser observation of massive star forming region IRAS18144-1732 and IRAS20198+3716, 8th East Asia VLBI Workshop, (Sapporo, Japan, Jul. 8-10, 2015).

Shino, N.: 2016, Investigating methanol maser observation of massive star forming region IRAS18144-1723, The 10th NARIT-KaVA Joint Science WG meeting, (Krabi, Thailand, Feb. 22-24, 2016).

Shirahata, M., Matsuura, S., Tsumura, K., Arai, T., Sano, K., Ohnishi Y., Matsumoto, T., Bock, J., Zemcov, M., Korngut, P., Lanz, A., Hristov, V., Battle, J., Wada, T., Cooray, A., Smidt, J.: 2015, Development of the telescope and imagers for the Cosmic Infrared Background ExpeRiment 2, The Near-IR Background II: From reionization to the present epoch, (Munich, Germany, Jun. 1-3, 2015).

Shirasaki, M.: 2015, Search for Gamma-ray from Luminous Red Galaxies, ICM Physics and Modeling, (Garching, Germany, June 15-17, 2015).

Shirasaki, M.: 2015, Probing cosmology with weak lensing selected clusters, Theoretical and Observational Progress on Large-scale Structure of the Universe, (Garching, Germany, Jul. 20-24, 2015).

Shirasaki, Y., Komiya, Y., **Ohishi, M.**, **Mizumoto, Y.**: 2015, Properties of galaxies around the most massive SMBHs, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Shirasaki, Y., **Zapart, C.**, **Ohishi, M.**, **Mizumoto, Y.**, **Kawasaki, W.**, **Kobayashi., T.**, **Kosugi, G.**, Kawaguchi, T., Eguchi, S., Ishihara, Y., Yamada, H., Hiyama, T., Nakamoto, H.: 2015, Current status of JVO portal, ADASS XXV, (Sydney, Australia, Oct. 25-29, 2015).

Shoda, A.: 2015, Torsion-bar Antenna Experiment, GWADW2015, (Alaska, USA, May. 17-22, 2015).

Shimojo, M.: 2015, Solar observations with ALMA, NRO-ALMA Science/ Development Workshop 2015, (Nagano, Japan, Jul. 28-30, 2015).

Sirbu, D., Thomas, S. J., Belikov, R., **Lozi, J.**, Bendek, E., Pluzhnik, E., Lynch, D. H., Hix, T., Zell, P., Schneider, G., **Guyon, O.**: 2015, EXCEDE technology development IV: demonstration of polychromatic contrast in vacuum at 1.2λ/D, SPIE Optics + Photonics, (San Diego, CA, USA, Aug. 9-13, 2015).

Soma, M.: 2015, When and where were the observations made for the celestial map in the Kitora Tumulus?, International Symposium on Historical Astronomy, (Seoul, Korea, Sept. 23-24, 2015).

Sotani, H.: 2015, Mass formula for low-mass neutron stars and its application, 5th International Symposium on Nuclear Symmetry Energy (NuSYM15), (Krakow, Poland, Jun. 29-Jul. 2, 2015).

Sotani, H.: 2015, Nuclear equation of state and crustal torsional oscillations, Compact Stars and Black Holes, (Tuebingen, Germany, Jul. 7-9, 2015).

Sotani, H.: 2015, Prospect for Observational Discriminant of the Gravitational Theories, Fourteenth Marcel Grossmann Meeting (MG14), (Rome, Italy, Jul. 12-18, 2015).

Sotani, H.: 2015, Identifications of Quasi-Periodic Oscillations Observed in Soft-Gamma Repeaters with Crustal Torsional Oscillations, Fourteenth Marcel Grossmann Meeting (MG14), (Rome, Italy, Jul. 12-18, 2015).

Srikanth, S., **Gonzalez, A.**: 2015, ALMA band 2 optics: preliminary results, 1st URSI Atlantic Radio Science Conference, (Gran Canaria, Spain, May 18-25, 2015).

