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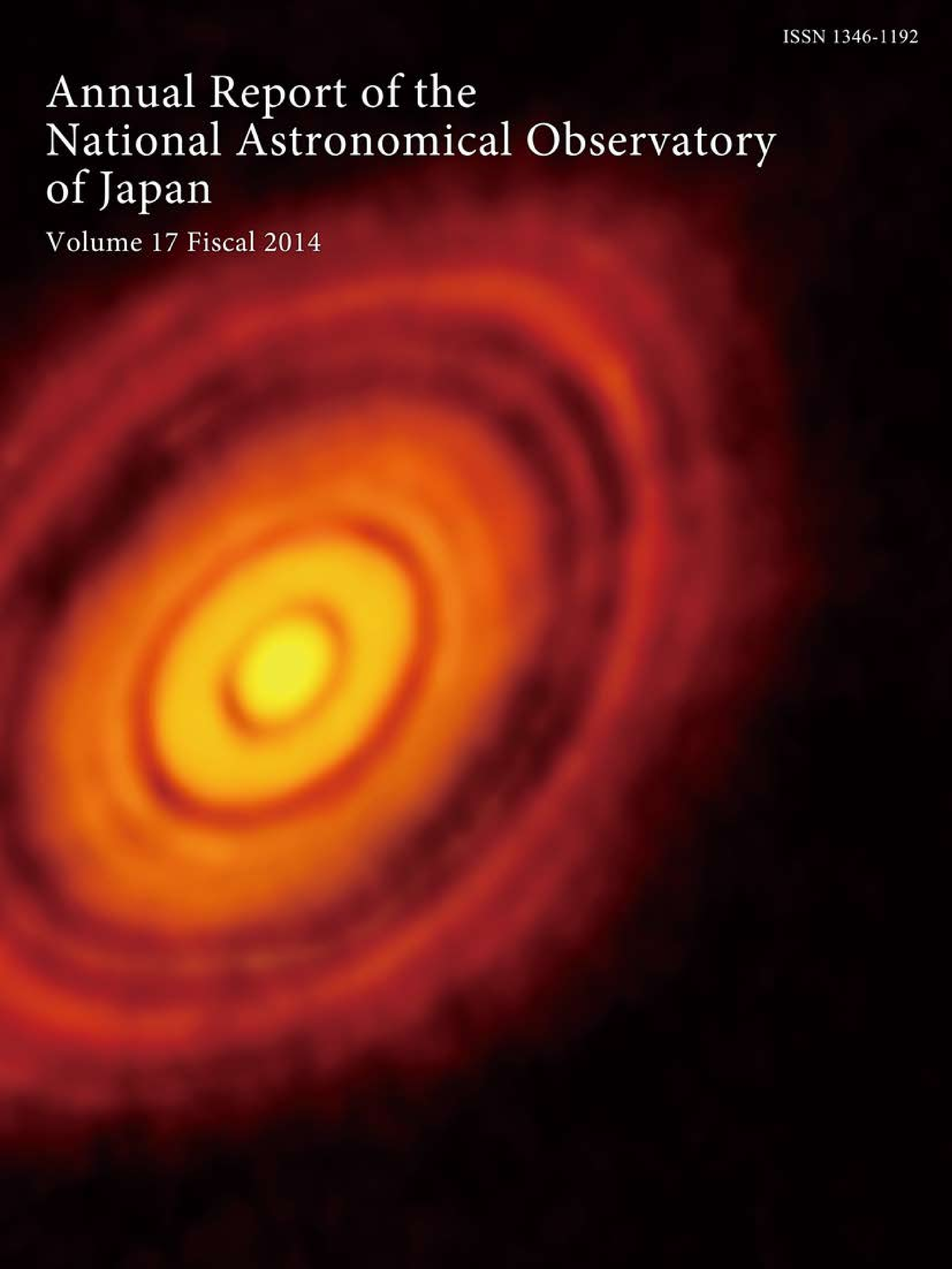

Cover Caption

ALMA image of the protoplanetary disk around HL Tauri.
The new ALMA observations reveal substructures within the disk that have never been seen before.
Credit: ALMA (ESO/NAOJ/NRAO)

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 **ATOMI co., Ltd.**
5-13-22 Ogawahigashicho, Kodaira, Tokyo 187-0031, Japan
TEX: +81-42-345-1155
FAX: +81-42-343-3517

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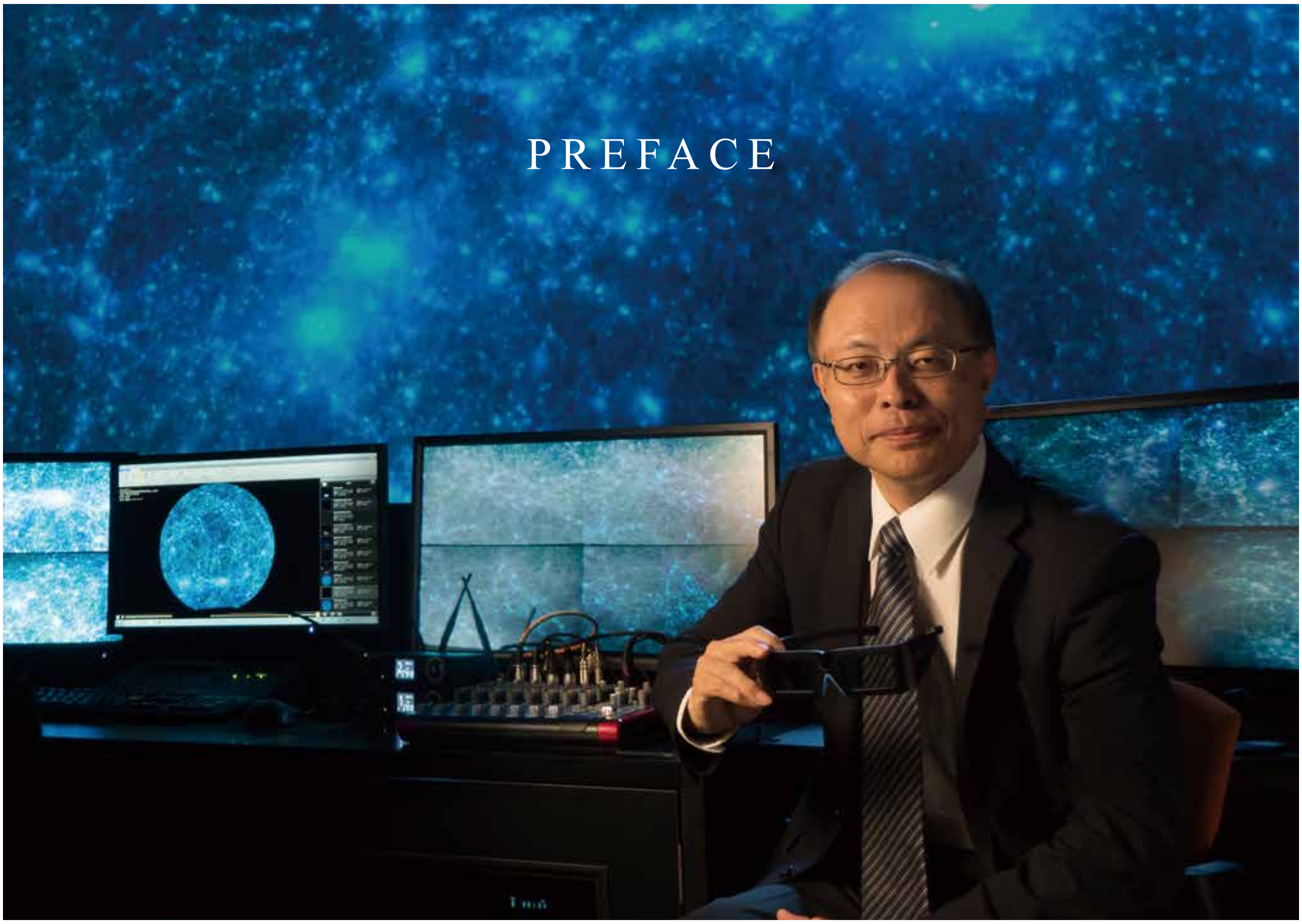
PREFACE



Masahiko HAYASHI
Director General of NAOJ

It is my pleasure to present the Annual Report of the National Astronomical Observatory of Japan for fiscal year 2014.

In February 2015, NAOJ conducted an External Review in order to evaluate our achievements over the last five years from an international standpoint. The first sentence of the evaluation report states, "The most significant development of the last five years must be the growing and highly successful Japanese participation in major international astronomical projects." This refers primarily to ALMA and TMT. With the Subaru Telescope, Japanese optical-infrared astronomy attained world leading status. But at the same time, that was also the limit of what Japan could accomplish as a single country in the field of large telescope construction. Now, NAOJ is making important contributions to major large-scale international projects, such as ALMA and TMT.

Thanks to our experiences with the Subaru Telescope, resistance in the Japanese astronomical community to building telescopes overseas disappeared. It was naturally assumed that for ALMA the radio antennas would be established overseas and that the construction and operation would be carried out as an international project. This was a new challenge for NAOJ. Fortunately as part of the reorganization and incorporation of NAOJ in 2004, the personnel system was reconsidered and the project system was established, allowing flexible reorganization to facilitate large international projects. It also became possible for individuals with valuable specialized skills to participate in large international projects as contracted staff. Furthermore, because NAOJ represents Japan in these kinds of large international projects, our obligations as an inter-university research institute are clear: to make large contributions to the advancement of research throughout all of Japan in the field of astronomy. I think the high evaluation we received from the international community in last fiscal year's External Review is a result of these changes in NAOJ's structure and philosophy.

In 2014, NAOJ's Philosophy was codified. Our Vision is "to be innovators striving to solve the mysteries of the Universe." Our Mission has 3 pillars: to develop and construct large-scale cutting-edge astronomical research facilities and promote their open access aiming to expand our intellectual horizons; to contribute to the development of astronomy as a world leading research institute by making the best use of a wide variety of large-scale facilities; and to bring benefits to society through astronomy public outreach. Our Products/Deliverables are: to explore the unknown Universe and provide new insight into astronomy; to make our research outcomes widely known to society and pass on our dreams to future generations; and to mentor next-generation researchers for their role on the world-stage.

With respect to the extremely large optical-infrared telescope TMT under construction in Hawai`i, the Master Agreement, which provides the foundation to proceed with construction within an international framework, was completed and President Katsuhiko Sato signed it on behalf of the National Institutes of Natural Sciences in April 2014. Having received this approval, the TMT International Observatory was incorporated as a nonprofit corporation in the following month (May) and a groundbreaking ceremony was held in October. TMT is a 30 m diameter optical-infrared telescope being constructed on Maunakea on Hawai`i Island by 5 countries including Japan, the United States of America (the University of California, the California Institute of Technology, and the National Science Foundation), the People's Republic of China, the Republic of India, and Canada. Japan bears responsibility for the most critical components, including the body of the telescope and production of the nearly 600 segments for the primary mirror. The search for signs of life in the Universe is one of the stated major targets for TMT. This statement sounds like a dream, but I am confident the day is approaching when it will be a reality.

ALMA is continuing commissioning (the process of confirming and adjusting the numerous devices one by one) while carrying out Cycle 2 observations. From September to November in 2014, long-baseline test observations spanning ranges of up to 15 km were conducted with surprisingly good results. Multiple concentric ring structures can be seen in the picture of the protoplanetary disk around the young star HL Tauri taken with a high angular resolution of 0.03 arcseconds. It is thought that these structures might indicate locations where planets are forming. Until now, there have been pictures drawn showing how sites of planet formation were expected to look, but an actual image is more powerful than I had ever imagined. This long-baseline capability will be offered for open use in Cycle 3, which begins in 2015. Using this, we can expect many planetary systems forming around young stars to be found rapidly in the coming years.

At the Subaru Telescope, the Strategic Science Program using the ultra-wide-field prime focus camera (Hyper Suprime-Cam) has started. This camera's survey speed (= limiting magnitude x area of the field of view) is over 10 times greater than previous surveys. What's more, thanks to this camera the Subaru Telescope's observations will be the world's forerunners without question, until LSST (America's Large Synoptic Survey Telescope) becomes operational in the mid-2020s. Observations with this camera will investigate the nature of dark matter and dark energy which determine the evolution of the large scale structure of the Universe.

Right now the Subaru Telescope is in its prime, continuously producing outstanding scientific results. In fiscal year 2014 for example, among the stars born in the early Universe, a star with peculiar chemical abundance ratios was discovered relatively close to the Solar System within our Milky Way Galaxy. This star is thought to have been formed from the gas left over after the first stars born after the Big Bang, with masses hundreds of times that of the Sun, exploded in supernovae. The first stars formed in the Universe were said to have had masses nearly 1000 times that of the Sun. But there had been no clear evidence to support that until now. These observational results provide the first proof.

The Subaru Telescope also observed a location where lithium had been produced in the gas expanding from a nova (an explosive nuclear fusion phenomenon which occurs when hydrogen accumulates on the surface of a white dwarf). Lithium, the next lightest element after hydrogen and helium, was produced in only trace amounts during the Big Bang (about one-billionth the number of hydrogen atoms). This lithium was absorbed into normal stars and destroyed in their cores. But in fact, the amount of lithium has increased as the Universe has evolved. Where this lithium was produced had been a mystery. This discovery directly verified the circumstances of lithium synthesis.

In addition to the 3 large projects listed above, VERA of the Mizusawa VLBI Observatory and the Korean KVN together formed KaVA to start joint VLBI observations. The large-scale cryogenic gravitational wave telescope KAGRA, supported in cooperation with the University of Tokyo Institute for Cosmic Ray Research and the High Energy Accelerator Research Organization, has made important progress, including starting construction of the laser interferometer.

Last fiscal year, in response to the aging of the 4D2U Dome Theater, the control computer network and projectors were upgraded. At the same time, the "3D glasses" were changed to an active shutter system. As a result, across the entire dome the image has become brighter and more vivid. Simulations of the large scale structure of the Universe or Saturn's rings can fool you into thinking that you are drifting in space. In addition, the seating capacity was doubled and it has become possible to enter without having to first remove your shoes. With these improvements, the number of days the Dome Theater is open to the public has been increased in FY 2015. So we expect more guests than ever to be able to enjoy it.

Finally, in 2014 the East Asian Observatory was founded. This was established with the goal of making a permanent basis for large international projects in East Asia in response to the increasing size and internationalization of telescope plans which I described above. The founding members are the National Astronomical Observatory of Japan; the Institute of Astronomy and Astrophysics of ACADEMIA SINICA in Taiwan; the Korea Astronomy and Space Science Institute; and the National Astronomical Observatories of the Chinese Academy of Sciences. There are still a number of unknowns about how the East Asian Observatory will develop after this. If we take as an example the European Southern Observatory, which is currently leading the world in ground-based telescope projects, we feel it is important to approach the activities of the East Asian Observatory calmly and deliberately.

Masahiko HAYASHI
Director General of NAOJ

I Scientific Highlights

(April 2014 – March 2015)

Solar Rotation Inferred from Radial Velocities of the Sun-as-a-Star during the 2012 May 21 Eclipse

TAKEDA, Yoichi (NAOJ)
OHSHIMA, Osamu (Mizushima Technical High School)

KAMBE, Eiji, TODA, Hiroyuki, KOYANO, Hisashi, NARITA, Norio, SEKII, Takashi (NAOJ)

SATO, Bun'ei (Tokyo Institute of Technology)
NAKAMURA, Yasuhisa (Fukushima University)

With an aim to examine how much information of solar rotation can be obtained purely spectroscopically by observing the Sun-as-a-star during the 2012 May 21 eclipse (Fig. 1) at Okayama Astrophysical Observatory, we studied the variation of radial velocities (V_r), which were derived by using the iodine-cell technique based on a set of 184 high-dispersion spectra consecutively obtained over the time span of ~ 4 hours.

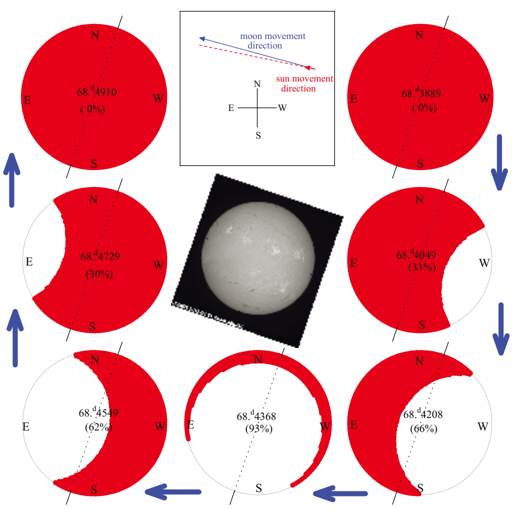


Figure 1: Solar eclipse on 2012 May 21 at Okayama Astrophysical Observatory.

The resulting $V_r(t)$ was confirmed to show the characteristic variation (Rossiter–McLaughlin effect) caused by time-varying visibility of the solar disk. By comparing the observed $V_r(t)$ curve with the theoretical ones, which were simulated with the latitude (ψ) dependent solar rotation law $\omega_{\mathrm{sidereal}}(\psi) = A + B\sin^2\psi$(deg day^{-1}), we found that the relation $B \simeq -5.5A + 77$ gives the best fit as seen from the minimum trough of $\sigma(A, B)$ (O−C standard deviation in the A–B plane; cf. Fig. 2), though separate determinations of A and B were not possible. This relationship is consistent with the real values known for the Sun ($A \simeq 14.5$, $B \simeq -2.8$), as can be confirmed in Fig. 3 where the theoretical curve corresponding to ($A = 14.5$, $B = -2.75$) case is compared with the observation. This consequence may provide a prospect of getting useful information on stellar rotation of eclipsing binaries from radial-velocity studies during eclipse, if many spectra of sufficiently high time-resolution are available. See [1] for more details of this study.

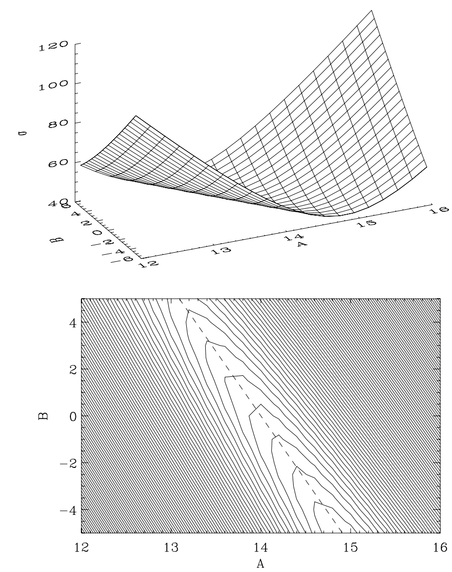


Figure 2: Behavior of $\sigma(A, B)$ (standard deviation in fitting the simulated $V_r(t)$ with the observed $V_r(t)$).

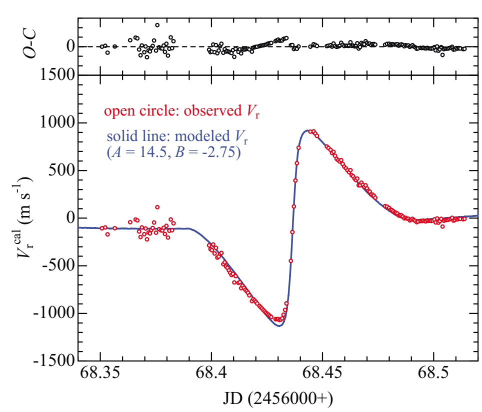


Figure 3: Comparison of the theoretical $V_r(t)$ coresponding to (A = 14.5, B = −2.75) with the observed $V_r(t)$.

Reference

[1] Takeda, Y., et al.: 2015, *PASJ*, **67**, 10.

The Opposition Effect of the Asteroid 4 Vesta

HASEGAWA, Sunao[1], MIYASAKA, Seidai[2], TOKIMASA, Noritaka[3], SOGAME, Akito[4], IBRAHIMOV, Mansur A.[5] YOSHIDA, Fumi[6], OZAKI, Shinobu[6], ABE, Masanao[1], ISHIGURO, Masateru[7], KURODA, Daisuke[6]

1: ISAS/JAXA, 2: Tokyo Metropolitan Government, 3: Sayo Town Office, 4: Tokai University, 5: Russian Academy of Sciences, 6: NAOJ, 7: Seoul National University

We present the results of photometric observations carried out for the asteroid 4 Vesta in the B, R_c, and z' bands at a minimum phase angle of 0.1 degrees with four small telescopes: the 0.064 m refracting telescope at ISAS, JAXA in Sagamihara, the 0.36 m Ritchey–Chrétien telescope at the Miyasaka Observatory, the 0.076 m refracting telescopeat the Nishiharima Astronomical Observatory, and the 0.6 m Zeiss reflecting telescope at the Maidanak Astronomical Observatory.

The magnitudes reduced to unit distance and phase angle were $M_B(1, 1, 0) = 3.83$, $M_{R_c} = 2.67$, and $M_{z'}(1, 1, 0) = 3.03$ mag. The absolute magnitude obtained from the IAU *H*–*G* function [1] is ~0.1 mag darker than the magnitude at a phase angle of 0 degrees determined from the Shevchenko function [2] and Hapke models with the coherent backscattering effect term [3] (see Fig. 1, 2). Our photometric measurement allowed us to derive geometric albedos of 0.35 in the B band, 0.41 in the R_c band, and 0.31 in the z' bands through the Hapke model with the coherent backscattering effect term [4]. The porosity of the optically active regolith on the asteroid 4 Vesta was estimated from the Hapke model to be ρ = 0.4–0.7 yielding the bluk density of $0.9–2.0 \times 10^3$ kg m^{-3} [4].

It is evident that the opposition effect for the asteroid 4 Vesta makes a contribution to not only the shadow-hiding effect, but also the coherent backscattering effect that appears from about 1 degrees. The amplitude of the coherent backscatter opposition effect for Vesta increases with a brightening of reflectance. By comparison with other solar system bodies, we suggest that multiple-scattering on an optically active scale may contribute to the amplitude of the coherent backscatter opposition effect (B_{C0}) [4].

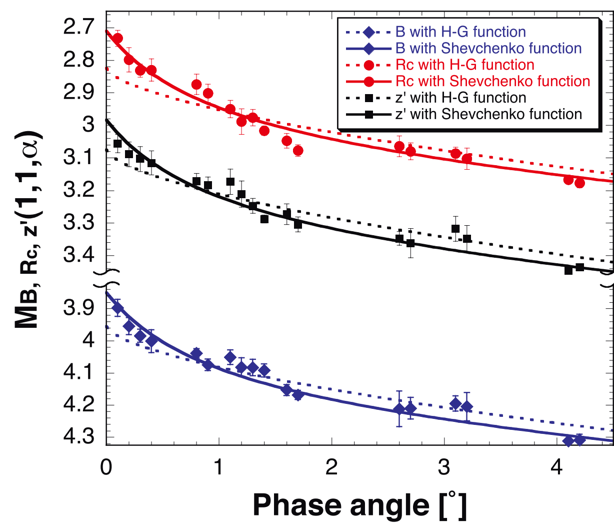


Figure 1: Fitted phase curves for asteroid Vesta using the IAU H–G phase function [1] and the Shevchenko function [2].

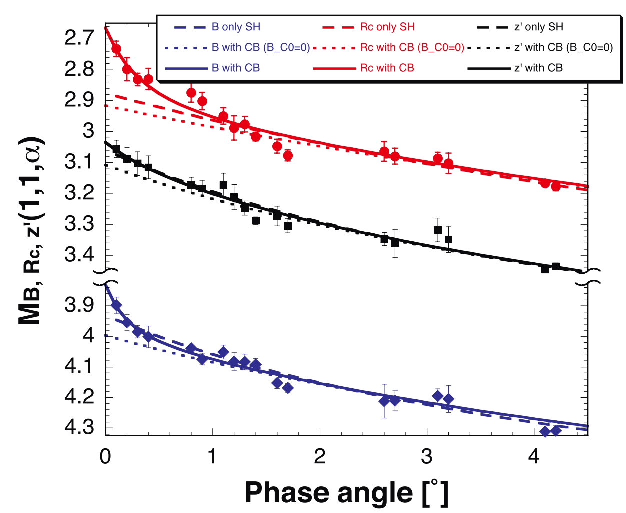


Figure 2: Fitted phase curves for asteroid Vesta obtained with the Hapke model [3].

References

[1] Bowell, E.. et al.: 1989, *Asteroid II*, 524.
[2] Shevchenko, V. G.: 1996, *Lunar Planet. Sci.*, **27**, 1193.
[3] Hapke, B.: 2002, *Icarus*, **157**, 523.
[4] Hasegawa, S., et al.: 2014, *PASJ*, **66**, 89.

Lightcurve Survey of V-Type Asteroids in the Inner Asteroid Belt

HASEGAWA, Sunao[1], MIYASAKA, Seidai[2], MITO, Hiroyuki[3], SARUGAKU, Yuki[3], OZAWA, Tomohiko[4]
KURODA, Daisuke[5], NISHIHARA, Setsuko[1/3], HARADA, Akari[1/3], YOSHIDA, Michitoshi[6]
YANAGISAWA, Kenshi[5], SHIMIZU, Yasuhiro[5], NAGAYAMA, Shogo[5], TODA, Hiroyuki[5], OKITA, Kichi[5]
KAWAI, Nobuyuki[7], MORI, Machiko[8], SEKIGUCHI, Tomohiko[9], ISHIGURO, Masateru[10]
ABE, Takumi[1], ABE, Masanao[1]

1: ISAS/JAXA, 2: Tokyo Metropolitan Government, 3: The University of Tokyo, 4: Misato Observatory, 5: NAOJ, 6: Hiroshima University, 7: Tokyo Institute of Technology, 8: Japan Women's University, 9: Hokkaido University of Education, 10: Seoul National University

To constrain the rotational rate distribution of asteroids sourced from asteroid 4 Vesta, the lightcurves of 13 V-type asteroids: 1933 Tinchen, 2011 Veteraniya, 2508 Alupka, 3657 Ermolova, 3900 Knezevic, 4005 Dyagilev, 4383 Suruga, 4434 Nikulin, 4796 Lewis, 6331 1992 FZ1, 8645 1998TN, 10285 Renemichelsen, and 10320 Reiland were observed using the 1.05 m Schmidt telescope and the 0.30 m Dall–Kirkham telescope (K.3T) at the Kiso Observatory (MPC code 381), the 0.36 m Ritchey–Chrétien telescopethe at the Miyasaka Observatory (MPC code 366), the 0.50 m Classical–Cassegrain telescope (MITSuME) at the Okayama Astrophysical Observatory (MPC code 371), the 1.05 m Cassegrain telescope at the Misato Observatory (no MPC code), and the 2.24 m telescope (UH88) in Hawaii (MPC code 568). Using past lightcurve data archive for V-type asteroids and our observations with the exception of 4434 Nikulin and 10285 Renemichelsen, we determined the rotational rates of V-type asteroids (e.g., Fig. 1, 2) [1].

The distribution of rotational rates of 59 V-type asteroids which includes our 11 new and 48 previous results in the inner main belt, including 29 members of the Vesta family, which are regarded as being ejecta from the asteroid 4 Vesta, is not consistent with the best-fit Maxwellian distribution. This inconsistency may be due to the effect of thermal radiation Yarkovsky–O'Keefe–Radzievskii–Paddack (YORP) torques, which implies that the collision event that formed vestoids is sub-billion to several billion years in age [1]. This is consistent with numerical simulations of the Vesta family [2] and crater counting of asteroid 4 Vesta by the Dawn mission [3].

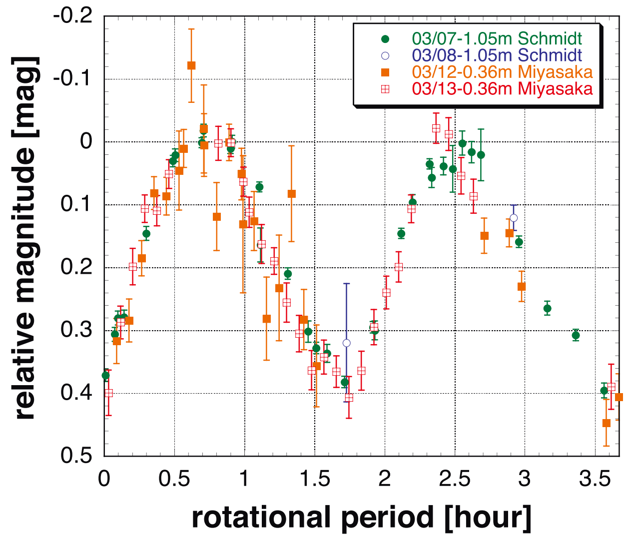


Figure 1: Composite rotational lightcurve of the asteroid 1933 Tinchen.

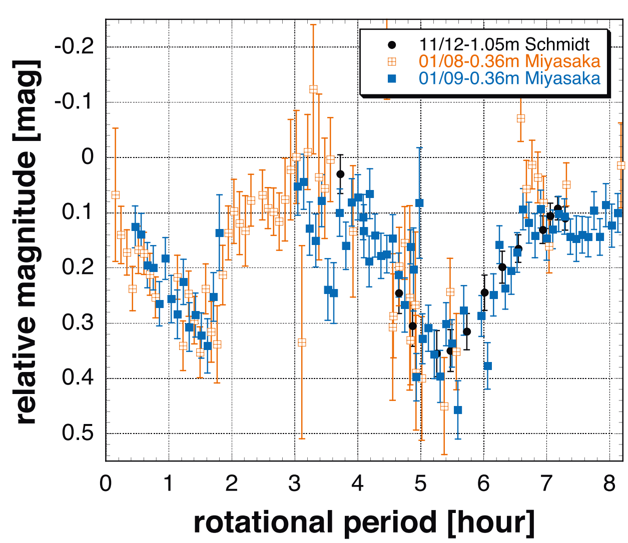


Figure 2: Composite rotational lightcurve of the asteroid 2011 Veteraniya.

References

[1] Hasegawa, S., et al.: 2014, *PASJ*, **66**, 54.
[2] Marzari, F., Farinella, P., Davis, D.: 1999, *Icarus*, **142**, 63.
[3] Marchi, S., et al.: 2003, *Science*, **336**, 690.

Near-Infrared Circular Polarization Survey in Star-Forming Regions: Correlations and Trends

KWON, J., TAMURA, M. (University of Tokyo/NAOJ)
HOUGH, J. H. (University of Hertfordshire)
KUSAKABE, N. (NAOJ)
NAGATA, T. (Kyoto University)
NAKAJIMA, Y. (Hitotsubashi University)
LUCAS, P. W. (University of Hertfordshire)
NAGAYAMA T. (Kagoshima University)
KANDORI, R. (NAOJ)

We have conducted a systematic near-infrared circular polarization (CP) survey in star-forming regions, covering high-mass, intermediate-mass, and low-mass young stellar objects [1]. All the observations were made using the SIRPOL imaging polarimeter on the Infrared Survey Facility 1.4 m telescope at the South African Astronomical Observatory. We present the polarization properties of 10 sub-regions in 6 star-forming regions (Figure 1). The polarization patterns, extents, and maximum degrees of linear and circular polarizations are used to determine the prevalence and origin of CP in the star-forming regions. Our results show that the CP pattern is quadrupolar in general, the CP regions are extensive, up to 0.65 pc, the CP degrees are high, up to 20 %, and the CP degrees decrease systematically from high- to low-mass young stellar objects. The results are consistent with dichroic extinction mechanisms generating the high degrees of CP in star-forming regions.

Reference

[1] Imanishi, M., Saito, Y.: 2014, *ApJ*, **780**, 106.

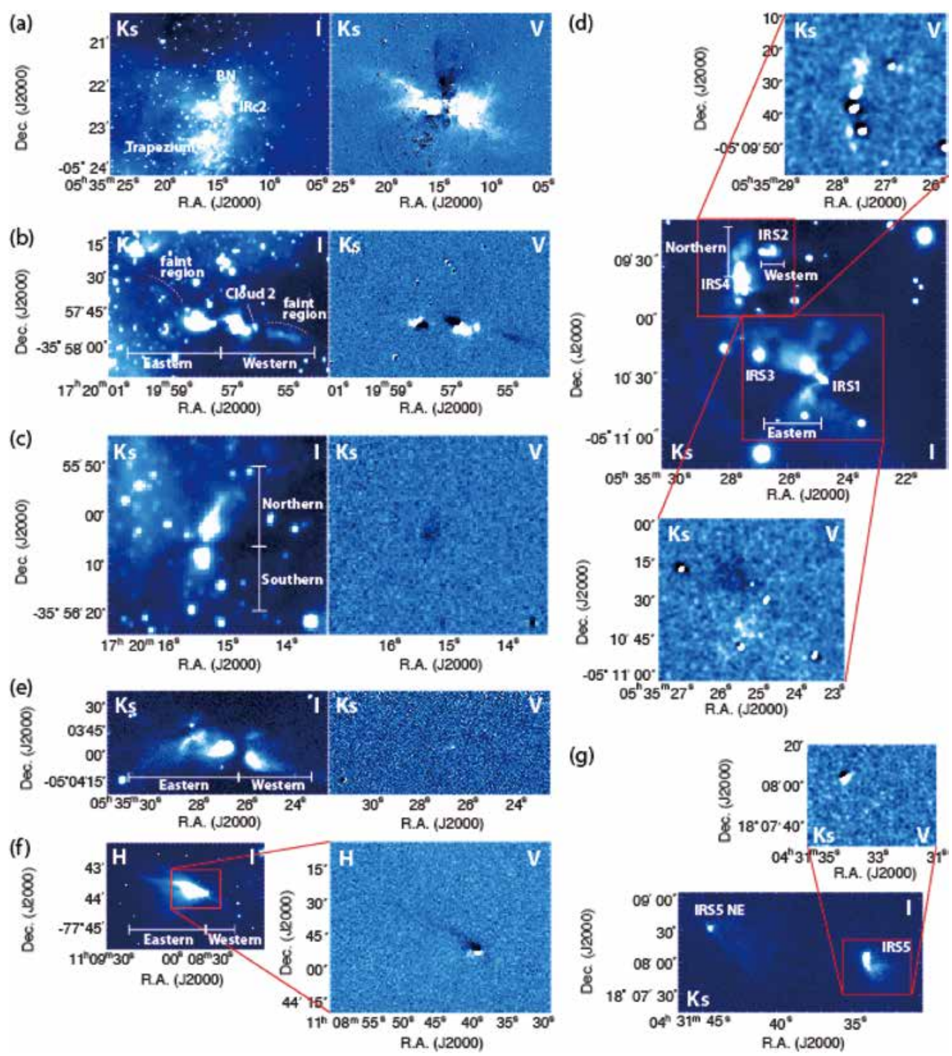


Figure 1: Stokes I and V images observed from the IRSF 1.4-m telescope. (a) OMC-1 (b) NGC 6334-V (c) NGC 6334-IV (d) OMC-2 (e) OMC-3 (f) Cha IRN (g) L1551. (Credit: KWON, Jungmi)

Near-Infrared Spectroscopy of M Dwarfs.
I. CO Molecule as an Abundance Indicator of Carbon

TSUJI, Takashi (The University of Tokyo)
NAKAJIMA, Tadashi (NAOJ)

M dwarfs are the largest stellar group in the solar neighborhood. Because of their small masses, the lifetimes of M dwarfs are longer than the age of the Universe, and M dwarfs are composed of the samples of all the populations including very old ones. Unfortunately, our understanding of this large and rich stellar group is rather poor compared to other stellar groups. This is largely due to the difficulty of observing M dwarfs because of their faintness. Recent progress, however, overcame the observational barriers to some extent, especially in the field of stellar interferometry, infrared spectroscopy, astrometry and photometry from space.

Based on the near-infrared spectra of 42 M dwarfs, carbon abundances are determined from the ro-vibrational lines of the CO(2–0) band. We apply $T_{\rm eff}$ values based on the angular diameters if available or use the $T_{\rm eff}$ values in a log $T_{\rm eff} - M_{3.4}$ relation ($M_{3.4}$ is the absolute magnitude at 3.4 μm based on the WISE *W1* flux and the Hipparcos parallax) to estimate $T_{\rm eff}$ values of objects for which angular diameters are unknown.

On the observed spectrum of the M dwarf, the continuum is depressed by the numerous weak lines of H_2O and only the depressed continuum or the pseudo-continuum can be seen. On the theoretical spectrum of M dwarf, the true continuum can be evaluated easily but the pseudo-continuum can also be evaluated accurately thanks to the recent H_2O line database. Then the spectroscopic analysis of the M dwarf can be done by referring to the pseudo-continuum both on the observed and theoretical spectra. Since the basic principle of the spectroscopic analysis should be the same whether the true- or pseudo-continuum is referred to, the difficulty related to the continuum in cool stars can in principle be overcome. Then the numerous CO lines can be excellent abundance indicators of carbon, since almost all the carbon atoms are in stable CO molecules which suffer little effect of the uncertainties in photospheric structure, and carbon abundances in late-type stars can best be determined in M dwarfs rather than in solar type stars.

The resulting C/Fe ratios for most M dwarfs are nearly constant at about the solar value based on the high classical carbon abundance rather than the recently revised lower value. This result implies that the solar carbon abundance is atypical for its metallicity among the stellar objects in the solar neighborhood if the downward revised carbon abundance is correct.

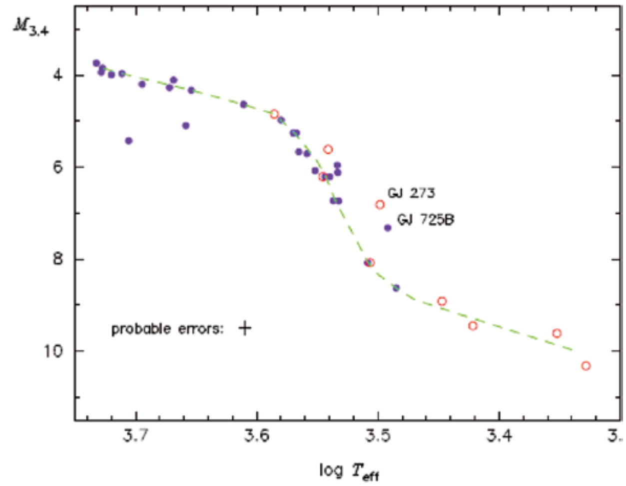


Figure 1: log $T_{\rm eff} - M_{3.4}$ relation. $T_{\rm eff}$ values are based on interferometry (blue) or infrared flux method (red).

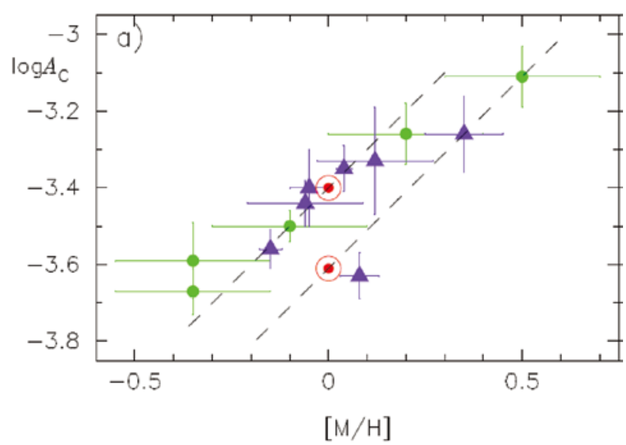


Figure 2: Carbon abundances log A_C vs. Metallicities obtained by other infrared spectroscopy. The upper(/lower) locus is C/M ratio for the high(/low) solar value (⊙).

Reference

[1] Tsuji, T., Nakajima, T.: 2014, *PASJ*, **66**, 98.

Coronal Mass Ejections Observed at the Total Solar Eclipse on 13 November 2012

HANAOKA, Yoichiro (NAOJ)
NAKAZAWA, Jun (Yamanashi Cement Company)
OHGOE, Osamu (Solar Eclipse Information Center)
SAKAI, Yoshiaki (Chiba Prefectural Kazusa High School)
SHIOTA, Kazuo (Solar Eclipse Information Center)

White light observations of the total solar eclipse on 13 November 2012 were made at two sites, where the totality occurred 35 minutes apart. Structure of the corona from the solar limb to a couple of solar radii was observed with a wide dynamic range and a high signal-to-noise ratio [1].

At the east limb, a flare, which was accompanied by a coronal mass ejection (CME), occurred between the two observations of the eclipse, and a CME was observed at the second totality (Figure 1a and the left square in the Figure 1b). The eclipse observation shows both of the CME and related dimming between 1–2 $R_\odot$. This fact suggests that the CME material had been located in this height range.

On the other hand, a balloon-like structure at the west limb (Figure 1b, the right square) observed at the eclipse developed to a CME later on, and was observed by SOHO/LASCO (Figure 1d). The balloon-like structure located between 1–2 $R_\odot$ is considered to be the source of the CME.

Both the CMEs show that the source region of CMEs was located in this height range, where the material and the magnetic field of CMEs were located before the eruption. This height range includes the gap between the extreme ultraviolet observations of the lower corona and the spaceborne white-light observations of the higher corona, but the eclipse observation shows that this height range is essentially important to study the CME initiation. The eclipse observation is basically just a snapshot of CMEs, but it indicates that future continuous observations of CMEs within this height range are promising.

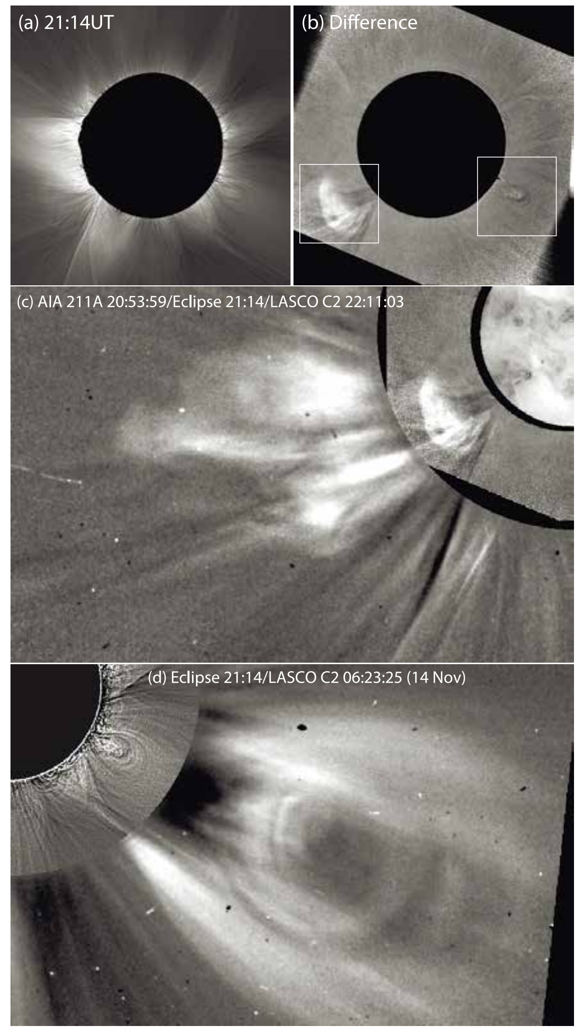


Figure 1: (a) Image of the white-light corona at 21:14 UT of the 13 November 2012 eclipse. Many raw images were stacked to increase the signal-to-noise ratio, and fine structures of the corona were enhanced. (b) Relative difference of the eclipse corona between 20:39 UT and 21:14 UT. Squares show the CME-related structures. (c) Aligned composite of the CME at the east limb on a SDO/AIA 211 Å image (negative) at the flare maximum (20:53:59) (< 1 $R_\odot$), the eclipse corona difference image (21:14−20:39; 1–2.1 $R_\odot$), and a SOHO/LASCO relative difference image between 22:11:03 and 20:39:45 (> 2.1 $R_\odot$). (d) Aligned picture of the CME at the west limb consisting of an image of the eclipse corona showing the pre-CME loop structure (< 2.1 $R_\odot$), and a SOHO/LASCO relative difference image between 20:39:45 (13 November) and 06:23:25 (14 November) (> 2.1 $R_\odot$). The solar north is to the top in all the panels.

Reference

[1] Hanaoka, Y., Nakazawa, J., Ohgoe, O., Sakai, Y., Shiota, K.: 2014, *Solar Phys.*, **289**, 2587.

Mare Volcanism:
Reinterpretation Based on Kaguya Lunar Radar Sounder Data

OSHIGAMI, Shoko (NAOJ)
WATANABE, Shiho, YAMAGUCHI, Yasushi (Nagoya University)
YAMAJI, Atsushi (Kyoto University)
KOBAYASHI, Takao (Korean Institute of Geoscience and Mineral Resources)
KUMAMOTO, Atsushi, ISHIYAMA, Ken, ONO, Takayuki (Tohoku University)

The volumes of single geological units with different ages and compositions are essential for revealing characteristics of mare volcanisms and for constraining the thermal history of the Moon. Recently, the thicknesses of mare basalt units were indirectly estimated from Clementine multispectral data [1]. The results were derived for only limited areas and showed a wide variation, implying large uncertainty. At present, the geological structures under the lunar maria are directly investigated using sounder observations. The Lunar Radar Sounder (LRS) onboard Kaguya detected widespread horizontal reflectors under some nearside maria [2]. The LRS detects echoes from subsurface horizons with abrupt changes in dielectric constants [3] at the apparent depths smaller than about 1 km [4]. Oshigami et al. [5] concluded that the reflectors correspond to the interfaces between basalt units with different FeO contents. Therefore the LRS data allow us to discuss the volume of each basalt unit.