Suematsu, Y.: 2015, Fine-scale Structure and Motion of Penumbral Filaments Revealed with Hinode G-band and CaII H Filtergrams, 9th Hinode Science Meeting, (Belfast, UK, Sep. 14-17, 2015).

Suematsu, Y.: 2015, The SOLAR-C Mission, AGU Fall meeting 2015, (San Francisco, CA, USA, Dec. 14-18, 2015).

Suematsu, Y., Solar-C Working Group: 2015, The SOLAR-C Mission: Science Objectives and Current Status, Coimbra Solar Physics Meeting: Ground-based Solar Observations in the Space Instrumentation Era, (Coimbra, Portugal, Oct. 5-9, 2015).

Sugimoto, K.: 2015, CASA update, ALMA/45m/ASTE/Mopra Users Meeting 2015, (Tokyo, Japan, Oct. 20-22, 2015).

Tagawa, H., Umemura, M., **Gouda, N.**: 2015, Accretion versus merger in the early growth of massive black holes, "Quarks to Universe in Computational Science", (Nara, Japan, Nov. 4-8, 2015).

Tagawa, H., Umemura, M., **Gouda, N.**: 2015, Early cosmic merger of multiple black holes, First stars, galaxies, and black holes: Now and Then, (Groningen, Netherland, June 15-19, 2015).

Takahashi, H. R.: 2016, 3D-reconection of supercritical accretion disks in relativistic radiation magnetohydrodynamics, 2016 US-Japan Workshop on Magnetic Reconnection (MR2016), (Napa, CA, USA, Mar. 7-11, 2016).

Takahashi, H. R., **Ohsuga, K.**, **Kawashima T.**, Sekiguchi, Y.: 2015, Relativistic Radiation Magnetohydrodynamic Simulations of Black Hole Accretion Disks and Outflows, "Quarks to Universe in Computational Science", (Nara, Japan, Nov. 4-8, 2015).

Takahashi, H. R., **Ohsuga, K.**, **Kawashima T.**, Sekiguchi, Y.: 2015, Numerical Study of Super Critical Accretion Disks, Black Hole Accretion and AGN Feedback, (Shanghai, China, Jun. 1-5, 2015).

Takakuwa, S., Yen, H.-W., **Ohashi, N.**, Chou, T.-L., Aso, Y., Saigo, K., **Saito, M.**, Machida, M. N., Tomida, K., Aikawa, Y., **Tomisaka, K.**, Koyamatsu, S., Takahashi, S. Z.: 2015, SMA and ALMA Studies of Protoplanetary-Disk Formation around Low-mass Protostars, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Takata, T.: 2016, Status of database/Data release plan, HSC Collaboration Meeting, (Taipei, Taiwan, Jan. 13-15, 2016).

Takato, N.: 2015, PFS activities at Subaru in 2015, 7th PFS collaboration meeting, (Marseille, France, Dec. 14-18, 2015).

Takeda, T., **Kokubo, E.**, **Agata, H.**, **Kato, T.**, **Nakayama, H.**, **Narasaki, Y.**, **Fukushi, H.**: 2015, Four Dimensional Digital Universe Project, Int. Symp. on the NAOJ Museum, (Tokyo, Japan, Sep. 27-29, 2015).

Takeda, Y.: 2016, Activities and related properties of solar-type stars,

Superflare Workshop 2016 “Superflares on Solar-type Stars and Solar Flares, and Their Impacts on Exoplanets and the Earth”, (Kyoto, Japan, Mar. 1-4, 2015).

Takeda, Y.: 2016, Fundamental parameters of red giants in collaboration with asteroseismology and high-dispersion spectroscopy, Workshop on “Galactic archaeology - Asteroseismology”, (Mitaka, Tokyo, Japan, Mar. 22, 2016).

Takekoshi, T.: 2015, Physical Properties of the 1.1 mm selected Giant Molecular Clouds in the Small Magellanic Cloud, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Takiwaki, T.: 2015, Study of Core-Collapse Supernova Explosions, Comprehensive Studies of Neutron Stars, (Saitama, Japan, Nov. 24, 2015).

Takiwaki, T.: 2015, Asymmetric ejecta in three dimensional simulations of core-collapse supernovae, Symposium on Supernovae and Supernova Remnants (SNSNR2015), (Sagamihara, Japan, Nov. 9, 2015).

Takiwaki, T.: 2015, A new class of rotational explosion in core-collapse supernovae, QUCS 2015, (Nara, Japan, Nov. 4-8, 2015).

Takiwaki, T.: 2015, Dependence of nuclear equation of state on supernova explosion, International Numazu Workshop on Challenges of Modeling Supernovae with Nuclear Data, (Shizuoka, Japan, Sep. 1-4, 2015).

Takiwaki, T.: 2015, How supernova simulations are affected by input physics, Workshop on Microphysics In Computational Relativistic Astrophysics (MICRA2015), (Stockholm, Sweden, Aug. 17-21, 2015).

Takiwaki, T.: 2015, How equation of state affects explosions of core-collapse supernovae, Physics and Astronomy of Neutron Stars and Supernovae, (Tokyo, Japan, Jun. 21-22, 2015).

Takiwaki, T.: 2016, Gravitational wave signals from three dimensional simulations of Core-Collapse Supernovae, 4th Annual Symposium of the Innovative Area on Multi-messenger Study of Gravitational Wave Sources, (Chiba, Japan, Feb. 18- 20, 2016).

Tamura, M.: 2015, Subaru Direct Imaging Survey of Wide-Orbit Exoplanets and Solar-System-Scale Disks, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Tamura, M.: 2015, Development of Astrobiology with Exoplanet Explorations, Japan Geoscience Union Meeting 2015, (Chiba, Japan, May 24-28, 2015).

Tamura, M.: 2015, NINS Astrobiology Center: Development of Astrobiology with Exoplanet Explorations, NAI/EC and Iternational Partner In-person Meeting, (Chicago, USA, Jun. 19-20, 2015).

Tamura, M.: 2015, Subaru Observations of Exoplanets and Toward TMT: A Role of the New Astrobiology Center at NINS, Astrobiology Workshop, (Kiel, Germany, Dec. 9, 2015).

Tamura, M.: 2016, Workshop summary, Post-SEEDS Workshop, (Mitaka, Japan, Feb. 21, 2016).

Tamura, M.: 2016, Exoplanet exploration with IRSF/SIRIUS and future, IRSF Workshop 2016, (Cape Town, South Africa, Mar. 3, 2016).

Tamura, M., SEEDS team: 2016, Five Years of SEEDS: Strategic Exploration of Exoplanets and Disks with Subaru, Subaru Users Meeting FY2015, (Atami, Japan, Jan. 19-21, 2016).

Tamura, M., SEEDS team: 2016, Five Years of the Subaru SEEDS Direct Imaging Survey and Next Steps, Exoplanets and Disks: Their Formation and Diversity III, (Ishigaki, Japan, Feb. 21-24, 2016).

Tamura, Y., Imai, H.: 2015, ITRF Coordinates of the NRO 45 m Telescope, ALMA/45 m/ASTE/Mopra Users Meeting 2015, (Tokyo, Japan, Oct. 20-22, 2015).

Tamura, Y.: 2016, Measuring the Atmospheric Effects with External Data, Australia-Japan School on Low Frequency Astrometry in the SKA Era, (Kagoshima, Japan, Mar. 28-31, 2016).

Tanaka, M.: 2015, Electromagnetic Emission from Compact Binary Mergers, The 25th Workshop on General Relativity and Gravitation in Japan, (Kyoto, Japan, Dec. 7-11, 2015).

Tanaka, M.: 2015, Radiative Transfer Simulations in Compact Star Mergers, Quarks to Universe in Computational Science, (Nara, Japan, Nov. 4-8, 2015).

Tanaka, M.: 2015, Supernovae: Toward Multiwavelength Studies, Paving the Way to Simultaneous Multi-Wavelength Astronomy, (Leiden, Netherlands, July 13-17, 2015).