We correlated subsurface reflectors with the surface geologic units, the ages of which have been estimated by several researchers [e.g., 6], to evaluate the thicknesses and volumes of the units. The estimated thicknesses and volumes of the geologic units were the order of 10^1 to 10^2 m (Figure 1) and 10^3 to 10^4 km^3 (Figure 2), respectively, and showed positive correlations with unit ages within the same mare basin [7]. Previous studies indicated that the typical thicknesses of single basalt flows were about 10 m or less in most of the studied sites [8]. These estimations suggest that the geologic units are made up of dozens of lava flows. The long-term average eruption rates were estimated to be the order of 10^{-5} to 10^{-2} km^3/yr (Figure 3) [7].

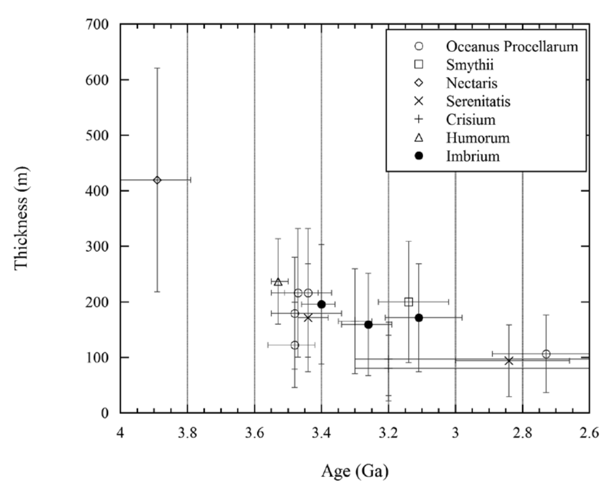


Figure 1: Estimated thicknesses of mare basalt units.

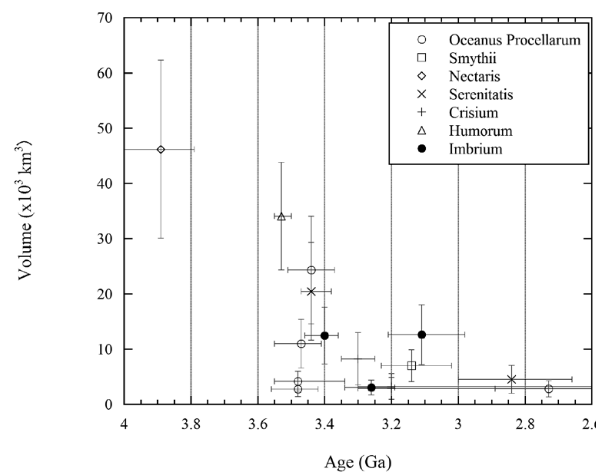


Figure 2: Estimated volumes of mare basalt units.

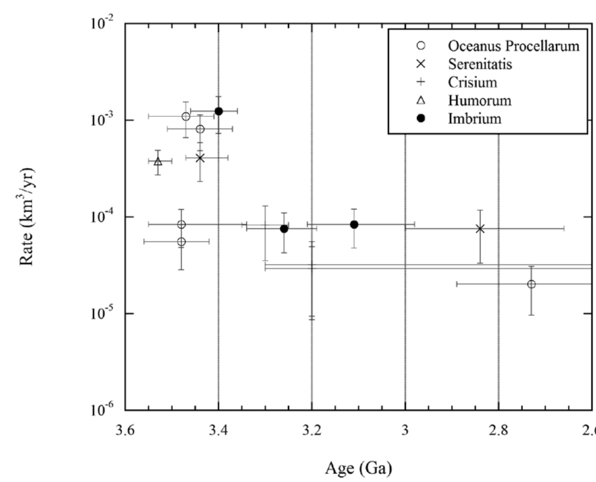


Figure 3: Estimated average eruption rate of mare basalt.

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Statistical Analysis of the Horizontal Divergent Flow in Emerging Solar Active Regions

TORIUMI, Shin (NAOJ)
HAYASHI, Keiji (Stanford University)
YOKOYAMA, Takaaki (The University of Tokyo)

It is widely accepted that the formation of active regions of the Sun is caused by emerging magnetic fields from the convection zone [1]. In the previous MHD simulation studies (e.g., [2]), we pointed out that the emerging magnetic fields push up the local (non-magnetized) plasma above their heads. It is therefore expected that the horizontal divergent flow (HDF) appears before the magnetic flux itself emerges at the visible surface of the Sun. In fact, the HDF was observationally detected in a flux emergence event we selected [3]. In this work [4], we analyzed the HDFs in many more flux emergence events and investigated the physical state of the subsurface magnetic fields, which we cannot directly observe.

We analyzed flux emergence events that were observed by the Helioseismic and Magnetic Imager (HMI) on board the Solar Dynamics Observatory (SDO). We searched for the events that appeared in the eastern hemisphere with a heliocentric angle $\theta \leq 60°$ during the period between 2010 May and 2011 June (14 months) and picked up 23 events. Figure 1(a) is a sample of the events, showing the line-of-sight magnetic field.

Out of the 23 events, 6 clear HDFs were detected by the method previously developed in [3], while 7 additional events that were detected by visual inspection were added to this statistic analysis. The distribution of the events is shown in Figure 1(b). From this map, one may find that the flux emergence events are distributed in the mid-latitude bands of both hemisphere and that the clear HDFs are concentrated in the area with a heliocentric angle $\theta > 30°$. As a result of the statistical analysis, we found that the duration of the HDF is on average 61 minutes and the maximum HDF speed is on average 3.1 km s^{-1}. We also estimated the rising speed of the subsurface magnetic fields to be 0.6–1.4 km s^{-1}. These values are consistent with the previous one-event analysis [3] as well as the numerical simulation results [2].

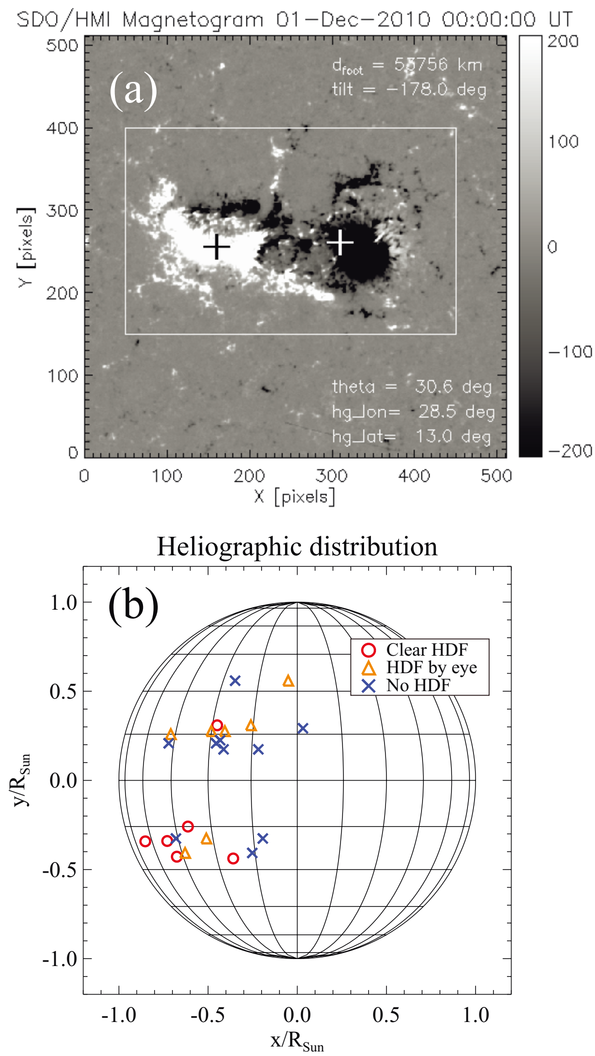

Figure 1: (a) Example of flux emergence data showing line-of-sight magnetic field strength. The black and white plus signs are the flux-weighted centers of positive and negative polarities, respectively, measured in the rectangular box. 1 pixel corresponds to 0.5 arcsec. (b) Heliographic distribution of the flux emergence events. Figures reproduced from [4].

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Energy Diagnostics of Nearby Luminous Infrared Galaxies Using ALMA

IMANISHI, Masatoshi, NAKANISHI, Kouichiro
(NAOJ)

Luminous infrared galaxies (LIRGs) are formed by gas-rich galaxy mergers. Their large infrared luminosities are powered by starburst and/or supermassive-blackhole-driven, active galactic nucleus (AGN) activity in dust-obscured regions. To investigate the nature of these dust-obscured energy sources of LIRGs, observations at the wavelengths of low dust extinction are crucial. An AGN has two important different properties, when compared to starburst activity. First, an AGN has much higher emission surface brightness, and so produces a larger amount of hot (several 100 K) dust, than a starburst. Second, the X-ray to UV luminosity ratio is higher in an AGN than a starburst. Due to these different properties, AGN and starburst can have different physical/chemical effects to the surrounding molecular gas, and so can produce different molecular line flux ratios. Since rotational transition lines of molecules are found at the almost dust-extinction-free (sub)millimeter wavelength, emission line flux ratios of multiple molecules could be a powerful tool to scrutinize dust-obscured energy sources of LIRGs. Since molecular gas in LIRGs is usually at high density, observations of molecules with high dipole moments, such as HCN, HCO^+, and HNC, are useful to investigate the physical properties of LIRGs. We have conducted HCN, HCO^+, HNC J = 4–3 observations, at the submillimeter 350 GHz range, of six LIRGs whose energy sources were diagnosed based on previously obtained infrared spectra [1]. Our primary aim is to confirm the dichotomy of molecular line flux ratios as a function of primary energy source (i.e., AGN or starburst), and to investigate if this method is effective to scrutinize unknown dust-obscured energy sources of distant LIRGs.

Figure 1 shows an example of ALMA data. Figure 2 plots the observed molecular line flux ratios. Among five sources marked with filled stars, four (except IR22491) were diagnosed to be buried-AGN important, and tend to show higher HCN/HCO^+ J = 4–3 flux ratios than starburst-dominated regions in the LIRG, NGC 1614 (marked with filled circles). This HCN flux enhancement in AGNs could be qualitatively explained by widely proposed scenarios of (1) HCN abundance enhancement, relative to HCO^+, in an AGN, (2) HCN J = 4–3 flux enhancement by infrared radiative pumping, in addition to collisional excitation, and (3) more HCN J = 4–3 excitation (higher critical density than HCO^+ J = 4–3) in an AGN than a starburst. The energy source of the remaining one LIRG (IR22491) is still uncertain. In this LIRG, further investigations are required, because its molecular line flux ratio could be largely affected by galaxy-wide turbulence, as inferred from its large molecular line width [1]. Future ALMA observations of other LIRGs with known energy sources at other rotational transition lines are needed to confirm the effectiveness of molecular line flux ratios as the method of energy diagnostics of LIRGs and to understand the physical origin of the observed molecular line flux ratios.

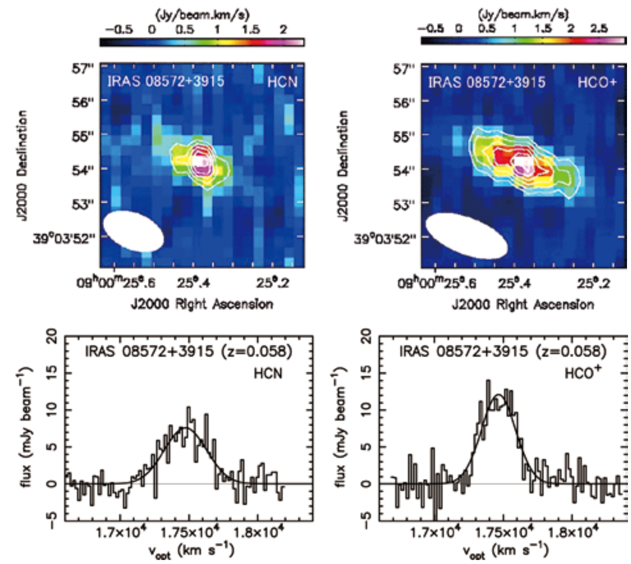

Figure 1: Integrated intensity maps (Top) and spectra (Bottom) of the LIRG, IRAS 08572+3915. (Left): HCN J = 4–3, (Right): HCO^+ J = 4–3. In the integrated intensity maps, the filled elliptical circles at the lower-left parts represent ALMA beam sizes. In the spectra, the ordinate is flux (mJy $beam^{-1}$) and the abscissa is optical velocity (km s^{-1}).

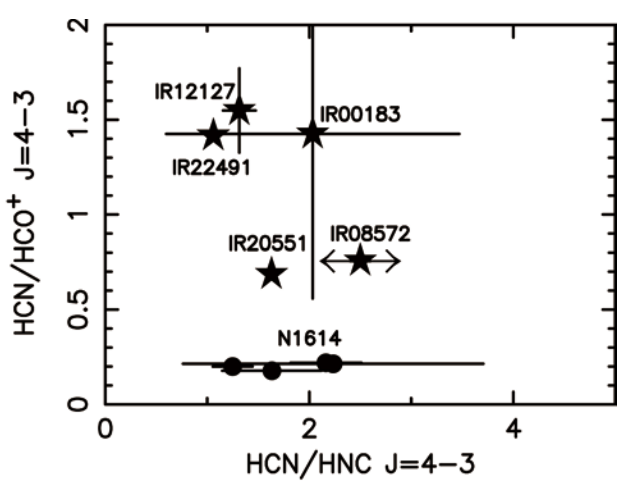

Figure 2: Molecular line flux ratios of LIRGs obtained in our ALMA Cycle 0 data. The abscissa is HCN/HNC J=4–3 flux ratio, and the ordinate is HCN/HCO^+ J=4–3 flux ratio.

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Growth Process of a Protostellar Binary Revealed with ALMA

TAKAKUWA, Shigehisa (ASIAA)
SAITO, Masao (NAOJ)
SAIGO, Kazuya (Osaka Pref. University)
MATSUMOTO, Tomoaki (Hosei University)
LIM, Jeremy (University of Hong-Kong)
HANAWA, Tomoyuki (Chiba University)
HO, Paul, T. P. (ASIAA)

We report results of our ALMA Cycle 0 observation of a protostellar binary L1551 NE, which show that the protostellar binary is growing through the mass accumulation from the surrounding circumbinary material [1].

More than half of stars with masses similar to the Sun are known to be binaries [2,3]. Studies of formation and growth processes of binaries are thus essential for comprehensive understanding of star formation. Protostellar binaries are surrounded by disks of molecular gas and dusts, "circumbinary disks" (hereafter CBDs), and are considered to grow through accumulation of the materials from the CBDs. Resolutions and sensitivities of previous observations are, however, not high enough to investigate the structures and gas motion in the CBDs, and to discuss the feeding process of the materials to the central protostellar binaries. The spatial resolution and sensitivity of our ALMA Cycle 0 observation of L1551 NE are ~1.6 times and ~6 times higher than those attained in our previous SMA observations [4,5], respectively, and thus we are able to investigate internal structures and gas motions in the circumbinary disk of L1551 NE in detail.

Figure 1 (*left*) shows the observed L1551 NE image of the dust-continuum emission at a 0.9-mm wavelength. There are compact components associated with the individual binary stars (cross marks), "circumstellar disks". The circumstellar disks are surrounded by a larger (r ~300 AU) CBD, which exhibits *U*-shaped feature to the south of the protostellar binary, emission protrusions to the northwest which curls to the northeast, and emission minima between these features and the protostellar binary. Gas motions in the CBD as revealed in the $C^{18}O$ ($J = 3–2$) line show faster rotations than the local Keplerian rotation and expanding motions in these continuum features, and slower rotations and infalling motions in the regions of the continuum emission minima.

To interpret physics of these observed structures and gas motions in the CBD around L1551 NE, we conducted numerical simulations of the CBD using the supercomputer ATERUI in National Astronomical Observatory of Japan (NAOJ) (Figure 1 *right*) [6]. The theoretical image shows two spiral arms stemming from the individual binary stars, which constitute the CBD. In those spiral arms the gas rotates with the velocity faster than the local Keplerian rotation velocity, and exhibits expanding motion. On the other hand, in the inter-arm regions the gas rotates slower, and exhibits infalling motion toward the central protostellar binary. This is because of the exchange of the angular momenta inside the CBD, caused by the non-axisymmetric gravitational torques from the central binary. These simulation results reproduce the observed structures and gas motions in the CBD around L1551 NE quantitatively; that is, our ALMA observation unveiled the growth process of the protostellar binary by removing the angular momenta of the surrounding material and capturing those materials.

Our ALMA Cycle 2 proposal to observe L1551 NE at a ~0.″1 angular resolution has been approved, and the observation will be made in the summer 2015. We anticipate that the observation will reveal the spiral arm features and gas motions in the CBD unambiguously, and that we will be able to discuss physical mechanism to set final masses and mass ratios of binary stars.

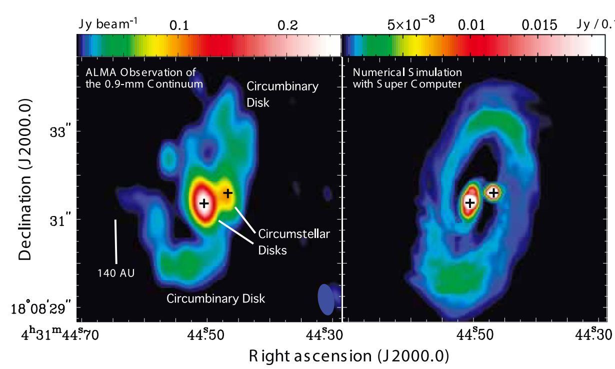

Figure 1: (*Left*) ALMA image of L1551 NE in the 0.9-mm dust-continuum emission. Crosses denote the positions of the protostellar binary, and a filled ellipse at the bottom-right corner the synthesized beam (0.″72×0.″36; P.A.=9.1°). (*Right*) Theoretically-predicted 0.9-mm dust-continuum image of L1551 NE obtained from our numerical simulation using the NAOJ supercomputer ATERUI.

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Gas Kinematics of Lyman α Emitters at $z \sim 2.2$

SHIBUYA, Takatoshi (ICRR)
OUCHI, Masami (ICRR/University of Tokyo)
NAKAJIMA, Kimihiko* (California Institute of Technology)
HASHIMOTO, Takuya (Lyon Observatory)
ONO, Yoshiaki (ICRR/University of Tokyo)
RAUCH, Michael (Observatories of the Carnegie Institution of Washington)
GAUTHIER, Jean-Rean (California Institute of Technology)
SHIMASAKU, Kazuhiro, GOTO, Ryosuke (University of Tokyo)
MORI, Masao, UMEMURA, Masayuki (University of Tsukuba)

Lyα Emitters (LAEs) are an important population of high-z star-forming galaxies in the context of galaxy formation. Additionally, LAEs are used to measure the neutral hydrogen fraction at the reionizing epoch, because Lyα photons are absorbed by intergalactic medium. However, Lyα emitting mechanism is not fully understood due to the highly-complex radiative transfer of Lyα in the interstellar medium.

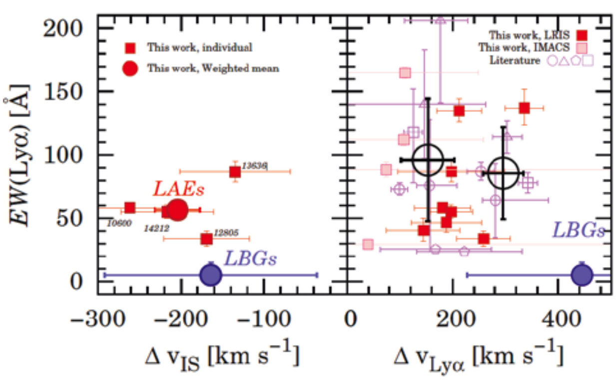

Figure 1: Rest-frame Lyα EW as a function of $\Delta v_{\mathrm{Ly}\alpha}$ and Δv_{IS}. Red symbols represent our $z \sim 2.2$ LAEs [2].

Lyα emissivity may not only depend on the spatial ISM distribution, but on the gas kinematics as well. The gas kinematics of LAEs has been evaluated from the Lyα velocity offset ($\Delta v_{\mathrm{Ly}\alpha}$) with respect to the systemic redshift (z_{sys}) traced by nebular emission lines (e.g, [O III]). Hashimoto et al. (2013) find an anti-correlation between Lyα equivalent width (EW) and $\Delta v_{\mathrm{Ly}\alpha}$ [1]. However, $\Delta v_{\mathrm{Ly}\alpha}$ is thought to increase with both resonant scattering in H I gas clouds as well as galactic outflow velocity. The gas kinematics can be investigated more directly from the velocity offset between interstellar (IS) absorption lines of the rest-frame UV continuum and z_{sys} (IS velocity offset; Δv_{IS}).

We present a statistical study of $\Delta v_{\mathrm{Ly}\alpha}$ and Δv_{IS} for LAEs at $z \simeq 2$. We make a sample of 22 LAEs based on our deep Keck/LRIS observations, in conjunction with spectroscopic data from the Subaru/FMOS program and the literature [2,3]. We confirm the anti-correlation between Lyα EW and $\Delta v_{\mathrm{Ly}\alpha}$ (Fig. 1). Our LRIS data successfully identify blue-shifted multiple IS absorption lines in the UV continua of four LAEs on an individual basis (Fig. 2). The average Δv_{IS} is $-200 \sim -300$ km s^{-1}, indicating LAE's gas outflow with a velocity comparable to typical LBGs. The results of our study suggest that LAEs have a small N_{HI} compared to LBGs.

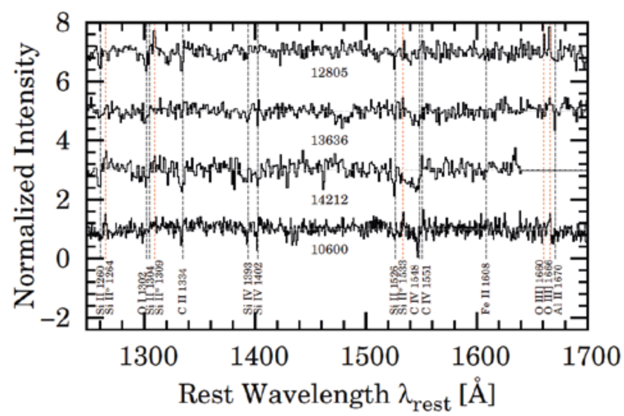

Figure 2: Normalized UV spectra of the four continuum detected LAEs [2].

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* NAOJ at the time of publication.

High-Speed Fluid Dynamics in Magnetic Reconnection in a Low-β Plasma

ZENITANI, Seiji
(NAOJ)

In the solar corona, in the planetary magnetosphere, and in other astrophysical settings, magnetic reconnection often occurs in a low-β plasma, in which the magnetic pressure is higher than the plasma pressure. Surprisingly, much less is known about low-β reconnection, partially due to numerical difficulties and partially due to lack of attention. Recently, new features of low-β reconnection were reported in magnetohydrodynamic (MHD) simulations with shock-capturing codes. Zenitani et al. [1,2] discovered new normal shocks and a repeated shock-reflection near a magnetic island (plasmoid) at the reconnection jet front.

In this work, we extend our previous researches on the plasmoid structure in low-β reconnection. Using a high-accuracy HLLD code [3], shocks, discontinuities, and their intersections are resolved and clarified in unprecedented detail. Figure 1 is a snapshot of the reconnection-plasmoid system in run 1 in Ref. [4]. The color indicates vertical MHD velocities. There are two triangle-trains, as indicated by the white circles. They correspond to shock-reflections in a supersonic jet, the so-called "shock diamonds." The right ones are over-expanded shock-diamonds in front of the plasmoid. The left ones are under-expanded shock-diamonds, hidden inside the reconnection jet. In addition, contact discontinuities and a slow expansion fan from shock-crossing points are found. All these structures are summarized in the 2015 edition of the "plasmoid diagram" (Figure 2).

From the physics viewpoint, these structures are outcome of high-speed fluid effects or compressible fluid effects. High-speed fluid dynamics plays an important role in a low-β plasma, because an Alfvénic reconnection jet easily becomes transonic or supersonic. Underlying mechanisms are similar to those in aerospace engineering and in astrophysical jet physics. Since the mechanisms are common, similar shocks and shock-dissipation will take place in plasmoid-dominated turbulent reconnection. We have a prospect that the high-speed effects will be important in various astrophysical MHD systems, in which Alfvén speed becomes supersonic.

The simulation code for Ref. [4] is publicly available at arXiv:1503.01920. Fortran 90 files are archived in a gzipped tar file in the "Other formats" link.

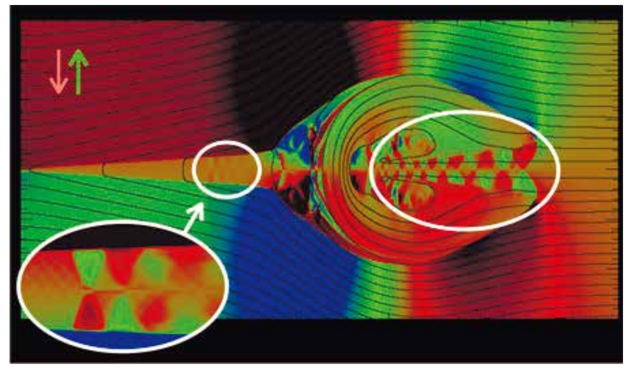

Figure 1: A snapshot of run 1 in Ref. [4]. Vertical MHD velocities are shown in color: the upward (downward) velocity in green (red). The black curves show the magnetic field lines.

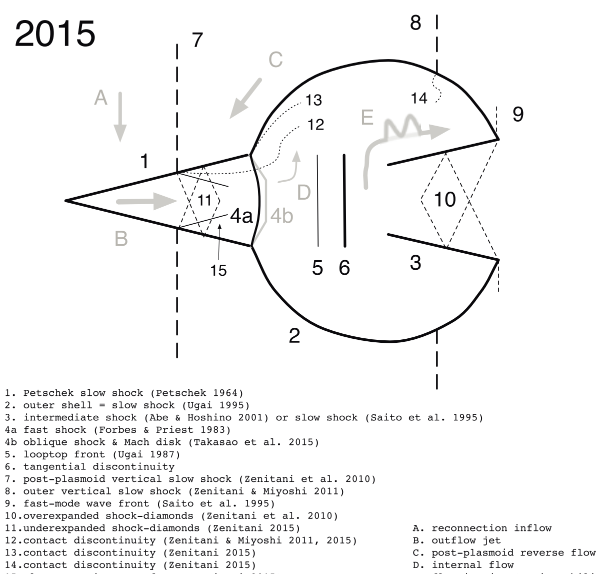

Figure 2: Schematic diagram of the plasmoid structure. Based on Fig. 7 in Ref. [2], it further contains recent updates in Ref. [4].

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Structure and Mass of Filamentary Isothermal Cloud Threaded by Lateral Magnetic Field

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 [4]. Figure 1 shows typical solutions of cross-cut of these filaments. Top and bottom panels show solutions with low and high center-to-surface density ratios, respectively.

We obtained an empirical relation between the maximum supported mass against the self-gravity, $\lambda_{\max}$, and magnetic flux, $\Phi_{\rm cl}$, as,

$$\lambda_{\max} \simeq 0.24\,\Phi_{\rm cl}/G^{1/2} + 1.66\,c_s^2/G,$$

where $\Phi_{\rm cl}$, G, and c_s represent, respectively, one-half of the magnetic flux per unit length of the filament, Newton's gravitational constant, and the isothermal sound speed of the filament gas. For $\Phi_{\rm cl} > 3\,{\rm pc}\,\mu{\rm G}(c_s/190\,{\rm m\,s^{-1}})^2$, the magnetic force (the Lorentz force) plays more important role than the thermal pressure in determining the equilibria. It is known that axisymmetric isothermal clouds have a maximum mass which is supported against the self-gravity by the magnetic field as $M_{\max} \simeq \Phi_{\rm 2D}/2\pi G^{1/2}$, where $\Phi_{\rm 2D}$ represents the magnetic flux threading the cloud. The importance of this article is that structure and the maximum mass of the filaments, which are building blocks of molecular clouds, are firstly determined theoretically.

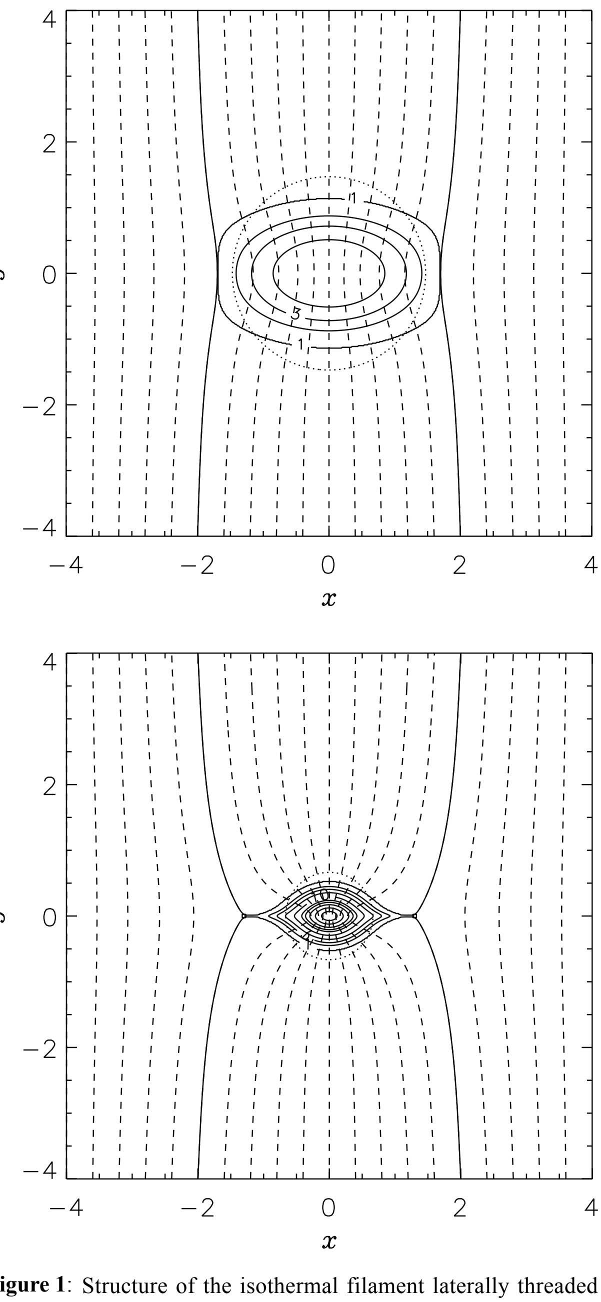

Figure 1: Structure of the isothermal filament laterally threaded by magnetic field. Long dashed lines running vertically represent the magnetic field lines. Closed solid lines are iso-density contours. Contour lines are placed for 1, 2, 3, 5, 10, 20, 30, 50, 100, and 200 times the density at the surface. Non-dimensional initial radius of the filament is taken as $R_0 = 2$ and the plasma beta of the ambient gas outside the filament is taken as $\beta_0 = 1$. We plotted two typical solutions with different center-to-surface density ratios, 10 (upper) and 300 (lower). Vertical and horizontal axes mean nondimensional distances from the center of the filament.

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Two γ-Ray Bursts from Dusty Regions with Little Molecular Gas

HATSUKADE, Bunyo
(NAOJ)

Long-duration gamma-ray bursts (GRBs) are thought to be associated with the explosions of massive stars. Because GRBs are bright enough to be observable in the cosmological distances, they are expected to be a new tool to scrutinize the obscure details of the distant Universe. Although multi-wavelength observations of GRB host galaxies have been conducted, the environment where GRBs occur is still unclear due to the lack of spatially-resolved observations of molecular gas and dust. Previous searches for CO in GRB host galaxies did not detect any emission [1,2,3,4]. Molecules have been detected as absorption in the spectra of GRB afterglows [5], but absorption lines probe the interstellar medium only along the line of sight, so it is not clear whether the molecular gas represents the general properties of the regions where the GRBs occur.

We conducted observations of the CO emission line and 1.2-mm continuum towards two GRB hosts (GRB 020819B at $z = 0.41$ and GRB 051022 at $z = 0.81$) using the Atacama Large Millimeter/submillimeter Array (ALMA). The CO emission line is clearly detected at the nuclear region of the GRB 020819B host and the GRB 051022 host (Figure 1). This is the first case for detecting spatially resolved molecular gas emission in GRB hosts [6]. The 1.2-mm continuum emission is also detected in both GRB hosts. The spatially resolved continuum map of the GRB 020819B host shows that the emission is significantly detected only at the GRB site.

We found that the spatial distributions of molecular gas and dust are clearly different in the GRB 020819B host. The ratio of molecular gas mass to dust mass at the GRB site is significantly lower than that of the nuclear region, indicating that the GRB occurred under particular circumstances within the host. The molecular gas-to-dust ratio at the GRB site is also lower than those of the Milky Way and nearby star-forming galaxies [7], suggesting that the star-forming environment where GRBs occur is different from those in local galaxies. The possible reasons for the deficit of molecular gas in the GRB site are that much of the dense gas has been dissipated by a strong interstellar UV radiation field, which is expected in regions with intense star formation. The lack of molecular gas in optical spectra of GRB afterglows has been reported [8] and a possible explanation is the dissociation of molecules by ambient UV radiation with 10–100 times the Galactic mean value from the star-forming regions [8,9].

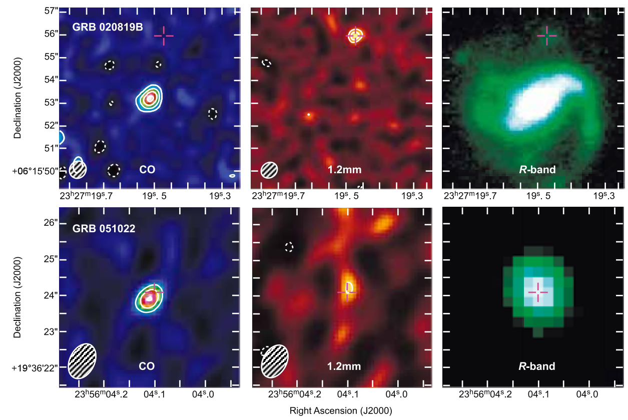

Figure 1: Velocity-integrated CO maps (left), 1.2-mm continuum maps (middle) obtained with ALMA, and optical *R*-band images (right) of the GRB 020819B host (top) and the GRB 051022 host (bottom). The magenta cross represents the position of radio afterglow. ALMA beam is shown at the bottom left. Original figure from [6].

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Fine Strand-Like Structure in the Solar Corona from Magnetohydrodynamic Transverse Oscillations

ANTOLIN, Patrick (NAOJ)
YOKOYAMA, Takaaki (University of Tokyo)
VAN DOORSSELAERE, Tom (KU Leuven)

The organisation of fine-scale structure in the coronal high-Reynolds environment is a major unknown in solar physics. One of the leading theories for explaining the heating of the solar corona consists on the ubiquitous existence of small-scale locations where efficient energy release through magnetic reconnection takes place, a scenario leading to the concept of nanoflares [1]. According to that theory, coronal loops, closed magnetic flux tubes permeating the solar corona, are expected to have a braided field substructure, which would favour the occurrence of magnetic reconnection and therefore nanoflares. Due to the strongly anisotropic thermal conduction in the corona, nanoflares are expected to produce strand-like structure. The existence of strands as substructure of larger coronal structure such as loops has therefore been considered as strong evidence for a leading role of reconnection in the heating of the corona [2].

Transverse MHD waves are now known to be ubiquitous in the solar atmosphere [3-6]. Such waves are characterised by periods of a few minutes, amplitudes of a few km/s and show generally strong damping, which is usually explained through resonant absorption, a process of energy conversion from the transverse motion to local Alfvén waves at the boundary of the flux tube [7-9]. In this Letter [10] we have suggested an alternative mechanism for generation of strand-like structure in EUV lines by establishing a link with the ubiquitous small amplitude transverse MHD oscillations observed in the corona. Through three-dimensional MHD simulations combined with proper forward modelling we have shown that small amplitude transverse MHD waves can lead in a few periods time to strand-like structure in loops in EUV intensity images. Low amplitude transverse MHD oscillations matching those presently observed in the corona lead to Kelvin-Helmholtz instabilities (KHI) that deform the cross-sectional area of loops [11-13]. Azimuthal flows at the boundary of the flux tube are enhanced by resonant absorption, thereby facilitating the onset of the instability. A coupling takes place in which the KHI extracts the energy from the resonance and dumps it into heat through the generation of vortices and current sheets. Strands result as a complex combination of the vortices and the line-of-sight angle, and can be observed for spatial resolutions of a tenth of loop radius. Transverse MHD waves may therefore play an important role in the heating and morphology of the solar corona.

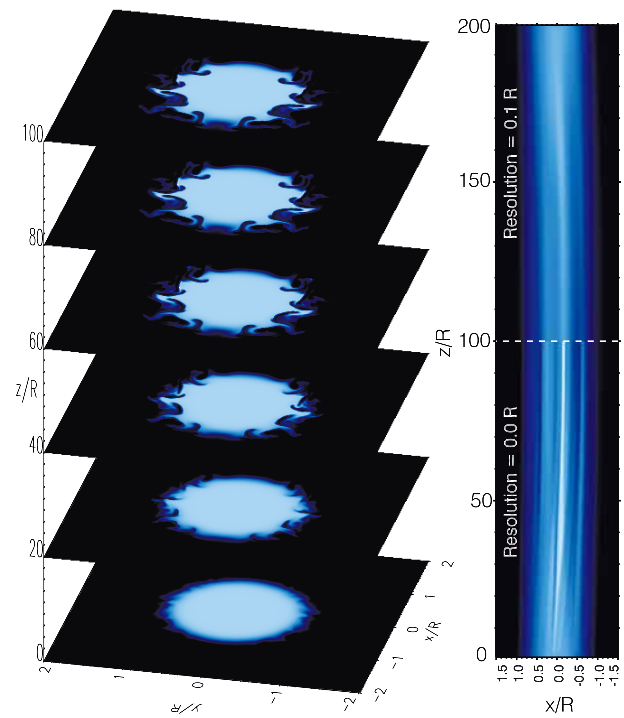

Figure 1: Left: Snapshot of the emission line flux of Fe IX 171.073 Å for several cross-sections along half a coronal loop subject to a transverse MHD wave. Right: KHI vortices produced by the wave appear as strand-like structure in intensity. The lower half of the loop shows the full numerical resolution, while the upper half corresponds to a spatial resolution of 10 % the loop radius R.

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Formation of Carbon Grains in Red-Supergiant Winds of Very Massive Population III Stars

NOZAWA, Takaya (NAOJ)
YOON, Sung-Chul (Seoul National University)
MAEDA, Keiichi (Kyoto University)
KOZASA, Takashi (Hokkaido University)
NOMOTO, Ken'ichi (Kavli IPMU)
LANGER, Norbert (Argelander-Institut für Astronomie der Universität Bonn)

The origin of cosmic dust in the early universe has been hotly debated since the discoveries of huge amounts of dust grains in high-redshift ($z \geq 5$) quasars.Although the characteristic mass of the early generation of stars remains to be clarified, recent calculations of stellar evolution found that non-rotating Population III stars with the zero-age main sequence mass of $M_{\rm ZAMS} > 250\,M_\odot$ undergo convective dredge-up of a large amount of carbon and oxygen from the helium-burning core to the hydrogen-rich envelope during the red-supergiant (RSG) phase [1]. This may lead to enrichment of the surrounding medium with CNO elements via RSG winds, which can serve as formation sites of dust in the early universe.

We investigate the formation of carbon dust in a stellar wind during the RSG phase of a very massive Population III star with $M_{\rm ZAMS} = 500\,M_\odot$ [2].The calculations are performed by applying the formulation of non-steady-state dust formation [3]. The formula enables us to evaluate the size distribution of newly formed grains and their condensation efficiency defined as the fraction of free carbon atoms that are locked up in grains.

The results of the calculations show that, in a carbon-rich wind with a constant velocity, carbon grains can form with a lognormal-like size distribution, and that all of the carbon available for dust formation finally condense into dust for wide ranges of the mass-loss rate ($\geq 8 \times 10^{-5}\,M_\odot\,{\rm yr}^{-1}$) and wind velocity (1–100 km s^{-1}) (see Figs. 1 and 2). These results indicate that, at most, 1.7 $M_\odot$ of carbon grains can form in total during the RSG phase of 500 $M_\odot$ Population III stars. We note that these newly formed grains could not be destroyed by the blast wave arising from a supernova explosion because such a very massive star would finally collapse into a black hole. Thus, the derived high dust yield could place very massive primordial stars as important sources of dust at the very early epoch of the universe if the initial mass function of Population III stars was top-heavy.

We also propose a new formation scenario of carbon-rich ultra-metal-poor stars; such primitive low-mass stars were born in the gas clouds that were enriched with carbon grains and CNO elements from Population III RSGs.

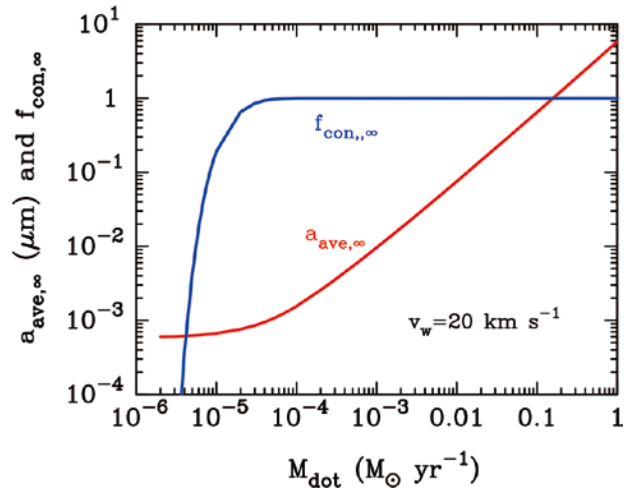

Figure 1: Final average radius ($a_{\rm ave,\infty}$) and final condensation efficiency ($f_{\rm con,\infty}$) of carbon grains formed in mass-loss winds of a 500 $M_\odot$ Popularion III RSG as a function of mass-loss rate $\dot{M}$ for a fixed wind velocity of $v_{\rm w}$ = 20 km s^{-1}.

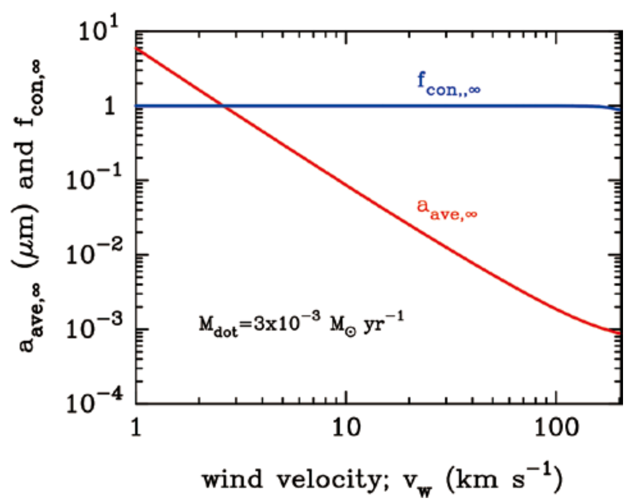

Figure 2: Same as Figure 1, but as a function of wind velocity $v_{\rm w}$ for a fixed mass-loss rate of $\dot{M} = 3 \times 10^{-3}\,M_\odot\,{\rm yr}^{-1}$.

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Origins of Large Amounts of Dust Grains and Unusual Extinction Curves in High-Redshift Dusty Quasars

NOZAWA, Takaya
(NAOJ)

ASANO, Ryosuke S., TAKEUCHI, Tsutomu T.
(Nagoya University)

HIRASHITA, Hiroyuki
(ASIAA)

There are many pieces of evidence that the extinction curves of quasars beyond $z = 4$ are different from those of low-z quasars and that a huge amount of dust is present in their host galaxies. These indicate that the early interstellar medium (ISM) was rapidly enriched with dust grains whose properties were different than the nearby ones. The previous dust evolution models argued that, in addition to dust grains ejected from supernovae and asymptotic giant branch stars, grain growth via accretion of gaseous metals in the ISM is required to account for the observed dust mass. However, these models assumed a representative grain size or a specific grain size distribution throughout the galaxy evolution, and thus could not make any prediction on extinction curves.

Recently, we constructed an evolution model of size distribution of interstellar dust by taking into account the fundamental physical processes of formation and destruction of dust [1]. This model enables us to predict the extinction curves in galaxies as a function of time [2]. Based on this state-of-the-art dust evolution model, we investigate how the massive amounts of dust and the unusual extinction curves in high-z dusty quasars can be reproduced in a self-consistent manner.

First, we demonstrate that the Milky-Way extinction curve is reproduced by introducing a moderate fraction ($\simeq 0.2$) of dense molecular-cloud phases in the ISM for a graphite-silicate dust model. Then, we show that the peculier extinction curves in high-z quasars can be explained by taking a much higher molecular-cloud fraction (≥ 0.5) (Fig. 1), which leads to more efficient grain growth and coagulation. The large dust content in high-z quasar hosts is also found to be a natural consequence of the enhanced dust growth (Fig. 2). We also find that the major composition of carbonaceous dust in high-z dusty quasars is amorphous carbon rather than graphite. These results indicate the differences in the properties of carbonaceous dust and in the condition of the ISM between low-z and high-z galaxies.