Tanaka, M.: 2015, Radioactively-powered emission from compact binary mergers, Gravitational Wave Physics and Astronomy Workshop (GWPAW) 2015, (Osaka, Japan, June 17-20, 2015).

Tanaka, M.: 2015, Optical/infrared emission from neutron star mergers, South American Supernovae (SAS) 2015, (Santiago, Chile, Apr. 28-30, 2015).

Tanaka, M., Chiba, M., **Komiyama, Y.**: 2015, Discovery of new dwarf galaxies around NGC4631 with Subaru/Hyper Suprime-Cam, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Tanaka, M.: 2015, HSC Website / Reports from the Photo-z, Low-z, Archeology Working Groups, HSC Collaboration Meeting, (Princeton, NJ, USA, Jul. 27-19, 2015).

Tanaka, M.: 2015, Photometric Redshifts, 新学術領域「なぜ宇宙は加速するのか? - 徹底的究明と将来への挑戦 -」発足シンポジウム, (Tokyo, Japan, Sep. 20-21, 2015).

Tanaka, M.: 2015, Some thoughts on the PFS-SSP galaxy survey, PFS-SSP galaxy survey workshop, (Kashiwa, Japan, Nov. 13, 2015).

Tanaka, M.: 2015, Strategic Surveys with Hyper Suprime-Cam and Prime-Focus Spectrograph, Workshop for ALMA Large Proposal of gAlactic Cold gAs (ALPACA) Survey, (NAOJ, Japan, Dec. 1-2, 2015).

Tanaka, M.: 2016, Photometry / Reports from the Photo-z and Low-z Working Groups / HSC website, HSC Collaboration Meeting, (Taipei, Taiwan, Jan. 13-15, 2016).

Tanaka, M.: 2016, The Missing Satellite Problem Outside of the Local Group, IAU Symp. 321: Fornation and evolution of galaxy outskirts, (Toledo, Spain, Mar. 14-18, 2016).

Tanaka, Y., Yamada, Y., **Kurokawa, T.**: 2015, Distance measurement using second harmonic signal component of two-photon absorption photocurrent from Si-APD, CLEO 2015, (San Jose, CA, USA, May 10-15, 2015).

Tanikawa, K., **Soma, M.**: 2015, On the eclipse of 延烏郎 and 細烏女 in Samguk-Yusa, International Symposium on Historical Astronomy, (Seoul, Korea, Sept. 23-24, 2015).

Tatematsu, K.: 2015, Statistics from cycle 2, and APRC results for cycle 3, ALMA/45 m/ASTE/Mopra Users Meeting 2015, (Tokyo, Japan, Oct. 20-22, 2015).

Tatematsu, K.: 2015, New capabilities and observing mode for cycle 4, ALMA/45m/ASTE/Mopra Users Meeting 2015, (Tokyo, Japan, Oct. 20-22, 2015).

Tazaki, F.: 2015, M87 Image at 43 GHz with “Sparse Modeling”, 8th East Asia VLBI Workshop, (Sapporo, Japan, Jul. 8-10, 2015).

Terazono, J., **Sakamoto, S.**, Yoshikawa, M., Wakabayashi, N., **Watanabe,**

J.: 2015, Japanese Lunar and Planetary Exploration Outreach - 17 years' history of "The Moon Station", Int. Symp. on the NAOJ Museum, (Tokyo, Japan, Sep. 27-29, 2015).

Tokuda, K., Onishi, T., Saigo, K., **Kawamura, A.**, Fukui, Y., Matsumoto, T., Inutsuka, S., Machida, M. N., Tomida, K., Tachihara, K.: 2015, ALMA Observations of a High-density Core in Taurus: Dynamical Gas Interaction at the Possible Site of a Multiple Star Formation, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Toriumi, S., Iida, Y., Kusano, K., Bamba, Y., Imada, S.: 2015, Observation and Modeling of a Quadrupolar Flare-productive Active Region, Flux Emergence Workshop 2015, (Boulder, CO, USA, Jun. 15-19, 2015).

Toriumi, S., **Katsukawa, Y.**, Cheung, M. C. M.: 2015, Hinode, SDO and IRIS observation and MHD modeling of light bridge structures, 9th Hinode Science Meeting, (Belfast, UK, Sep. 14-17, 2015).

Toriumi, S., **Katsukawa, Y**, Cheung, M. C. M.: 2015, Light Bridge Structures Formed in Emerging Active Regions, Flux Emergence Workshop 2015, (Boulder, CO, USA, Jun. 15-19, 2015).

Toriumi, S., **Katsukawa, Y**, Cheung, M. C. M.: 2015, Hinode, SDO and IRIS observation and MHD modeling of light bridge structures, Hinode 9, (Belfast, UK, Sep. 14-17, 2015).

Toriumi, S.: 2015, Light Bridge Structure in a Developing Sunspot Region, 5th International workshop on small scale solar magnetic fields, (Bairisch Kölldorf, Austria, Apr. 21-24, 2015).

Toriumi, S.: 2015, Solar Active Regions: From Birth to Eruption, Japan Geoscience Union Meeting 2015, (Chiba, Japan, May 24-28, 2015).

Toriumi, S.: 2015, Emerging flux and active region evolution, Hinode 9 (Solar-C meeting), (Belfast, UK, Sep. 18, 2015).

Tsujimoto, T.: 2015, Chemical footsteps of r-nuclides in satellite galaxies of Local Group, In the footsteps of galaxies: Tracing the evolution of environmental effects, (Soverato, Italy, Sep. 7-11, 2015).

Ueda, J., **Iono, D.**, Yun, M. S., Crocker, A. F., Narayanan, D., **Komugi, S.**, **Espada, D.**, **Hatsukade, B.**, Kaneko, H., **Matsuda, Y.**, Tamura, Y., Wilner, D., **Kawabe, R.**, Pan, H.-A.: 2015, Investigating nuclear and extended molecular gas disks in the final stages of mergers, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Ueda, J., **Iono, D.**, Yun, M. S., Crocker, A. F., Narayanan, D., **Komugi, S.**, **Espada, D.**, **Hatsukade, B.**, Kaneko, H., **Matsuda, Y.**, Tamura, Y., Wilner, D., **Kawabe, R.**, Pan, H.-A.: 2015, Investigating nuclear and extended molecular gas disks in the final stages of mergers, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Umemoto. T.: 2015, NRO Galactic Plane Survey (FUGIN) Legacy Project, ALMA/45m/ASTE/Mopra Users Meeting 2015, (Tokyo, Japan, Oct. 20-22, 2015).

Umemoto. T.: 2015, Nobeyama 45m CO Galactic Plane Survey: Progress of 2014, NRO-ALMA Science/Development Workshop 2015, (Nagano, Japan, Jul. 28-30, 2015).

Usuda-Sato, K.: 2015, Introduction of the NAOJ Museum Plan, Int. Symp. on the NAOJ Museum, (Tokyo, Japan, Sep. 27-29, 2015).

Usuda-Sato, K., Iizuka, R., Yamaoka, H., **Agata, H.**, NameExoWorlds Working Group Members: 2015, Inspiring People to Participate in the NameExoWorlds Contest, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Uyama, T., **Tamura, M.**, **Hashimoto, J.**, Kuzuhara, M.: 2015, Search for Exoplanets around Young Stellar Objects by Direct Imaging, American Astronomical Society, ESS meeting #3, (Hawaii, USA, Nov. 29-Dec. 4, 2015).

Uzawa, Y., Makise, K., **Kojima, T.**, Saito, S., **Kroug, M.**, **Fujii, Y.**, **Gonzalez, A.**, **Kaneko, K.**, Terai, H., Wang, Z.: 2015, Characterization of NbTiN Films for Superconducting Terahertz Circuitry, 15th Int. Superconductive Electronics Conf. 2015 (ISEC2015), (Nagoya, Japan, Jul. 6-9, 2015).