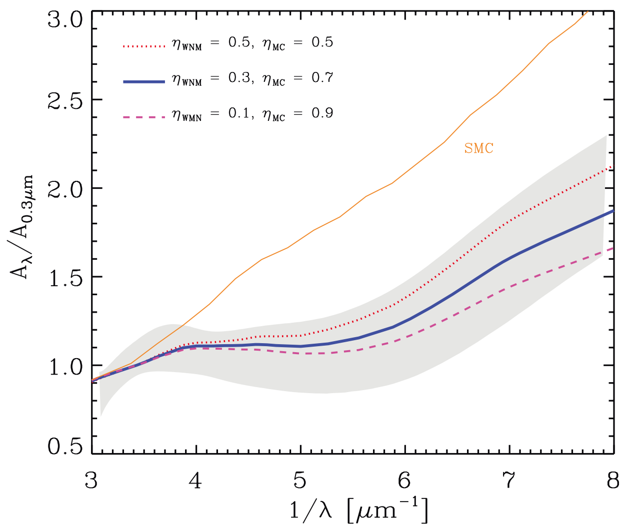

Figure 1: Calculated UV extinction curves at t = 1 Gyr. The dotted, thick solid, and dashed lines show the results for the mass fraction of the molecular-cloud phase of 0.5, 0.7, and 0.9, respectively. The hatched region draws the range of the extinction curve for the high-z quasar J1048+4637 at z = 6.2 [4]. For comparison, the SMC extinction curve is denoted by the thin solid line. The figure is taken from [3].

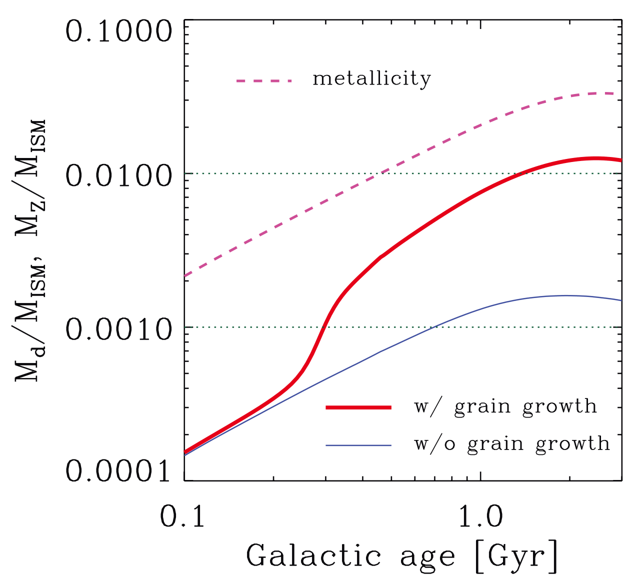

Figure 2: Time evolutions of dust-to-gas mass ratios (solid) and metallicity (dashed) obtained from the dust evolution model in a high-z quasar. The case with grain growth (red solid) can reach the observed high dust-to-gas mass ratio ($\simeq$ 0.01), while the case without grain growth (blue solid) cannot. The figure is taken from [3].

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Waves and Electron Heating in the Reconnection Separatrix Regions

FUJIMOTO, Keizo
(NAOJ)

Magnetic reconnection is a natural energy converter, releasing explosively the magnetic field energy into plasma kinetic energy. It is a typical multi-scale phenomenon where the magnetic dissipation takes place predominantly in a microscopic region formed around the x-line, while the topological change of the field lines causes large-scale plasma convection. Magnetic reconnection is universal process in space plasma leading to explosive phenomena such as geomagnetic substorms and solar flares. The purpose of this research is to understand the fundamental processes of magnetic reconnection and to establish the universal model applicable to real phenomena under complicated initial/boundary conditions. In particular, this paper focuses on the roles of microscopic waves in the reconnection processes.

Recent satellite observations in the geomagnetotail have shown that the wave activities are significantly enhanced in a broad range of frequency around the separatrices of anti-parallel magnetic reconnection where the guide-field is negligibly small [1]. The waves were recognized as lower hybrid waves, Langmuir waves, electrostatic solitary waves (ESWs), and whistler waves. In most cases, they were associated with cold electron beams and density cavity. However, because of the limited space-time resolutions of the observations, it has been difficult to identify the generation mechanisms of the waves and their roles in magnetic reconnection.

We have developed a new electromagnetic particle-in-cell model with adaptive mesh refinement (AMR-PIC model) in order to achieve efficient multi-scale kinetic simulations [2]. Recently we further applied an open boundary condition to the AMR-PIC model, which enabled us to pursue longer-time evolution of magnetic reconnection. Using the 2D AMR-PIC code, we have performed a large-scale simulation of anti-parallel magnetic reconnection with more realistic parameters of the geomagnetotail (e.g., the mass ratio $m_i/m_e = 400$ and the background density $n_b/n_0 = 0.04$) than most previous simulations.

As a result, the simulation has successfully reproduced the waves consistent with those observed frequently in the separatrix regions of magnetic reconnection in the geomagnetotail (see upper panel of Fig. 1). The key process generating the waves is intense parallel acceleration of the electrons due to an electrostatic potential jump formed in a localized region of the inflow side of the separatrices. The intense electron beams trigger the electron two-stream instability and the beam-driven whistler instability. The Buneman instability is also excited due to moderate electron beams arising upstream the potential jump. The electron two-stream instability generates the Langmuir waves, while the Buneman instability gives lower hybrid waves. Both modes evolve the ESWs in the nonlinear phases. The Langmuir waves trap the electrons in the parallel direction and forms a flat-top distribution with high-energy cutoff (lower left panel of Fig. 1), which is well consistent with the observations. On the other hand, the whistler waves scatter the electrons in the perpendicular direction, producing isotropic distribution with non-thermal high-energy tail [3] (lower right panel of Fig. 1).

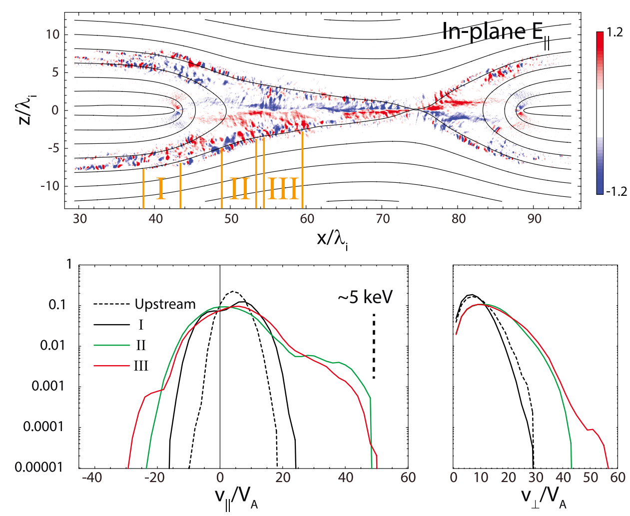

Figure 1: Wave activities seen in the parallel electric field around the reconnection region (upper panel) and the electron distribution functions (lower panels) in each wave active region.

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Explosive Lithium Production in the Classical Nova V339 Del

TAJITSU, Akito, AOKI, Wako
(NAOJ)
SADAKANE, Kozo
(Osaka Kyoiku University)
NAITO, Hiroyuki
(Nagoya University/Nayoro Observatory)
ARAI, Akira
(Kyoto Sangyo University/University of Hyogo)

Lithium (Li) is a key element in the study of the chemical evolution of the universe because it likely has been produced by Big Bang nucleosynthesis,interactions between energetic cosmic rays and interstellar matter, evolved low-mass stars, novae, and supernova explosions. The observed Li evolutionary curve has a plateau for young Galactic ages (< 2.5 Gyr) followed by a steep rise. This indicates that a relatively low-mass stellar component is a major source of Li in the recent universe [1]. Some low-mass evolved stars have indeed been found to have Li-enriched surfaces. However, such Li could be easily depleted by convection in stellar surface and envelope, because Li should be destroyed inside stars where temperature is higher than 2.5 million K. Nova eruptions, which have evolved from low-mass binaries, are also assumed to be candidates for Li suppliers. No direct evidence, however, for the supply of Li from evolved stellar objects to the Galactic medium has yet been found. The origin of Li and its production process have long been an unsettled question in cosmology and astrophysics.

We have provided the first direct evidence to solve this question by spectroscopic observations of a classical nova [2]. The post-outburst spectra of V339 Del (=Nova Delphini 2013) were obtained using the high dispersion spectrograph (HDS) of the 8.2-m Subaru Telescope at four epochs (+38, +47, +48, and +52 days after the maximum). These spectra contain a series of broad emission lines originating from neutral hydrogen and other permitted transitions of neutral or singly ionized species (e.g., Fe II, He I, Ca II). Most of these broad emission lines are accompanied by sharp and blue-shifted multiple absorption lines at their blue edges ($v_{\rm rad} \sim -1000\,{\rm km\,s^{-1}}$). Among these absorption line systems, we have noticed two remarkable pairs of absorption features in the UV range near 312 nm. These correspond to the absorption components originating from the resonance doublet lines of a singly ionized radioactive isotope of beryllium, ^{7}Be. Figure 1 displays the blue-shifted absorption line systems of Hη, Ca II K, and the ^{7}Be II doublet in the spectrum obtained at +47 day. After ruling out the possibilities of alternative identifications, we concluded that these absorption features at 312 nm are caused by ^{7}Be.

Our spectroscopic detection of ^{7}Be in a classical nova immediately connects to the production of ^{7}Li. The production of ^{7}Be via the nuclear reaction $^{3}{\rm He}(\alpha,\gamma)^{7}{\rm Be}$ in novae has been studied theoretically [3]. Furthermore, the ^{7}Be absorption lines are found in highly blue-shifted flows. This means that it will soon decay to ^{7}Li in cooler interstellar or circumstellar matter on a time scale given by the half-life of ^{7}Be (53.22 days). The ^{7}Be abundance in the absorbing gas system estimated from the strengths of their absorption lines is perhaps 3–10 times as much as models predict. Since V339 Del appears to be one of the ordinary classical novae, the ^{7}Be production found in this object might be occurring in many classical novae. In near future, more observations of other nova explosions will provide much clearer model of Li evolution.

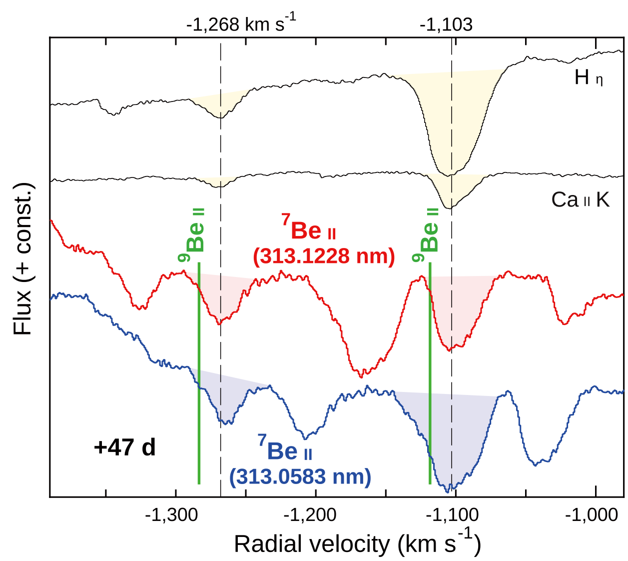

Figure 1: The blue-shifted absorption line systems in +47 days. All lines have two components of velocities at −1268 and −1103 kms^{-1}. Thanks to the high resolution of the spectrum (~ 0.0052 nm), we can clearly distinguish them from the doublet of ^{9}Be II at 313.0422 and 313.1067 nm (green lines).

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Discovery of Dramatic Optical Variability in a Possible Radio-Loud Narrow-Line Seyfert 1 Galaxy

TANAKA, Masaomi (NAOJ)
MOROKUMA, Tomoki (University of Tokyo)
ITOH, Ryosuke, AKITAYA, Hiroshi (Hiroshima University)
TOMINAGA, Nozomu (Konan University)
and KISS collaboration

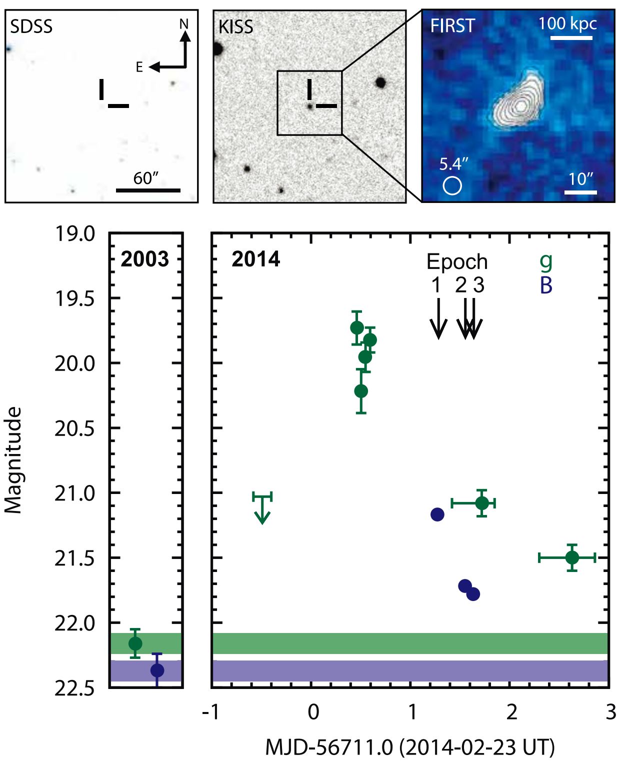

Figure 1: *Upper*: Discovery image of SDSS J1100+4421 taken on 2014 Feb 23 UT (middle), compared with the SDSS image (left) and the FIRST 1.4 GHz radio image (right). *Lower*: Light curves of SDSS J1100+4421 around the discovery epoch.

It is widely accepted that active galactic nuclei (AGNs) are powered by supermassive black holes (BHs) accreting at high rates. Among AGNs, narrow-line Seyfert 1 galaxies (NLS1s) are of a particular interest, since AGNs of this peculiar type are believed to have relatively small BH masses (10^6–$10^8\,M_\odot$) and very high accretion rates. By these properties, it had been inferred that NLS1s are a radio-quiet class of AGNs, and that young BHs in NLS1s that undergo rapid growth via high-rate accretion do not produce relativistic jets.

We discovered dramatic variability in SDSS J1100+4421 (Figure 1) by the high-cadence optical transient survey Kiso Supernova Survey (KISS, [1,2]). The source brightened in the optical by at least a factor of three within about half a day (Figure 1). Spectroscopic observations with Subaru/FOCAS suggest that this object is likely a NLS1 at $z = 0.840$ (Figure 2), however with unusually strong narrow emission lines. The estimated black hole mass of $\sim 10^7\,M_\odot$ implies bolometric nuclear luminosity close to the Eddington limit.

Interestingly, SDSS J1100+4421 is also found to be an extremely radio-loud object, with a radio loudness parameter of $R \simeq 4\times10^2 - 3\times10^3$, which implies the presence of relativistic jets. In addtion, the 1.4 GHz radio image of the source shows an extended structure with a linear size of about 100 kpc (Figure 1). If SDSS J1100+4421 is a genuine NLS1, this radio structure would then be the largest ever discovered in this type of active galaxies. Our discovery demonstrates that high-cadence surveys are potentially useful to search for such a rare class of AGNs and to study the jet production/duty cycle in the growing BHs.

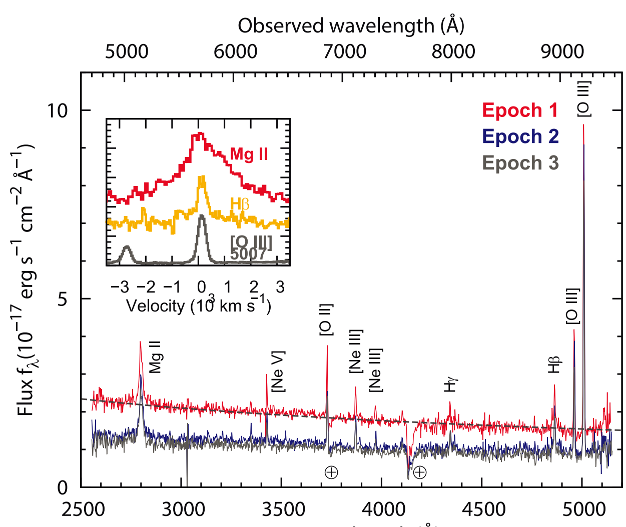

Figure 2: Optical spectra of SDSS J1100+4421 taken with Subaru/FOCAS.

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Universal Profiles of the Intracluster Medium from Suzaku X-Ray and Subaru Weak Lensing Obesrvations

OKABE, Nobuhiro[1/2], UMETSU, Keiichi[3], TAMURA, Takayuki[4], FUJITA, Yutaka[5], TAKIZAWA, Motokazu[6] ZHANG, Yu-Ying[7], MATSUSHITA, Kyoko[8], HAMANA, Takashi[9], FUKAZAWA, Yasushi[1] FUTAMASE, Toshifumi[10], KAWAHARADA Madoka[4], MIYAZAKI, Satoshi[9], MOCHIZUKI, Yukiko[8] NAKAZAWA, Kazuhiro[11], OHASHI, Takaya[12], OTA, Naomi[13], SASAKI, Toru[8], SATO, Kosuke[8], TAM, Sutieng[14]

1: Hiroshima University, 2: Kavli IPMU, University of Tokyo, 3: ASIAA, 4: JAXA, 5: Osaka University, 6: Yamagata University, 7: Universität Bonn, 8: Tokyo University of Science, 9: NAOJ, 10: Tohoku University, 11: University of Tokyo, 12: Tokyo Metropolitan University, 13: Nara Women's University, 14: National Taiwan University

We conduct a joint X-ray and weak-lensing study of four relaxed galaxy clusters (Hydra A, A478, A1689 and A1835) observed by both {\it Suzaku} and Subaru out to virial radii, with an aim to understand recently-discovered unexpected feature of the intracluster medium (ICM) in cluster outskirts. We show that the average hydrostatic-to-lensing total mass ratio for the four clusters decreases from ~70 % to ~40 % as the overdensity contrast decreases from 500 to the virial value. The average gas mass fraction from lensing total mass estimates increases with cluster radius and agrees with the cosmic mean baryon fraction within the virial radius, whereas the X-ray-based gas fraction considerably exceeds the cosmic values due to underestimation of the hydrostatic mass. We also develop a novel advanced method for determining normalized cluster radial profiles for multiple X-ray observables by simultaneously taking into account both their radial dependence and multivariate scaling relations with weak-lensing masses. Although the four clusters span a range of halo mass, concentration, X-ray luminosity and redshift, we find that the gas entropy, pressure, temperature and density profiles are all remarkably self-similar when scaled with the weak-lensing M_{200} mass and r_{200} radius. As shown in Figure 1 [1], the entropy monotonically increases out to $\sim 0.5\, r_{200} \sim r_{1000}$ following the accretion shock heating model $K(r) \propto r^{1.1}$ [2], and flattens at $\gtrsim 0.5\, r_{200}$. The universality of the scaled entropy profiles indicates that the thermalization mechanism over the entire cluster region ($> 0.1\, r_{200}$) is controlled by gravitation in a common way for all clusters, although the heating efficiency in the outskirts needs to be modified from the standard $r^{1.1}$ law. The bivariate scaling functions of the gas density and temperature reveal that the flattening of the outskirts entropy profile is caused by the steepening of the temperature, rather than the flattening of the gas density. Thus, gas clumpiness [4], leading to an overestimate of the observed gas density, cannot be responsible for all of the flatness of the outskirts entropy.

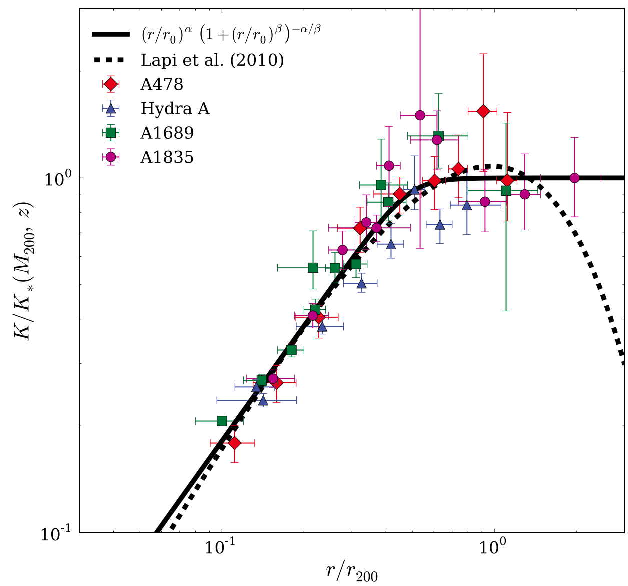

Figure 1: Normalized entropy profile as a function of the radius scaled by r_{200}. Red diamonds, blue triangle, green squares and magenta circles denote the normalized entropy for A478, Hydra A, A1689, and A1835, respectively. The normalization is $K_*(M_{200}, z)=K_0 E(z)^{-4/3} (M_{200} E(z)/10^{14}\, h_{70}^{-1}\, M_\odot)^a$, where K_0=359.61 [keV cm^2] and $a = 0.63$. The black solid curve represents the best-fit universal entropy profile. The entropy profile at $r \lesssim 0.5\, r_{200}$ follows $r^{1.1}$ as predicted by the standard model [2] and becomes flat at $r \gtrsim 0.5\, r_{200}$. The black-dashed curve shows the best-fit profile for the other model [3].

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Spectrum of Gamma-Ray Burst's Afterglow Indicates the Beginning of the Reionization Process

NIINO, Yuu
(NAOJ)

TOTANI, Tomonori
(University of Tokyo)

The intergalactic gas became neutral by the cosmic recombination. On the other hand, the intergalactic gas is ionized in the present Universe. To account for this difference between the past and present, there must have been a transition era of re-ionization after the dark age of the Universe, which was filled with neutral gas. However, scientists do not yet know when this transition occurred or understand how the process took place. One strong possibility is that the ultraviolet (UV) radiation from the first-generation galaxies in the one-billion-year-old Universe ionized the hydrogen gas in the intergalactic space. Therefore, it is very important to identify when the re-ionization occurred relative to the formation of the first generation of light-emitting objects.

Previous studies of the re-ionization have focused on galaxies or quasars. Observations of galaxies are indirect in that a number-count decreases when neutral hydrogen gas obscures their light. Observations of quasars directly measure the absorption features in their spectra caused by neutral hydrogen. However quasars occur in the most developed regions of galaxy evolution, and their own radiation ionizes the surrounding material. These factors make it difficult to estimate the neutral gas in this environment. In contrast, GRBs allow the direct measurement of neutral hydrogen and also overcome the drawbacks of the quasar approach.Although studies based on GRBs are highly desirable, the rare occurrence of GRBs bright enough to enable detailed analysis has been a challenge. The only previously available data about re-ionization was the current team's 2006 report of data from observations of GRB 050904 from the Subaru Telescope. This past data proved that the ionization rate was already high in that era, without any sign of intergalactic neutral hydrogen [1].

A research team composed of scientists from the University of Tokyo, the National Astronomical Observatory of Japan, the Tokyo Institute of Technology and others observed the afterglow of GRB 130606A on June 6, 2013 and studied its spectrum in great detail [2]. Its afterglow was bright enough in the visible wavelength to allow for analysis, despite its great distance at a redshift of 5.913. Its distance situates the object at a time close to the presumed re-ionization era. The data from Subaru Telescope clearly show that intergalactic, neutral hydrogen gas accounts for the observed absorption feature (Figure 1). Further analysis led the team to conclude that more than 10 % of the hydrogen gas was neutral relative to the total amount of hydrogen. This means that the Universe still had a high proportion of neutral hydrogen gas when it was one billion years old. This is the first time that a research team has made a quantitative measurement of such a high proportion of neutral gas during this era.

This finding marks a significant beginning for scientists to understand the era that preceded re-ionization. Next generation telescopes, whether in space or ground-based, such as the future Thirty-Meter-Telescope (TMT), will definitely show how the first generation galaxies formed in the primordial Universe and more clearly define the process of transition from an opaque, neutral-hydrogen-filled Universe to a transparent, re-ionized one.

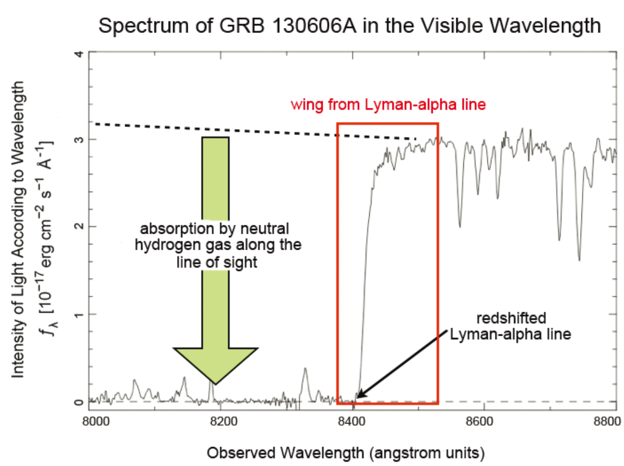

Figure 1: Visible wavelength spectrum of the afterglow of GRB 130606A at redshift of $z=5.913$, when the Universe was a mere one billion years old. Due to its redshift, the Lyman-alpha line (originally 1215 Å) is at 8400 Å. The analysis of a distinctive feature (i.e., the wing feature) between 8000–8400 Å contributed to the estimate of the ratio of neutral hydrogen relative to the entire amount of hydrogen.

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Pitch Angle of Galactic Spiral Arms

MICHIKOSHI, Shugo, KOKUBO, Eiichiro
(NAOJ)

In a differentially rotating disk, a leading density pattern rotates to a trailing one due to the shear. If Toomre's Q value is larger than unity but not too much, the amplitude of the pattern can be enhanced during the rotation. This mechanism is called swing amplification [1]. If a perturber such as the corotating overdense region exists, trailing patterns form. In N-body simulations, since a disk consists of a finite number of stars, small density noise always exists. Thus, even if there is not a perturber, the small leading wave always exists, and the trailing wave can grow spontaneously due to the swing amplification mechanism. The spirals generated by the swing amplification are not stationary but transient and recurrent, which appear and disappear continuously. This transient and recurrent picture is supported by N-body simulations for multi-arm spirals [2].

One of the key parameters that characterize spiral arms in disk galaxies is a pitch angle that measures the inclination of a spiral arm to the direction of galactic rotation. The pitch angle differs from galaxy to galaxy, which suggests that the rotation law of galactic disks determines it [3]. In order to investigate the relation between the pitch angle of spiral arms and the shear rate of galactic differential rotation, using local N-body simulations and linear analyses, we study the pitch angle of the spiral arms with various parameter sets [4].

We performed local N-body simulations of pure stellar disks based on the epicycle approximation. We do not consider an entire disk but a small rotating patch by employing a local shearing box. This treatment reduces the number of necessary particles in a simulation significantly, and enables us to perform high resolution simulations. The typical density snapshot and the autocorrelation function are shown in Figure 1. The x-axis is directed radially outward, the y-axis is parallel to the direction of rotation. Spiral or wake structures are formed due to gravitational instability and they are trailing.

We quantitatively evaluated the pitch angle using the autocorrelation function with various parameters. The result is summarized in Figure 2. We found the clear trend that the pitch angle θ decreases with the shear rate Γ.

Using the formulation of the collisionless Boltzmann equation, we performed linear analyses of the swing amplification and found that the pitch angle of the most amplified wave for $Q \gtrsim 1.5$ is given as

$$\tan\theta = \frac{2}{7}\frac{\sqrt{4-2\Gamma}}{\Gamma} \qquad (1)$$

As shown in Figure 2, the pitch angle formula agrees well with the results of the numerical simulations. These results suggest that the spiral arms in this simulation are formed by the swing amplification from the leading wavelet in the density fluctuation.

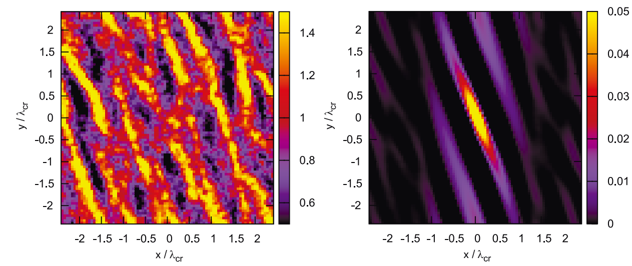

Figure 1: Surface density snapshot (left) and the autocorrelation function for the shear rate $\Gamma = 1.0$.

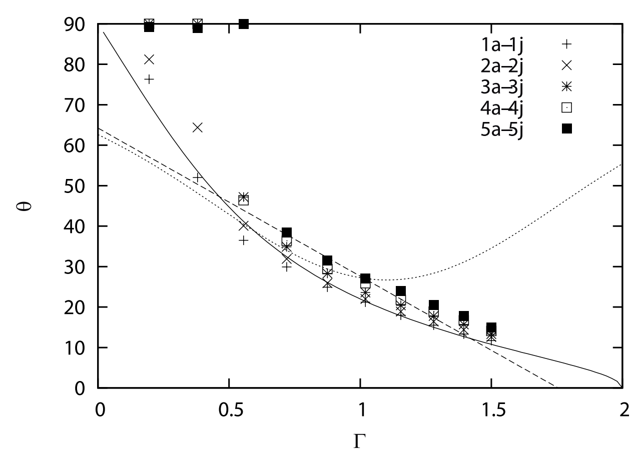

Figure 2: The pitch angle of the spiral arms in N-body simulations as a function of Γ. The solid curve denotes the pitch angle formula given by Equation (1).

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Identification of the Progenitors of Rich Clusters and Member Galaxies in Rapid Formation at $z > 2$

SHIMAKAWA, Rhythm, KODAMA, Tadayuki (NAOJ/SOKENDAI)
TANAKA, Ichi (NAOJ)
TADAKI, Ken-ichi (Max-Planck-Institut)
HAYASHI, Masao, KOYAMA, Yusei (NAOJ)

Galaxy clusters are the largest self-gravitational system in the Universe, in which member galaxies have some unique characteristics in their morphology, dynamics and such as. However, nobody has not reached yet on revealing their physical origins observatinally.

Such an environmental dependence of galaxy formation seen in between galaxy clusters and general fields is a key issue to understand an entire picture of galaxy formation process. In order to resolve this problem, protoclusters above the redshift of two are the ideal laboratories since cluster galaxies are still in vigorous forming processes in those regions.

With this background, we conducted the near-infrared spectroscopic observation to Hα-selected galaxies associated with two rich protoclusters (PKS1138–262 at z=2.2 and USS1558–003 at z=2.5) in March–April 2013. These protoclusters are found by our distant-protocluster survey named 'MAHALO-Subaru' [1]. The observation motivates on confirming dynamical masses and velocity structures of the protoclusters [2], and also on studying physical properties of star-forming galaxies in them. This will provide us with crucial insights on searching for an early phase of environmental dependence of galaxy formation.

As a result, total integration time of more than 2 hrs for each target gave us with line spectra located at 1.3–2.5 μm in 27 & 36 objects in PKS1138–262 and USS1558–003, respectively. Those data were derived from low resolution grism (HK500) attached with MOIRCS, near-infrared multi-object spectrograph on the Subaru telescope. We observed 80 % out of the targets during 5 nights, and then finally confirmed 70 % spectroscopically among them (Fig. 1).

Founded on the datasets, we explore the dynamical masses of the protoclusters by using velocity dispersion of the members located at those cluster cores. The results show that both of two protoclusters have about $10^{14}\,M_{\odot}$. Interestingly, this exactly follows the typical mass growth history of today's most massive class of galaxy clusters ($\sim 10^{15}\,M_{\odot}$) predicted by cosmological simulations [3,4].

So far, we have some non-confirmed members and need to investigate more details of velocity structures of these quite rich protoclusters. Future MOSFIRE (on the Keck I telescope) observation will satisfy such requirements.

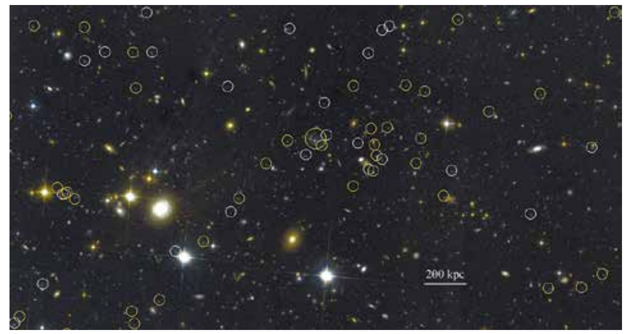

Figure 1: Composite color image of the protocluster PKS1138–262, based on the data taken by Hubble Space Telescope (F814W & F475W). Yellows are spectroscopically confirmed members including the past works. Whites do not still have spectroscopic data, and yet are Hα-selected galaxies by our past narrow-band imaging.

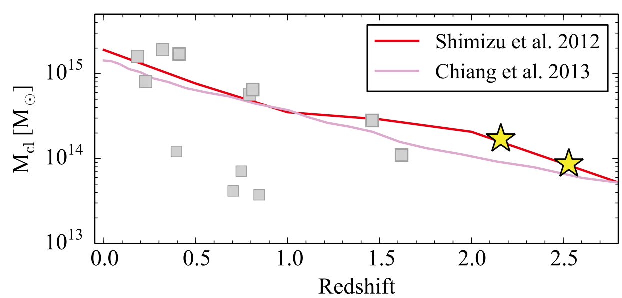

Figure 2: Redshift versus cluster dynamical masses. The yellow stars show our results and the others are derived from the past works. The red and the pink lines are the typical mass growth history of massive cluster haloes with $1\text{–}2\times10^{15}\,M_{\odot}$ predicted by theoretical simulations [3,4].

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An Early Phase of Environmental Effects on Galaxy Properties Unveiled by Near-Infrared Spectroscopy of Protocluster Galaxies at $z>2$

SHIMAKAWA, Rhythm, KODAMA, Tadayuki (NAOJ/SOKENDAI)
TADAKI, Ken-ichi (Max-Planck-Institut)
HAYASHI, Masao, KOYAMA, Yusei, TANAKA, Ichi (NAOJ)

Metals in the Universe are produced in the interiors of stars as they evolve and then released into surrounding gas through supernova explosions or stellar winds known as 'chemical evolution'. This means that the metallicity of the gases provides us with crucial insights on formation mechanisms of the galaxies. This work tries to diagnose the presence of environmental dependence of galaxy formation by investigating the gaseous metallicity of the protocluster galaxies at the redshift around two.

The metallicity of the gases in the protocluster galaxies can be derived from line ratios of multiple spectral lines emitted from them. Based on the line spectra taken by MOIRCS on the Subaru telescope, we estimated their gaseous metallicities [1] and compared them with those in the general field [3]. As a result, we find the excess of their gaseous metallicities in the protocluster regions by 0.10–0.15 dex relative to those of galaxies in the general fields (Figure 1). The metallicity excess in the protoclusters suggests biased star-formation histories in the dense regions. This may be caused by several effects as below,

- Recycling chemically enriched gas
- Stripping metal poor HI gas in outer region
- Advanced stage of downsizing galaxy evolution
- Top-heavy initial mass function
- Sampling bias

Among these possibilities, we suggest that the above two scenario may be the most effective factors that cause different gaseous metallicities of the protocluster galaxies, because gas inflow/outflow processes strongly control the chemical enrichment along with the stellar nucleosynthesis. If so, we can also explain the larger offset of the gaseous metallicities of the protoclusters from those in the fields at higher redshifts (Figure 1) since the redshift around two is considered to be the peak epoch of inflow and outflow activities. The result suggests that galaxy formation has already been influenced by environmental conditions in the era that star-formation activities are the most active across the universe. This would be an early phase of strong environmental effects seen in the present galaxy clusters.

However, we cannot fully rule out the other possibilities so far, and therefore we need to continue exploring the detailed physical properties of individual forming galaxies in the protoclusters to find clear evidence that proves such a hypothesis.

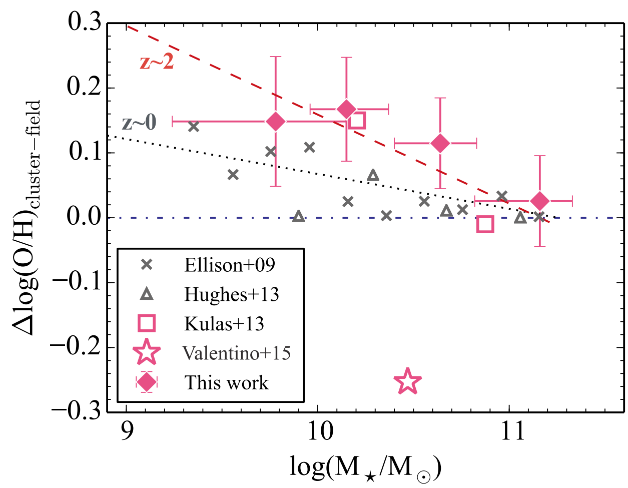

Figure 1: The offset of the averaged gaseous metallicities 12+log(O/H) of protocluster at $z\sim2$ (red; [1,4,7]) & cluster at $z\sim0$ (black; [5,6]) galaxies from those in general fields in the literature plotted against stellar mass.

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Visible-Wavelength Spectroscopy of Subkilometer-Sized Near-Earth Asteroids with a Low Delta-*v*

KURODA, Daisuke[1], ISHIGURO, Masateru[2], TAKATO, Naruhisa[1], HASEGAWA, Sunao[3], ABE, Masanao[3]
TSUDA, Yuichi[3], SUGITA, Seiji[4], USUI, Fumihiko[4], HATTORI, Takashi[1], IWATA, Ikuru[1]
IMANISHI, Masatoshi[1], TERADA, Hiroshi[1], CHOI, Young-Jun[5], WATANABE, Sei-ichiro[6], YOSHIKAWA, Makoto[3]

1: NAOJ, 2: Seoul National University, 3: ISAS/JAXA, 4: The University of Tokyo, 5: Korea Astronomy and Space Science Institute, 6: Nagoya University

The research on near-Earth asteroids (hereafter NEAs) has entered a new phase thanks to sample-return space explorations together with state-of-the-art large ground-based telescopes. NEAs with a low delta-v, which is defined in terms of the criterion for accessibility, are known as potential candidates for exploration including flybys, rendezvous, sample return, and human missions. However, only a small percent of known NEAs have been observed in the effort to acquire physical characteristics, because most such asteroids have short windows of observable opportunity.

In our work [1], to investigate the spectroscopic properties of the unclassified asteroids, we performed visible spectroscopic observations during two years from 2011 at the Subaru (FOCAS: [2]), GEMINI-North (GMOS: [3]), GEMINI-South (GMOS) and Okayama 188 cm (KOOLS: [4]). Ten NEAs among these asteroids share features of both the sub-kilometer-size with $18.8 \leq H < 21.7$ and the low delta-v of less than 7 km/sec. All observations were in the long-slit mode with the wide slit (2–6″ wide slit), and the low resolution grating (or grsim). The reflectance spectrum of an asteroid was obtained from the raw asteroid spectrum by dividing it by the spectrum of a standard solar analog star. The final spectrum of each asteroid was summed up and re-binned to match a resolution based on the instrument settings. Figures 1 shows the asteroid spectra from FOCAS. All spectra provide wavelength coverage from roughly 0.5 to 0.9 μm.

A total of 13 asteroids were classified by comparing a best fit between our data and the visible parts of the mean Bus-DeMeo spectra [5]. We find that eleven asteroids are classified as S-complex[1)] and one asteroid as V-type. Most S-complex asteroids (eight out of eleven, ~70 %) have spectra similar to subgroups of Q or Sq-type, suggesting that these objects are less matured against space weathering.

In [1], we show their spectra and discuss dominance of S-complex asteroids based on the previous research. It is clear that S-complex asteroids make up the majority of low delta-v asteroids. We further found that the fractions of S/C-complexes[2)] are less dependent on delta-v. Although we examined the fractions based on the absolute magnitude H to study the observational bias, we concluded that the dominance of S-complex asteroids is not sampling bias based on either delta-v or absolute magnitude H criteria.

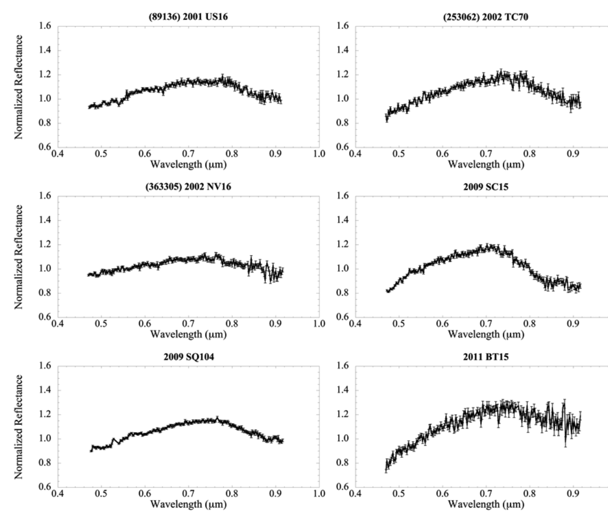

Figure 1: Visible spectra of six NEAs obtained with FOCAS at the Subaru telescope. All spectra are normalized to 0.55 μm. Their error bars are evaluated in terms of Poisson errors including the gain and readout noise and the uncertainty depending on the airmass mismatch.

1) S-type or the associated types of Q, O, A, Sr, Sq-type
2) C-type or the associated types of B, F, G type

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Mapping Observations of the Continuum Emission in Orion KL with ALMA

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

We have carried out high-resolution observations of millimeter and submillimeter continuum emission from the Orion KL region, the nearest site of massive star-formation, using ALMA cycle 0 data [1]. Total 11 compact continuum sources are identified in both ALMA band 6 (245 GHz) and band 7 (339 GHz) images, including the Hot Core, Compact Ridge, SMA1, IRc4, IRc7, and Source I (Figure 1). A spectral energy distribution (SED) of each source can be determined to constrain physical properties such as size, mass, hydrogen number density, and column density assuming the dust graybody emission.

Among 11 identified compact continuum sources, Source I, which is a massive protostar candidate, is the brightest with an unresolved structure even in the longer uv length than 200 kλ. It is thought that the continuum emission from Source I is associated with a circumstellar disk around a massive protostar object. We investigate its SED from centimeter to submillimeter wavelengths employing previously published result (Figure 2). The SED of Source I can be approximately fitted with a single power-law index of 1.97 suggesting an optically thick black body emission. To explain this SED, we employ the H^- free-free emission as an opacity source, which is an interaction between neutral hydrogen atoms/molecules and electrons. The temperature, density, and mass of the circumstellar disk associated with Source I are constrained by the SED of H^- free-free emission. Nevertheless, the fitting result shows a significant deviation from the observed flux densities. We next calculate the SED by including the thermal dust graybody SED to explain excess emission at higher frequency. Future higher resolution and high frequency observations with ALMA will be crucial to constrain the emission mechanism and physical properties of the circumstellar disk associated with Source I.

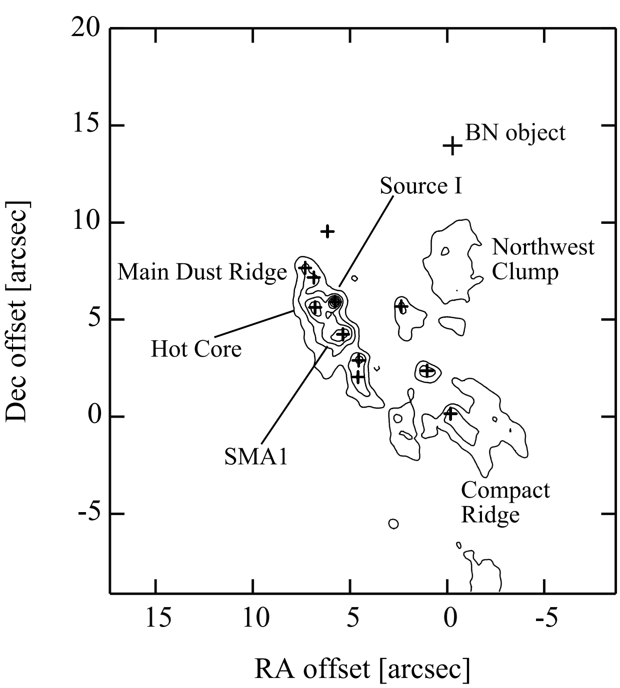

Figure 1: Continuum map of Orion KL observed with ALMA at band 7. The contours start at the -5σ level with an interval of 10σ (5, 15, 25, ...). Crosses indicate the positions of the point sources identified by our mapping.

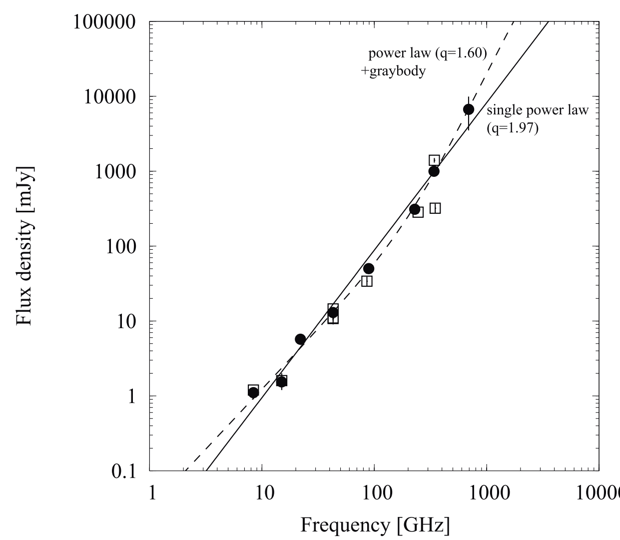

Figure 2: Spectral energy distribution of Source I, the most brightest continuum source in Orion KL. Flux densities are taken from previous literatures [2], except for our 245 GHz and 339 GHz data.A solid line indicates the best-fit single power-law model, $F_\nu = p\nu^q$, with the index of 1.97. A dashed line indicates the combination of power-law and graybody SEDs, with the power-law index of 1.60.