Uzawa, Y., **NAOJ receiver group**, NICT remote sensing group: 2016, Terahertz radio astronomy applications and activities at NICT, Spain-Japan Joint workshop on Millimetre-wave and Terahertz, (Madrid, Spain, Mar. 17-18, 2016).

Wakita, S., **Matsumoto, Y.**, **Oshino, S.**, **Hasegawa, Y.**: 2016, Planetesimal Collisions as a Heating Event for Chondrule Formation, 47th Lunar and Planetary Sci. Conf., (The Woodlands, TX, USA, Mar. 21-25, 2016).

Watanabe, J.-i., **Nakagiri, M.**: 2015, Candidates of World Heritage Sites of Astronomy in Japan, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Watanabe, J.-i., **Sasaki, G.**, **Nakagiri, M.**, Ohshima, N.: 2015, Discovery of Japan's Oldest Photographic Plates of a Starfield, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Watanabe, K., Masuda, S.: 2015, A Statistical Approach to a Better Understanding of the Conditions that Produce White-Light Enhancements in Solar Flares, 9th Hinode Science Meeting, (Belfast, UK, Sep. 14-17, 2015).

Watanabe, K., Masuda, S., Kitagawa, J.: 2015, Characteristics that enhance white-light emission in solar flares, AOGS 12th Annual Meeting, (Singapore, Aug. 2-7, 2015).

Watanabe, K., Uchida, K., **Kobayashi, K.**, Matsushima, F., Moriwaki, Y.: 2015, Laser Spectroscopic Study of CaH in the B 2S+ and D 2S+ States, Int. Symp. on Molecular Spectroscopy, 70th meeting, (Urbana-Champagne, IL, USA, Jun. 22-26, 2015).

Watanabe, K., Masuda, S., Kitagawa, J.: 2015, Characteristics that enhance white-light emission in solar flares, Japan Geoscience Union Meeting 2015, (Chiba, Japan, May 24-28, 2015).

Watanabe, T., Solar-C WG, **Office for Solar-C**: 2015, The Solar-C Mission, 9th Hinode Science Meeting, (Belfast, UK, Sep. 14-17, 2015).

Wootten, A., Corder, S. A., **Iono, D.**, Testi, L.: 2015, ALMA: Millimeter/submillimeter Astronomy at high sensitivity and resolution, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Wu, Y. W.: 2015, Trigonometric parallax of HMSFR G035.20-1.74, 8th East Asia VLBI Workshop, (Sapporo, Japan, Jul. 8-10, 2015).

Wu, Y. W.: 2016, Current Calibration strategies for VLBI astrometry, Australia-Japan School on Low Frequency Astrometry in the SKA Era, (Kagoshima, Japan, Mar. 28-31, 2016).

Yaji, K.: 2015, Coodinated Solar Observation with High Schools - let's observe the sun with Hinode, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Yaji, K.: 2015, Communicating Solar Astronomy to the Public, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Yaji, K.: 2015, Solar Observation Data Education in Classroom, GHOU2015, (Honolulu, HI, USA, Aug. 4-5, 2015).

Yamada, R., Shiraishi, H., Nebut, T., Lognonne P., **Asari, K.**, Tanaka, S.: 2015, Seismic observation using the broadband seismometers targeted for moonquake, 30th ISTS, (Kobe, Japan, Jul. 4-10, 2015).

Yamada, Y., **Gouda, N.**, Yoshioka, S.: 2015, JASMINE data analysis, Division A meeting at the XXIX General Assembly of IAU,

(Honolulu, USA, Aug. 7-10, 2015).

Yamashita, T., **Komugi, S.**, Matsuhara, H., Armus, L., Inami, H., **Ueda, J.**, **Iono, D.**, Kohno, K., Stierwalt, S., Arimatsu, K., Evans, A.: 2015, The Nobeyama 45 m ^{12}CO(J=1–0) Survey of local Luminous Infrared Galaxies, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Yanagisawa, K., Yoshida, M., Ohta, K., Kawai, N., **Izumiura, H.**: 2015, Wide Field NIR Imager at Okayama Astrophysical Observatoty, Gravitational Wave Physics and Astronomy Workshop (GWPAW) 2015, (Osaka, Japan, June 17-20, 2015).

Yanagisawa, K.: 2016, Current Status of OAO-WFC, 4th Annual Symposium of the Innovative Area on Multi-messenger Study of Gravitational Wave Sources, (Chiba, Japan, Feb. 18-20, 2016).

Yeh, S. C. C., Seaquist, E. R., Matzner, C. D., Pellegrini, E. W.: 2015, Molecular and Ionized Hydrogen in 30 Doradus, Feedback in the Magellanic Clouds, STSci Workshop, (Baltimore, MD, USA, Oct. 5-7, 2015).

Yeh, S. C. C., Tsai, C.-W., Geballe, T. R., **Herrera, C. N.**: , Mid-infrared [NeII] Imaging of Young Massive Star Clusters Near Galactic Nuclei, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Yoshida, H.: 2016, A trip searching for integrability criteria over 120 years, 3-rd Conference on Finite Dimensional Integrable Systems in Geometry and Mathematical Physics 2015, (Bedlewo, Poland, Jul. 12-17, 2015).

Yun, M. S., Gim, H., Morrison, G., Hales, C. A., Momjian, E., Owen, F., Kellermann, K., Aretxaga, I., Giavalisco, M., Hughes, D., Lowenthal, J., Miller, N., **Kawabe, R.**, Kohno, K.: 2015, Tracing Evolution of Starbursts and AGNs using Ultra-deep Radio and mm/smm Surveys, IAU XXIX General Assembly, (Honolulu, HI, USA, Aug. 3-14, 2015).

Zenitani, S.: 2015, Numerical Modeling of Relativistic Reconnection: Kinetic, Two-fluid, and MHD Simulations, Relativistic Jets: Creation, Dynamics, and Internal Physics, (Krakow, Poland, Apr. 20-24, 2015).

Zenitani, S.: 2015, Particle acceleration in relativistic magnetic reconnection, AOGS 12th Annual Meeting, (Singapore, Aug. 2-7, 2015).

Zenitani, S.: 2015, High-speed fluid dynamics in magnetic reconnection in a low-beta plasma, AGU Chapman Conference, (Fairbanks, AK, USA, Sep. 27-Oct. 2, 2015).

Zenitani, S.: 2015, High-speed fluid dynamics in magnetic reconnection in a low-beta plasma, ISAS Workshop: Magnetospheric Plasmas 2015, (Tokyo, Japan, Dec. 1-3, 2015).

Zenitani, S.: 2015, Loading Relativistic Maxwell Distributions in Particle Simulations, AGU Fall meeting 2015, (San Francisco, CA, USA, Dec. 14-18, 2015).

Zenitani, S.: 2016, Particle dynamics in the electron current layer in collisionless magnetic reconnection, 2016 US-Japan Workshop on Magnetic Reconnection (MR2016), (Napa, CA, USA, Mar. 7-11, 2016).

Zenitani, S.: 2016, High-speed fluid dynamics in magnetic reconnection in a low-beta plasma, 2016 US-Japan Workshop on Magnetic Reconnection (MR2016), (Napa, CA, USA, Mar. 7-11, 2016).

Zenitani, S.: 2016, Particle dynamics and nongyrotropic distribution functions in collisionless magnetic reconnection, International GEMSIS and ASINACTR-G2602 Workshop, (Nagoya, Japan, Mar. 22-25, 2016).

Zenitani, S., **Miyoshi, T.**: 2015, High-speed fluid dynamics in magnetic reconnection in a low-beta plasma, AOGS 12th Annual Meeting, (Singapore, Aug. 2-7, 2015).

Annual Report of the National Astronomical Observatory of Japan

Volume 18 Fiscal 2015