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VERA and ALMA Observations of the Maser Burst in Orion KL

HIROTA, Tomoya, HONMA, Mareki (NAOJ/SOKENDAI)
KURONO, Yasutaka (NAOJ/JAO)
TSUBOI, Masato (ISAS/JAXA)
FUJISAWA, Kenta (Yamaguchi University)
KIM, Mi-Kyoung (KASI)
IMAI, Hiroshi (Kagoshima University)
YONEKURA, Yoshinori (Ibaraki University)

We have been carrying out monitoring observations of the 22 GHz H_2O maser burst (supermaser) in the nearest massive star-forming region Orion KL using VERA since 2011 March [1,2]. In the present study, we have continued our monitoring of the supermaser until the end of 2013, and revealed the detailed properties of its time variation. As a result, we detect several flux maxima during our monitoring period in 2011–2013, and the maximum flux density is recorded in June 2012 with the flux density of 135000 Jy (Figure 1). This flux maximum is smaller by a factor of 10 compared with the previous bursts in 1979–1985 and 1998–1999. In addition, the time variation in each flux maximum show a symmetric flux increase/decrease with timescales of 2–7 months. The supermaser is found to consist of two spatial/velocity components with proper motions almost parallel to the northeast-southwest bipolar outflow in Orion KL (Figure 2).

With the newly obtained ALMA data, we investigate the physical properties of environment of the supermaser. We find that the supermaser is located in the Compact Ridge, which is an interacting region with the bipolar outflow and the ambient cloud. We identify the supermaser close to the methylformate ($HCOOCH_3$) line and continuum emission peaks. The velocity structure of the $HCOOCH_3$ line shows an evidence of shocked molecular gas. On the other hand, we can not detect submillimeter H_2O lines in the Compact Ridge, suggesting that the submillimeter H_2O lines are thermalized.

Our results support a scenario that the supermaser is excited in the shocked molecular gas in the Compact Ridge, and it could be explained by a beaming effect during the amplification process rather than changes in physical conditions.

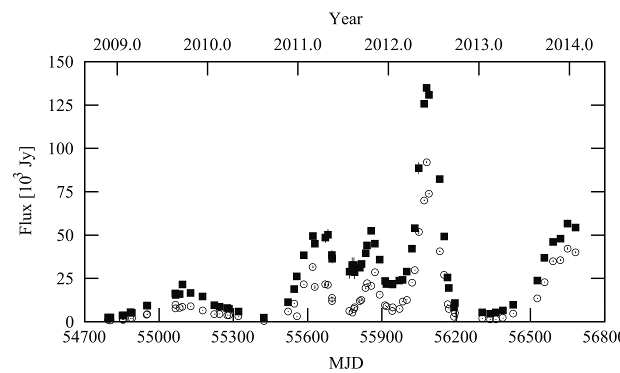

Figure 1: Flux density variation of the 22 GHz supermaser observed with VERA. Filled and open symbols represent the total and correlated flux densities, respectively, for the 7.5 km s^{-1} component.

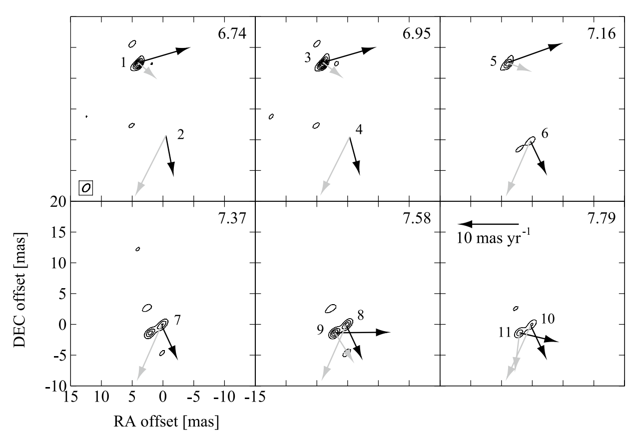

Figure 2: Channel maps of the 22 GHz supermaser observed with VERA. Each arrow indicates the proper motion vector. Contour levels are 2000, 4000, 6000, 8000, 10000, and 12000 Jy beam^{-1}. Gray arrows represent the absolute proper motions while black arrows indicate the proper motion with respect to the powering source of the bipolar outflow, Source I.

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Evidence for a Gas-Rich Major Merger in a Proto-Cluster at $z = 2.5$

TADAKI, Ken-ichi, KODAMA, Tadayuki (NAOJ)
TAMURA, Yoichi (University of Tokyo)
HAYASHI, Masao, KOYAMA, Yusei (NAOJ)
SHIMAKAWA Rhythm (SOKENDAI/NAOJ)
TANAKA, Ichi (Subaru Telescope)
KOHNO Kotaro (University of Tokyo)
HATSUKADE, Bunyo (NAOJ)
SUZUKI, Kenta (University of Tokyo)

Properties of galaxies seen in the local universe strongly depend on their surrounding environments, as is well known from the morphology–density relation. Early-type galaxies are frequently observed in high-density regions such as clusters and late-type galaxies are common in low-density regions. Such spatial segregation could be related to formation processes and subsequent quenching mechanisms of star formation, which probably take place at high redshift. Given high number densities of star-forming galaxies in proto-clusters at $z>2$, we naturally expect a high frequency of major-merger events.

We have conducted CO $J=1-0$ emission line observations with the Jansky Very Large Array (JVLA) [1]. The target field is a proto-cluster at =2.53, USS1558-003, including 20 Hα emitters (HAEs). We have detected the CO emission line from three galaxies (ID 191, ID 193, and ID 213) of our sample. Using MIPS 24 μm and JVLA 33 GHz images, we derive a total infrared (IR) luminosity of $L_{\rm IR} = 5.1\times10^{12} L_{\odot}$ for ID 193. Assuming that the bulk of the IR luminosity is powered by star formation, we find ID 193 to have a high SFR of 886 $M_{\odot}$ yr^{-1}.

The separation between ID 191 and ID 193 is about 4 arcsec corresponding to 32 kpc in the physical scale and the velocity offset is 300 km s^{-1}, suggesting that they are probably in the initial stage of a merger. Moreover, the derived SFR of 886 $M_{\odot}$ yr^{-1} in ID 193 is higher by a factor of about seven with respect to the M_*-SFR relation of normal HAEs (*main~sequence*) and is similar to that of SMGs, where extremely high star formation is thought to be driven by major mergers. In Figure 1, we also plot ID 193 on the $L_{\rm IR}$-$L'_{\rm CO}$ diagram to compare this with other populations taken from the literature. ID 193 has a higher IR luminosity compared to normal star-forming galaxies at a fixed CO luminosity and are situated close to the regime of low-redshift ULIRGs.

Given a violent star-formation activity (SFR=886 $M_{\odot}$ yr^{-1}), high $L_{\rm IR}/L'_{\rm CO}$ ratio (high SFE) and red optical color, we interpret ID 193 as a star-bursting galaxy driven by a gas-rich merger with ID 191 or another galaxy.

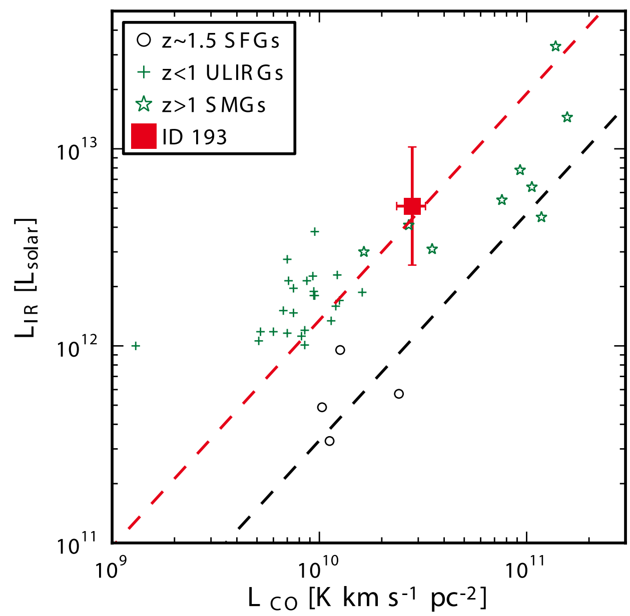

Figure 1: IR vs. CO $J=1-0$ luminosities of ID 193 (red square) along with SMGs at $z>1$ (green stars: [2,3,4]), ULIRGs at $z<1$ (green crosses: [5]), and optical/near-IR selected star-forming galaxies at $z>1$ (black circles: [6]). Dashed black and red lines show the best-fitting relations for normal star-forming galaxies and luminous mergers [7].

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Near-Infrared Brightness of the Galilean Satellites Eclipsed in Jovian Shadow: A New Technique to Investigate Jovian Upper Atmosphere

TSUMURA, Kohji[1], ARIMATSU, Ko[2], EGAMI, Eiichi[3], HAYANO, Yutaka[2], HONDA, Chikatoshi[4]
KIMURA, Jun[5], KURAMOTO, Kiyoshi[6], MATSUURA, Shuji[7], MINOWA, Yosuke[2], NAKAJIMA, Kensuke[8]
NAKAMOTO, Taishi[5], SHIRAHATA, Mai[2], SURACE, Jason[9], TAKAHASHI, Yasuto[6], WADA, Takehiko[10]

1: Tohoku University, 2: NAOJ, 3: Arizona University, 4: University of Aizu, 5: Tokyo Institute of Technology, 6: Hokkaido University, 7: Kwansei Gakuin University, 8: Kyushu University, 9: California Institute of Technology, 10: Japan Aerospace Exploration Agency

Using the Subaru Telescope and Hubble Space Telescope, we have found that Ganymede and Callisto remain slightly bright at near-infrared (~1.5 μm) even when in the Jovian shadow and not directly illuminated by the Sun (Fig. 1) [1]. Their eclipsed brightness was ~10^{-6} of their uneclipsed brightness, which is low enough that this phenomenon has been undiscovered until now. In addition, Europa in eclipse was not detected except a rare case explained later. Likewise, Ganymede was not detected at 3.6 μm by the Spitzer Space Telescope, suggesting a significant wavelength dependence (Fig. 2).

We considered several possibilities to understand why the satellites remain ever-so-slightly bright even when they are in eclipse. A possibility of illumination from Jupiter by lightning, aurora, and nightside airglow was investigated. However, it is difficult for these illuminators to explain the fact that the brightness of Europa was much darker than the others because Europa was located closer to Jupiter. Next possibility of atmospheric emission from the satellites was also rejected, because the non-detection of Ganymede in eclipse at 3.6 μm is difficult to explain by its atmosphere expected to have OH molecules (Fig. 2) [2]. Only once we detected Europa in eclipse, and it was explained by sunlight reflected from Io out of eclipse located near Europa on that day, but we also confirmed that such reflection from other satellites out of eclipse cannot explain the brightness of Ganymede and Callisto in eclipse we detected.

The most plausible explanation is indirect forward scattering of sunlight by hazes in the upper Jovian atmosphere. Based on this theory, the fact that Europa was darker than the others can be explained because the effect of the scattered sunlight should be less at a satellite closer to Jupiter. In addition, the similarity between spectra of Jupiter and Ganymede in eclipse (Fig. 2) can be also explained because Ganymede was illuminated by the sunlight through Jovian upper atmosphere. If it is the case, this new method of studying the upper atmosphere of Jupiter via transmitted sunlight provides a basis for the study of the exoplanet atmosphere, whose atmosphere is investigated via transmitted starlight during transit observations.

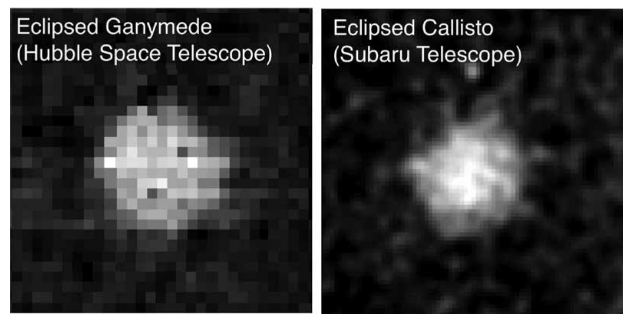

Figure 1: Images of Ganymede (left) and Callisto (right) obtained while they are eclipsed by Jupiter.

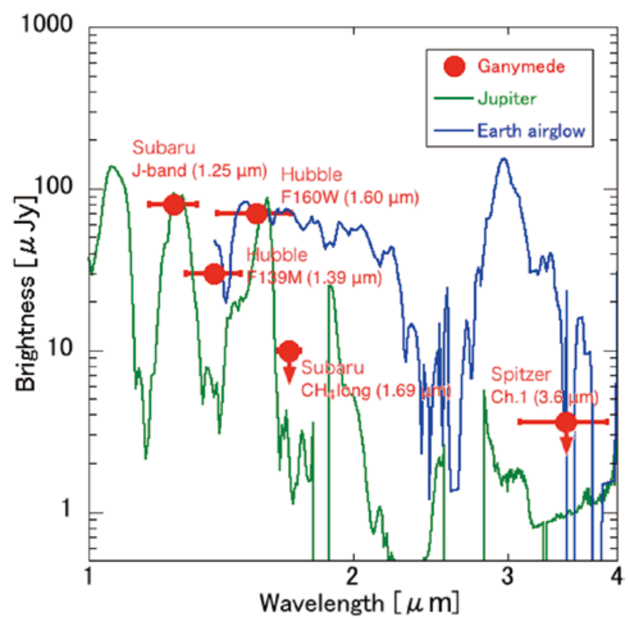

Figure 2: Spectral energy distribution of Ganymede in eclipse. Spectra of Jupiter [3] and the Earths atmosphere [4] are also shown, scaled to the Ganymede brightness.

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Discovery of Extended Ionized Clouds in a Cluster of Galaxies at $z \sim 0.4$

YAGI, Masafumi (NAOJ) GU, Liyi (SRON) NAKATA, Fumiaki, HATTORI, Takashi (NAOJ)
KOYAMA, Yusei, KODAMA, Tadayuki (NAOJ/SOKENDAI) YOSHIDA, Michitoshi (Hiroshima University)

Extended ionized clouds (EIGs) in intergalactic space has been reported by several studies of nearby cluster of galaxies [1-8] The clouds are thought to be made by ram-pressure stripping and/or galaxy interactions. Parent galaxies of EIGs tend to show post-starburst signature, especially in lower mass galaxies [8]. The stripping of the gas is therefore thought to be an important mechanism of the evolution of galaxies in clusters. There is also a study that the number of post-starburst galaxies in a cluster increases with redshift and typical luminosity of the post-starburst galaxies is larger at $z = 0.4$ than our neighborhood [9]. One can thus expect that there are more EIGs at $z = 0.4$. Nevertheless, no systematic survey has been tried so far.

There are two $z \sim 0.4$ cluster of galaxies obtained with the Subaru prime focus camera (Suprime-Cam), which have narrow-band data of redshifted Hα at the cluster's redshift; Abell 851 (A851) and CL0024+17 (CL0024) [10-12]. We re-analyzed the data with an improved method for extended objects and searched for EIGs. In A851, we found 9 EIGs, while none in CL0024.

We then identified possible parent galaxy of the 9 EIGs in A851. Five have redshift information in literature and/or unpublished data. We used Faint Objects Camera and Spectrograph (FOCAS) of the Subaru Telescope to obtain the rest 4, to confirm that all of the 9 parent galaxies are the member of A851. Moreover, in 30×25 arcmin of field of view of Suprime-Cam, the 9 EIGs exist within 2.3 arcmin (750 kpc) from the center of the cluster. These results suggests that the EIGs exist in A851 and they are ionized hydrogen clouds.

Six of the nine parents show an emission out of stellar distribution (Fig. 1 top), which implies a ram-pressure stripping. We also used Hubble Space Telescope (HST) images to see the morphology. Four of the nine show asymmetry in the distribution of stars (Fig. 1 bottom), which implies a recent galaxy interaction. The spectrum and color of the parents shows that the parents are either starforming galaxy or post-starburst one.

Regarding kinematics, we found that 6 or 7 EIG parents belong to a subcluster of A851 which is now infalling onto the main cluster. Compared with CL0024, which has no EIGs, the infalling subcluster shows a higher fraction of EIG parents with a statistical significance. Our result resembles an example in a near cluster [3] that gas stripping is caused by the infall of subcluster.

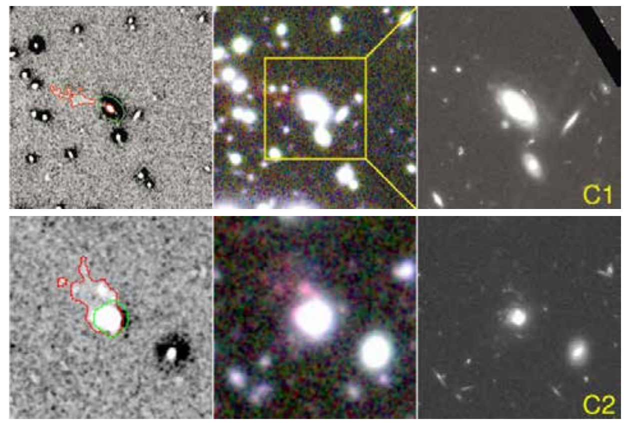

Figure 1: Examples of EIG in A851. Top-left and top-center are 50 arcsec (270 kpc) square, and the others are 25 arcsec (140 kpc) square. North is top, and east to the left. (Left) broad-band (z)-subtracted narrow-band (NB921) image from Subaru Suprime-Cam archived data. White shows strong emission in NB, and it corresponds to Hα at the A851 redshift. The red contour is 3σ isophote of NB-z, and the green contour shows 90 % flux isophote of the parent galaxy. The enclosed black ring around objects are artifacts caused by different seeing size of NB and z. (Center) Three color composite of NB921, z, and R. Hα is red in this color assignment. (Right) ACS/HST F816W image from the HST archive. The bottom galaxy (C2) shows asymmetric stellar distribution.

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Rapid Change of the Plasma Tail of C/2013 R1 (Lovejoy)

YAGI, Masafumi (NAOJ) KODA, Jin (Stony Brook University) FURUSHO, Reiko (Tsuru University/NAOJ)

KOYAMA, Yusei, KODAMA, Tadayuki (NAOJ/SOKENDAI) YOSHIDA, Michitoshi (Hiroshima University)

In Dec. 2013, we had a time in morning twilight in an open use program of extragalactic objects with the Subaru Prime Focus Camera. As a bright comet (C/2013 R1 (Lovejoy)) was seen, we took its image in I-band and V-band for educational and public outreach purposes. We then found that the shape of the plasma tail changed in a few minutes [1].

The comet was at 0.55 au from the earth, and sun-comet-earth angle was 83°.2 at the observation time. We observed the plasma tail nearly edge-on, which is an ideal condition for the study on the time variation of the structure of the tail. The physical scale of the tail was about 400 km/arcsec considering the slight inclination.

We quantitatively evaluated two changes of the shape, which were first visually identified; a motion of two knots in the tail and the change of the width of the tail. The knots was detected and measured in unsharp-masked images after masking of elongated background stars (Figure 1). In plasma tails of comets, we observe CO^+ and H_2O^+ in I-band, while mainly CO^+ in V-band. Thus the difference of shapes in I- and V-bands may be due to the difference of distribution of these ions. We however consider that the same knots were observed in I and V-bands, because the motion of the two knots in the I- and V-bands lie on the same relation as shown in Figure 2. The speed of them are 20, 25 km/s along the tail, and 3.8, 2.2 km/s across the tail. The speed of knots along the tail would correspond to the speed of the flow of the plasma tail. The change of the width is then measured in I-band, considering the flow speed, and it was 8 km/s at each side in 8 minutes (from the start of the first exposure to the end of the last exposure).

In Table 1, the speed of structures in plasma tails along the tails in literature are summarized. The speed obtained in this study, ~22 km/s, are less than half of the previous studies. As we observed the knots near to the nucleus (~300,000 km), the value may reflect the initial speed of the tail before the acceleration by the solar wind. However, three times larger speed was obtained in study of 1P/Halley at a comparable distance from the nucleus. We need to accumulate the data in order to identify what is the key parameter to the speed; size of the structure, solar activity, ecliptic latitude, solar distance of the comet, etc. Efficient observation strategy is required including a use of large telescopes.

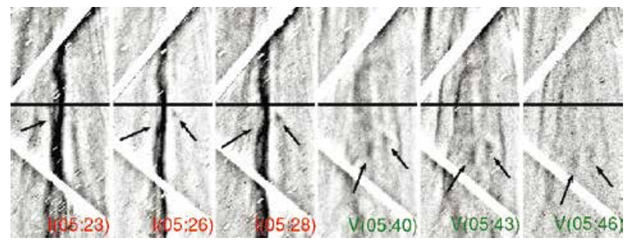

Figure 1: Cutouts of unsharped masked images of the comet tail. The nucleus to the top, the plasma tail is along y-axis, and the two arrows show the knots. Six exposures were shown in order of time from the left to the right. Black horizontal line indicates 300,000 km distance from the nucleus. The knots moved downstream.

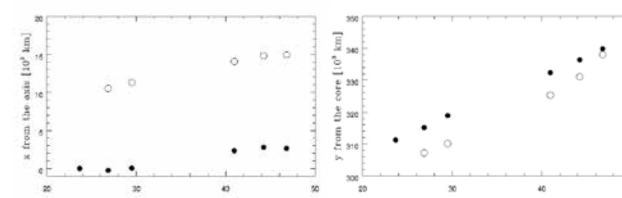

Figure 2: Motion of the two knots. Open and filled circle correspond to each knot. The left panel shows motion across the tail, the right along the tail. Left three data points are in I-band, and right three are in V-band.

comet	speed	Distance from nucleus
various [2]	44±10.9 km/s	< 10^7 km
1P/Halley [3]	65.8 km/s	4−9×10^5 km
C/1996 B2 [4]	99.2 km/s	~5×10^6 km
C/1995 O1 [5]	500 km/s	~7×10^7 km
C/2001 Q4,		
C/2002 T7 [6]	50−100 km/s	~10^6 km
C/2013 R1 (this work)	20−25 km/s	~3×10^5 km

Table 1: Speed of structures in comet tails.

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Studying Near-Infrared Extragalactic Background with the Cosmic Infrared Background ExpeRiment-2 (CIBER-2)

SHIRAHATA, Mai (NAOJ)
MATSUURA, Shuji, ARAI, Toshiaki, WADA, Takehiko (ISAS/JAXA)
TSUMURA, Khoji (Tohoku University)
SANO, Kei (University of Tokyo)
ONISHI, Yosuke (Tokyo Institute of Technology)
MATSUMOTO, Toshio (ASIAA)
BOCK, James, ZEMCOV, Michael, KORNGUT, Phillip (Caltech/JPL)
LANZ, Alicia, HRISTOV, Viktor, BATTLE, John, MASON, Peter, MORFORD, Tracy (Caltech)
COORAY, Asantha (University of California)
LEE, Dae-Hee (KASI)

We present the current status of the Cosmic Infrared Background ExpeRiment-2 (CIBER-2) project, whose goal is to make a rocket-borne measurement of the Cosmic Infrared Background (CIB), under collaborate with U.S.A., South Korea, and Taiwan.

The extragalactic background is the integrated light of all extragalactic sources of emission back to the early Universe. At near-infrared wavelengths, measurement of the CIB is a promising way to detect the diffuse light from the first collapsed structures at redshift $z\sim10$, which are impossible to detect as individual sources. However, recently, the intra-halo light (IHL) model [1] is advocated as the main contribution to the CIB, and our new result of the CIB fluctuation [2] is also supporting this model. In this model, CIB is contributed by accumulated light from stars in the dark halo regions of low-redshift ($z<2$) galaxies, those were tidally stripped by the interaction of satellite dwarf galaxies. Thus, in order to understand the origin of the CIB, both the spatial fluctuation observations with multiple wavelength bands and the absolute spectroscopic observations for the CIB are highly required.

After the successful initial CIBER experiment [3], we are now developing a new instrument CIBER-2 [4], which is a sounding-rocket borne payload comprising a 28.5-cm aluminum telescope and three broad-band, wide-field imaging cameras (Fig. 1). The three wide-field (2.3×2.3 degrees) imaging cameras use the 2K×2K HgCdTe Hawaii-2RG arrays, and cover the near-infrared wavelength range of 0.5–0.9 μm, 0.9–1.4 μm and 1.4–2.0 μm, respectively. Combining a large area telescope with the high sensitivity detectors, CIBER-2 will be able to measure the spatial fluctuations in the CIB after removing foreground point-sources at a >24 AB-mag limit. Additionally, we will use a linear variable filter installed just above the detectors so that a measurement of the absolute spectrum of the CIB is also possible.

In the year of 2014, the conceptual design of the instruments and the development of new technology have been completed. The lens fabrications, the manufacture of the lens barrel, and telescope assembly will be done in the year of 2015, and the performance evaluation test at the LN_2 temperature is also scheduled. CIBER-2 plans at least two flights in the same configuration described here. The first flight is planned for 2016 with the second flight to follow six months or one year later.

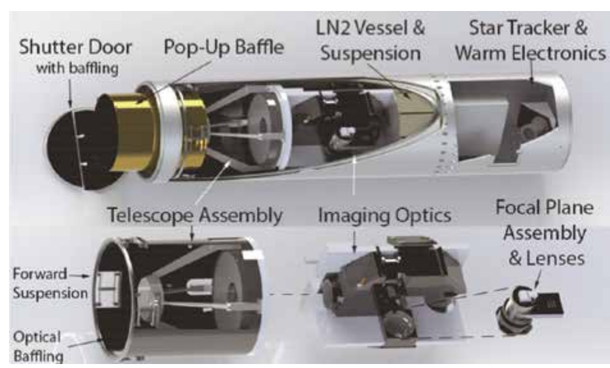

Figure 1: Model of the CIBER-2 instrument. A 28.5 cm Cassegrain telescope directs light into the imaging optics, where beam splitters divide the light into three imaging optics (Arm-S, Arm-M, Arm-L). Each optical path travels to one of three focal plane assemblies, where a broadband filter subdivided the light into two wavelength bands which are both recorded by a single detector array for a total of 6 bands. A small segment of each detector array is also covered by a linear-variable filter. The imaging optics is mounted to an optical bench that connects the Cassegrain telescope assembly to a liquid nitrogen cryostat. Radiative shielding is provided by a radiatively-cooled door and cryogenically-cooled pop-up baffle that extends during observations.

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A Study on the Methyl Formate in Its Ground and Torsional Excited States Toward Orion KL Using ALMA Sceience Verication Data

HIROTA, Tomoya (SOKENDAI/NAOJ)
KOBAYASHI, Kaori, SAKAI, Yusuke (University of Toyama)

Methyl formate ($HCOOCH_3$) was first identified toward Sgr B2 [1] and more than 1000 transitions were identified in the star-forming regions including Orion Kleinmann-Low (KL) since then. Methyl formate has an internal rotor which is equivalent to the torsional vibration. This mode is a low-lying state. The rotational transition in the first torsional excited state of this molecule was firtst identified toward Orion KL in 2007 [2]. In 2012, even transitions in the second torsional excited state were observed by using the Nobeyama 45 m Radio Telescope [3].

In this study, we analyzed the ALMA science verification data of Orion KL (band 6) that contains many transitions in the ground and torsional excited states. It was confirmed in the previous study [3] that there is a difference between the vibrational temperature and the rotational temperature. The higher spatial resolution of this new ALMA data will help us to clarify the difference. Figure 1 shows the integrated intensity maps of methyl formate. These maps shows the similarity of population in each vibrational state. We have analyzed two velocity components toward the Compact Ridge and one velocity component toward the Hot Core. It was confirned that the vibrational temperature and the rotational temperature of each component agreed within their uncertainties [4].

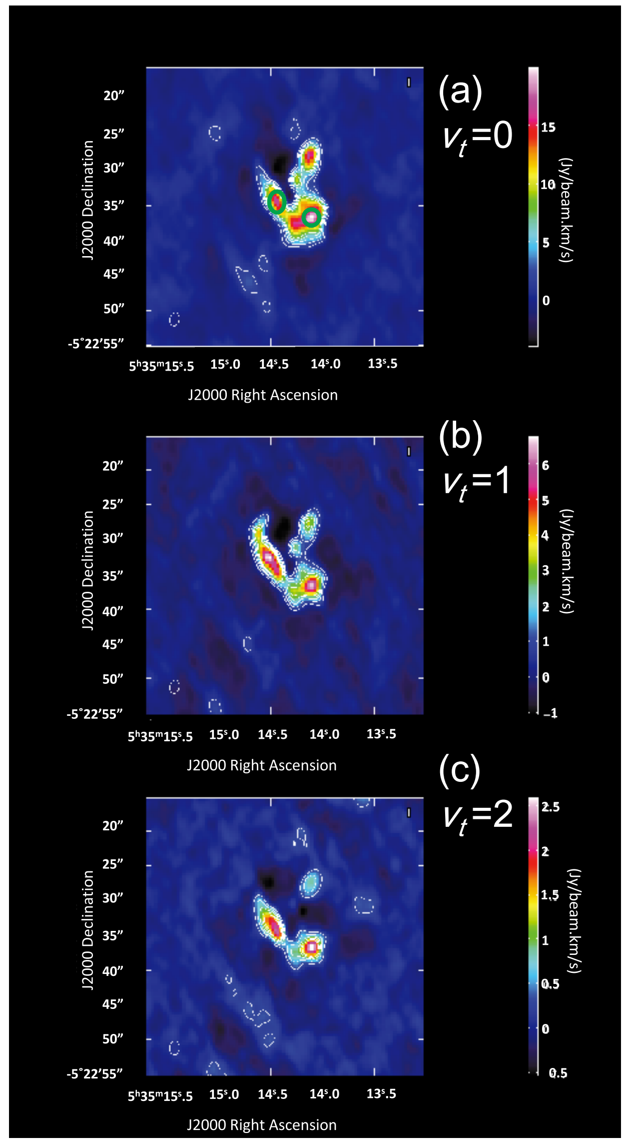

Figure 1: Integrated intensity maps of methyl formate in the ground, the first torsional excited, the second torsional excited states. The green circles shown represent the Compact Ridge and Hot Core.

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Discovery of a Disk Gap Candidate at 20 AU in TW Hya

AKIYAMA, Eiji[1], MUTO, Takayuki[2], KUSAKABE, Nobuhiko[1], KATAOKA, Akimasa[3], HASHIMOTO, Jun[1]
TSUKAGOSHI, Takashi[4], KWON, Jangmi[5], KUDO, Tomoyuki[1], KANDORI, Ryo[1], GRADY, Carol A.[6]
TAKAMI, Michihiro[7], JANSON, Markus[8], KUZUHARA, Masayuki[9], HENNING, Thomas[10]
SITKO, Michael L.[11/12], CARSON, Joseph[10/13], MAYAMA, Satoshi[14], CURRIE, Thayne[1]
THALMANN, Christian[15], WISNIEWSKI, John P.[16], MOMOSE, Munetake[4], OHASHI, Nagayoshi[1], ABE, Lyu[17]
BRANDNER, Wolfgang[10], BRANDT, Timothy D.[18], EGNER, Sebastian[1], FELDT, Markus[10], GOTO, Miwa[19]
GUYON, Olivier[1], HAYANO, Yutaka[1], HAYASHI, Masahiko[1], HAYASHI, Saeko[1], HODAPP, Klaus W.[20]
ISHII, Miki[1], IYE, Masanori[1], KNAPP, Gillian R.[18], MATSUO, Taro[21], MCELWAINE, Michael W.[22]
MIYAMA, Shoken[23], MORINO, Jun-Ichi[1], MORO-MARTIN, Amaya[24/25], NISHIMURA, Tetsuro[1]
PYO, Tae-Soo[1], SERABYN, Eugene[26], SUENAGA, Takuya[14], SUTO, Hiroshi[1], SUZUKI, Ryuji[1]
TAKAHASHI, Yasuhiro[1/5], TAKATO, Naruhisa[1], TERADA, Hiroshi[1], TOMONO, Daigo[1], TURNER, Edwin L.[5/18]
WATANABE, Makoto[27], YAMADA, Toru[28], TAKAMI, Hideki[1], USUDA, Tomonori[1], TAMURA, Motohide[1/5]

1: NAOJ, 2: Kogakuin University, 3: University of Heidelberg, 4: Ibaraki University, 5: The University of Tokyo, 6: Eureka Scientific, 7: Academia Sinica, 8: Stockholm University, 9: Tokyo Institute of Technology, 10: Max Planck Institute for Astronomy, 11: Space Science Institute, 12: University of Cincinnati, 13: College of Charleston, 14: The Graduate University for Advanced Studies, 15: ETH Zurich, 16: The University of Oklahoma, 17: Universite de Nice Sophia-Antipolis, 18: Princeton University, 19: Universitäts-Sternwarte München, 20: University of Hawaii, 21: Kyoto University, 22: Goddard Space Flight Center, 23: Hiroshima University, 24: Space Telescope Science Institute, 25: Johns Hopkins University, 26: Jet Propulsion Laboratory, 27: Hokkaido University, 28: Tohoku University

Explorations and studies of protoplanetary disks reveal important physical processes that are fundamental to the formation and evolution of planetary systems.

As part of the Strategic Explorations of Exoplanets and Disks with Subaru (SEEDS) project for exploring the circumstellar disk structure, TW Hya, an analog of the early solar nebula, was selected because it is particularly accommodating to investigations of its geometrical structure with high spatial resolution and sensitivity due to its close distance of 54 pc.

As results of the observations, the scattered light from the disk was detected from 0.2 to 1.5 asec (11–81 AU) from the central star and the polarized image shows a ring-like depression, probably a gap at ~20 AU from the central star as shown in Fig. 1 [1], similar to the 80 AU gap previously reported from the Hubble Space Telescope (HST) images [2]. Several gap formation mechanisms, such as disk–planet interaction, photoevapolation, grain growth, or dust filtration, has been proposed. Our observation suggests the possibilities of planet formation and grain growth because the observed radial profile can well be explained by the gap formation model by a planet [3] and the observed depression can also be reproduced by a change in dust scale height due to grain growth.

In addition to the HST result, our observation revealed the multiple ring-like gap structure in TW Hya, implying that multiple planets are forming as a planetary system. In near future, ALMA and next-generation astronomical telescope, TMT, will provide convincing information about the origin of gaps and shed new light on planet formation.

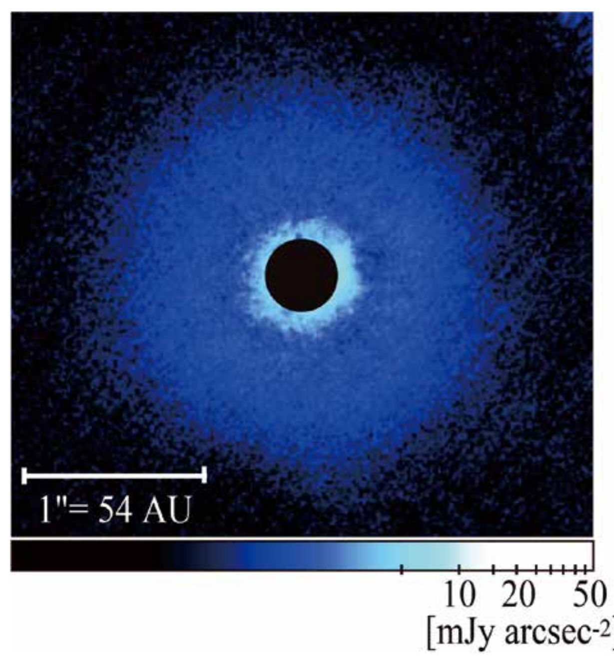

Figure 1: *H*-band polarized intensity image of TW Hya. The dark filled circle at the center indicates a software mask with $r = 0.2$ asec.

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Revised Big-Bang Nucleosynthesis with Exotic Dark Matter Particle: Detailed Quantum Mechanical Calculation

KUSAKABE, Motohiko (Korea Aerospace University/Soongsil University)
KIM, K. S. (Korea Aerospace University)
CHEOUN, Myung-Ki (Soongsil University)
KAJINO, Toshitaka (NAOJ/University of Tokyo)
KINO, Yasushi (Tohoku University)
MATHEWS, Grant. J. (University of Notre Dame)

We extensively reanalyze effects of an exotic long-lived negatively charged massive particle [1], i.e., X^-, on big bang nucleosynthesis (BBN). The BBN model with the X^- particle was suggested to explain the discrepancy between ^{6,7}Li abundances predicted in standard BBN model and those inferred from spectroscopic observations of metal-poor stars (e.g., [2]). In this model, ^{7}Be is destroyed via the recombination with X^- followed by radiative proton capture, i.e., $^7\mathrm{Be}(X^-,\gamma)^7\mathrm{Be}_X(p,\gamma)^8\mathrm{B}_X$ [3,4].

First, we study the effects of uncertainties in nuclear charge distributions for X-nuclei in BBN. We show that different charge distributions can result in resonant nuclear reaction rates that differ by significant factors through changes in resonance energy heights.

Second, we calculate precise rates for the radiative recombinations of ^{7}Be, ^{7}Li, ^{9}Be, and ^{4}He with X^-. We calculate nonresonant rates taking account of respective partial waves of scattering states and respective bound states. It is found that the finite sizes of nuclear charge distributions cause deviations in bound and continuum wave functions from those derived assuming that nuclei are point charges. We find that for a heavy mass, $m_X \gtrsim 100$ GeV, the transition, d-wave $\rightarrow$ 2P, is the most important recombination reaction for ^{7}Li and ^{7,9}Be with an X^- particle. This fact is completely different from the case of hydrogen-like electronic ions. As for ^{7}Be and ^{7}Li, bound states of the nuclear first excited states ($^7\mathrm{Be}^*$ and $^7\mathrm{Li}^*$) with X^- can operate as effective resonances. The resonant reaction rates are then also calculated.

Figure 1 shows rates for the nuclear recombination with X^- as a function of temperature $T_9 = T/(10^9\,\mathrm{K})$ for $m_X = 1000$ GeV. Curves correspond to the sums of nonresonant and resonant reaction rates. The new rates for ^{7}Be, ^{7}Li, and ^{9}Be are larger than the previous rates, while that for ^{4}He is smaller than the previous rate. Importantly, the ^{7}Be rate in the present study is more than 6 times larger than the existing rate. This improvement leads to a significantly better constraint on the X^- properties. The present rates for ^{7}Li and ^{9}Be are also significantly larger than the previous rates. The present ^{4}He rate is, on the other hand, not significantly different for temperatures $T_9 \lesssim 0.1$ where the recombination effectively proceeds.

Third, we suggest a new reaction for ^{9}Be production: the radiative recombination of ^{7}Li and X^- followed by the deuteron capture. This reaction can enhance the primordial ^{9}Be abundance which may be detectable in future observations of metal-poor stars.

We derive binding energies and mass excesses of X-nuclei, and rates and Q-values for β-decays and nuclear reactions involving the X^- particle. We calculate BBN and find that amounts of ^{7}Be destruction depend significantly on the charge distribution of the ^{7}Be nucleus.

Finally, the most realistic constraints on the initial abundance and the lifetime of the X^- are deduced. Parameter regions for the solution to the ^{7}Li problem are derived, and primordial ^{9}Be abundances in the parameter regions are also predicted.

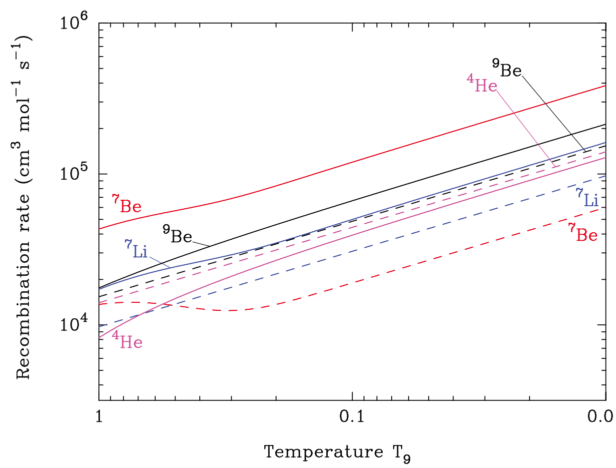

Figure 1: Total rates for nuclear recombination with X^- in the case of $m_X = 1000$ GeV as a function of temperature. Solid lines show the recombination rates derived in this study, while dashed lines show the rates adopted in the previous studies (e.g., [3,4]). This is reprinted from [5].

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Asymmetric Neutrino Emission from Magnetized Proto-Neutron Stars: Effects of Absorption Cross-Sections in Iso-Entropical Conditions [1]

MARUYAMA, Tomoyuki (Nihon University)
KAJINO, Toshitaka (NAOJ/University of Tokyo)
HIDAKA, Jun (Meisei University)
YASUTAKE, Nobutoshi (Chiba Institute of Technology)
CHEOUN, Myung-Ki, RYU, Chung-Yeol (Soongsil University)
MATHEWS, Grant. J. (University of Notre Dame)

In our previous works [2], we calculated neutrino scattering and absorption cross sections on hot and dense magnetized proto-neutron-star (PNS) matter including hyperons under a strong magnetic field in a relativistic mean field (RMF) theory. The calculation results showed that the magnetic contribution increases the neutrino momentum emitted along the direction parallel to the magnetic field and decrease it along the opposite direction.

These works have been done in the isothermal model, which is not realistic because the temperature decrease as the radial position becomes farther from the center of the PNS. In addition, the mean-field used in the previous works cannot allow neutron stars mass of 2 $M_{\odot}$.

To get more realistic results, we introduce the new parameter-sets of RMF and calculate the neutrino cross-sections in the isoentropic conditions. Fig. 1 shows total energies per baryon, temperature profiles, and number fractions for constituent particles in an isoentropic system with entropy per baryon S/A = 1.

In Fig. 2, we show the magnetic part of the absorption cross-section as a function of the initial neutrino angle in the matter with S/A =1 and $B = 10^{18}$ G.

At $\rho_B = \rho_0$, the magnetic field suppresses the absorption cross-sections in a direction parallel to the magnetic field by about 8.3 % for an entropy per baryon of S/A = 1. The suppression of σ_A for S/A = 1 at $\rho_B = \rho_0$ turns out to be much larger than in an isothermal model with T = 20 MeV, because the temperature at this density in the isoentropic model is only about T = 7 MeV. At lower temperature the magnetic contribution becomes larger. However, at higher densities and temperatures the suppression is comparable in the two models.

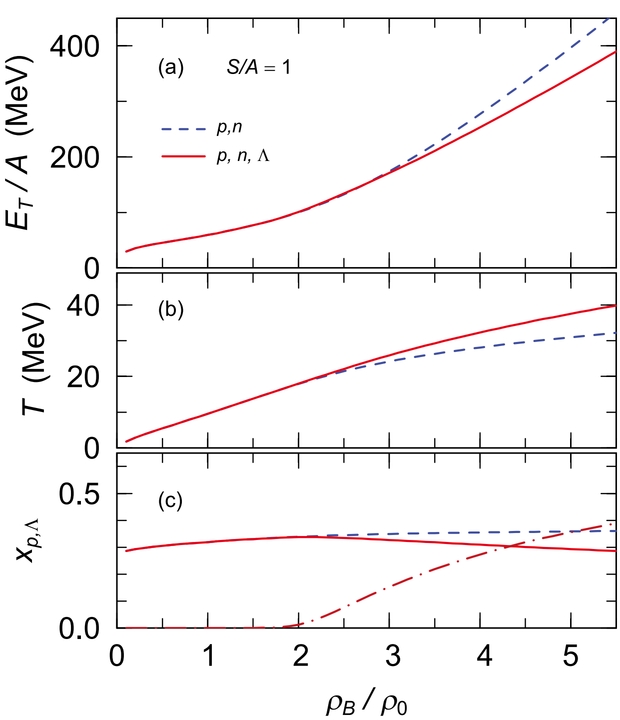

Figure 1: Density dependence of the total energy per baryon E_T/A (a), Temperature T (b) and proton fractions x_p of neutron-star matter at a lepton fraction Y_L = 0.4 and for entropy per baryon S/A = 1. Solid and dashed lines represent results with and without Λ particles, In the lower panel (c) a dot-dashed line indicates the x_Λ fraction.

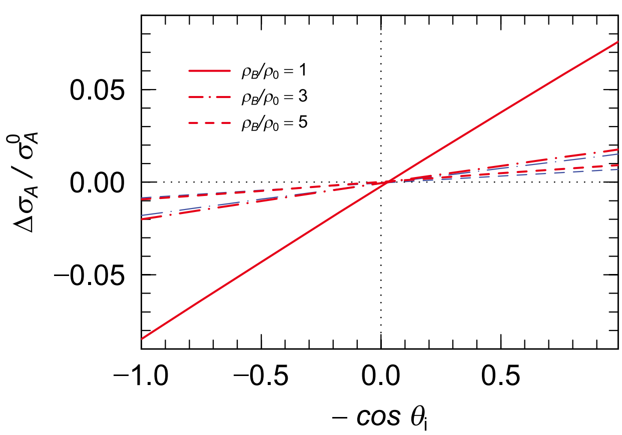

Figure 2: Ratio of the magnetic part of the absorption cross-section $\Delta\sigma_A$ to the cross-section without a magnetic-field σ_A^0. The thick and thin lines indicate the results for matter with and without Λs, respectively. The strength of the magnetic field is $B = 10^{18}$ G, and neutrino incident energies are taken to be equal to the neutrino chemical potentials.

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Cosmological Solutions to the Big-Bang Lithium Problem: Big-Bang Nucleosynthesis with Photon Cooling, X-Particle Decay and a Primordial Magnetic Field

YAMAZAKI, Dai G. (NAOJ)
KUSAKABE, Motohiko (Korea Aerospace University/Soongsil University)
KAJINO, Toshitaka (NAOJ/University of Tokyo)
MATHEWS, Grant. J. (University of Notre Dame)
CHEOUN, Myung-Ki (Soongsil University)

The ^{7}Li abundance calculated in BBN with the baryon-to-photon ratio fixed from fits to the CMB power spectrum is inconsistent with the observed lithium abundances on the surface of metal-poor halo stars. Previous cosmological solutions proposed to resolve this ^{7}Li problem include photon cooling (possibly via the Bose-Einstein condensation of a scalar particle) or the decay of a long-lived X-particle (possibly the next-to-lightest supersymmetric particle). In this paper we reanalyze these solutions, both separately and in concert. We also introduce the possibility of a primordial magnetic field (PMF) into these models. We constrain the X-particles and the PMF parameters by the observed light element abundances using a likelihood analysis to show that the inclusion of all three possibilities leads to an optimum solution to the lithium problem. We deduce allowed ranges for the X-particle parameters and energy density in the PMF that can solve ^{7}Li problem.

We have calculated BBN taking into account three possible cosmological extensions of the standard BBN. These include photon cooling, the radiative decay of X particles, and the possible existence of a PMF. In particular, we consider the possible combination of all three paradigms simultaneously in a new hybrid model. We then utilized a maximum likelihood analysis to deduce constraints on the parameters characterizing the X particles (τ_X[s], ζ_X[GeV]) and the energy density of the PMF ($\rho_B = B^2/8\pi$) from the observed abundances of light elements up to Li.

From Fig. 1, as a result, we obtained ranges for the X-particle parameters given by

$$4.06 < \log(\tau_X[\mathrm{s}]) < 6.10 \ (95\,\%\ \mathrm{C.L.}),$$

$$-9.70 < \log(\zeta_X[\mathrm{GeV}]) < -6.23 \ (95\,\%\ \mathrm{C.L.}),$$

also find that the hybrid model with a PMF gives the better likelihood than that without a PMF, and the best fit and 2σ upper bound on the energy density of the PMF are

$$B = 1.89\,\mathrm{nG} \text{ at } a = 1.0 \text{ (the best fit)},$$

$$B < 3.05\,\mathrm{nG} \text{ at } a = 1.0 \ (95\,\%\ \mathrm{C.L.}),$$

We discussed the degeneracy between the parameters of the X particle and the PMF. Since the parameters of X particle are mainly constrained by the D and ^{7}Li abundances, while the energy density of the PMF is constrained by the ^{4}He abundance, we found there are no significant degeneracies between parameters of the PMF and the X particle.

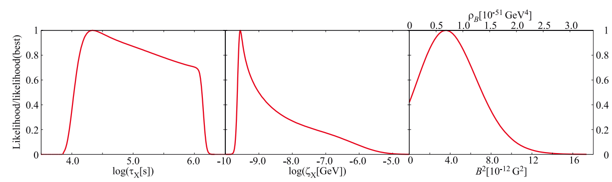

Figure 1: Constraint on the X particle parameters and the PMF strength and energy density.

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Supernova Nucleosynthesis of ^{26}Al and Nuclear Structure of ^{26}Si [1]

KOMATSUBARA, T. (Institute for Basic Science) KUBONO, S. (RIKEN) HAYAKAWA, T., SHIZUMA, T. (JAEA)

OZAWA, A., ITO, Y., ISHIBASHI, Y. (University of Tsukuba) MORIGUCHI, T. (NCCCRI) YAMAGUCHI, H., KAHL, D. (CNS)

HAYAKAWA, S. (INFN, Catania) BINH, Dam Nguyen (Vietnamese Academy for Science and Technology) CHEN, A. A., CHEN, J. (McMaster University)

SETOODEHNIA, K. (University of Notre Dame) KAJINO, T. (NAOJ/University of Tokyo)

The level scheme above the proton threshold in ^{26}Si is crucial for evaluating the ^{25}Al$(p,\gamma)^{26}$Si stellar reaction, which is important for understanding the astrophysical origin of the long-lived cosmic radioactivity ^{26}Al ($T_{1/2}$ = 7.17×10^5 y) in the Galaxy. The β-delayed γ-ray from the ^{26}Al was measured by satellite γ-ray telescope. Therefore, the ^{26}Al is considered to be created in supernovae, classical novae, and massive stars. Because the half-life of this isotope is much shorter than the age of the Galaxy, it has been continuously created reached equilibrium value.

The isotope ^{26}Al is produced the nucleosynthesis flow of ^{25}Al$(e^+\nu)^{25}$Mg$(p,\gamma)^{26}$Al. There is a bypass flow ^{25}Al$(p,\gamma)^{26}$Si$(e^+\nu)^{26m}$Al$(e^+\nu)^{26}$Mg, that does not emit the characteristic γ-ray. Therefore, the ^{25}Al$(p,\gamma)^{26}$Si reaction is a key reaction to evaluate the production of the ^{26}Al. The reaction rate of the (p,γ) reaction is dominated by narrow-resonant reactions with 0^+, 1^+, and 3^+ states. Those are sensitive to their excitation energies above the proton threshold in ^{26}Si.

The excited states in ^{26}Si have been studied using an in-beam γ-ray spectroscopy technique with the ^{24}Mg$(^3$He$, n\gamma)^{26}$Si reaction. γ-rays emitted from excited states in ^{26}Si have been measured using large volume HPGe detectors. As the result of the experiments the level scheme of ^{26}Si is shown in Figure 1. The 0^+ and 1^+ states were well observed above the proton threshold. The spin-parity of one of the most important states at 5890.0-keV has been assigned as 0^+ by $\gamma-\gamma$ angular correlation measurements in this work.

According to the newly determined excitation energies the astrophysical nuclear reaction rate is calculated as a function of temperature T_9 as shown in Figure 2. The contribution of the 0^+ resonance is modestly increased; however, the role of the 3^+ level is still dominant as discussion [2]. In order to elucidate the abundance of galactic ^{26}Al more extensive effort might be essential to observe the crucial 3^+ state just above the proton threshold.

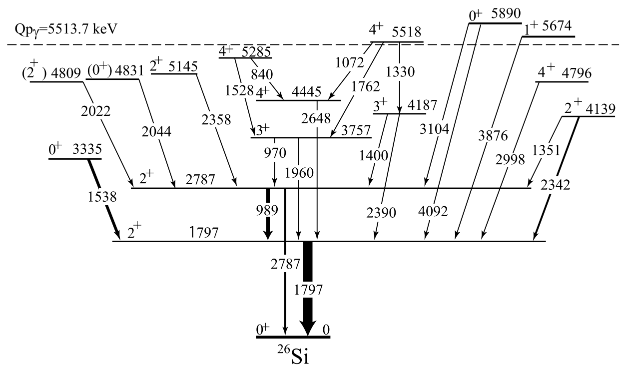

Figure 1: Level scheme of ^{26}Si. The 0^+ level at 5890 keV above the proton threshold has been observed with present work.

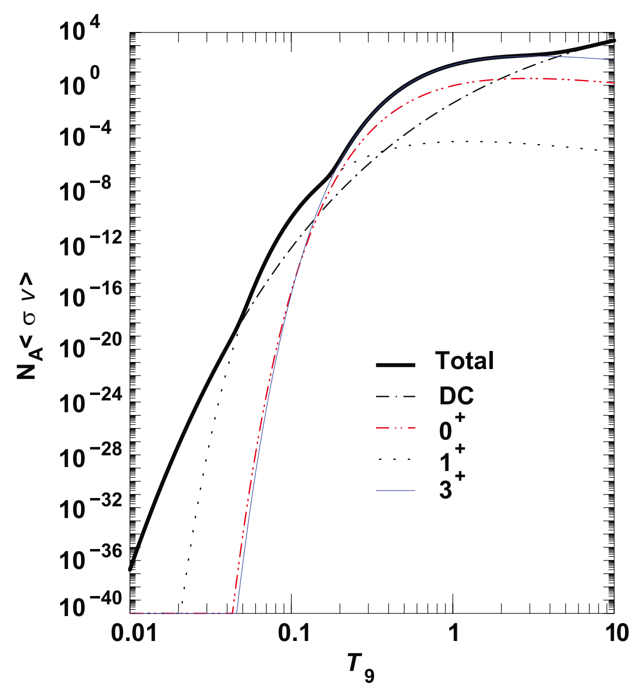

Figure 2: Astrophysical reaction rate $N_A<\sigma v>$ for the ^{25}Al$(p,\gamma)^{26}$Si reaction. Resonance reactions through 0^+, 1^+, and 3^+ are shown as well as the direct component DC. Contribution by the 3^+ is dominant at high temperature.

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Accelerated Evolution of the Lyα Luminosity Function at $z \gtrsim 7$ Revealed by the Subaru Ultra-Deep Survey

KONNO, Akira, OUCHI, Masami, ONO, Yoshiaki, SHIMASAKU, Kazuhiro, SHIBUYA, Takatoshi
(University of Tokyo)

FURUSAWA, Hisanori
(NAOJ)

NAKAJIMA, Kimihiko
(Observatoire de Geneve)

NAITO, Yoshiaki, MOMOSE, Rieko, YUMA, Suraphong
(University of Tokyo)

IYE, Masanori
(NAOJ)

Cosmic reionization is an event where protons and electrons being combined at $z \sim 1100$ were reionized. Lyα photons emitted from Lyα emitters (LAEs) at the epoch of reionization ($z \gtrsim 6$) would be attenuated by the neutral hydrogen (HI) in the intergalactic medium (IGM) around the LAEs. Therefore, evolution of the Lyα luminosity function (LF) is used as a probe of cosmic reionization. In previous studies, whether or not the Lyα LF evolves from $z = 6.6$ is debated [1,2]. Observations for $z \sim 7.3$ LAEs with Subaru telescope have also been conducted [3]. However, they cannot clearly conclude whether the Lyα LF evolves from $z = 6.6$ to ~ 7.3 due to the relatively shallow imaging that just reaches the bright Lyα luminosity limit of $L(\mathrm{Ly}\alpha) \sim 1.0 \times 10^{43}$ erg s^{-1}.

To solve the debate, one needs to detect a number of $z = 7.3$ LAEs down to the Lyα luminosity limit comparable to those of $z = 6.6$ LAE samples, and to derive the Lyα LF at $z = 7.3$ with a good accuracy. We have developed a new custom narrowband filter, *NB101*, to detect faint LAEs at $z = 7.3$. Since our *NB101* has a significantly narrower/sharper FWHM than filters used in the previous Subaru $z \sim 7.3$ surveys, *NB101* is more sensitive to an emission line than these filters. Using Subaru/Suprime-Cam with our *NB101*, we have observed SXDS and COSMOS fields (~ 0.5 deg^2) with a total integration time of 106 hr, which is one of the longest ever performed at Subaru telescope. We have reached a limiting luminosity of $L(\mathrm{Ly}\alpha) = 2.4 \times 10^{42}$ erg s^{-1}, which is about four times deeper than those achieved by the previous Subaru studies for $z \sim 7.3$ LAEs and comparable to the luminosity limits of previous Subaru $z = 3 - 6$ LAE surveys. Our observations allow us to derive the Lyα LF at $z = 7.3$ with an unprecedented accuracy.

We identify in total of seven LAEs at $z = 7.3$ (Fig. 1) and conclude that the Lyα LF decreases from $z = 6.6$ to 7.3 at the >90 % confidence level [4]. Moreover, by calculating the Lyα luminosity densities, we find a rapid decrease of the Lyα LF at $z \sim 7$ for the first time (Fig. 2). Because no such accelerated evolution of the ultraviolet (UV) LF or the cosmic star formation rate (SFR) is found at $z \sim 7$, this accelerated Lyα LF evolution is explained by physical mechanisms different from a pure SFR decrease [4]. By the comparison of simple theoretical models, we estimate the HI fraction, x_{HI}, of IGM at $z = 7.3$. However, because there is a possible tension between our x_{HI} estimate and the measurements of Thomson scattering optical depth of cosmic microwave background, the accelerated Lyα LF evolution cannot be explained by a simple scenario of rapid increase of x_{HI} [4]. These results may support new physical pictures suggested by recent theoretical studies, such as the existence of HI clouds within cosmic ionized bubbles [5]. We refer the reader to our published paper [4] for more details.

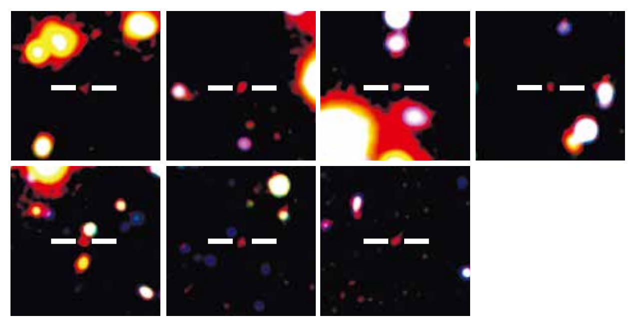

Figure 1: Color composite images of $z = 7.3$ LAEs found in the *NB101* ultra-deep imaging survey [6].

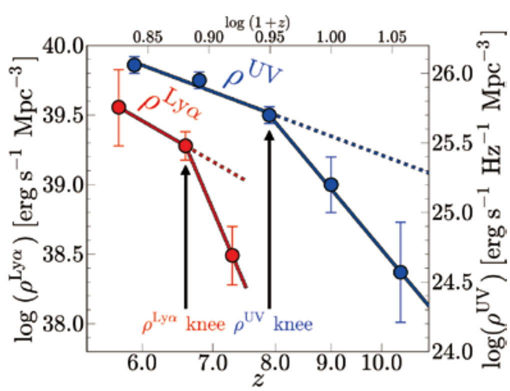

Figure 2: Evolution of Lyα (red) and UV (blue) luminosity densities [4]. The evolution of Lyα luminosity density is accelerated at $z \gtrsim 7$, while the UV luminosity density rapidly decreases at $z \gtrsim 8$.

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Opacity of Fluffy Dust Aggregates

KATAOKA, Akimasa
(SOKENDAI/NAOJ)

OKUZUMI, Satoshi
(Tokyo Institute of Technology)

TANAKA, Hidekazu
(Hokkaido University)

NOMURA, Hideko
(Tokyo Institute of Technology)

Planetesimals are believed to form by coagulation of dust grains in protoplanetary disks [1]. How micron-sized dust grains grow to kilometer-sized planetesimals has been an unsolved problem toward the complete planet formation theory; the intermediate-sized bodies have been believed to be poorly sticky, easily disrupted by collisions, or to quickly fall onto the central star.

On the other hand, observations on protoplanetary disks have put a constraints on planet formation theory. The sub-mm emission of the disk carries information of dust grains in protoplanetary disks because the emission is believed to be optically thin and thus it directly reflects the opacity of dust grains. In addition to SMA or CARMA, the launch of ALMA enables us to investigate even the spatial distribution of dust grains in protoplanetary disks. The proposed planetesimal formation theory should be tested by observations.

The recent study has shown that dust grains coagulate in protoplanetary disks to form fluffy aggregates. Theoretical studies have shown that the internal density of dust aggregates is expected to be as small as 10^{-4} g cm^{-3} [2]. Disk observations, on the other hand, are interpreted as the emission from compact grains. The emission may come from fluffy aggregates. Therefore, the previous observations should be reinterpreted with highly porous aggregates instead of compact grains. As a first step, in this paper, we investigate the optical properties of such highly porous aggregates.

Figure 1 shows the main result of the paper [3]. If the dust aggregates have a radius a and the filling factor f, the absorption opacity $\kappa_{\rm abs}$ does not change if the product af has a constant value. Figure 1 shows the case of af = 1 mm (see the paper [3] for physical understanding).

This result suggests that the sub-mm emission of protoplanetary disks might not be from millimeter-sized compact grains but from fluffy dust aggregates that have 10 meter in size and 10^{-4} in filling factor. We also proposed a way to distinguish between compact grains and porous dust aggregates with spatial distribution of spectral index of the sub-mm emission of protoplanetary disks. It requires a high spatial resolution and a high sensitivity, which is achievable with ALMA. In near future, therefore, ALMA observations is expected to reveal whether there are fluffy dust aggregates in protoplanetary disks.

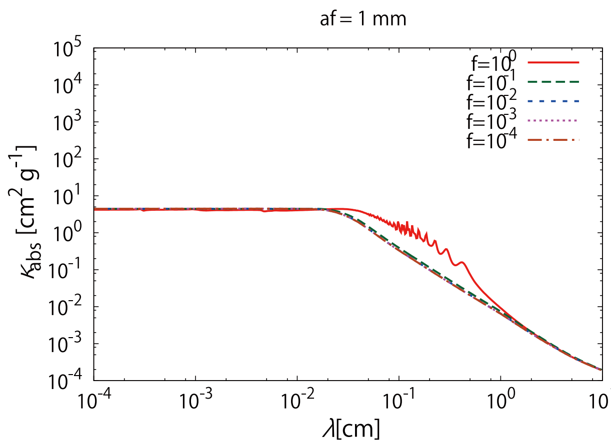

Figure 1: This figure represents $\kappa_{\rm abs}$ [cm^2 g^{-1}] in the case of af = 1 mm. Each line shows the cases of the filling factor of f = 1, 10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}.

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Survey Observations of Geosynchronous Orbit Objects and Short-Term Variability Observations Using the Time-Delay Integration Method

OKUMURA, Shin-ichiro (Japan Spaceguard Association/NAOJ)
YANAGISAWA, Toshifumi (JAXA)
NAKAYA, Hidehiko (NAOJ)
TANAKA, Wataru (Japan Space Forum)
NISHIYAMA, Kota, TAKAHASHI, Noritsugu (Japan Spaceguard Association)
YOSHIKAWA, Makoto (JAXA/ISAS)

The "Time-Delay Integration (TDI)" method is an electronic scan technique which captures the image of a moving object across the field of view. In this case an exposure is made by shifting electrical charge while a mechanical shutter is open. To make the electronic scan, the CCD parallel registers (the CCD columns) are precisely oriented in the direction of the moving object and the clocking rate of parallel charge transfer must be synchronized to the motion of the object. In its simplest use in astronomy, the parallel transfer rate is tuned to sidereal rate, so that the charge is moving across the CCD at the same rate as the sky moving across the field of view, when the telescope tracking is turned off. This technique was used to perform the Sloan Digital Sky Survey [1] and many other digital sky surveys.

In contrast to this method, the TDI technique can be applied backwards in case of detecting geosynchronous Earth orbit objects [2,3]. In this manner, the CCD chip is aligned such that its parallel registers are oriented in the East-West direction but turned 180°. The telescope tracks at sidereal rate and the charge on the CCD is shifted in reverse, also at the sidereal rate. The two sidereal rates cancelled each other and the effect of Earth rotation is removed.

To synchronize the parallel charge transfer rate to the motion of the object, charge transfer timing can be set by editing a clock pattern description file. For an object drifting northward or southward, its drift motion can be canceled by adjusting the mount position angle of the CCD, e.g., by using the mechanical Cassegrain instrument rotator [3].

We also propose a new application method of getting short-term light curves with TDI mode. When the stationary object is observed in TDI mode, it is imaged as a streak. The light curve is easy to extract from the streak, because the streak is sure to be horizontal. We applied this technique to observe short-term light curves of space debris, with the telescope drive at the "track rate" (object-tracking) mode [3].

Figure 1 shows an example of the extraction of the light curve of a geosynchronous object. Light curves of the reference stars can also be extracted from the image and used to correct the short-term variation in atmospheric conditions. The time resolution can be adjusted suitably according to the brightness and the variable period of the object. This method of detecting a short-term variability can be applied for a variety of objects such as stars, solar system bodies, geosynchronous orbit objects, and low Earth orbit objects. It can also be used for the light-curve observations of transient objects which might show short-term variability and of which the precise time information is needed.

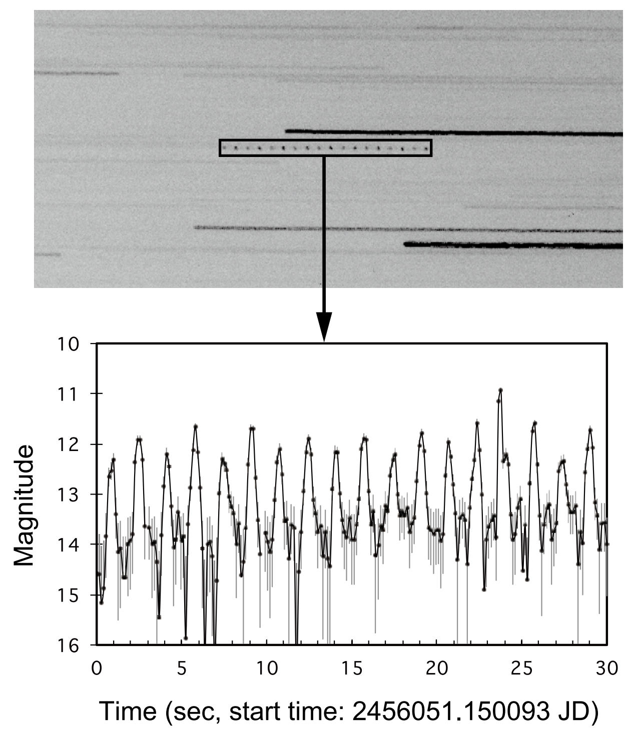

Figure 1: Example of the extraction of the light curve of a geosynchronous object. Upper: close-up of a TDI image obtained with a 30-s exposure, lower: light curve of the object, extracted from the upper image. Sampling interval is 0.14 sec.

References

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Statistical Analysis of Current Helicity and Twist in Solar Active Regions over the Phases of the Solar Cycle Using the Spectro-Polarimeter Data of Hinode

OTSUJI, Kenichi, SAKURAI, Takashi
(NAOJ)

KUZANYAN, Kirill
(IZMIRAN)

Magnetic flux tubes in the solar convection layer emerge to the surface and form sunspots and emerging flux regions. The active regions including sunspots have magnetic fields exceeding 3000 G and produce many active phenomena. The magnetic field in an active region can be twisted by the solar dynamo process when it is generated, or by the interaction with the convection motion during its ascent from the bottom of the convection zone. To measure the twist of the field, the current helicity was introduced. The current helicity is derived from vector magnetic field components at the solar surface, i.e. photosphere. The line-of-sight (z) component of current helicity H_{Cz} is,

$$H_{Cz} = \langle B_z J_z \rangle , \qquad J_z = \frac{dB_y}{dx} - \frac{dB_x}{dy}. \qquad (1)$$

where $\langle \cdots \rangle$ represents the spatial averaging, x and y are solar east-west and north-south directions, respectively. From the definition, the right/left-handed helical field lines are characterized by positive/negative current helicity. The preceding studies found a tendency that the negative/positive helicity is dominant in the northern/southern hemisphere. The data used for these studies are, however, obtained from the ground-based observations, which suffered from the atmospheric seeing effect and so on.

We have carried out a statistical study on the current helicity of solar active regions observed with the Spectro-Polarimeter (SP) of Hinode Solar Optical Telescope (SOT). We used SOT-SP data of 558 vector magnetograms of a total of 80 active regions obtained from 2006 to 2012. This period covers from the end of the solar cycle-23 to the middle of cycle-24. To avoid the projection effect, we excluded the data obtained near the solar limb. We divided the area of an active region into weak (<300 G) and strong (300~1000 G) field ranges to compare the contributions from different field strengths. Figure 1 shows the time-latitude diagram of current helicity calculated for individial active regions. The color and size of the circles indicate the sign and magnitude of current helicity.

The result of weak field area shows the same distribution of current helicity as the preceding studies. On the other hand, the strong field area shows the opposite dependency, i.e. positive current helicity in the northern hemisphere and negative in the south. This opposite natures may come from the difference of the origins of strong and weak magnetic fields. To investigate more detailed and long period variations of the current helicity on active regions, a larger statistical analysis using SOT/SP data up to the current date (~2015) is now ongoing.

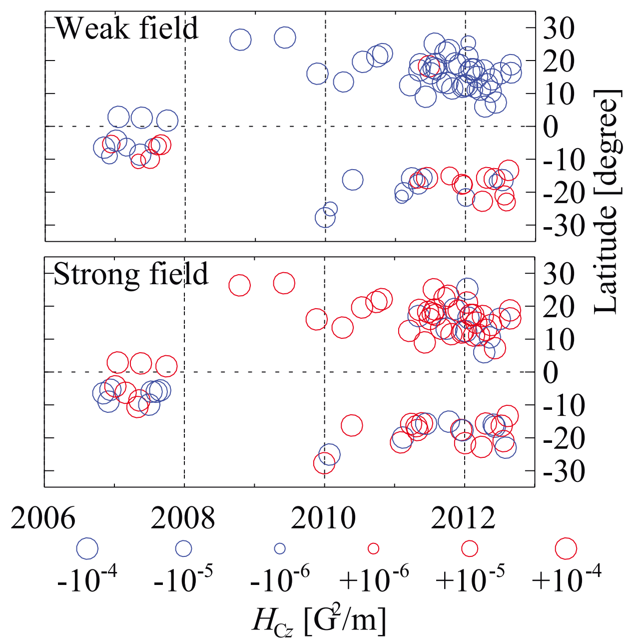

Figure 1: The temporal-latitude diagram of current helicity for every active regions observed by SOT/SP from 2006 to 2012. The upper/lower image represents the result of the area with weak (<300 G)/strong (300~1000 G) field range, respectively.

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Developments of Wide Field Millimeter/Submillimeter Instruments

SEKIMOTO, Y., NOGUCHI, T., KARATSU, K., NITTA, T.*, MATSUO, H., DOMINJON, A.
OKADA, N., MITSUI, K., TSUZUKI, T.
(NAOJ)

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

NARUSE, M.
(Saitama University)

MKID (Microwave Kinetic Inductance Detector) group of Advanced Technology Center is developing superconductive camera in millimeter and submillimeter wavelengthes for Antarctica terahertz telescope which observes distant galaxies with a wide field of view and for LiteBIRD which detects CMB B-mode polarization in collaboration with University of Tsukuba, Saitama University, KEK, and Riken. We reported four papers with a theme of wide field of view millimter/submillimeter instruments in 2014 fiscal year.

1. Wide Field 0.1 K Cryosytem [1]

MKID camera which is a new technology (P. Day et al. 2003) is a Cooper pair breaking detector. Superconducting resonators in MKID sense surface impedance variations owing to quasi-particles generate by incoming photons. It is necessary to cool MKID to1/7 of the superconducting critical temperature (T_c). We have developed a compact 0.1 K cryosystem (Fig. 1) with a dilution refrigerator by Taiyo Nissan Co. As a result, an MKID detector of T_c = 700 mK can be operated in this cryostat, which can detect photons of higher frequencies than 50 GHz. The key to the wide field of view is a large diameter silicon lens and its anti-reflection coating. Moreover, nested reflective baffles reduce stray lights.

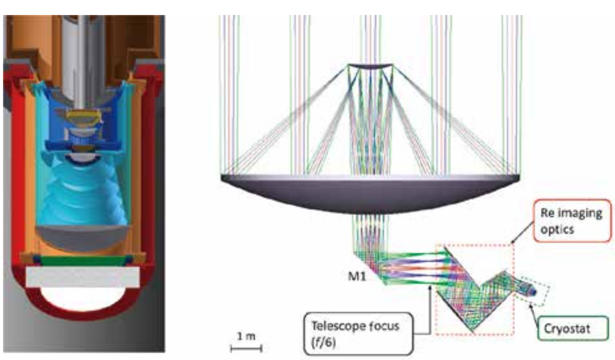

Figure 1: Compact 0.1 K cryosystem [1] and wide FoV (1.0 degree) terahertz optics [2].

2. Wide Field Terahertz Optics [2]

A wide field of view (FoV) optics with a main observation frequency 0.85 THz of Antarctica 10 m terahertz telescope has been designed (Figure 1). It relays from a F #6 Nasmyth focus to a F #1 detector focus with four reflective mirrors and one cooling refractive. The free-forming surface is used for the mirrors to expand the FoV. The cooling lens is an alumina lens of 60 cm in the diameter. Wide FoV survey at terahertz is realized by combining 20000 pixels MKID camera.

3. 700 pixels Si Lens Array [3]

To detect submillimeter-waves efficiently, the camera combined a lens array with superconducting planar antenna. A 700 pixels silicon lens array was machined with a high-speed spindle (Figure 2). Moreover, a mixed epoxy anti-reflection coating [5] was applied with the same way. The thickness of the ARC is controlled with 1 % accuracy. With these technologies, superconducting cameras with high efficiency became possible.

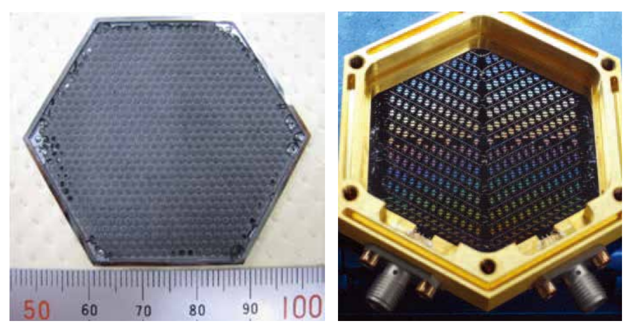

Figure 2: 700 pixels Si lens array and 220 GHz MKID camera.

4. CMB B-mode Polarization [4]

Observations of B-mode polarization of cosmic microwave background radiation (CMB) sense the inflation theory (K. Sato 1981). This paper reports MKID developments in collaboration with NAOJ, KEK, Riken. It demonstrates noise of the detector, the beam measurement, and the readout circuit. The polarization sensitivity is higher than that of BICEP2.

At ATC, we are developing broad band devices with MKIDs as well as wide FoV instruments.

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* JSPS PD fellow, from 1-Apr-2015, Univ. of Tsukuba

The Gas Inflow and Outflow Rate in Star-Forming Galaxies at $z \sim 1.4$

YABE, Kiyoto* (University of Tokyo/Kavli IPMU)
OHTA, Kouji (Kyoto University)
AKIYAMA, Masayuki (Tohoku University)
IWAMURO, Fumihide (Kyoto University)
TAMURA, Naoyuki (University of Tokyo/Kavli IPMU)
YUMA, Suraphong (University of Tokyo/ICRR)
DALTON, Gavin, LEWIS, Ian (Oxford University)

The gas flow into and out of galaxies have a significant impact on the formation and evolution of galaxies. The outflow of enriched gas causes the decrease of the gas metallicity (hereafter metallicity) of galaxies and results in a presence of the stellar mass-metallicity relation of galaxies. Feedback from outflows plays an important role for the star-formation activity and the structure formation of a galaxy. On the other hand, the inflow of gas into galaxies is relatively difficult to observe. In this work, we try to constrain the gas inflow and outflow rate of star-forming galaxies at $z \sim 1.4$ by employing a simple analytic model for the chemical evolution of galaxies. The sample is constructed based on a large near-infrared (NIR) spectroscopic sample observed with Subaru/FMOS [1].

The sample used in this work is originated from the K-band selected galaxy sample in the Subaru XMM-Newton Deep Survey and UKIDSS Ultra Deep Survey field (SXDS/UDS). We selected galaxies with $K \leq 23.9$ mag, phot-z of $1.2 \leq z_{ph} \leq 1.6$, the stellar mass of $M_* \geq 10^{9.5}\,\mathrm{M}_\odot$, and the expected H$\alpha$ flux of $F(\mathrm{H}\alpha) \geq 5\times10^{-17}$ erg s^{-1} cm^{-2}. During the FMOS/GTOs, engineering runs, and open-use observations, ~1200 objects were observed by using FMOS with low resolution mode with the typical on-source exposure time of 3 – 4 hours. In total, significant Hα emission lines with signal-to noise ratio (S/N) ≥ 3 are detected from 343 objects [2,3].

The metallicity is derived from the [N II] λ6584/Hα emission line ratio. We use the calibration of N2 method [4]. The resulting metallicity ranges widely from ~0.3 to ~1.4 $\mathrm{Z}_\odot$. The gas mass is estimated from the observed Hα luminosity by assuming the Kennicutt-Schmidt (K-S) law [5], where the SFR surface density (Σ_{SFR}) is calculated from the intrinsic Hα luminosity corrected for the dust extinction and r_{50} derived from the image in B-band as the galaxy size. The gas mass fraction (μ) is defined as $\mu = M_{gas}/(M_* + M_{gas})$, where M_{gas} and M_* are gas mass and stellar mass, respectively. The resulting gas mass fraction is widely distributed from ~0.2 to ~0.8 with the median value of 0.47.

We employ the least-χ^2 fittings for the observed gas mass fraction, stellar mass, and metallicity with a simple analytic model of chemical evolution of galaxies:

$$Z = \frac{y_Z}{f_i}\,\{1 - [(f_i - f_o) - (f_i - f_o - 1)\mu^{-1}]^{\frac{f_i}{f_i - f_o - 1}}\}, \quad (1)$$

where y_Z is a true yield, and f_i and f_o are infall and outflow rate which are normalized by the SFR, respectively, and

$$\mu = \frac{M^0_{gas} + (f_i - f_o - 1)M_*}{M^0_{gas} + (f_i - f_o)M_*}, \quad (2)$$

where M^0_{gas} is the initial primordial gas mass. The joint χ^2 fitting shows the best-fit inflow rate is ~1.8 and the outflow rate is ~0.6 in unit of star-formation rate (SFR).

By applying the same analysis to the previous studies at $z \sim 0$ and $z \sim 2.2$, it is shown that the both inflow rate and outflow rate decrease with decreasing redshift, which implies the higher activity of gas flow process at higher redshift. The decreasing trend of the inflow rate from $z \sim 2.2$ to $z \sim 0$ agrees with that seen in the previous observational and theoretical works with different methods, though the absolute value is generally larger than the previous works. The outflow rate and its evolution from $z \sim 2.2$ to $z \sim 0$ obtained in this work agree well with the independent estimations in the previous observational works.

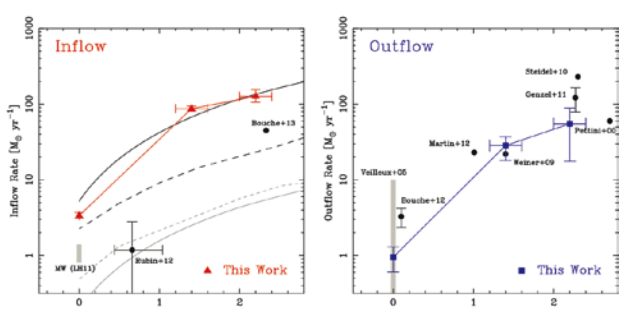

Figure 1: The best-fit inflow rate (left) and outflow rate (right) in unit of $\mathrm{M}_\odot\,\mathrm{yr}^{-1}$ as a function of redshift. The results are compared to the previous results at various redshifts in theoretical and observational works.

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Enhancement of CO(3–2)/CO(1–0) Ratios and Star Formation Efficiencies in Supergiant HII Regions

MIURA, Rie E.[1/2], KOHNO, Kotaro[3/4], TOSAKI ,Tomoka[5], ESPADA, Daniel[1/6/7], HIROTA, Akihiko[1]
KOMUGI, Shinya[1], OKUMURA, Sachiko K.[8], KUNO, Nario[1/7], MURAOKA, Kazuyuki[9]
ONODERA, Sachiko[10], NAKANISHI, Kouichiro[1/6/7], SAWADA, Tsuyoshi[1/6], KANEKO, Hiroyuki[1/7/11]
MINAMIDANI, Tetsuhiro[1], FUJII, Kosuke[1/2], KAWABE, Ryohei[1/6]

1: NAOJ, 2: University of Tokyo, 3: Institute of Astronomy, 4: Research centre for Early Universe, 5: Joetsu University of Education, 6: Joint ALMA Observatory, 7: Graduate University for Advanced Studies, 8: Japan Woman's University 9: Osaka Prefecture University, 10: Meisei University, 11: University of Tsukuba

Based on wide-field and high-sensitivity (1σ = 16−32 mK in $T_{\rm mb}$ for a velocity resolution of 2.5 km s^{-1}) CO(J=3−2) observations with a spatial resolution of 100 pc using the ASTE 10 m telescope [1], we present evidence that super giant HII regions (GHRs) and other disk regions of the nearby spiral galaxy, M33, occupy distinct locations in the correlation between molecular gas, $\Sigma_{\rm H_2}$, and the star formation rate surface density, $\Sigma_{\rm SFR}$ [2]. Star formation efficiencies (SFEs), defined as $\Sigma_{\rm SFR}/\Sigma_{\rm H_2}$, in GHRs are found to be ~1 dex higher than in other disk regions (Fig. 1). The CO(3−2)/CO(1−0) integrated intensity ratio, $R_{3-2/1-0}$, is also higher than the average over the disk (Fig. 2). Such high SFEs and $R_{3-2/1-0}$ can reach the values found in starburst galaxies, which suggests that GHRs may be the elements building up a larger-scale starburst region. Three possible contributions to high SFEs in GHRs are investigated: (1) the $I_{\rm CO}$-N(H_2) conversion factor, (2) the dense gas fraction traced by $R_{3-2/1-0}$, and (3) the initial mass function (IMF). We conclude that these starburst-like properties in GHRs can be interpreted by a combination of both a top-heavy IMF and a high dense gas fraction, but not by changes in the $I_{\rm CO}$-N(H_2) conversion factor. We suggest a scenario that the parental molecular gas would tend to get denser in the accumulated gas around the first generation stars, while rapidly consumed by SF, eroded, and dissipated due to more massive stars in GHRs. This results in high SFE and densities.

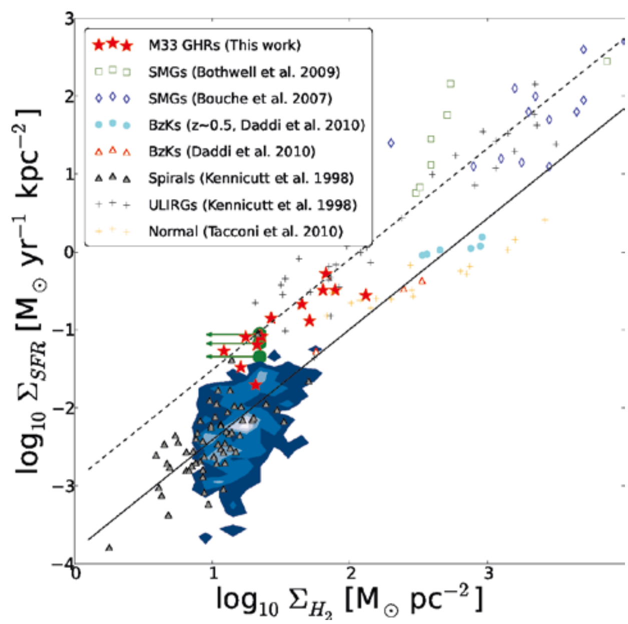

Figure 1: SFR vs. molecular gas surface densities for GHRs (red filled stars, NGC 604 and NGC 595) and for non-GHRs (blue filled contour) in M33, compared with that of other galaxies from [3] (and references therein).

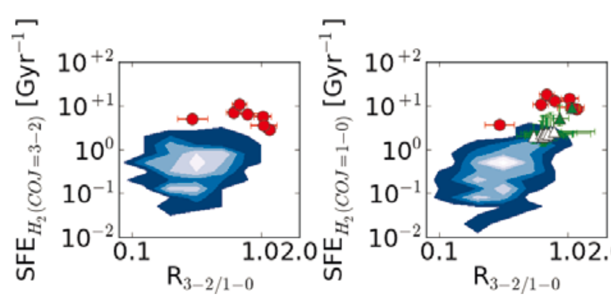

Figure 2: Plot of the $R_{3\text{-}2/1\text{-}0}$ vs. SFE$_{\rm H_2\,(CO\,J=3-2)}$ (left) and SFE$_{\rm H_2\,(CO\,J=1-0)}$ (right). Data for GHRs are shown as red points, while that for non-GHRs as blue contours. The data points in several annuli of starburst galaxy M83 are shown as green filled (unfilled) triangles, representing the centre (disk).

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Witness of Gas Infall and Outflow in the Young Starburst Dwarf Galaxy NGC 5253

MIURA, Rie E.[1], ESPADA, Daniel[1/2/3], SUGAI, Hajime[4], NAKANISHI, Kouichiro[1/2/3], HIROTA, Akihiko[1/2]

1: NAOJ, 2: Joint ALMA Observatory, 3: Sokendai University, 4: Kavli Institute for the Physics and Mathematics of the Universe

The nearest (d=3.8 Mpc) young nuclear starburst, NGC 5253, is arguably the best laboratory for understanding the star-formation process at the very early stage of a starburst. NGC 5253 is a compact blue dwarf galaxy, hosting several young clusters with ages ranging between <2.5–50 Myr and experiencing a few bursts in a short period. In the center of the galaxy, there is a deeply embedded radio compact (1–2 pc size) HII region excited by 4700 O stars. It is powered by two massive ($\sim 3 \times 10^6 M_\odot$) and young (~3.5 Myr) super stellar clusters (SSCs) separated by 0″.3 (correponding to ~6 pc).

We present ^{12}CO(2–1) observations towards the dwarf galaxy NGC 5253 using the Submillimeter Array (Fig. 1; [1]). The data shows that a large amount of molecular gas is located in the central ~200 pc starburst region, physically associated with two young super stellar clusters (SSCs). The molecular gas traced by ^{12}CO(2–1) is elongated along the minor axis (dust lane) of the galaxy and its kinematics suggest that there is an inflow of molecular gas to the direction of the central SSCs, as is also observed in HI gas at a larger scale. Due to their correlation in spatial and velocity domains, the central SSCs were likely formed from molecular gas in the nucleus. We compare the ^{12}CO(2–1) with available H_2 1–0 S(1) data, and show that while the relatively cold gas traced by ^{12}CO(2–1) is distributed along the dust lane, the warm gas traced by H_2 1–0 S(1) is associated with the central HII region and other star-forming regions. Interestingly, a cavity in the H_2 1–0 S(1) emission is found to be spatially correlated with a Hα shell. This Hα shell may trace a bipolar outflow from the central SSCs and the H_2 1–0 S(1) gas the shocked gas by the outflow encountering the surrounding quiescent gas. We calculate molecular gas inflow rate of $\sim 2\,M_\odot\,\mathrm{yr}^{-1}$, star formation rate of 0.3–$0.5\,M_\odot\,\mathrm{yr}^{-1}$, and an ionized gas outflow being emitted from the SSCs with a rate of $(5$–$25)\times10^{-3}\,M_\odot\,\mathrm{yr}^{-1}$.

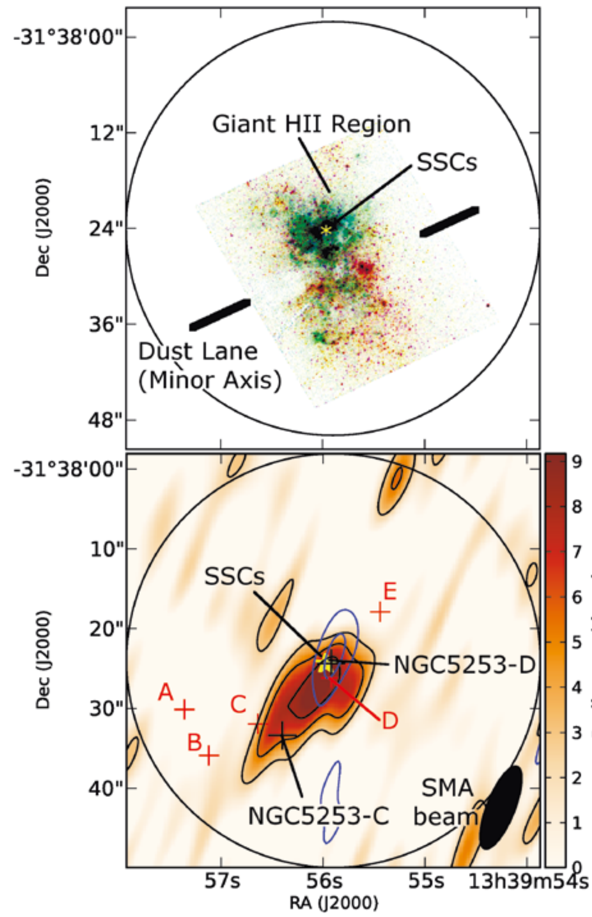

Figure 1: Top) The three-color composite image of *HST/ACS F300W* (blue), *F658N* (Hα; green), and *F814W* (red) images. The field of view of the SMA observations is shown as a circle. Bottom) The SMA CO(2–1) map of NGC 5253 in color scale and black contour. The blue contours correspond to the 230 GHz continuum emission. The yellow star corresponds to the two massive and young SSCs. The black crosses are the two identified giant molecular clouds in this study. The synthesized beam size of the SMA observations is shown at the right bottom corner.

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Unresolved Mixed Polarity Magnetic Fields at Flux Cancellation Site in Solar Photosphere at 0″.3 Spatial Resolution

KUBO, Masahito (NAOJ)

LOW, Boon Chye, LITES, Bruce W. (High Altitude Observatory)

Mutual disappearance of opposite-polarity magnetic elements from the solar surface following their apparent "collisions" are often observed in line-of-sight magnetograms. This phenomenon is called "magnetic flux cancellation". The study of magnetic flux cancellation is important for understanding the nature of the flux removal process from the solar surface layers. Five flux cancellation events at granular scales were investigated with the vector magnetic field measurements at high spatial resoluiton by *Hinode* spectropolarimeter, and the horizontal magnetic fields between the canceling opposite-polarity magnetic elements were detected in only one event that takes place in a small emerging flux region [1]. This finding is interesting since almost all theoretical scenarios proposed to explain photospheric flux cancellation expect an increase in the horizontal magnetic field between the canceling opposite-polarity magnetic elements.

We investigate circular polarization (Stokes *V*) profiles at the polarity inversion line (PIL) formed by canceling opposite-polarity magnetic elements (Figure 1) [2]. This cancellation event was located just outside an active region NOAA 10944 on 2007 March 2 and its temporal evolution was investigated in Ref [1]. The *Hinode* spectropolarimeter provides the Stokes profiles with a 0″.15 slit width and a 0″.16 pixel sampling along the slit. A highly asymmetric, strongly redshifted Stokes *V* profile in the Fe I 630.25 nm line is observed at the PIL (Figure 2*b*). The observed anomalous Stokes *V* profile is reproduced successfully by a simple summation of the nearly symmetric Stokes *V* profiles observed at pixels immediately adjacent to the PIL, as shown by the diamond symbols in Figure 2*b*. Similar results are obtained at the neighboring pixel along the PIL (Figure 2*d*) or obtained for Fe I 630.15 nm line. This result suggests that the anomalous Stokes *V* profiles observed at the PIL are not indications of a flux removal process, but are the result of a mixture of unresolved, opposite-polarity magnetic fields at an estimated resolution element of about 0″.3. The hitherto undetected flux removal process accounting for the larger-scale disappearance of magnetic elements during the observing period is likely to also fall below resolution.

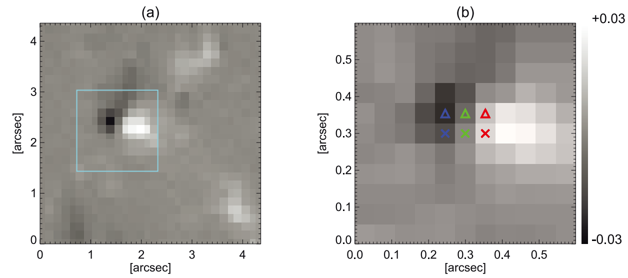

Figure 1: Total circular polarization map for the whole flux cancellation region (panel *a*), and for the canceling magnetic bipole (panel *b*). The solid box of panel *a* is identical to the field of view of panel *b*. The green symbols in panel *b* represent pixels at the polarity inversion line. The blue and red symbols represent pixels next to the polarity inversion line, and they have negative and positive magnetic polarity, respectively.

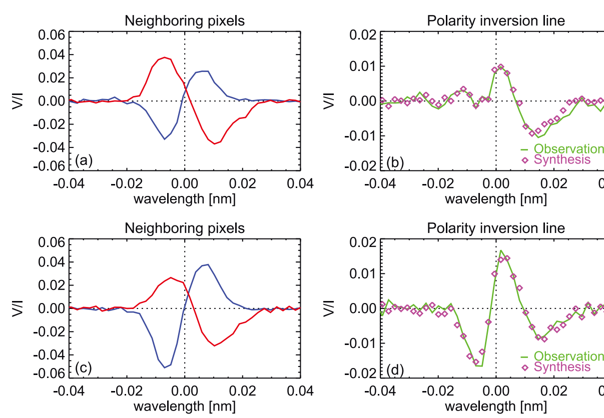

Figure 2: The red and blue solid lines in panel *a* and the green line in panel *b* represent the observed Stokes *V* profiles of the Fe I 630.25 nm line at pixels represented by red, blue, green cross symbols in panel *b* of Figure 1, respectively. The diamond symbols in panel *b* show the profile synthesized from the observed red and blue profiles in panel *a*. Panels *c* and *d* are same as their upper panels, but for the pixels represented by the triangle symbols in panel *b* of Figure 1. The vertical dotted line represents the averaged position of the line centers over the map.

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The First Very Long Baseline Interferometry Image of a 44 GHz Methanol Maser with the KVN and VERA Array (KaVA)

MATSUMOTO, Naoko (NAOJ)
HIROTA, Tomoya (SOKENDAI/NAOJ)
SUGIYAMA, Koichiro (Ibaraki University)
KIM, Kee-Tae, KIM, Mikyoung (KASI)
KaVA SFR group members

We obtained a first VLBI image of a 44 GHz class I methanol maser with KaVA (KVN and VERA Array), which is a newly combined array of KVN (Korean VLBI Network) and VERA (VLBI Exploration of Radio Astrometry) (Figure 1) [1].

The imaged 44 GHz methanol maser is associated with a millimeter core MM2 in a massive star-forming region IRAS 18151–1208. The distance of this source is estimated to be 3 kpc [2]. This 44 GHz methanol maser source was newly detected in the course of KVN single-dish survey as one of the brightest source with a total flux density of about 500 Jy [3].

The absolute positions of the maser component with $v_{\rm LSR}$ = 29.4 km s^{-1} is derived to be $\alpha_{J2000.0}$ = $18^h17^m49.^s95$, $\delta_{J2000.0} = -12°08'06.5''$ with the error of ~ 20″ from a fringe-rate mapping in our VLBI data [1]. This result suggest that the maser components detected in our observation are associated with a region around the younger millimeter core MM2 than MM1 [5] which is pre-UC HII region [4].

The compact maser components were detected with the synthesized beam size of 2.7 milliarcseconds × 1.5 milliarcseconds (mas) [1]. Minimum size in the maser components is ~ 5 mas × 2 mas, corresponding to the linear size of ~ 15 AU × 6 AU at the distance of 3 kpc. Brightness temperature of the maser components ranges ~ $3.5 \times 10^8 - 1.0 \times 10^{10}$ K. These values are higher than a lower limit of 10^8 K estimated with the previous highest spacial resolution image with ~ 50 mas observed with Very Large Array (VLA).

This VLBI observation for 44 GHz methanol maser would be expected to be powerful tool to obtain accurate positions and proper motions to identify maser pumping sources.

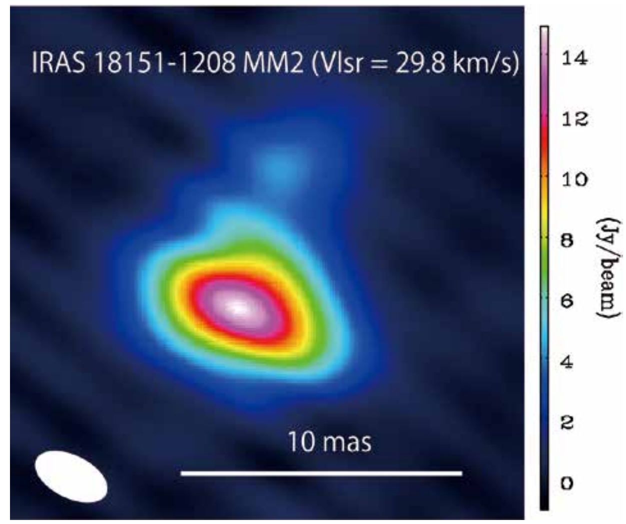

Figure 1: An intensity map of a 44 GHz methanol-maser component of $v_{\rm LSR}$ = 29.8 km s^{-1} associated with IRAS 18151–1208 MM2. Synthesized beam is shown in the bottom-left corner.

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Torus-Fitting Method in Two-Dimensional Galactic Potentials

YANO, Taihei (NAOJ) UEDA, Haruhiko (Akita University) HARA, Takuji (University of Tokyo) GOUDA, Naoteru (NAOJ)

A new method called a torus-fitting method (hereafter TF method), by which a generating function is derived numerically for models of the Galactic potential in which almost all orbits are regular is proposed. We found that the TF method can be applied to major orbit families (box and loop orbits) in some two-dimensional potentials. Furthermore, the TF method is still applicable to resonant orbit families. Hence, the TF method is useful for analysing real Galactic systems in which a lot of resonant orbit families might exist [1].

The surface of section (x, px) with y = 0 in the logarithmic potential with q = 0.9 and Rc = 0.14 is shown in Fig. 1. The solid curves represent the target tori derived by the direct calculation of the orbits of five test particles. The plus symbols show the reconstructed target tori by use of the TF method. We find that the reconstructed tori correspond very well to the tori derived directly from the orbits. It proves that the TF method works very well for major orbits. Furthermore, the square symbols represent the target tori derived by the TF method in which the generating functions are estimated by the interpolation technique. The interpolation also works very well for major orbits.

We aply this mehod also for minor orbits. The brief procedure for the minor orbit is as follows. Illustration of the resonant torus and the additional curve is shown at left in Fig. 2. The resonant torus can be reconstructed by the two pseudotori. One of the pseudo-tori consists of the additional curve (except for the additional curve inside the resonant tours) and the upper part of the resonant torus as shown at upper right. Another one consists of the additional curve (except the additional curve inside the resonant tours) and the lower part of the resonant torus as shown at lower right. We can reconstruct the minor orbit using these two pseudo-tori.

The surface of section (x, px) with y = 0 in the logarithmic potential with q = 0.6 and Rc = 0.14 is shown in Fig. 3. The solid lines represent the target tori derived by the numerical calculation of the orbits of test particles. The plus symbols show the reconstructed target tori containing resonant tori reconstructed using the above procedure. This shows that the TF method works very well also for minor orbits.

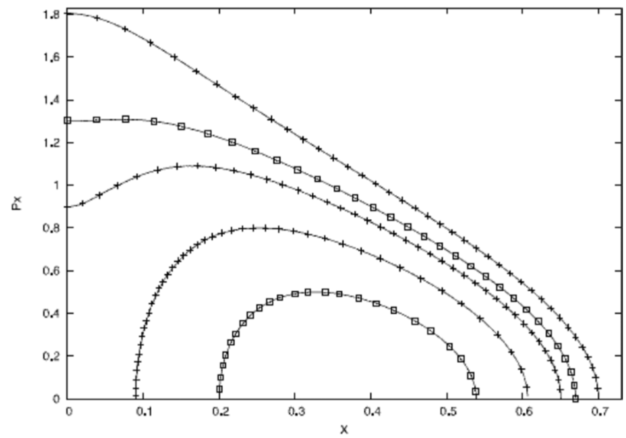

Figure 1: The surface of section (x, px) with y = 0 in the logarithmic potential. Solid lines represent the target tori derived by the numerical calculations. The plus symbols show the reconstructed target tori. The square symbols represent the target tori using the interpolation technique.

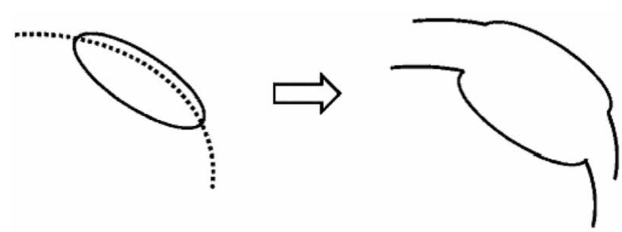

Figure 2: Method to aply for the minor orbit.

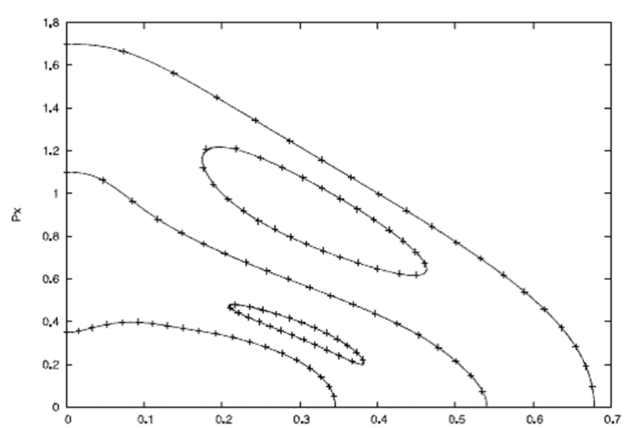

Figure 3: Application of the torus fitting method to the minor orbit.

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Discovery of Star Formation in the Extreme Outer Galaxy Possibly Induced by a High-Velocity Cloud Impact [1]

IZUMI, Natsuko, KOBAYASHI, Naoto, YASUI, Chikako, HAMANO, Satoshi
(University of Tokyo)

TOKUNAGA, Alan T.
(University of Hawaii)

SAITO, Masao
(NAOJ/SOKENDAI)

The extreme outer galaxy (EOG), which we define as the region with a Galactocentric radius (R_G) of more than 18 kpc [2], has a very different environment from the solar neighborhood with a much lower gas density (< 1/10) [3], lower metallicity (~1/10) [4], and little or no perturbation from the spiral arms. Such a region not only defines the size and shape of our Galaxy, but it also serves as an excellent laboratory for studying the star-forming process in low-density and low-metallicity environments. Because such environments may have similar characteristics that existed in the early phase of Galaxy formation [2], we might be able to directly observe the galaxy formation processes in unprecedented detail at a much closer distance than distant galaxies.

Digel Clouds, which are composed of eight molecular clouds (Cloud1-8), were discovered by the very first survey of molecular clouds in EOG [5]. We observed Cloud1, which has the largest dynamical mass among all of the Digel Clouds and perhaps the largest Galactocentric radius (R_G = 22 kpc; kinematic distance) among all known clouds in the Galaxy, at CO lines with NRO 45 m telescope as well as NIR wavelengths (J, H, K_S bands) with Subaru 8.2 m telescope, and discovered star forming regions (Figure 1).

Using the cluster member, we estimated the photometric distance of the clusters to be $R_G \geq 19$ kpc, which is consistent with the kinematic distance. We also derived the age of the clusters to be less than 1 Myr, using the disk fraction of the clusters, which is the percentage of cluster members with a optically thick circumstellar dust disk [6,7]. The clusters have lower star formation efficiency (~1 %) than in the solar neighborhood, which might suggest some environmental dependence.

Because of the low-density, triggered formation as opposed to spontaneous formation may play a crucial role in the EOG [8,9]. On the sky, Cloud 1 is located very close to the HI peak of high-velocity cloud (HVC). [10,11] suggested the interaction between the HVC and the Galactic disk, and there are some HI intermediate velocity structures between the HVC and the Galactic disk, which indicates an interaction between them. We suggest the possibility that the HVC impacting on the Galactic disk has triggered star formation in Cloud 1. Such process may have occurred frequently in the early phase of the formation of the Galaxy.

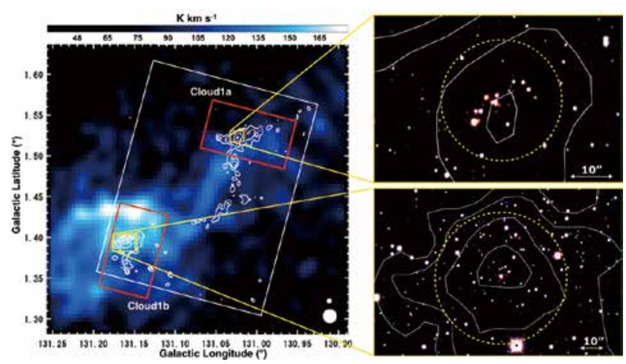

Figure 1: Left) HI map around Cloud 1 (from DRAO data: v_{LSR} = −104.5 ~ −99.6 km s^{-1}). The white contours show the integrated ^{12}CO(1–0) map of Cloud 1 (from our NRO 45 m telescope data: v_{LSR} = −104.1 ~ −99.1 km s^{-1}), and contour levels are at 2σ, 3σ, 5σ, 7σ (1σ = 0.5 K km s^{-1}). The white and red boxes show the mapping size of the NRO 45 m observation and the field of view of the Subaru (4′ × 7′; MOIRCS), respectively. The large and small white filled circles at the lower right corner show the resolution of the DRAO (~58″) and NRO 45 m telescope (~17″), respectively. Right) *JHK* pseudo color images of the Cloud 1 clusters from our Subaru data. The white contours show the same as the ^{12}CO map as in the left panel. The yellow dotted circles show the defined cluster regions (radius of Cloud 1a circle: 14″, Cloud 1b: 28″).

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Discovery of a Rich Galaxy Cluster Candidate at z = 1.52

KOYAMA, Yusei (NAOJ/JAXA)
KODAMA, Tadayuki (NAOJ)
TADAKI, Ken-ichi (MPE/NAOJ)
HAYASHI, Masao, TANAKA, Ichi (NAOJ)
SHIMAKAWA, Rhythm (GUAS)

Galaxy environment has strong impacts on galaxy properties. It is well established that high-density environments such as clusters of galaxies are dominated by red passive galaxies, whilst low-density field environments are dominated by blue star-forming galaxies [1]. Distant galaxy clusters are progenitors of local massive clusters, and therefore, they are important targets for studying how the cluster galaxies grow within high-density environments through cosmic time.

Searching distant clusters generally requires a square-degree scale huge area survey as they are rare objects. An alternative, effective way to find galaxy over densities is to investigate the field around high-z radio galaxies. High-z radio galaxies are believed to be progenitors of present-day central cluster galaxies (cD galaxies), and a number of studies have successfully reported "proto-clusters" around high-z radio galaxies (e.g. [2]).

We have completed an imaging survey of a field of the radio galaxy 4C 65.22 (z = 1.52) with Suprime-Cam and MOIRCS on the Subaru Telescope. In addition to the $Br'z'JHK_s$ broad-band photometry, we also used a narrow-band filter NB1657 on MOIRCS (λ_c = 1.657 μm) which can capture the Hα emission lines at the radio galaxy's redshift [3].

Our data revealed the large-scale distribution of galaxies around the radio galaxy as shown in Fig. 1. In this plot, the black and red symbols represent $z\sim1.5$ galaxies selected with photometric redshift technique, demonstrating a factor of > 10× over-density around the radio galaxy. In particular, the red symbols in the plot denote those having red $z' - J$ colors; they are expected to be quiescent galaxies. It is interesting to point out that the trend that such red (quiescent) galaxies are strongly clustered at the peak of galaxy distribution is qualitatively consistent with the situation in the local universe.

For those having significant excess in the NB1657 photometry, we carefully inspected their broad-band colors to identify the Hα emitters at $z\sim1.52$ (shown with the blue squares in Fig. 1). Clearly, the Hα emitters are distributed in the outskirts of the cluster core (avoiding the highest-density region), which is consistent with our similar Hα study in a $z\sim0.8$ cluster [4]. Therefore we suggest that the newly discovered structure at $z\sim1.5$ reported here is likely a rich galaxy cluster at $z \approx 1.52$.

Interestingly, our recent star-forming galaxy survey in another cluster at a similar redshift [5] reported a high fraction of star-forming galaxies within cluster core environments. Therefore our new data suggest that there is a diversity in the properties of $z\sim1.5$ clusters, and we speculate that the redshift of $z\sim1.5$ is a key epoch for understanding the cluster galaxy evolution.

By comparing the Hα emitters near the central cluster and in the outer fields, we also reported that there is no strong environmental dependence of the star formation rate (SFR) versus stellar mass ($M_\star$) relation at $z\sim1.5$, which is consistent with our recent study [6]. Our study thus demonstrates that the fraction of star-forming galaxies does change with environment (at $z\sim1.5$), but as long as we focus on star-forming galaxies, their properties are not strongly correlated with environment.

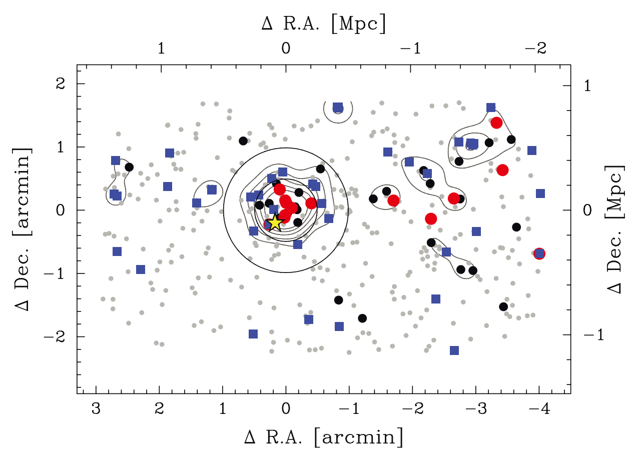

Figure 1: A 2-D map of galaxies around the 4C 65.22 radio galaxy (shown with yellow star). The photo-z selected galaxies with 1.3 < z_{phot} < 1.7 are shown with black circles (and their density shown with contours), among which red symbols show the location of red (passive) galaxies selected with z'–J colors. The blue squares show Hα emitters at z = 1.52. Two large circles show 250 and 500 kpc from the density peak.

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A Chemical Signature of First-Generation Very-Massive Stars

AOKI, W.[1], TOMINAGA, N.[2], BEERS, T. C.[3], HONDA, S.[4], LEE, Y. S.[5]

1: NAOJ, 2: Konan University, 3: University of Notre Dame, 4: University of Hyogo, 5: New Mexico State University

First-generation stars are objects formed in the early Universe from gas clouds containing only hydrogen and helium. They are the probable precursors of the formation of the Universe's structure and chemical enrichment. Recent numerical simulations suggest that a fraction of very-massive stars with masses exceeding one hundred times that of the Sun could have formed in the early Universe, even though the large majority of first stars formed with masses of ten to a hundred times that of the Sun [1]. Their strong UV radiation and energetic explosions are likely to have had a significant impact on the evolution of stellar systems.

Supernova explosions ejected elements formed by the first massive stars and dispersed them into the gas that formed the next generations of stars. Stars with masses slightly less than the Sun's have very long lifetimes enough to survive until now. The Milky Way contains such low-mass stars with low overall metal content, including the elements produced by the first massive stars. The distinctive chemical abundance patterns of these stars can be used to estimate the masses of the first stars.

High-resolution spectroscopy for low-mass stars with low metallicity determines their chemical abundances and identifies stars that recorded the abundance patterns associated with the first stars that had several tens of solar masses and produced large amounts of carbon and other light elements [2]. However, no previous research of low-mass metal-poor Milky-Way stars has found the signature of supernova explosions of very-massive stars with more than 100 solar masses, which synthesize large amounts of iron but little carbon.

Searches for such stars require larger surveys of very metal-poor stars, which was realized by the Sloan Digital Sky Survey (SDSS). We selected candidates for very metal-poor stars from the SDSS spectra, and used the High Dispersion Spectrograph mounted on the Subaru Telescope to conduct a high-resolution spectroscopic follow-up of a large sample of low-mass metal-poor stars. We discovered a star, SDSS J001820.5-093939.2 (SDSS J0018-0939), that exhibits a very peculiar set of chemical abundance ratios [3]. Whereas the star contains an amount of iron 300 times lower than the Sun's, it is significantly deficient in lighter elements such as carbon and magnesium.

Nucleosynthesis models for supernova explosions of massive stars, which successfully reproduce the abundance ratios found in most of the early-generation stars previously known, do not readily explain the chemical abundance ratios observed in the newly discovered star (Figure 1). Rather, explosion models of very-massive stars can explain both the relatively high abundance ratio of iron as well as the low abundances of lighter elements. This means that this star most likely preserves the elemental abundance ratios produced by a first-generation very-massive star.

Further modeling of chemical yields of first-generation very-massive stars is strongly desired. If more detailed study of this star confirms the existence of very-massive stars, this new discovery will provide strong support for the predictions of the mass distribution of first stars.

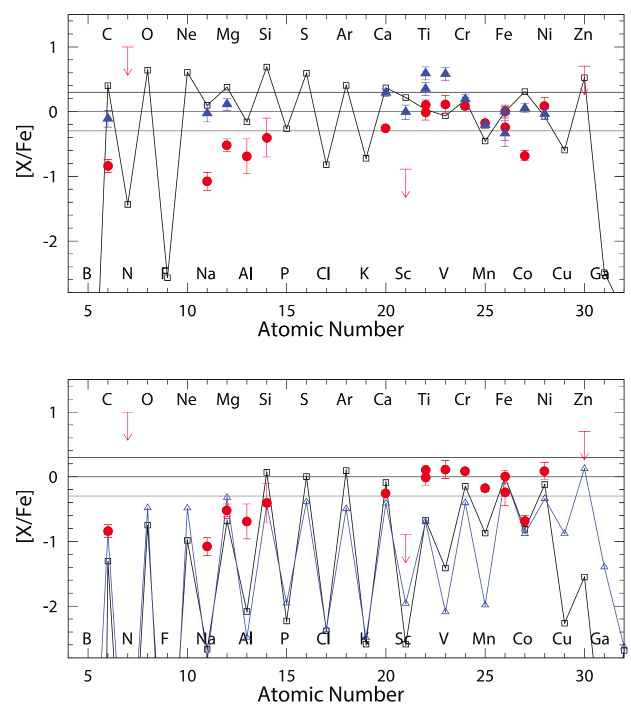

Figure 1: Elemental abundances measured for SDSS J0018-0939 (circles) and a comparison star (triangles) compared with supernova nucleosythesis models. (upper) The abundance pattern of the comparison star is explained by a core-collapse supernova model, whereas that of SDSS J0018-0939 is not reproduced by possible variations of the models. Cobalt and Scandium, as well as heavy neutron-capture elements, are also deficient. (lower) Some basic features of the abundance pattern of SDSS J0018-0939 are explained by supernova nucleosynthesis models for very massive stars.

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The Moment Approach for Resolving the Orbital Elements of Astrometric Binaries: Possible Application to Cygnus X-1

YAMADA, Kei, ASADA, Hideki (Hirosaki University)
YAMAGUCHI, Masaki (NAOJ)
GOUDA, Naoteru (SOKENDAI/NAOJ)

Resolving the orbital elements of astrometric binaries has been the important issue for measuring the masses of stars. The masses of main sequence stars are important to clarify the stellar population and evolution. The masses of compact objects, i.e., white dwarfs, neutron stars, and black holes, are important to clear the nature of these objects.

"A moment approach" is one of methods for resolving the orbital elements, which is developed by Iwama et al [1]. The future astrometric observations such as Gaia and Small-JASMINE enable us to measure the stellar positions at a precision of the 10-microarcsecond level. This means that we may be able to measure the orbital elements of close binaries such as high mass X-ray binaries with the period of a few days, i.e., Cygnus X-1, whose period is about 6 days. Here, we should note that the observational data are numerous, for example, about 100 data points for Gaia and about 10^5 data points for Small-JASMINE. If these data points are isochronous, they are expected to show a spacial bias due to the difference of the velocity of the star on the celestial sphere. Therefore the spacial moments due to the bias allow us to measure the orbital elements of astrometric binaries. This moment approach would be useful for obtaining recovered values as trial values of the steepest descent method for reaching the best-fitting parameter values.

The previous study [1] have room for improvement. Temporal information is not incorporated in the previous approach, where only the spacial bias is considered and the time of each data is neglected. The stellar position is determined by the orbital phase which is directly related to the time, so that the information of the time is important to constrain the orbital parameter. To incorporate temporal information, of N observed points we average the coordinate of n_a observed points which are neighboring positions. Using averaged data points, which show better accuracies, we apply the moment approach to calculate the orbital elements.

Figure 1 shows the apparent orbits for the mean values of the recovered parameters using the approach in the paper [1] and the present one. Here, σ represents the observational error for each position measurement in unit of the semi-major axis of the trial binary. In Figure 1, we set (σ, N, n_a) = (5, 10000, 100). We see that the present approach significantly improves the previous one for the orbit shape.

Let us consider a possible application to Cyg X-1, whose angular radius is ~0.03 mas. The required precision of the Small-JASMINE is 0.01 mas, so that we expect that the orbit of Cyg X-1 will be detected by Small-JASMINE. The calculational results show that the semi-major axis is expected to be recovered with an accuracy comparable to the true value from astrometric observations alone. Therefore, it is more convenient to start with the values that are recovered from the present moment approach and next to use the steepest descent method for finally reaching the best-fitting parameter values. This manuscript is a review of the paper [2].

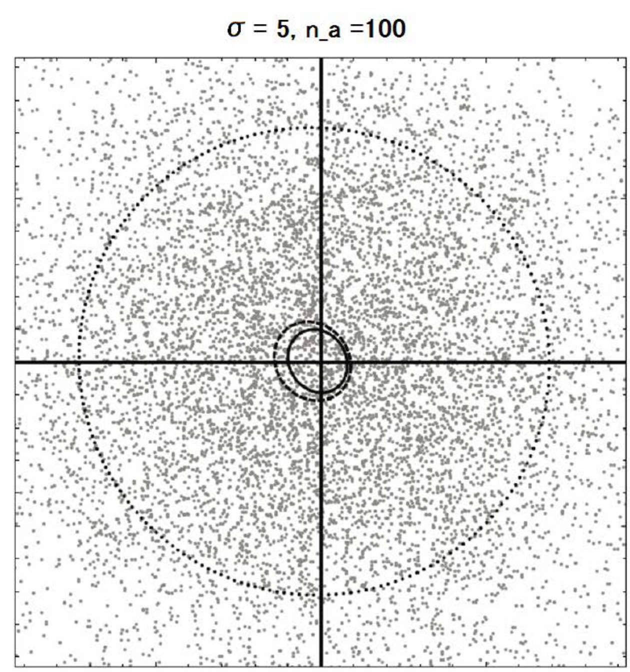

Figure 1: The apparent orbits for the mean values of the recovered parameters. The solid curve is the apparent ellipse for the true parabeters, and the dotted and dashed curves denote orbits for the mean value of the recovered parameters from the approach in [1] and the present one, respectively.

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Photospheric Flow Field Related to the Evolution of the Sun's Polar Magnetic Patches Observed by Hinode SOT

KAITHAKKAL, A. J., SUEMATSU, Y., KUBO, M. (SOKENDAI/NAOJ)
SHIOTA, D. (Nagoya University)
IIDA, Y., TSUNETA, S. (ISAS/JAXA)

The distribution and evolution of the Sun's polar magnetic field is of vital importance to understand the origin of the solar magnetism, its periodic variation and the heliospheric magnetic flux. Recent high resolution observations from the Hinode satellite have revealed that the polar region is dominated by unipolar magnetic patches which possess magnetic fields with field strengths exceeding 1 kG. The basic properties, mechanism of formation and reversal of the polar magnetic fields are topics which are yet to be resolved.

To investigate the role of photospheric flow fields in the formation and evolution of the polar magnetic patches, we conducted spectro-polarimetric observations with Hinode SOT-SP in the north and south polar caps on 2013 Nov 11, 2013 Nov 13, 2013 Dec 08, 2013 Dec 11, 2014 Jan 17, 2014 Jan 23 and 2014 Mar 08. The SP recorded full Stokes spectra of the two Fe I lines at 630.15 nm and 630.25 nm with the fast map mode whose slit-scanning step is 0.32″ and integration time in each step is 3.2s. Image sequences were obtained with a cadence of 16 minutes and the FOV was 80″×164″. Photospheric vector magnetic fields were derived by Milne-Eddington inversion for those pixels with Stokes Q, U or V peaks larger than 5 sigma. The variation of the flows with height was examined by the bisector analysis of the Fe I 630.15 nm line profile at four line depths.

We found many unipolar appearances and disappearances in the data. Converging horizontal flows are observed outside the magnetic patches during the entire lives of the patches. The converging flow is best observed at a height close to the solar photosphere. We also observed a weak converging flow around the retraced patch location 16 minutes before the patch appearance. The result implies that polar magnetic patches are formed by the accumulation of flux fragments by the horizontal converging flows. In addition to direct cancellation between opposite polarity patches, we observed unipolar disappearance of polar patches. We speculate that these patches diffuse away into smaller fragments with flux below the detection limit of the instrument and eventually undergo cancellation with opposite polarity fragments.

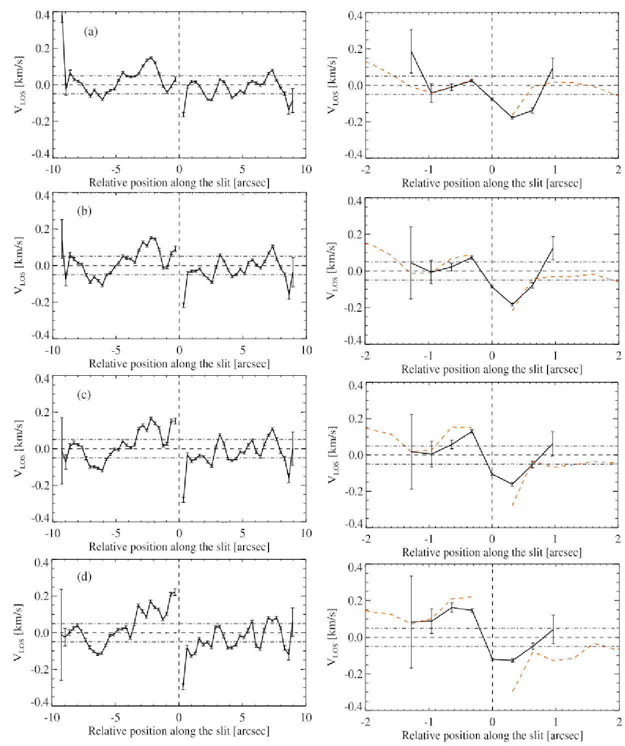

Figure 1: The average Doppler velocity profiles along N-S direction indicating converging flows at line bisector positions in the order of line intensity from top to bottom panel at time of patch appearance. The plots on the left panel represent horizontal velocity field outside the patch and that on the right represent the velocity field within the patch.

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ALMA Observation of 158 μm [CII] Line and Dust Continuum of a $z = 7$ Normally Star-Forming Galaxy in the Epoch of Reionization

OTA, Kazuaki[1], WALTER, Fabian[2], OHTA, Kouji[3], HATSUKADE, Bunyo[4], CARILLI, Chris L.[5]
DA CUNHA, Elisabete[6], GONZÁLEZ-LÓPEZ, Jorge[2], DECARLI, Roberto[2], HODGE, Jacqueline A.[5]
NAGAI, Hiroshi[4], EGAMI, Eiichi[7], JIANG, Linhua[8], IYE, Masanori[4], KASHIKAWA, Nobunari[4]
RIECHERS Dominik A.[9], BERTOLDI, Frank[10], COX, Pierre[11], NERI, Roberto[12], WEISS, Axel[13]

1: University of Cambridge, 2: Max-Planck Institute for Astronomy, 3: Kyoto University, 4: NAOJ, 5: National Radio Astronomy Observatory, 6: Swinburne University of Technology, 7: University of Arizona, 8: Peking University, 9: Cornell University, 10: University of Bonn, 11: ALMA, 12: Institut de Radio Astronomie Millimétrique, 13: Max-Planck Institute for Radio Astronomy

High-z star-forming galaxies in the epoch of reionization (EoR) have been usually detected via their Lyα lines or UV continua. However, as UV light traces only ionized gas/stars, we have seen merely a portion of star formation in galaxies. Another aspect yet unexplored is dust-obscured star formation, and rest frame far-infrared (FIR) lines and continuum can probe it as they reflect fuel for star formation and light from stars once absorbed and re-emitted by dust, respectively. FIR lights from EoR galaxies are redshifted to (sub)millimeter and observable from the ground by Atacama Large Millimeter/submillimeter Array (ALMA). Among many FIR lines, 158 μm [CII] is the strongest line of an interstellar medium and suited for probing faint distant galaxies.

We conducted ALMA observations of the [CII] line and FIR continuum of a normally star-forming galaxy in EoR, a z=6.96 Lyα emitter (LAE) IOK-1 [1]. We found it undetected in both [CII] and continuum to $\sigma_{\rm line}$ = 240 μJy beam^{-1} (40 km s^{-1} channel) and $\sigma_{\rm cont}$ = 21 μJy beam^{-1}. Comparison of UV–FIR spectral energy distribution (SED) of IOK-1, including our ALMA limit, to those of several types of galaxies suggests that IOK-1 is similar to local dwarf/irregular galaxies in SED shape rather than highly dusty/obscured galaxies (Figure 1). Moreover, our 3σ FIR continuum limit implies intrinsic dust mass $M_{\rm dust} < 6.4 \times 10^7 M_\odot$, FIR luminosity $L_{\rm FIR} < 3.7 \times 10^{10} L_\odot$ (42.5–122.5 μm), total IR luminosity $L_{\rm IR} < 5.7 \times 10^{10} L_\odot$ (8–1000 μm) and dust-obscured star formation rate (SFR) $< 10 M_\odot$ yr^{-1}, if we assume that IOK-1 has a dust temperature and emissivity index typical of local dwarf galaxies. This SFR is 2.4 times lower than one estimated from the UV continuum, suggesting that < 29 % of the star formation is obscured by dust. Meanwhile, 3σ [CII] flux limit converts to luminosity $L_{\rm [CII]} < 3.4 \times 10^7 L_\odot$. Locations of IOK-1 and previously observed LAEs on the $L_{\rm [CII]}$ vs. SFR and $L_{\rm [CII]}/L_{\rm FIR}$ vs. $L_{\rm FIR}$ diagrams imply that LAEs in EoR have significantly lower gas and dust enrichment than AGN-powered systems and starbursts at similar/lower redshifts as well as local star-forming galaxies (Figure 2).

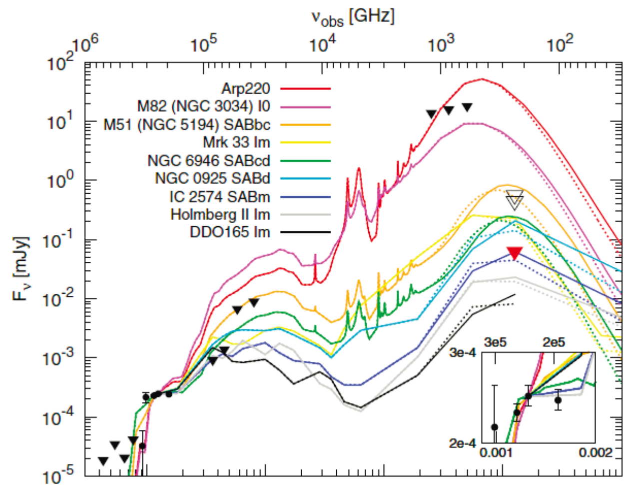

Figure 1: SED of IOK-1 (Data points. Triangles are 3σ upper limits). Our ALMA 3σ upper limit on 1.26 mm continuum is the red triangle while those from previous studies the open triangles. For comparison, various local galaxy SEDs including (not including) cosmic microwave background effects on FIR continua are shown by color coded dotted (solid) lines.

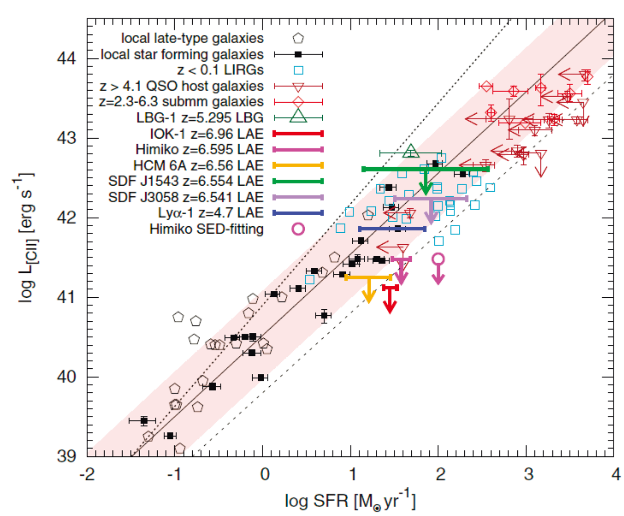

Figure 2: $L_{\rm [CII]}$ versus SFR for different types of objects compiled by us [1]. The arrows indicate upper limits. The dotted line is the correlation for local late-type galaxies. The solid line with shaded region is the correlation for local star-forming galaxies with 2σ scatter. The dashed line is the correlation for $L_{\rm FIR} > 10^{12} L_\odot$ sources.

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KVN and VERA Array (KaVA) Observations of Bright AGN Jets

NIINUMA, K. (Yamaguchi University)
LEE, S. S., KINO, M., SOHN, B.W. (Korea Astronomy and Space Science Institute)

On Behalf of KaVA AGN Sub Working Group/KaVA Science Working Group
(http://kava.kasi.re.kr/kava main.php)

KaVA is a VLBI array that combines the Korean VLBI Network (KVN) and the VLBI Exploration of Radio Astrometry (VERA), and its baseline lengths range from 305 to 2270 km. The observing frequencies of 23 GHz and 43 GHz are available. Table 1 summarizes the specifications of each array. As shown in Table 1, each array compensates for the weakness of the other, they are complementary, which makes KaVA a very promising VLBI facility.

Table 1: Brief array specications of each VLBI facility.

	Array		
	KVN	VERA	KaVA
Baseline [km] (Shortest/Longest)	305／476	1019／2270	305／2270
Fringe spacing [mas] (K-/Q-band)	5.6／3.0	1.2／0.6	1.2／0.6

To evaluate the imaging capability of KaVA for extended sources, we carried out test observations for 4C 39.25 (relatively compact structure), 3C 273 (extended bright knotty jet structure), and M 87 (extended smooth jet structure) at both K-/Q-band with bandwidth of 32 MHz on 2013 April 13 and 14. Only 128 Mbps recording mode (bandwidth of only 32 MHz) allows us to conduct test observations in commissioning phase.

Based on the test observations, we clarified KaVA can achieve the substantially high dynamic range exceeding 1000 for the sources having the extended structures with even the bandwidth of only 32 MHz and the on-source time of an hour, if we perform the observation as covering the spatial frequency uniformly within an hour angle spread of a total observation time of 6–8 h [1]. As shown in Figure 1, an extended jet structure in KaVA images are well reproduced compared with the one in VERA image. The dynamic range derived from KaVA observations is at least three times higher than only VERA observations. This imaging capability of KaVA has a great advantage for the AGN jet science.

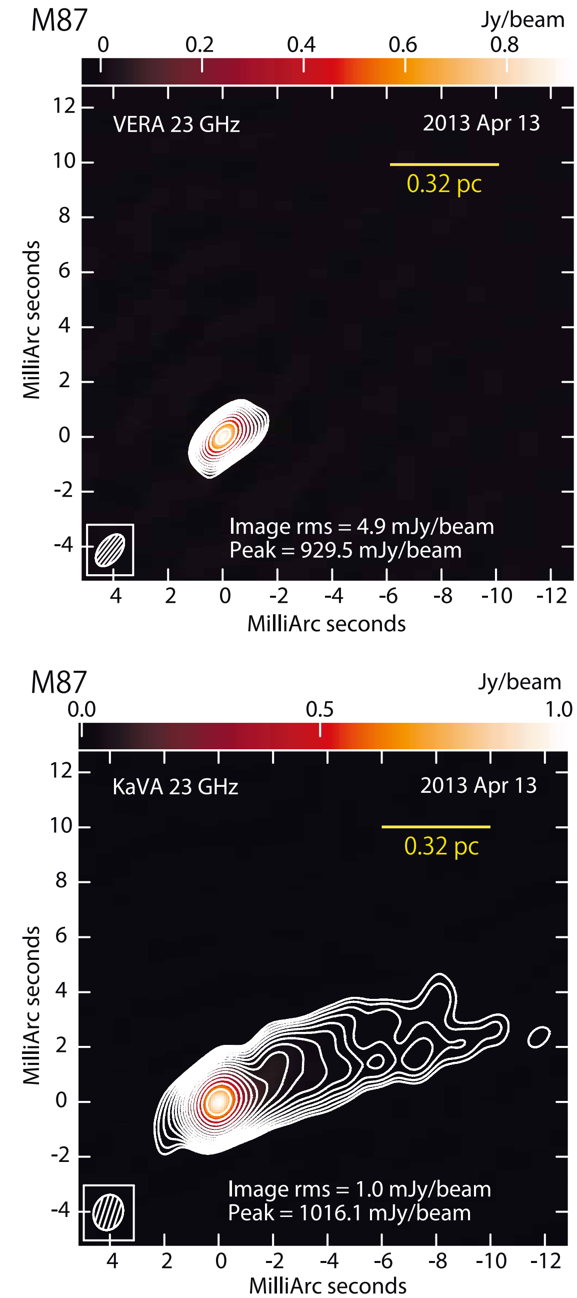

Figure 1: VLBI images of M87 observed by VERA (*top*) and KaVA (*bottom*) at 23 GHz, respectively. In each panel, peak intensities and image noise levels are indicated in the bottom-right corner and synthesized beams are also shown in the bottom-left corner in each image. In the top-right corner, the date and linear scale at the distance of each source are shown. Contours of each image begin at five times of image rms, and increase in $2^{n/2}$ steps.

Reference

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Photospheric Properties of Warm EUV Loops and Hot X-Ray Loops

KANO, Ryouhei (NAOJ)
UEDA, Kohei (University of Tokyo)
TSUNETA, Saku (ISAS/JAXA)

We investigated the photospheric properties (vector magnetic fields and horizontal velocity) in a well-developed active region, NOAA AR 10978, by using the *Hinode* Solar Optical Telescope (SOT), especially for discussing what makes coronal loops so different in temperature from “warm loops” (1–2 MK) observed in EUV wavelengths to “hot loops” (> 3 MK) in X-rays [1]. We found that outside sunspots the magnetic filling factor f in network varies with location, and anti-correlated with the horizontal random velocity v_{SD} (Figure 1). For explaining this anti-correlation, it is not necessary to use the hypothesis that the dense magnetic flux tubes suppresses their mobility on the photosphere [2]. If we accept that the observed magnetic features consist of unresolved magnetic flux tubes, this anti-correlation can be explained by the ensemble average of the flux-tube motion driven by small-scale random flows. This simple model suggests the equation of

$$v_{\mathrm{SD}} = v_{\mathrm{o}}\, d\, D^{-1} f^{-1/2} \quad \text{for } f<(d/\lambda)^2, \qquad (1)$$

$$= v_{\mathrm{o}} \lambda D^{-1} \quad \text{for } f>(d/\lambda)^2, \qquad (2)$$

where d and D are the diameter of flux tube and the resolution of this analysis, respectively, and v_{o} and λ are the small-scale flow velocity and its spatial scale, respectively. The observed data are consistent with $d \sim 77$ km, $v_{\mathrm{o}} \sim 2.6$ km s^{-1} and $\lambda \sim 120$ km as shown by the dashed line in Figure 1a.

We also found that outside sunspots there is no significant difference between warm and hot loops either in the magnetic properties except the inclination or in the horizontal random velocity at their footpoints, which are identified with the *Hinode* X-ray Telescope (XRT) and the Transition Region and Coronal Explorer (TRACE). The energy flux injected into the coronal loops by the observed photospheric motion of the magnetic fields is estimated to be 2×10^6 erg s^{-1} cm^{-2}, which is the same for both warm and hot loops (Figure 2). This suggests that coronal situation (e.g. loop length) plays more important role for making a variety of temperature in active-region coronal loops than the photospheric parameters.

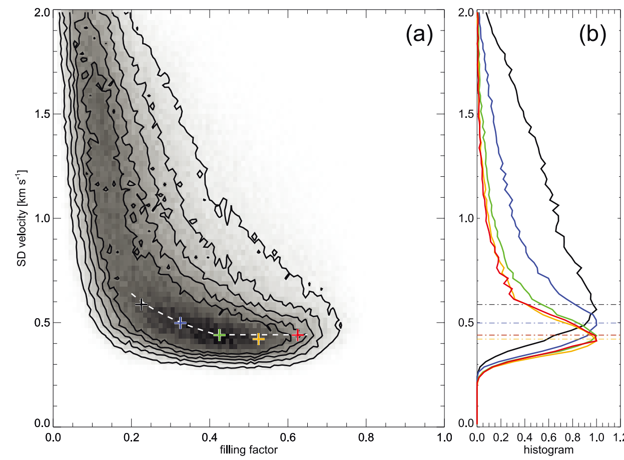

Figure 1: (a) Scattered plot between magnetic filling factor and horizontal random velocity. A gray scale and contours show the number density of the data points outside sunspots. (b) Histograms of the horizontal random velocity outside sunspots. Different lines indicate different filling factors: 0.20–0.25 (black), 0.30–0.35 (blue), 0.40–0.45 (green), 0.50–0.55 (orange) and 0.60–0.65 (red). The peaks indicated by dot-dashed lines are also shown by crosses in panel-(a).

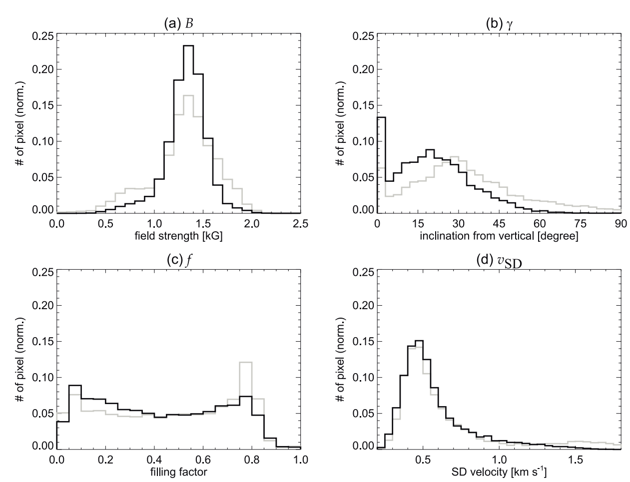

Figure 2: Histograms of photospheric properties at the footpoints located outside sunspots: (a) intrinsic field strength, (b) inclination and (c) filling factor of magnetic fields, and (d) standard deviation of horizontal velocity. Grey and black lines correspond the footpoints of warm and hot loops, respectively.

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Toward the Inversion of the Scattering Polarization and the Hanle Effect in the Hydrogen Lyα Line

ISHIKAWA, Ryohko[1], ASENSIO RAMOS, Andrés[2], BELLUZZI, Luca[3], MANSO SAINZ, Rafael[2]
ŠTĚPÁN, Jiří[4], TRUJILLO BUENO, Javier[2], GOTO, Motoshi[5], TSUNETA, Saku[6]

1: NAOJ, 2: Instituto de Astrosica de Canarias, 3: Istituto Ricerche Solari Locarno/Kiepenheuer-Institut für Sonnenphysik, 4: Astronomical Institute of the Academy of Sciences, 5: National Institute for Fusion Science, 6: ISAS/JAXA

The chromosphere and the transition region of the Sun are the interface region between the cool photosphere of 10^4 K, where the ratio of gas to magnetic pressure $\beta > 1$, and the 10^6 K corona, where $\beta < 1$. In this region, it is believed that energy dissipation and energy transportation to the upper layers are taking place via the magnetic fields. Thus, magnetic field measurements in the upper chromosphere and above (i.e., low β region), are essential for understanding the thermal structure and dynamical activities of the solar atmosphere. However, the familiar Zeeman effect has the limited applicability since the magnetic field there is expected to be rather weak and the spectral lines originating from these atmospheric layers are broad. The Hanle effect, that magnetic field induces the modification of the linear polarization caused by the anisotropic radiation field (i.e., scattering polarization), is expected to be a suitable diagnostic tool. Indeed, recent developments in the theory and modeling of polarization in spectral lines have suggested that information on the magnetic field in low β region could be encoded in some UV lines via the Hanle effect [1], and motivated the development of the CLASP sounding rocket experiment, which aims to measure the linear polarization profiles at the hydrogen Lyα line ($\lambda = 121.6$ nm) for the first time [2,3,4].

In our work [5], we clarify the information that the Hanle effect can provide by applying a Stokes inversion technique by means of a database search in view of the CLASP experiment. The database contains all theoretical Lyα Q/I and U/I profiles for all possible values of the field strength, inclination, and azimuth, assuming a one-dimensional semi-empirical model of the quiet-sun atmosphere. We focus on understanding the sensitivity of the inversion results to the noise as well as the ambiguities inherent to the Hanle effect. We find that it is difficult to uniquely determine the magnetic parameters only from the CLASP observables (i.e., linear polarization profiles) (Fig. 1), and simultaneous measurements to constrain one of magnetic parameters are critically important. Our conclusion is that spectro-polarimetry with CLASP can be a suitable diagnostic tool for investigating the magnetism of the transition region, especially when complemented with the information on the azimuthal direction of the magnetic field that can be derived from other instruments.

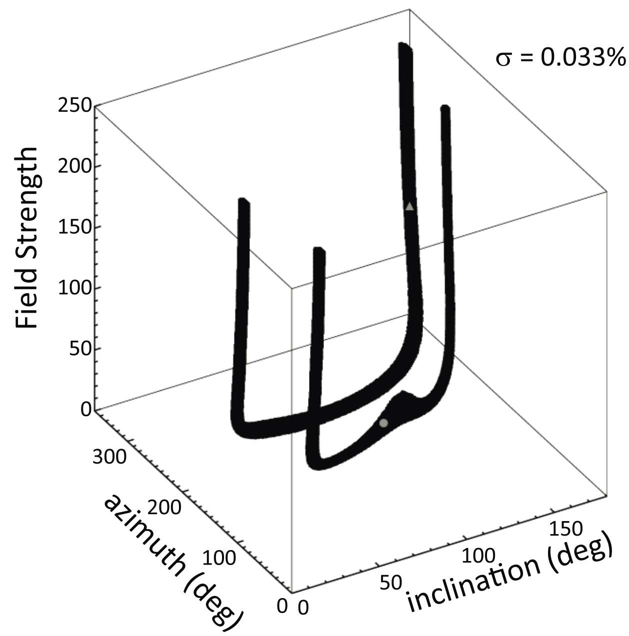

Figure 1: χ^2 map in the parameter space of field strength, inclination, and azimuth (magnetic parameters which are statistically accepted at one σ level as a result of inversion of a given simulated observable are shown with black) [5]. Noise expected for the CLASP experiment [3] is assumed.

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Sterile Neutrino Oscillations in Core-Collapse Supernova Simulations

WARREN, MacKenzie L., MEIXNER, Matt, MATHEWS, Grant J.
(University of Notre Dame)

HIDAKA, Jun
(Meisei University)

KAJINO, Toshitaka
(NAOJ/University of Tokyo)

Despite recent developments in computational methods and better understanding of the relevant micro-physics and hydrodynamics [1], the detailed explosion mechanism for core-collapse supernovae is still not known. Nevertheless, whatever the explosion mechanism is, it is clear the neutrinos play a very important role even if new neutrino physics may ultimately required to drive the explosion.

In our paper [2] we have explored a new way by which even non-exploding spherical supernova models can be made to explode. In this case the explosion occurs via the introduction of new neutrino physics during the explosion. Specifically, we consider the possible resonant mixing [3,4] between a sterile neutrino and an electron neutrino (or anti-neutrino). A sterile neutrino is a postulated right-handed neutrino that does not interact with normal matter except by vacuum oscillations [2].

We have made core-collapse supernova simulations [2] that allow oscillations between electron neutrinos (or their anti particles) with right-handed sterile neutrinos. We have considered a range of mixing angles and sterile neutrino masses including those consistent with sterile neutrinos as a dark matter candidate. We then examined whether such oscillations can impact the core bounce and shock reheating in supernovae. We identified the optimum ranges of mixing angles and masses that dramatically enhance the supernova explosion by efficiently transporting electron anti-neutrinos from the core to behind the shock where they provide additional heating. We show that an interesting oscillation in the neutrino luminosity develops due to a cycle of depletion of the neutrino density by conversion to sterile neutrinos that shuts off the conversion, followed by a replenished neutrino density as neutrinos transport through the core.

We found that, for a broad range of sterile neutrino masses and mixing angles, an efficient transport of anti-neutrino flux can occur by the resonant conversion of electron anti-neutrinos into sterile neutrinos in the core followed by the reverse process behind the shock. This is illustrated in Figure 1 from put paper which shows that a substantial enhancement in the explosion energy can occur by this efficient transfer of energy out of the core by the conversion of electron anti-neutrinos to sterile neutrinos. In particular, sterile neutrino masses consistent with a dark matter candidate can lead to an explosion.

Thus, we can solve both the supernova explosion problem and dark matter problem with a single solution. We have also shown [2] that this process could lead to a unique neutrino luminosity evolution that may be detectable with a future detector like Hyper-Kamiokande.

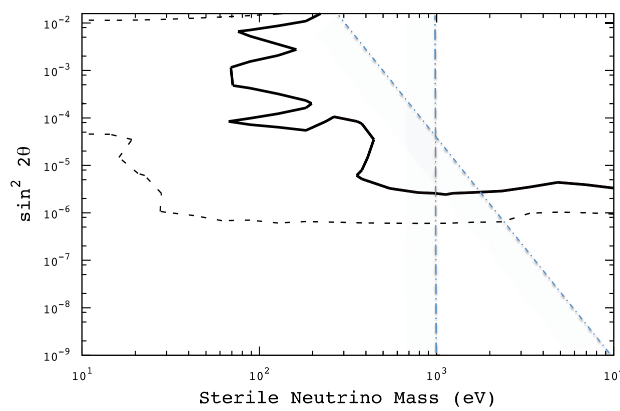

Figure 1: Contours from [2] showing the enhancement in the supernova kinetic energy, relative to an explosion without a sterile neutrino present. The dashed line encloses the region of a factor of 1.5× enhancement to the kinetic energy and the solid line encloses the region of a factor of 10× enhancement. The region of the parameter space that characterizes dark matter candidates is below the intersection of the two shaded lines of the figure.

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Supernova Relic Neutrinos and the Supernova Rate Problem: Analysis of Uncertainties and the Role of Failed Supernovae

MATHEWS, Grant J. (University of Notre Dame)
HIDAKA, Jun (Meisei University)
KAJINO, Toshitaka (NAOJ/University of Tokyo)
SUZUKI, Jyutaro (NAOJ)

We have investigated [1] the possibility of detecting the various contributions to the supernova relic neutrino background in a 10^6 ton next-generation water Čerenkov detector such as the proposed Hyper-Kamiokande. Massive stars ($M \geq 8\, M_{\odot}$) culminate their evolution as core collapse supernovae (CC-SNe). Such supernovae are unique sources for all three flavors of energetic neutrinos.

Neutrinos emerge from deep within the interior of core collapse supernovae. As such, supernova neutrinos have the potential to provide information regarding the physical processes that take place inside the star. The emitted neutrinos can almost freely stream from the time of the early galaxy formation epoch until the present time without absorption in the intergalactic material. Hence, the detection of this diffuse background of accumulated neutrinos can be used to study the supernova history from the beginning of galaxy formation [1,2] and also provide information on neutrino properties such as flavor oscillations and/or the neutrino temperatures produced in supernova explosions.

We analyzed prospects for measuring the average neutrino temperatures and also the prospect of solving the disparity between the supernova rate inferred from the cosmic star formation rate and that directly observed [2]. Figure 1 shows an example of the predicted neutrino spectrum in the case that a large population of faint black-hole forming supernovae are needed to explain the supernova rate problem [1]. Figure 2 illustrates how one might determine the average electron anti-neutrino temperature from the detected positron event rate. This figure shows the ratio of the event rate at the observed spectrum peak to the rate at 25 MeV. There is a very strong correlation between this ratio and neutrino temperature that characterizes the different representative supernova models identified. Even in different neutrino oscillation cases the relationship between characteristic neutrino temperature from the supernova models and this ratio is quite robust.

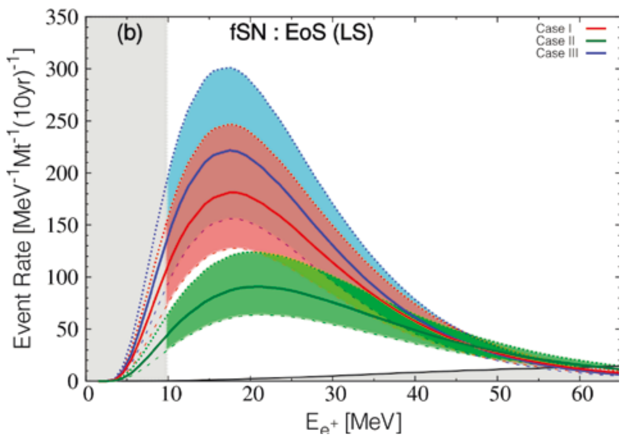

Figure 1: Example of the predicted e^+ energy spectra from relic neutrinos as a function of e^+ energy where $E_\nu = E_{e^+} + 1.3$ MeV. In this case failed fSNe account for a factor of two difference between supernova rate deduced from the massive SFR and the observed supernova rate. Different bands correspond to different neutrino oscillation scenarios. Grey areas denote the backgrounds from terrestrial reactors and atmospheric neutrinos.

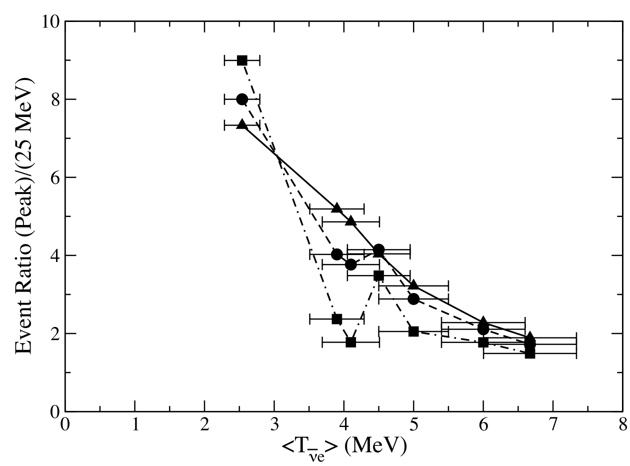

Figure 2: Sensitivity or the average neutrino temperature ratio of events at the observed positron peak to events with a positron energy of 25 MeV, corresponding to the 7 fiducial SN collapse models studied in [1].

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The In-Medium Effects on the Neutrino Reaction in Dense Matter

CHEOUN, M.-K. (Soongsil University)
KIM, K. S. (Korea Aviation University)
KIM, Hungchong (Kookmin University)
SO, W. Y. (Kangwon University)
KAJINO, Toshitaka (NAOJ/University of Tokyo)
MARUYAMA, Tomoyuki (Nihon University)

Nowadays neutrino scattering becomes one of useful tools for understanding neutrino physics as well as neutrino astrophysics. But most of the scattering data were extracted by the neutrino scattering off target nuclei. Moreover incident neutrino energy ranges from a few MeV to tens of GeV. As well known in other projectiles, we need to understand target nuclear structure probed by the weak interaction. Then it would be very helpful to know from which energy region we have to include the structure effect and how to include it in the analysis of neutrino scattering.

Moreover, strong recent evidence for the modification of nucleon properties in a nuclear medium has been reported using the electromagnetic (EM) nucleon form factors measured in polarized ($\vec{e}$, e' $\vec{p}$) and ($\vec{e}$, e' $\vec{n}$) scattering on some light nuclei [1]. Since the weak form factors also may be affected by the modification of the EM form factors, Since the weak-vector currents and EM currents form iso-vector and vector currents, one might naturally expect that the modification of weak-vector form factors occurs in a similar manner to that of the EM form factors. Refs. [2] explored nuclear structure effects in those data directly using robust nuclear structure and reaction theories in the relativistic framework.

In this work, we report one of the answers regarding the question. In Fig. 1, we show our theoretical total cross sections of neutrino and anti-neutrino scattering off hydrogen and ^{12}C target and compared to the MiniBooNE and NOMAD neutrino data, whose energy ranges are up to about 10^0 and 10^2 GeV, respectively [3]. These results were carried out by the elementary process, i.e. neutrino scattering off a free nucleon, by taking into account the in-medium effect for ^{12}C using the density-dependent form factors estimated by the quark meson coupling (QMC) model [4]. Effects of the in-medium (difference between red and black curves) turn out to be small compared to the experimental error bars. In particular, neutrino scattering above 1 GeV can be properly described by the elementary process, irrespective of neutrino types and their current types. But, below 1 GeV region, it is found that one needs to include nuclear structure as well as Fermi motion of nucleons for the neutrino scattering.

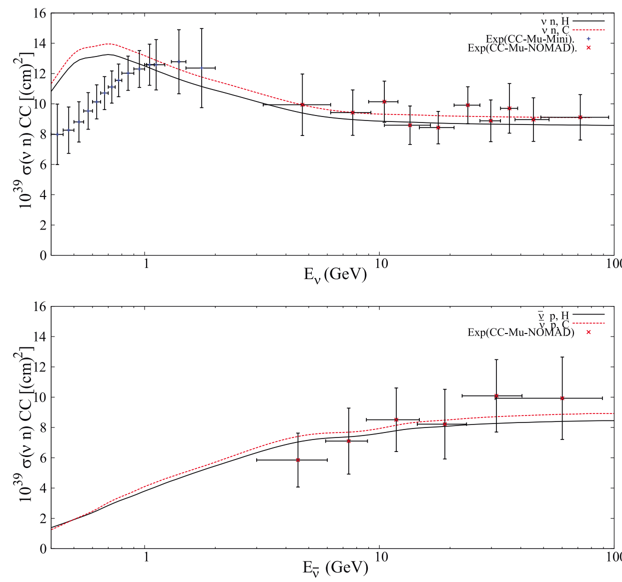

Figure 1: (Color online) Results of $\nu + n \rightarrow \mu^- + p$ (upper) and $\overline{\nu} + p \rightarrow \mu^+ + n$ (lower) for a nucleon in H and ^{12}C. Results for a free neutron (proton) and neutron (proton) in a carbon target are denoted as solid (black) and dotted (red) curves, respectively. Data are MiniBooNE and NOMAD in Refs. [5] and [6], respectively.

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Induced Amino Acid Chirality from Strong Magnetic Fields in Interstellar Environments

FAMIANO, Michael A. (Western Michigan University)
BOYD, Richard N., KAJINO, Toshitaka (NAOJ/University of Tokyo)
ONAKA, Takashi (University of Tokyo)
KOEHLER, Katrina (Los Alamos National Laboratory)
HULBERT, Sarah (The Ohio State University)

Recent work [1,2] has suggested that the chirality of the amino acids could be established in the magnetic field of a nascent neutron star from a core-collapse supernova via processing by the neutrinos that would be emitted. This model, the Supernova Neutrino Amino Acid Processing Model, or SNAAP model, not only appears to produce a small chiral imbalance, but al-ways produces the same sign of the chirality. This is also consistent with evidence that the origin of amino acid chirality may be non-terrestrial in nature [3,4,5].

We have studied the capability of the SNAAP model for selective destruction of one molecular chirality. This extends previous work [2] to include the dynamical effects that would be produced on the amino acids that were included in meteoroids that were large enough to escape destruction by the supernova photons as they passed by a nascent neutron star. This model has many similarities to nuclear magnetic resonance, even though it is essentially classical. The study does show that the amino acids contained in a large meteoroid could undergo orientation from the magnetic field of the neutron star, subsequent chiral sub-state selection from the combination of that field and the rotation of the meteoroids, and finally chiral selection by the neutrinos emitted as the neutron star produced by a core-collapse supernova cools over its characteristic few second cooling time.

A Monte Carlo code was written to simulate strong neutrino interactions with amino acids in the vicinity of neutron stars [6]. This model assumes that the neutrinos emitted from the nascent neutron star would interact with the amino acids, which had been oriented by the neutron stars magnetic field. These molecules would have to be contained in large meteoroids that happened to be passing by the star as it became a supernova, so that they could survive the high temperature environment existing near the star. The crucial interaction that destroys ^{14}N is $^{14}\mathrm{N} + \nu_e \rightarrow {}^{14}\mathrm{C} + e^+$. It was also assumed that some imbalance in the total angular momentum of the molecules would be achieved, perhaps by the Buckingham effect [7,8], so that the conversion of ^{14}N to ^{14}C would, because of a spin selection effect on the strength of the interaction, selectively destroy one orientation compared to the other. These amino acids would have to be contained in large meteoroids that happened to be passing by the star as it became a supernova, so that they could survive the high temperature environment existing near the star.

For this study, the bulk polarization of ^{14}N was calculated for various meteoroid impact parameters (distance of closest approach), speeds, rotational speeds, and neutron star magnetic field. A subset of results are shown in Figure 1 for various impact parameters. Coupling the nitrogen spin to the molecular spin can result in a bulk molecular polarization coupling to the overall chirality.

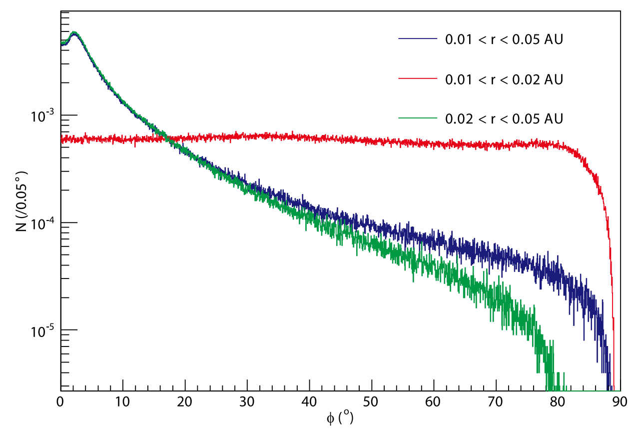

Figure 1: Polarization angle distributions for three models which vary by distance of closest approach.

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Neutrino Magnetic Moment, CP Violation and Flavor Oscillations in Matter [1]

PEHLIVAN, Y. (Mimar Sinan University/NAOJ)
BALANTEKIN, A.B. (University of Wisconsin)
KAJINO, Toshitaka (NAOJ/University of Tokyo)

In both the Early Universe, and the intense astrophysical neutrino sources such as the core collapse supernovae, neutrinos are believed to undergo nonlinear forms of flavor evolution which result from the many-body effects due to neutrino-neutrino scattering. These oscillations are very different from the vacuum oscillations of the neutrinos or the MSW effect in the sun, and are generally termed *collective neutrino oscillations*. Although the collective neutrino oscillations are highly nonlinear, they were shown to possess several dynamical symmetries under a two-flavor mixing scenario [2].

In this paper, we show that these symmetries also emerge in the realistic three-flavor mixing case and that they are present even when the CP-symmetry is broken in the neutrino sector. One practical consequence of the existence of such symmetries is that they give rise to conserved quantities which reduce the complexity of the nonlinear evolution and allow one to make some model independent statements [2]. For example, although the neutrino energy spectrum itself changes nonlinearly with time, the conserved quantities give rise to *invariant spectra* which are functionals of the former and constant in time (Fig. 1).

We also examine the interplay between the possible CP violation features of neutrinos, their anomalous magnetic moments, and the collective flavor oscillations with a particular focus on the inherent many-body nature and the symmetries of the latter. We show that, as long as neutrino magnetic moment can be ignored (e.g., if the magnetic field is not very strong) the CP-violating effects factor out of the evolution operator and evolve independently of the nonlinear flavor transformations. In particular, this tells us that, even if CP violation exist in the neutrino sector, collective oscillations can not amplify its effects the way they amplify some other features, such as the mass hierarchy.

However, even the tiny anomalous magnetic moments of neutrinos may play a part in some astrophysical and cosmological scenarios [3]. We show that, in this case the CP violating effects cannot be strictly factorized any more. However, one can carry out a mathematical trick and still factor out the CP violating effects from collective oscillations by defining an *effective magnetic moment*. This effective magnetic moment includes the CP-violating Dirac phase in its definition and is different for neutrinos and antineutrinos, reflecting the fact that CP violation and magnetic moment are intertwined in an inseparable way during the flavor evolution. However, since the neutrino magnetic moment is small enough to be conveniently studied in a first order perturbation approach, this allows us to treat the unfactorized CP violation effects perturbatively in the first order as well.

The formulation we use in this paper is based on the symmetries of the Hamiltonian describing the collective neutrino flavor evolution and therefore is valid under very general conditions. In particular, it is valid even in the presence of many-body quantum entanglements which are generally ignored by mean field type approximations.

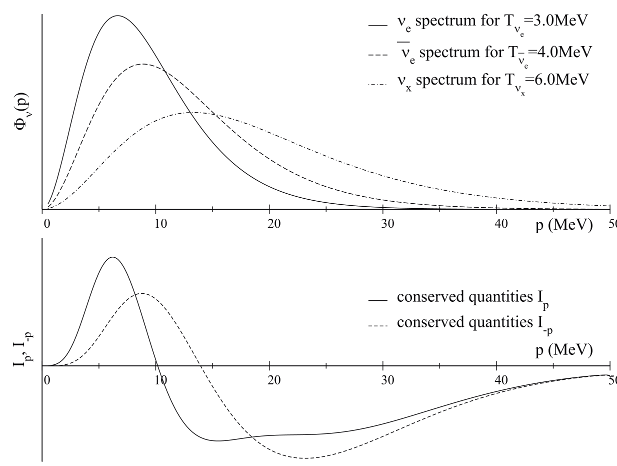

Figure 1: *Upper panel*: Energy spectra of the neutrinos from a proto-neutron star. *Lower Panel*: Corresponding invariant spectra.

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Neutrino Oscillation and Nucleosynthesis in Core-Collapse Supernova Explosion [1]

KAJINO, Toshitaka (NAOJ/University of Tokyo)
MATHEWS, Grant. J. (University of Notre Dame)
HAYAKAWA, Takehito (Japan Atomic Energy Agency)

Neutrino interactions are the key component of the mechanism for supernova explosions. Foremost is the role of neutrinos in the explosion itself. Much effort is now invested in understanding the transport of neutrinos from the core and the role of neutrino heated convection in the outer envelopes. They also play an important role in the associated nucleosynthesis, and current topics are regarding the synthesis of the ν-process isotopes ^{180}Ta, ^{138}La and light isotopes ^{7}Li and ^{11}B and impact on the neutrino-flavor oscillations [1].

Most important neutrino-flavor mixing is due to Mikheyev-Smirnov-Wolfenstein (MSW) matter effect [2]. The adiabatic condition can be written as

$$\left|\left(\frac{1}{\rho_e}\frac{d\rho_e}{dr}\right)^{-1}\tan(2\theta)\right| \gg \lambda_{m,res} = \frac{4\pi\epsilon_\nu}{\Delta m^2 \sin(2\theta)} \quad . \tag{1}$$

The flavor oscillations occur for a matter density ρ_{res} of

$$\rho_{res} = 1.4 \times 10^3 \left(\frac{\Delta m^2}{10^{-3}\mathrm{eV}}\right)\left(\frac{10\ \mathrm{MeV}}{E_\nu}\right)\left(\frac{Y_e}{0.5}\right)\cos 2\theta \ , \tag{2}$$

where ρ_{res} is in units of $\mathrm{g\,cm^{-3}}$, $\Delta m^2 \sim 10^{-3}$ eV is the difference in the square of the neutrino mass eigenstates, and θ is the relevant mixing angle. This implies that the resonant flavor mixing occurs among active neutrinos at the matter density ~$10^3\ \mathrm{g\,cm^{-3}}$ located just below the O/C layer at $M_r \approx (3.4\text{–}4)M_\odot$ as shown in Fig. 1.

The dependence on θ_{13} enters here for the 13-mixing resonance. The associated increase in the electron neutrino temperature increases the rates of charged-current ν-process reactions. Although the heavy ν-process elements are produced in the inner layers and unaffected by the MSW resonance, the light isotopes ^{7}Li and ^{11}B are sensitive to the 13 mixing. Moreover, the ratio depends on the still unknown neutrino mass hierarchy [1].

Since the recent reactor and accelerator experiments give $\sin^2 2\theta_{13} \sim 0.1$, the neutrino mass hierarchy can be determined from the strong, robust dependence of the abundance ratio ^{7}Li/^{11}B on the oscillation parameters [1]. According to a recent work based on the deduction of the ratio ^{7}Li/^{11}B from so-called pre-solar supernova grains of a meteorite [3], we can conclude that the inverted mass hierarchy is statistically more favored [4].

We also discussed the flavor mixing effects on the observed signals of supernova neutrinos on Earth [5]. Independent of the neutrino mass hierarchy in the efficient flavor mixing, the observed neutrino fluxes might become

$$\begin{aligned}\phi_{\nu_e} &= |U_{e1}|^2\phi^{(0)}_{\nu_e} + (1-|U_{e1}|^2)\frac{\phi^{(0)}_{\nu_\mu}+\phi^{(0)}_{\nu_\tau}}{2}, \\ \phi_{\nu_{\mu,\tau}} &= \frac{(1-|U_{e1}|^2)}{2}\phi^{(0)}_{\nu_e} + \frac{(1+|U_{e1}|^2)}{2}\frac{\phi^{(0)}_{\nu_\mu}+\phi^{(0)}_{\nu_\tau}}{2},\end{aligned} \tag{3}$$

where U_{ei} are elements of the Cabbibo-Kobayashi-Masukawa matrix in neutrino sector. We can predict the difference of the neutrino signals which depend on mass hierarchy and EoS of proto-neutron stars in mega-ton Gd loaded Water-Chrenkov detector at Hyper-Kamiokande [5].

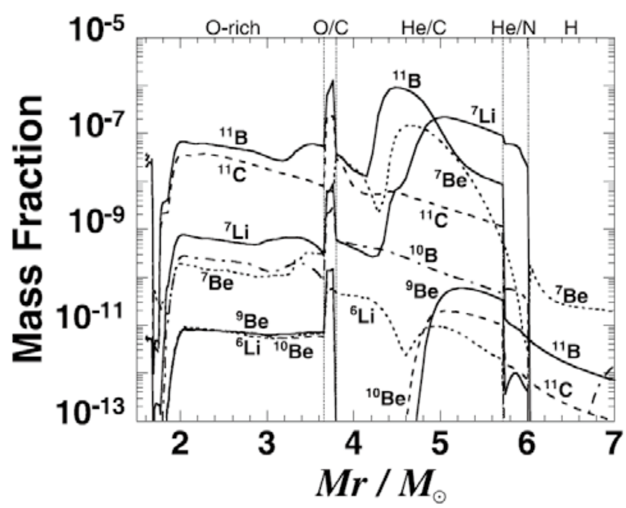

Figure 1: Produced Li, Be, and B isotopes as a function of interior mass of core-collapse supernova. Note the large spike in ^{11}B and ^{7}Li production in the O/C and He/C shells.

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Vacuum Ultraviolet Spectro-Polarimeter Design for Precise Polarization Measurements

NARUKAGE, Noriyuki (NAOJ)
CLASP team

Precise polarization measurements in the vacuum ultraviolet (VUV) region provide a new means for inferring weak magnetic fields in the upper atmosphere of the Sun and stars [1]. We propose a VUV spectro-polarimeter design ideally suited for this purpose (see Figure 1) [2]. This design is proposed and adopted for the NASA-JAXA Chromospheric Lyman-Alpha Spectro-Polarimeter (CLASP), which will record the linear polarization (Stokes Q and U) of the hydrogen Lyman-α line (121.567 nm) profile. The expected degree of polarization is on the order of 0.1 % [1].

Our spectro-polarimeter has two optically symmetric channels to simultaneously measure orthogonal linear polarization states with a single concave diffraction grating that serves both as the spectral dispersion element and beam splitter (see Figure 1). This design has a minimal number of reflective components with a high VUV throughput. Consequently, these design features allow us to minimize the polarization errors caused by possible time variation of the VUV flux during the polarization modulation and by statistical photon noise [3].

The CLASP has been assembled as shown in Figure 2 and shipped to United States in April 2015. The CLASP is planned to be launched at the White Sands Missile Range in New Mexico in September 2015.

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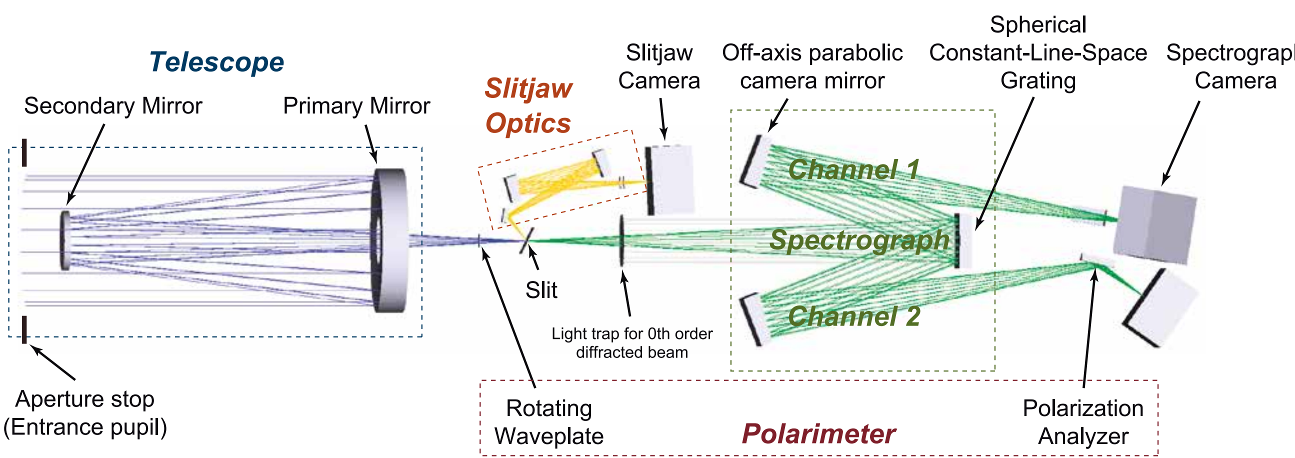

Figure 1: The VUV spectro-polarimeter design for CLASP. The complete optical layout of CLASP, consisting of the telescope, spectro-polarimeter, and slitjaw optics, is shown. A light trap is located between the slit and the grating to absorb the zeroth-order beam diffracted by the grating.

Figure 2: The assembled CLASP instrument. When the CLASP is launched, the instrument is covered with the rocket skin (semitransparent shell in this picture). The optical path is indicated with blue lines.

Evidence of Electron Acceleration around the Reconnection X-point in a Solar Flare

NARUKAGE, Noriyuki
(NAOJ)

Particle acceleration is one of the most significant features that are ubiquitous among space and cosmic plasmas. It is most prominent during flares in the case of the Sun, with which huge amount of electromagnetic radiation and high-energy particles are expelled into the interplanetary space through acceleration of plasma particles in the corona. Though it has been well understood that energies of flares are supplied by the mechanism called magnetic reconnection based on the observations in X-rays and EUV with space telescopes, where and how in the flaring magnetic field plasmas are accelerated has remained unknown due to the low plasma density in the flaring corona.

We report the first observational identification of the energetic non-thermal electrons around the point of the ongoing magnetic reconnection (X-point) [1]. The location of the X-point is identified by soft X-ray imagery (Figure 1 (b)–(d)). There is microwave emission from non-thermal electrons (negative alpha index) most clearly seen around the X-point (Figure 1 (k)–(m)). This indicates that there are energetic electrons present around the X-point during the course of the magnetic reconnection. Meanwhile, the soft X-ray observations of the flare were in good agreement, in a morphological sense, with the canonical reconnection picture (Figure 1 (a)) from which we expect, in addition to the inflow, bi-directional outflow of plasma particles and magnetic fields away from the X-point towards the bright soft X-ray loop and in the opposite direction. Assuming the presence of the expected reconnection outflow, it would be reasonable to conclude that the energetic non-thermal electrons are supplied from, namely, accelerated at, the region around the X-point rather than assuming that they travel from a region lower in altitude than the X-point against the counter-streaming downward outflow, or that they come from a region higher in altitude beyond the X-point against the counter-streaming upward outflow from the X-point.

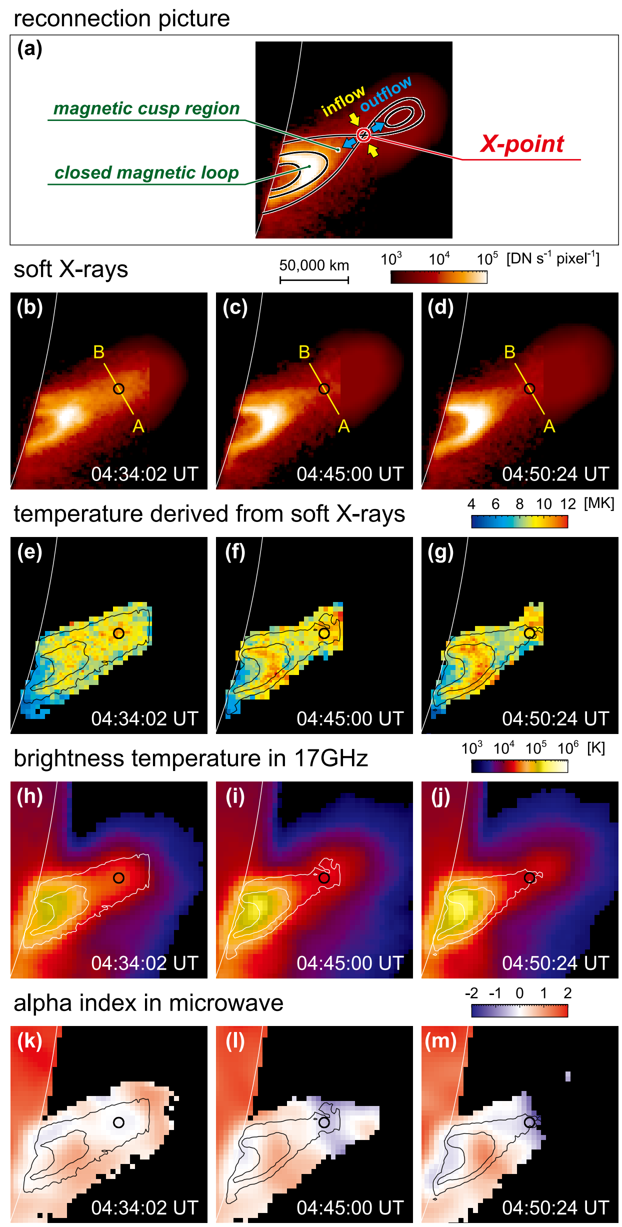

Figure 1: Soft X-ray and microwave observations of the 6 August 1999 flare. **(a)** Schematic illustration of the reconnection picture for the flare. **(b)–(d)** Soft X-ray images taken with the AlMg filter of *Yohkoh*/SXT. The location of the reconnection X-point is indicated by a black circle in each panel. **(e)–(g)** Electron temperature distribution derived with the filter ratio method from pairs of soft X-ray images obtained with the AlMg and Be119 filters of *Yohkoh*/SXT. **(h)–(j)** 17 GHz microwave brightness temperature maps from Nobeyama Radioheliograph (NoRH). **(k)–(m)** Spatial distribution of power-law index of microwave flux density spectra (alpha index) derived from NoRH 17 GHz and 34 GHz data.

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II Status Reports of Research Activities

1. Subaru Telescope

1. Subaru Telescope Staff

As of the end of FY 2014, the Subaru Telescope Project staff consisted of 19 dedicated faculty members including six stationed at Mitaka, six engineers, and three administrative staff members. Additional staff members include five research experts, one postdoctoral fellow, and seven administration associates, all of whom are stationed at Mitaka. Moreover, 11 research/teaching staff members, 10 of whom are stationed at Mitaka, and two engineers at Mitaka are posted concurrently. The project also has 83 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 the FY 2014, Subaru Telescope produced many outstanding scientific outcomes which were published in major international journals. Below are some examples:

(1) Deep high-z imaging observation with Suprime-Cam, the optical wide-field camera, discovered seven Ly-alpha emitters at $z \sim 7$. The very low number density of such high-z galaxies (only 1/5 of that at $z < 6.6$) strongly suggests that the neutral gas fraction (HI) in the Universe increases rather abruptly from $z = 6.6$ towards $z \sim 7$, which thus prevents Ly-alpha photons from escaping and reaching us. This result has a strong impact on the study of re-ionization in the early Universe.

(2) High resolution optical spectroscopy with HDS of a very metal poor star in the Milky Way Galaxy revealed an abnormal abundance pattern of chemical elements, characterized by low abundances of Carbon, Magnesium and Cobalt. This pattern can only be reproduced by a model of the supernova explosion of a super massive star (1000 times more massive than the Sun). Such a high mass for the first generation of stars had been theoretically favored and proposed, but this was the first observational evidence to support this scenario.

(3) High resolution optical spectroscopy with HDS of a nova, which was discovered in Aug 2013, revealed that a large amount of Lithium has been synthesized in this nova. Lithium is thought to be synthesized in many ways and at various places such as the Big-Bang, the inter-stellar medium, or in stars like novae and supernovae. Thus Lithium provides us key information about the origin and evolution of matter in the Universe. This was the first direct detection of a site where Lithium was synthesized and ejected. This confirmed that nova explosions are indeed the major supplier of the Lithium seen in the present-day Universe.

(4) High spatial resolution imaging of one of Jupiter's Galilean satellites with NIR camera IRCS assisted by adaptive optics unveiled the fact that the satellite is illuminated, though only at low level (1/100 of the normal brightness), even when it's eclipsed by Jupiter. This indicates that sun light refracted by the matter in the atmosphere above Jupiter's surface illuminates the Galilean satellite in Jupiter's shadow.

3. Open Use

The Subaru call for open use proposals is issued every six months. The periods are from February 1 to July 31 (S14A) and from August 1 to January 31 (S14B). The Mitaka office of the Subaru Telescope at the National Astronomical Observatory of Japan (NAOJ) campus accepts the submitted proposals. The Subaru Time Allocation Committee, established under the NAOJ advisory committee for optical and infrared astronomy, selects the proposals to accept, based on the evaluations and comments of the referees. In S14A, 70 programs (104 nights) were accepted out of 163 submitted proposals, requesting 403.6 nights in total. In S14B, 58 proposals (103 nights) were accepted out of 133 submitted proposals, requesting 366.7 nights in total. In S14A and S14B respectively, there were 11 and 3 accepted open use proposals by foreign principal investigators, excluding University of Hawai`i observing time. The number of applicants involved in the submitted proposals was 1806 for Japanese researchers (Japanese astronomers at any institute and non-Japanese astronomers belonging to Japanese institutes) and 642 for foreign researchers. The number of researchers in accepted proposals was 891 for Japanese astronomers and 260 for foreign astronomers.

In S14A and S14B, the number of open use visiting observers was 422, of which 60 were foreign astronomers. 34 astronomers observed remotely from Mitaka. The Mitaka office of the Subaru Telescope takes care of proposal handling and evaluation, travel procedures and travel support for the observers. The Hawai`i office makes the observing schedule and supports the accommodations and transportation for visiting observers in Hawai`i. In S14A and S14B, 94.8 % of the open use time (including University of Hawai`i time) was used for actual astronomical observations, after excluding the weather factor and downtime due to primary mirror coating. About 3.4 %, 0.2 %, and 1.6 % of observing time was lost due to instrument trouble, communication trouble, and telescope trouble, respectively.

In S14A and S14B, remote observations from Hilo were not conducted. However, remote observations from Mitaka, where observers in Mitaka could participate in observations remotely, in addition to on-site observers at the summit, were conducted with limited function as a trial, for 8 programs with 30 nights.

Service observations were made for 7 nights. To make the best use of the limited resources at observatories on top of Maunakea, Subaru Telescope has been exchanging telescope time with Keck and Gemini. The number of time exchange nights between Subaru Telescope and W. M. Keck Observatory was 5 in S14A and 3 in S14B. That between Subaru Telescope and Gemini was 6 in S14A and 5 in S14B.

4. Telescope Maintenance and Performance Improvement

The general performance of the Subaru Telescope continues to be maintained the same as in the previous year. This year, both the optical tertiary mirror and infra-red tertiary mirrors were recoated. During the recoating work, the mechanical drive of the tertiary mirrors was re-adjusted to improve reliability. Day crews took over the installation and removal work of both Hyper Suprime-Cam (HSC) and its filter exchange unit (FEU). As troubleshooting, the mirror cover open/close sensors, main shutter open/close sensors, and shutters of the Shack-Hartmann sensor were replaced. The rubber springs of the dome bogie have been replaced. Some new functions were added to the Top Unit Exchanger (TUE) for secure operation. The dome barcode system has also been upgraded. We also strived to conduct preventive maintenance.

In addition, while promoting improvements in the performance and operational efficiency of the Subaru Telescope, renovation proceeded for the telescope control units which have been in place for more than 10 years since installation. The following local control units were renovated or modified in this year: cover control unit (CVCU), field rotator control unit for primary focus (FRCU (PF)), atomic dispersion corrector control unit (ADCU), dome rotation servo control processor unit (DRPU), dome control unit (DCU), tertiary mirror control unit (TMCU), balancer control unit (BLCU), telescope control workstations (TWS), and primary mirror actuator CPU cards.

This year, maintenance of the main shutters, dome bogies, and the top screens was also carried out in addition to the annual mechanical maintenance. Of special note this year is the development of a script that checks whether certain telescope conditions should be expected or not. This script is run every morning and can find some minor problems, which indicate a potentially critical situation.

5. Instrument Operation and New Development

The nine open-use facility instruments of Subaru Telescope have been operated stably in FY 2014. 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 beginning of open-use observations in FY 2013, the software and hardware of HSC have been continuously improved. As a result, the operation of the filter exchange system, shutter, and auto-guider system have been stabilized significantly. Discussions on how to handover the operation and maintenance of HSC from the development team to the observatory are underway.

There are several upgrade projects for the other facility instruments: a MOS unit for HDS, an upgrade of the MOIRCS detectors, and implementation of polarimetric functions to IRCS and COMICS. For the HDS MOS unit, the supporting structure was transported to Hawai`i and study of its mechanical interface to the telescope has been started. The fabrication of optical components such as fibers is still ongoing in Japan. For the MOIRCS detectors, we have succeeded in operating the arrays and started characterization and parameter optimization. The IRCS polarization function has been tested on sky and, after characterizing the polarimetric performance and examining the calibration strategy, it was decided to open the polarimetry mode starting from S15B.

In parallel to those upgrade projects, discussions on how we maintain or stop operations of the facility instruments are underway. To establish the plan for Subaru Telescopes's instrumentation, we summarized information such as competitiveness, demand, publications, and work load for maintenance/troubleshooting of the facility instruments. Based on the results, an instrument plan was proposed to the community in the User's Meeting. Discussions and planning of Subaru Telescope's instrumentation including decommission of facility instruments are still ongoing.

In FY 2014, two carry-in (PI-type) instruments HiCIAO (high-contrast coronagraph imager) and Kyoto-3DII (optical integral field spectrograph) have continued to be operated. The commissioning of a coronagraphic extreme adaptive optics (SCExAO) instrument has been performed. The tests of some operation modes of SCExAO including low-order wavefront correction, quasi-static speckle nulling, and the aperture masking interferometer (VAMPIRE) which enables high-spatial resolution imaging in visible bands, have been completed in FY 2014. These operation modes have been used in open use observations since the S14B semester and are taking an important role in the direct imaging observation of extra-solar planets. SCExAO has been commissioning a high-order wavefront correction mode, which realizes extreme adaptive optics correction. There are plans to open this mode to open use observes on a trial basis starting from S15A.

A Multi-Object Adaptive Optics (MOAO) science demonstrator (RAVEN), which has been developed in collaboration with Canadian institutes, successfully saw first light at the Subaru Telescope in May 2014 and demonstrated the performance of the MOAO system. As a science demonstrator for a future TMT MOAO system, RAVEN will conduct additional test observations for evaluating its performance and perform science observation in S15A.

There are new PI-type instruments, IRD (InfraRed Doppler instrument) and CHARIS (Coronagraphic High Angular Resolution Imaging Spectrograph), which are currently being developed. The IRD project has been reviewed by the observatory since FY 2013 and officially approved in FY 2014. These two instruments are planned to be transported to the Subaru Telescope in FY 2015 and to conduct commissioning observations in FY 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). We are reviewing the acceptance of SWIMS and MIMIZUKU by considering the impacts to the existing observatory resources.

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 which feed the light of the astronomical objects to four identical spectrographs which will be placed in the telescope dome. The spectrograph modules cover wavelengths ranging from 0.38 μm to 1.26 μm simultaneously. Since the PFS is being developed through international collaborations between several countries with a large budget scale, the project has been reviewed by the NAOJ headquarter in terms of the management of the project before approving the PFS as an official project of the Subaru Telescope. In FY 2014, the Subaru Telescope officially approved the PFS project by considering the astronomical importance of the project and the future instrument plan of the Subaru Telescope.

We are conducting a conceptual study of Subaru Telescope's 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 ground-layer adaptive optics (GLAO), 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 2014, the design of the wide-field near-infrared multi-object spectrograph has been discussed in collaboration with an Australian institute. We are planning to have a conceptual design review which summarizes the studies of GLAO and near-infrared instruments discussed so far.

6. Computers and Network

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

Archiving observation data on the current system has been ongoing since the pervious year. The archive is operational without serious problems. We have been developing a user interface that is suitable to download large amounts of data in a batch process per requests by users who wish to download data taken by Hyper Suprime-Cam (HSC) with the Strategic Science Program (SSP).

The data archive system in Mitaka is also operating stably.

We officially rolled out remote observations from Mitaka using the Remote Observation Monitor System for a limited amount of time. In this fiscal year, 25 observation programs utilized the remote observation monitor system for 28 nights. More programs will use the remote system in the future. The proposal Management System (ProMS) also worked very well.

Computers for HSC data analysis were procured in Fiscal Years 2010 and 2011. This year, storage, an interactive processing server, and a database server were added to the system. The current system requires the storage to send and receive large amounts of data to/from the clients. But the current storage is not fast enough to handle that amount of data and makes overall performance subpar. Therefore, we decided to test a fast data I/O software replacing NFS. The test system including hardware and filesystem software was delivered by the end of this fiscal year. Setting up the test system is planned for early in the coming fiscal year.

The dedicated network link between Hawai`i and Mitaka has been procured with a single year contract since April 2014. Bidding was conducted to select the provider to supply the network link in this fiscal year. The link speed will become 2 Gbps, double the past speed, considering the increase in traffic due to HSC observations. 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 start from April 2015.

We have rolled out the online visitor form replacing paper/fax starting from the S14B semester. We are also developing another visitor form for Remote Observation Monitor users at Mitaka.

7. Education (Under-Graduate and Graduate Courses)

The number of Subaru 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 18 which constituted more than a half of the entire 32 SOKENDAI students hosted in NAOJ. Of which nine had supervisors who primarily belonged to Subaru Telescope.

In FY 2014, Subaru Telescope hosted four graduate students for long stays, of which two 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 throughout Japan who obtained master's degrees and PhD's based on Subaru Telescope data were 11 and 4, respectively. Of which 3 and 1 belonged to the division of Optical and IR Astronomy, respectively.

We also regularly hosted a series of educational programs at Subaru Telescope. In September 2014, we hosted a Subaru autumn school in which 6 graduate and 6 under-graduate students from all over Japan participated and learned the reduction and analysis of Subaru Telescope data and heard a series of lectures. In November, under the recommendation of the Subaru advisory committee, we co-hosted the 1st China-Subaru workshop in Shanghai in which many students and postdocs participated. Moreover, in October, we hosted two Subaru Telescope observation training courses, one for undergraduate students from all over Japan, and the other for new SOKENDAI students at NAOJ. In the Subaru Telescope Hilo office, we had regular Subaru seminars in English 2–3 times a month, where open-use observers, visitors, and Subaru Telescope staff members presented their newest research. Also in the Subaru Telescope Mitaka office, we had numerous 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 of 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 2014, there were 21 web-postings (10 in Japanese, 11 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 45 (24 in Japanese, 21 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 30 (28 in Japanese, 4 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 December when the tour program was suspended to allow safe work for the tertiary mirrors' recoating, a total of 559 people visited through this program. There are 111 additional groups who visited through special tour programs and resulted in the total head count of 1,252 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 base building 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 41 groups, with 451 people, visited the base facility this year.

Task3: Public outreach which includes lectures in the local community, special presentation in the schools, and remote presentation for Japanese schools or museums. PIO provided/coordinated 56 lectures at the base facility or in its vicinity such as at the ‘Imiloa Astronomy Center. There were 12 lectures outside of the island, and 14 remote lectures for off-site locations. The local lectures included 26 classroom presentations during the Journey Through The Universe program, and reached out to 736 students in the local schools.

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. 600 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.

2. Okayama Astrophysical Observatory

The Okayama Astrophysical Observatory, (hereafter the Observatory) serves as the observing and research base of 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.

About 230 nights at the 188-cm telescope are exploited for observations by researchers from across the country through open use every year. The Observatory maintains and operates the observing instruments and provides the observers with support for observations, travel expenses, accommodations, every day needs, etc. It also engages in improving the open-use observing instruments, developing new open-use instruments, and supporting brought-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) and use it 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 improve significantly 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 positively.

The personnel breakdown as of March 2015 was six full-time staff members, including two associate professors, one assistant professor, one chief research engineer, one engineer, and one chief clerk; twelve contracted staff members, including three research experts, one postdoctoral fellow, three research supporters, three administrative supporters, and two administrative maintenance staffs; and one temporary staff member.

1. Open Use

(1) Overview

The numbers of nights allotted to the open use in 2014 were 122.5 nights for the first semester (2014A, January to June) and 110.5 nights for the second semester (2014B, 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, and 12 general observation proposals in 2014A, and did 1, 1, and 12 in 2014B. A proposal from Turkey, one from the Republic of Korea, and one from Hawai`i were accepted in 2014B and the Observatory supported their observations with human resources. The anonymous application system was abolished after 2014A as planned and reverted to the previous system starting from 2014B. Open-use observation generally proceeded without incident.

(2) Observation/Research Results

The majority of objects observed through the open use in 2014 were stellar sources including pre-main sequence stars. Others included Solar System objects, AGNs, and quasi-stellar objects. The following primary observation themes were noted: searching for exoplanets via precise radial velocity measurement; exploration of the physical properties and activities of binary stars via high-dispersion spectroscopy; and the observation of exoplanet transits by precise near-infrared differential photometry, which increased precipitously in recent years. Optical low-dispersion spectroscopic observations of stars for classification and of sudden phenomena for follow-ups remained significant since last year. 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's drive and controller were renewed and the connections between the telescope and the observing instruments were established by the end of FY 2013. A report was published on the details of the refurbishment in FY 2014 (Kuroda et al. 2015, Report of the National Astronomical Observatory of Japan, Vol.17, 19–39). The telescope control software was elaborately improved to enhance its user-friendliness and safety while observing as well as its maintainability.

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. The 1.5-m primary mirror of the KANATA telescope at Hiroshima University and the primary mirror of the ISAS 1.3-m telescope were also accepted for re-aluminization in the period this year. Participants in the aluminization work from these organizations were given NAOJ-mandated safety and hygiene training as necessary. Lubrication of the telescope and dome was conducted in July. Utmost efforts were made to maintain high observing efficiency by conducting monthly cleaning of the primary, secondary, and tertiary mirrors of the 188-cm telescope after October. Also intensive maintenance was applied to the hydraulic system of the aluminization vacuum chamber, to prevent oil leakage which had been an issue to be solved for years, including refurbishment of the oil cylinders and renewal of the oil pipes from September to March.

The dome was checked daily. Other maintenance work was also performed, including repairing the worn-down guiding rails for the upper and lower slit doors in August, repairing the external panels of the dome hemisphere to prevent rain leakage in June and August, repainting the dome periphery in July, replacing deteriorated metal mesh at the bottom of the dome wind channel in August and November, installing an internal roof east of the north pier of the telescope inside the dome to prevent rain leakage from falling onto the observing instruments in September, repairing the painting of the cat walk floor in March, renewing deteriorated power lines and contactors (at any time), and replacing old lighting equipment on the first floor with LED lights in August. Asphalt pavement around the telescope dome was renewed as well.

Much attention was paid to the operation and maintenance of the facility and equipment. It is to be noted that sound-proofing work was done for the second time to a visitor's room on the second floor of the main building, resulting in four proofed rooms. Work safety was given priority in accomplishing the aforementioned maintenance work and observing instrument exchanges. As a result, no accidents or incidents whatsoever occurred during FY 2014.

(4) Conferences

The program subcommittee for the 188-cm telescope met on May 16 and November 14 to evaluate proposals for open use in 2014B and 2015A (first semester of 2015), respectively, and formulated an observation program for each semester. The Okayama Users Meeting, also known as the 25th Optical and Infrared Users Meeting, was held at Mitaka Campus of NAOJ on August 11 and 12.

Various reports were made: current status of the Observatory, execution summary of the program subcommittee, preparation status of remote observing facilities of the 188-cm telescope, two user-led plans to develop new observational instruments for the 188-cm telescope, etc. Reports by others included research results from open-use projects. Also discussed were the operations of other optical and infrared observational facilities such as the Higashi–Hiroshima Observatory and the networking of small- and mid-sized telescopes. On the second day of the meeting, a report was given on the progress of Kyoto University's Okayama 3.8-m New Technology Optical and Infrared Telescope project and proposals were presented for the initial research themes, observing instrument plan, and operation systems before and after completion. The proposals were followed by a stimulating debate.

In addition, the seventeenth liaison conference on cooperation for astronomical observations at Okayama Astrophysical Observatory of the National Astronomical Observatory of Japan led by the Okayama prefectural office was held in Okayama-city in October 2014, aiming at preserving the environment for astronomical observations. In the meeting, continuation of the cooperative framework was confirmed among the participants.

2. Developing 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. Major work pursued in FY 2014 included replacing the controller computer; improving the autoguider to cope with dimmer stars through stray light mitigation and software version-ups; and preparing for the adoption of KOOLS-IFU (see "(3) KOOLS" below) into the Cassegrain unit of the HIDES fiber link (see below). Accepted proposals to HIDES as a whole were 6 and 6 in 2014A and 2014B, including 1 and 1 project observations, respectively.

The observing capability of HIDES is currently being improved by introducing fiber links. The high-efficiency fiber link with approximately 50-K wavelength resolution now 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 link test observations were conducted in 2010, and it has been provided for open use since 2011. Two academic journal papers were published from the use of the fiber link in FY 2014. Seven open-use programs including those from three new PIs and one ToO observation were performed with it in 2014. It's usage increased steadily. Besides, a high resolution fiber link with a spectral resolution of nearly 100,000 was also developed. It was evaluated by providing it for trial use with the project observation program since 2015A. It will be provided for open use in CY 2016.

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

The instrument ISLE is a near-infrared imager and low- or mid-dispersion spectrograph, and has been available for the project observations and the academic degree support programs since the second semester of 2011 (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). Having achieved a high precision for relative photometry of one milli-magnitude level, ISLE is in greater demand for observations of exoplanet transits. The numbers of open-use programs using ISLE conducted in semesters 2014A and 2014B were 5 and 3, respectively, which included 1 and 1 academic degree support programs, respectively. Four of them were spectroscopy and the other four were imaging photometry of exoplanet transits.

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

This instrument was made available for open use as a PI-type instrument in FY 2008 and has since been in stable operation. The CCD output linearity is good enough. Non-sidereal motion objects can be tracked for long integration times. The open-use applications for KOOLS have increased due to a recent rise in demand for spectral classification and monitoring observations. There are 4 and 6 accepted proposals for 2014A and 2014B, respectively. An integral field unit (IFU) using a fiber-bundle was developed by a team at Kyoto University, as one of the candidate first generation instruments for Kyoto University's Okayama 3.8 m New Technology Optical and Infrared Telescope project. Its input part was installed into the Cassegrain unit of the HIDES fiber link and its output part into KOOLS under the support from the Observatory. Its commissioning was performed on two nights provided from the Observatory time. IFU will be delivered as a PI-type open-use instrument starting from semester 2015B. However, KOOLS itself has begun to have various small troubles and is in need of intensive maintenance for long-term usage.

(4) Others

A remote observing environment was prepared to enable observers to perform their open-use observations with the 188-cm telescope from remote sites over the internet in FY 2014. After testing it many times inside the Observatory, it was confirmed that smooth observations are feasible from outside the Observatory with the help of some open-use observers at remote sites. It will be further polished preparing to open the environment for open-use.

Meanwhile, a carry-in instrument newly developed for the 188-cm telescope, "MuSCAT," was accepted for performance verification (MuSCAT is an acronym for Multicolor Simultaneous Camera for studying Atmospheres of Transiting exoplanets). The Observatory allowed four observing nights from the Observatory time for the commissioning.

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 Nagoya University and Nano Optonics Energy Inc., regarding the 3.8-m telescope project as part of the future plan for the Observatory. Discussions were held on technological issues regarding the telescope and dome through weekly TV conferences and in-person meetings held every three months. The main telescope was constructed and tuned in a temporary hanger placed in the Observatory in FY 2014.

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

The Program has entered its fourth 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 35 nights worth of observational data on seven objects this year. Four of the objects were gamma-ray bursts, which are the main target of the Program. Afterglows were detected at multiple sites in the network for three of them. Another source was observed simultaneously by the Program and the inter-university VLBI cooperation program as a first trial. Two peer-reviewed papers were published utilizing OISTER. Another 61 peer-reviewed papers that have something to do with the Program were published, in 9 of which OISTER played a vital role. A joint special session "Inter-university cooperation across radio, optical, and infrared" between the Program and the inter-university VLBI cooperation program was held at the annual autumn meeting of the Astronomical Society of Japan in 2014. The fifth workshop of the Program was held, this time open for the first time to general researchers who did not belong to the network. Priority was given to publicizing the research results from the Program on the web page of OISTER this FY.

(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 2014, the automatic observation scheduler performed observations on nearly every possible night; 27 GRBs were observed, with optical afterglows successfully detected in three. Observation results were published as 16 GRB Coordinates Network (GCN) circulars. Besides, six peer-reviewed papers were produced from monitoring of Mira variables and comets and observations of supernovae, AGNs, and exoplanet transits that were conducted when the telescope was free.

(4) Other

The Observatory welcomed five third-year undergraduate students and the supervisor from the University of Tokyo between August 14 and 15 and provided them with an opportunity to conduct high-dispersion spectroscopic observation using the 188-cm telescope during the early half of the night on August 14. A summary of this activity over the past several years was presented by the supervisor on a poster at the users' meeting held on August 11 and 12.

4. Unique Research Projects

(1) Detection of the Afterglow of Distant GRBs and Survey of Variable Stars in the Galactic Plane Using the Ultra-Wide-Field Infrared Camera

A project is underway to identify infrared counterparts for objects such as distant GRBs and gravitational wave sources and to comprehensively survey infrared variable stars in the Galactic plane by converting the 91-cm telescope into an infrared camera with an ultra-wide field of view of 1 square degree. Almost uniform imaging quality was achieved across a square field of view of 0.48 degree by 0.48 degree (for 1-k detector) after a fine adjustment of the telescope optics in FY2014. An automatic focusing mechanism was installed and semi-automatic observations became available. A pilot monitoring program was initiated in the Ks-band toward a selected area in the Galactic Plane to assess the feasibility of variable star surveys.

(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 functionality 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. A function was developed to automatically correct for the drift of the best focus position by inferring the drift based on the temperature distribution across the telescope tube through thermos-sensors attached to the telescope truss tube in FY 2014 (see Kamiya et al. 2014, V220a at the Annual assembly of the autumn ASJ meeting 2014). Another new functionality was investigated to further improve the telescope pointing by measuring the small movement of the primary mirror in the cell and correcting the pointing error due to the movement, which would help advance the automation of the telescope operation and observation.

(3) East Asian Planet Search Network

The Observatory also conducts studies focusing on the search for exoplanetary systems, involving researchers from The Republic of Korea, the People’s Republic of China, the Republic of Turkey, and Russia. The efforts continued in FY 2014 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 1.88-m telescope for continued searches for exoplanetary systems around G-type giant stars. One exoplanet candidate was discovered from the collaboration with Chinese colleagues, and four binary systems consisting of a G-type giant and a low-mass companion were identified through the collaboration with Turkish and Russian colleagues in this fiscal year. Both results were published in peer-reviewed journals.

5. PR/Awareness Promotion Activities

An Observatory representative delivered a lecture to nearly 20 people in Okayama City on Monday, July 7 as part of the Nation-Wide Tanabata Participatory Lectures. Nearly 50 astronomy-related questions from the public were posed irregularly to the Observatory and were answered appropriately this year. The 4D2U screening, co-hosted with the Okayama Astronomical Museum, attracted 3,854 visitors.

Twenty-two Observatory tours were conducted, including those for pupils from local elementary schools in Asakuchi city and Yakage town. The Observatory also responded to six lecture requests made by local boards of education and community centers.

6. Contract Staff Transfers

The following transfers of contract staff members took place in FY 2014: Kouki Kamiya joined as a Research Supporter in October and Hiroyuki Maehara did so as a Research Expert in November. Research Supporter Yasuhiro Shimizu left at the expiration of his term at the end of March. Postdoctoral Fellow Akihiko Fukui left the position at the end of March when his term expired.

3. Nobeyama Radio Observatory

1. 45-m Radio Telescope

(1) Open Use Observations

The 33rd open use observations started on December 15, 2014 as scheduled (observers for the backup program stayed in the observatory starting from December 1, 2014).

The statistics of the proposals are as follows,

“General Proposal 1st period”: 16 accepted including 5 from abroad (34 submitted),

“General Proposal 2nd period”: 13 accepted including 4 from abroad (21 submitted),

“Short Program”: 9 accepted (15 submitted),

“Education Program” (1st and 2nd periods): 0 accepted (0 submitted).

“Backup Program”, which is carried out when weather is not acceptable for the main observations: 1 accepted (1 submitted).

In addition, the 45-m telescope joined the VERA open use observations: 3 proposals.

The multi-beam receiver BEARS and the AC45 spectrometer were decommissioned.

(2) Improvements and Developments

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

- The antenna foundation made of concrete was leveled because of its unacceptable amount of tilt. The design was completed for the subreflector servo system replacement to be installed next year.
- End to end holographic measurement tests were done aiming to improve the surface accuracy of the 45-m telescope.
- Test measurements for the improvement of the performance of the beam transmission system were carried out.
- The new multi-beam receiver FOREST was installed and used for the legacy project observations (observatory internal use) after basic performance evaluation and test observations.
- New AD converters were installed in the 4 intermediate frequency lines among the 16 lines and were used in open-use observations. They exhibit smaller frequent-spurious-signals

and show better linearity performance.

- NRO supported user instrument including the Z45 receiver at 45 GHz band, digital spectrometer ROACH, and a 90/150 GHz continuum camera.
- The help desk for open-use observers became operational, and its manual was released.

(3) Scientific Results

We are carrying out the (a) Star Formation Legacy 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.

(a) Star Formation Legacy Project

In the Star Formation Legacy Project, we conducted large-scale mapping observations toward nearby star-forming regions: the Orion A molecular cloud and W40 H II region in ^{13}CO and $C^{18}O$. For the Orion A cloud, we combined the 45-m ^{13}CO data with the CARMA interferometer data to obtain a ^{13}CO large-scale map whose angular resolution is about 5 arcsecond. From the combined map, we identified many filaments in the cloud. For the W40 region, we found shell-like dense molecular gas clumps around the H II region. The comparison between the infrared data and the 45-m data suggest that the gas clumps are interacting with the expanding shell created by the H II region.

(b) Galactic Plane Survey Project

We are conducting a simultaneous survey of the ^{12}CO, ^{13}CO, and $C^{18}O$ J = 1–0 emission lines in the Galactic Plane using the new multi-beam receiver FOREST installed on the 45-m telescope. We plan to make maps of the inner Galaxy (10d < l < 50d, b = ±1d) and the outer Galaxy (198d < l < 236d, b = ±1d) including the spiral arms and bar structure. In 2014, we covered areas with 24 and 7 square degree for a total of 31 square degree. We have revealed a wide range of molecular clouds and their fine structures, e.g. filaments that have not been seen in previous surveys.

2. SPART

To better understand the influence of the activities of host stars on the middle and lower atmospheres of terrestrial planets, including solar system planets and exoplanets, we have been performing monitoring observations for millimeter-waveband spectral lines of carbon monoxide (^{12}CO J = 1–0: 230.538 GHz, J = 2–1: 115.2712018 GHz, ^{13}CO J = 2–1: 230.3986765 GHz) in the middle atmospheres of Mars and Venus with a 10-m telescope, the Solar Planetary Atmosphere Research Telescope (SPART), since it was launched in 2011. The SPART employs highly sensitive 100- and 200-GHz double-band superconducting SIS heterodyne detectors and a 1-GHz-band digital fast-Fourier transform spectrometer with a frequency resolution of 61 kHz. Heterodyne spectroscopy with high frequency resolution is a powerful tool for observing the weak and narrow spectral lines of minor constituents in the middle atmospheres of planets.

This season we repaired the elevation-motor of the telescope. An example of the results we found from the SPART monitoring is that the disk-averaged mixing ratio of carbon monoxide derived at an altitude of approximately 80 km in Venus has slightly changed since 2012. This phenomenon may be linked to solar activities in the current 24th solar cycle. Middle atmospheres of terrestrial planets like Mars and Venus lacking magnetospheres may be directly affected by energetic events of the host stars.

Over the coming six years solar activities will be lowered toward the solar minimum phase. Therefore, it is important to continue the monitoring research with the SPART for understanding of how atmospheric conditions of terrestrial planets balance physically and chemically under activities of host stars.

3. Development of a Multicolor Millimeter/Submillimeter Camera for the Atacama Submillimeter Telescope Experiment (ASTE)

Extensive large-scale sky surveys in the millimeter/submillimeter bands with a multicolor continuum camera are indispensable for various types of research including estimating the redshift of submillimeter galaxies, using the Sunyaev-Zel'dovich effect to study the internal structure of hot plasma in clusters of galaxies, and constraining the physical properties of the dust in star-forming regions and the spectral index of the initial submillimeter afterglow of gamma ray bursts (GRBs).

Thus, we, in collaboration with the University of Tokyo, Hokkaido University, the University of California Berkeley, and McGill University, are developing a multicolor millimeter/submillimeter camera based on a very sensitive Transition Edge Sensor (TES) bolometer for observations at wavelengths of 1.1 mm, 0.87 mm, and 0.46 mm.

We deployed our bolometer camera on the ASTE Telescope during March and April of 2014. At that time, thanks to the excellent observing conditions, we managed to explore the star-forming regions in our Galaxy, submillimeter galaxies, and GRBs outside our Galaxy. Thus, this year, we've been focused on analyzing the observational data obtained in that run, and improving the performance and efficiency of the observing system based on these results. We've worked out the solution to the problems in the yield of the bolometer array and the readout device, and the time consuming algorithm for tuning the operating parameters of the bolometers. Solving these problems will increase the observing sensitivity and efficiency, respectively. Furthermore, we've worked on an issue inherent to bolometers with TES sensors; namely that they lose sensitivity if the weather improves after they have been tuned. We came up with a solution to overcome this issue by employing a movable blackbody radiation source. This will drastically widen the range of weather conditions for which observations are possible.

In order to increase the number of observing bands in the future, increasing the number of pixels read out is inevitable. Therefore, the multiplexing technologies to double the number of bolometer pixels read out per readout device from 8 to 16 were carefully considered. As a result, we showed that increasing the multiplexing factor to 12 pixels per a readout device is possible with minor changes to the current readout system. Finally, we've started the development of the add-on fore optics which will open a new window to conduct polarization sensitive observations with our bolometer camera.

4. Misc.

(1) PR Activities at the Nobeyama Campus

The Nobeyama Campus has been accessible to the public since the inauguration of the observatory in 1982. The number of visitors this summer decreased compared with previous years due to bad weather. The campus received a cumulative total of 51,535 visitors throughout the year, including participants of the special open house events in August. This is the smallest number except the opening year 1982. Staff members conducted 30 guided tours, including tours for Science Partnership Programs (SPPs) participants, Super Science High School (SSH) students, and the Campus Tour Week. Additionally, five requests for lectures and 22 requests for on-site filming and interviews were granted. These kinds of requests increased owing to improved relations with Local Communities.

The Campus Tour Week was scheduled during summer and was aimed at educational institutions (elementary, junior high, and high schools). Staff members gave guided tours for this program as well. Six groups took advantage of this opportunity. Most visitors from the participating schools said they thoroughly enjoyed their visits. For the workplace visit initiative conducted between July and October, 18 students from 7 schools, primarily local junior high schools, visited the observatory and had a chance to experience the observatory's routine work under staff guidance. For SPP/SSH initiatives, six schools visited the NRO and participated in lectures, student presentations, and hands-on guidance of future activities. Furthermore, the Radio Astronomical Observations workshop using the 45-m radio telescope was held again this year from June 2 to 6, with 12 undergraduate students in attendance. Because senior students can take part in the workshop in June, the grade composition of the participants is different from the normal year. Although instruction to the students, from observations to presentation of the results, requires significant staffs' effort, the event offers an invaluable opportunity for undergraduates to experience observations using a radio telescope.

In the area for permanent public access, an antenna model is available along with posters and panel displays. A video continuously played in the visitor room shows various facilities, introduces the history of the NRO, and explains research results with the 45-m telescope. For Internet-based PR activities, the NRO runs a website which is expanding to include observational results as well as introductory descriptions of radio astronomy. In particular, these posters, panel displays, and web pages were modified to reflect the close of Nobeyama Solar Radio Observatory at the end of the fiscal year.

(2) Cooperation with Local Communities

The annual Nobeyama Special Open House Day was held with contributions by Nagano Prefecture as well as Minamimaki Village, and the Minamimaki Chamber of Commerce along with its youth division. Jimoto Kansha Day (Thanks Day for the Locals) was held as the Special Open House for locals (Minamimaki and Kawakami villages) with Nobeyama Station of Education and Research, Center of Alpine Field Science, in the Faculty of Agriculture of Shinshu University and Yatsugatake-forest in the Agriculture and Forestry research center of Tsukuba University. Special sponsorship was provided to the Sora-girl event "Tebura de Hoshizora Kansho-kai" ("Drop-by Star Gazing Event") hosted by the Minamimaki Tourism Association. The NRO also joined the Japan Three Major Scenic Location for Star Gazing with the Minamimaki Tourism Association: Night Sky Summit that took place in Ishigaki City, Okinawa Prefecture. Also, two lectures were held 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).

(3) Referbishment Plan for the Nobeyama Millimeter Array Building

The building for the Nobeyama Millimeter Array will be renovated to install an exhibition area focusing on the National Institutes of Natural Science (NINS) as well as the NAOJ, in order to establish a PR center for not only astronomy, but also for all of the natural sciences. The preliminary survey and the design of the building were complete before the construction work scheduled in the next year.

(4) NRO Conference Workshops

- July 15, 2014
  NRO Galactic Plane Survey Mini-Workshop (representative: Tomofumi Umemoto)
- July 23-24, 2014
  32nd NRO Users Meeting (representative: Shuro Takano)
- July 28-31, 2014
  44th Summer School on Astronomy and Astrophysics for Young Researchers 2014 (representative: Akira Oka)

(5) Education

NRO accepted two postgraduate students. The one visiting student from Kagoshima University got a Ph.D. on polarization capability of a new receiver this year. The other visiting student from Toho University got her Master degree on chemical reaction of carbon chain molecules.

(6) Part-time Research Staff Transfers

- Specially Appointed Research
  Tatsuya Takekoshi: Specially Appointed Research, NAOJ Chile Observatory
- Researcher
  Kana Morokuma: Specially Appointed Research, NAOJ Chile Observatory
- Researcher Supporter
  Hiroyuki Nishitani: Engineer, NAOJ Nobeyama Radio Observatory

4. Nobeyama Solar Radio Observatory

1. Closure of the Nobeyama Solar Radio Observatory Project and Future Operation of the Nobeyama Radioheliograph and the Nobeyama Radiopolarimeters

The termination of the operation of the Nobeyama Radioheliograph (NoRH), which has been the main observational instrument of the Nobeyama Solar Radio Observatory (NRSO), was scheduled to occur in FY 2014. Along with this, the closure of NSRO was also scheduled at the end of the FY 2014. On the other hand, some users had thought to continue the operation of the Radioheliograph. They proposed that the Solar Terrestrial Environment Laboratory (STEL) of Nagoya University borrows the instrument from NAOJ and operates it through cooperation with an international consortium (ICCON) formed by some institutes, both foreign and domestic, who are willing to help the operation financially. NAOJ approved this proposal, and an agreement between NAOJ and Nagoya University was made to continue the operation of NoRH for three (six at maximum) years, with technical support by the Nobeyama Radio Obseravtory (NRO).

The continuation of the operation of the Nobeyama Radiopolarimeters (NoRP) was also requested by some users. NAOJ decided to transfer it to NRO from NSRO to continue the operation.

Data from these instruments will be released by the Astronomical Data Center of NAOJ and STEL of Nagoya University from now on, and the environment for the data analysis has been prepared. Researchers in the world can freely access the data as always.

Because it was decided to continue to operate instruments, maintenance work has been done intensively in this fiscal year to operate the instruments steadily after next fiscal year. It was decided to move the personnel of NSRO who are working at the Nobeyama campus to NRO, where they will deal with the remaining work for the solar radio instruments as a part of their duties. Various duties of NSRO were mainly taken over by NRO, and the NSRO project was dissolved at the end of FY 2014 as scheduled.

2. Radioheliograph- and Radio Polarimeter-Based Solar Observations

At the beginning of FY 2014, operation of NoRH and NoRP were assumed to be terminated in the middle of the fiscal year to wind up the NSRO project. However, because it was decided to continue the operation of both of the instruments from FY 2015 on, the termination of the operation was cancelled and the solar observations until the end of the fiscal year were continued almost stably, though there was some instrument trouble.

3. Open Use, Joint Research, and Consortium Activities

All observational data are made available to the public, and researchers working in relevant fields in Japan and abroad have utilized this information for their studies on solar phenomena, space weather, and space climate. The data are also leveraged for the purposes of education and PR. A consortium of university users, represented by Satoshi Masuda, promotes open use in Japan (http://solar.nro.nao.ac.jp/HeliCon_wiki/). A data analysis workshop (CDAW14: September 29–October 3, 2014) held to actively promote open use in Japan had 18 participants. Lectures and exercises were offered; four groups practiced data analysis, and attendees subsequently reported the experience at various research conferences and to the astronomical society. The Japan Solar Physics Community held a symposium entitled “Solar Activity at the 24th Solar Maximum and Future Prospect for Solar Physics” at Nagoya University from February 16 to 18, and the Observatory presented its undertakings as well as studies conducted during CDAW14.

Drs. H. Ezawa and H. Matsuo of NAOJ carried out an experiment to use NoRH as an intensity interferometer, and they confirmed that NoRH element antennas can work as an intensity interferometer.

Regarding visiting international researchers, Drs. B. Hnat, D. O'Connell, and D. Kolotkov from the University of Warwick (UK) studied oscillatory phenomena using the data from NoRH. Drs. J. Huang and Y. Zhang from the National Astronomical Observatories of China studied solar flares and their precursors. From the USA, Dr. S. White made synoptic charts of the circular polarization to investigate the global chromospheric magnetic field, and Dr, S. Yashiro (NASA) prepared tools for remote operation by members of ICCON.

4. Other

An issue of the Astronomical Herald, entitled “The Special Issue for the Nobeyama Radioheliograph”, including six articles related to NoRH, was published by the Astronomical Society of Japan. Graduate students of SOKENDAI, Tokai University, and Ibaraki University, and undergraduate students of Shinshu University and Meisei University studied solar physics with the data from NSRO. The Cutting Edge Solar Research Experience Tour, which was organized jointly by solar-related research institutions in Japan, offered lectures and a guided tour of the observatory to 11 participants. Regarding initiatives aimed for high schools, Komagane Technical High School in Nagano installed its own radio telescope, for which the observatory rendered support, and its students participated in the SPP program, and the observation results from this telescope were presented to the junior session of the Annual Spring Meeting of ASJ.

At the end of the fiscal year, K. Shibasaki (Professor) retired. K. Iwai (Postdoctoral Fellow) departed upon completion of his term. From the next fiscal year, M. Shimojo (Assistant Professor) will belong to the Chili Observatory, and N. Shinohara (Senior Engineer), M. Takemura and H. Shinkai (Administrative Supporters) will belong to NRO.

5. Mizusawa VLBI Observatory

At NAOJ Mizusawa VLBI Observatory, we operate VLBI (Very Long Baseline Interferometry) facilities such as VERA (VLBI Exploration of Radio Astrometry) and KaVA (KVN and VERA Array), and provide these unique facilities to the user community in Japan and East Asia to support the research activities at universities and research institutes. At the same time, we conduct astronomical research using these VLBI arrays on the Galactic structure, star-forming regions, late-type stars, AGNs and so on. In addition to the operation of VERA, which is a dedicated array for VLBI astrometry, we support the maintenance and operation of the Yamaguchi 32-m Radio Telescope and two 32-m radio telescopes at Ibaraki in collaboration with local universities. Furthermore, we promote international collaboration, particularly in the East Asian region through the joint operation of KaVA and the East Asian Correlation Center at KASI (Korea Astronomy and Space Science Institute) as well as through preparatory operation of the East Asian VLBI Network which is a joint array between the People's Republic of China, Japan, and the Republic of Korea.

Also we keep Japan Central Standard Time as an obligation of NAOJ, and maintain Esashi Earth Tides Station for geophysics researches, and Ishigaki-jima Astronomical Observatory mainly for public outreach.

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 2014, we conducted a total of 399 (3,733 hours) observations with VERA, such as common use observations, project observations, 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.

VERA common-use call-for-proposals with the 43, 22, and 6.7 GHz bands for semesters 2014B (July to December) and 2015A (January to June) were released in June and November, respectively. A total of 15 proposals, which requested a total time of 632.5 hours, were submitted.

Referees elected from scientists in related fields and by the VLBI program committee evaluated the proposals and a total of 9 proposals (270.5 hours) were accepted in 2014B and 2015A.

(2) Science Result

Last year, we continued the project observations of VERA and produced science outputs on high-accuracy maser astrometry. In particular, we have published the third VERA Special Issue in PASJ (Publications of the Astronomical Society of Japan) succeeding the previous ones in FY 2008 and FY 2011. In this special issue, seven papers were published in FY 2014, and more papers are to come in another volume. The published outputs in FY 2014 include astrometric measurements of Galactic star-forming regions IRAS 20056+3350, IRAS 20143+3634, IRAS 22555+6213, NGC 2264, NGC 6334, and late-type stars RW Lep, T Lep and so on. Also, we have been continuously trying to improve the astrometric accuracy of VERA. We are now getting hints of parallaxes for 10-kpc sources. We will continue this activity and will hopefully be able to regularly obtain parallaxes for 10-kpc sources.

We also conducted simulation work to evaluate the accuracy of Galactic parameters that would be obtained by VLBI astrometry of 300 to 500 maser sources. It turned out that those Galactic rotation parameters would be determined to the level of a few percent and parameters of perturbations (such as spirals) would be determined to the 10 percent level, provided parallaxes could be measured for a few hundred sources. In addition to this work, we published a review paper summarizing the most up to date science outputs and technology development of high-accuracy VLBI astrometry.

Beyond VLBI astrometry, VERA produced interesting results on Orion-KL source I through joint observations with ALMA, and also on gamma-ray active AGN monitoring as a part of GENJI (Gamma-ray Emitting Notable AGN monitoring with Japanese VLBI) program.

2. JVN (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, ISAS, JAXA, NICT, and GSI, distributed throughout Japan. VLBI observations by JVN were done for 400 hours at 3 bands of 6.7, 8, and 22 GHz in FY 2014. Single Dish Observations related to JVN were also done from 2,000 to 4,000 hours at each telescope.

The main subjects of research are active galactic nuclei and masers-star formation.

Scientific results obtained with JVN were published as four papers, while eight more papers reported JVN related scientific studies. FUJISAWA Kenta et al. (2014) reported the first result of a 6.7 GHz methanol maser survey by JVN, where the Shanghai 25-m Telescope took part in the observation. This is the first result of EAVN (East-Asian VLBI Network) Observatory. Masers can be used as tracers for gases around high-mass young stellar object. SUGIYAMA Kouichiro et al. (2014) reported the first detection of rotation and infalling motions around a high-mass YSO, Cepheus A-HW2. The Astronomical Society of Japan held a special session of "University Collaboration in Astronomy" in "The 2014 Autumn Meeting", in which more than 30 invited contribution review talks were presented.

Education is also one of the aims of university collaboration in VLBI. More than 20 students conducted under-graduate study using JVN. Similarly, more than 10 master-course students completed their master's theses using JVN, and two Ph.D. students finished their theses using JVN directly or indirectly. Research meetings related to JVN were held six times in FY 2014, and many university students made presentations and talks in these meetings.

3. Japan-Korea VLBI

(1) Observations and Common Use Observations

A total of 80 (757 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 Correlation Center at KASI Daejeon campus in Korea.

KaVA common-use call-for-proposals for semesters in 2014B and 2015A were made in June and November, respectively. In total, 14 proposals requesting a total time of 498 hours were submitted. Through the evaluations by referees elected from scientists in related fields and subsequent decision made by the VERA and KVN combined Time Allocation Committee, a total of nine proposals (330 hours) were accepted in 2014B and 2015A.

(2) Results of Research

Last year, we published two refereed papers reporting on the initial results of KaVA observations. One of the reports was on the first VLBI images of 44 GHz methanol masers in massive-star-forming regions, and the other showed the AGN jet imaging capability of KaVA. These papers are the first papers ever made based on KaVA data, and both demonstrate the high imaging capability of the seven station array. Furthermore, another paper is under preparation to report multi-transition SiO maser observations of late-type stars. These activities are made through KaVA science working groups consisting of researchers not only at NAOJ and KASI, but also at universities and research institutes in Japan and Korea. These KaVA science working groups have been discussing and preparing the KaVA large programs, in which relatively large amounts of KaVA observation time will be invested, so that the science outputs and uniqueness of KaVA will be further extended.

4. EAVN

EAVN has been developed under the agreement of our Consortium. An observation team for conducting EAVN test experiments, which consists of representatives from Japan, China, and Korea, was organized in FY 2013. Since then, the team has been leading VLBI experiments linking existing radio telescopes in East Asia through close international collaboration.

In FY 2014, VLBI experiments aiming to detect interferometric fringes from the telescopes in East Asia have been conducted several times. The telescopes which participated in the experiments were: VERA and 32-m telescopes located at Yamaguchi and Ibaraki Universities, the Tsukuba 32-m Telescope, Shanghai 25-m and 65-m Telescopes, Kunming 40-m Telescope, Urumqi 25-m Telescope, and three telescopes of the Korean VLBI Network. The experiments were conducted at 8 and 22 GHz, and VLBI data were processed by using the "Korea-Japan Correlation Center" located at Daejong in Korea. VLBI fringes were detected from most of these telescopes and detailed data analysis is ongoing.

These activities are being reported in EAVN workshops which are held almost every year, where future plans for experiments are discussed as well. The latest EAVN workshop was held in the Republic of Korea. And this year, the workshop will take place in July at Sapporo.

5. Geodesy and Geophysics

The regular geodetic sessions of VERA are allocated two or three times every month to maintain baseline accuracy. Among these geodetic sessions, VERA internal geodetic observations are performed once or twice every month at K-band, and Mizusawa and Ishigaki-jima participate in IVS sessions at S/X-band on a once per month basis. Thanks to the high sensitivity at K-band, the maximum number of scans at K-band is 800 per station per day. In FY 2014, we participated in six T2 sessions and four JADE sessions.

VERA internal geodetic observations were carried out 17 times. The final estimation of the geodetic parameters is derived by using the software developed by the VERA team.

After "The Great East Japan Earthquake" (Mw=9.0), VERA Mizusawa was displaced by coseismal crustal movement and postseismic creeping. For FY 2014, the creeping continued, though the speed declined. According to the newest analysis, the coseismal steps are X = −2,013 mm, Y= −1,380 mm, and Z = −1,072 mm, and the displacement by creeping during 2014 is X = −91 mm, Y = −61 mm, and Z = −31 mm.

Continuous GPS observations at VERA stations are carried out in order to detect short term coordinate changes and to estimate atmospheric propagation delay. The results of GPS positioning also show large postseismic creeps even though 4 years have passed since the occurrence of "The Great East Japan Earthquake." The crustal deformation observed by the strainmaters at "Esashi Earth Tides Station" is consistent with the postseismic displacements observed by VLBI and GPS.

Continuous gravity observations with superconducting gravimeters are carried out at Mizusawa and Kamioka. Similar observation is carried out at Ishigaki-jima as a joint project with other university groups. The features of the annual change are observed and studied by several techniques including VLBI, GPS, and gravimeters.

6. System Development

We replaced the magnetic tape recorders with new hard disk recorders and also replaced the FX correlator working at a 1 Gbps data rate with software correlation. We confirmed sufficient performance in scientific processing and continuous operation after small revisions to the software. We allocated the software correlator systems to Mizusawa, and contributed modifications to the KJCC (Korea-Japan Correlation Center) system with scientific evaluations of the observations by KaVA. We started intense consideration of future plans for the observatory. A possible plan to join the SKA (Square Kilometer Array) project and the development of high frequency VLBI are being discussed. We performed several basic development projects including ultra-wideband A/D convertors and a high-accuracy antenna surface for the primary reflector for mm/sub-mm VLBI observations.

7. Timekeeping Office Operations

The Timekeeping Office operates four cesium atomic clocks together with a hydrogen maser atomic clock at Mizusawa VERA 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; more than 900,000 daily visits have been recorded last year.

The master clock has been changed from Cs8 to Cs6, which showed better stability characteristics than Cs8 last year. The layout of the Timekeeping Operation Room has been reorganized because VERA AOC has been moved from Mitaka to Mizusawa.

8. Ishigaki-Jima Astronomical Observatory

Thirteen years have passed since the completion of VERA Ishigakijima and the start of the “Star Festival of South Island” in Ishigakijima. As the main event of the star festival, 8,000 people participated in the “Light-down Starry Sky Party”, even though it was cloudy.

In unison with “Star Festival of South Island”, the first “Meteorite Exhibition” ever held in Okinawa Prefecture was held in cooperation with Nayoro Municipal Observatory, and 754 people enjoyed the exhibition.

The Annual Planetarium Screenings were held from August 7 to 10, and 734 people participated.

The Second Japan Starlight Sky Summit was held in Ishigakijima on October 19 in cooperation with the Bisei Astronomical Observatory and the Nobeyama Radio Observatory.

Professor HASEGAWA Tetsuo who is the director of NAOJ Chile Observatory gave a memorial lecture in which 350 people participated. At the same time, we performed the planetarium program “Wish upon a star of the Southern Island”, which was jointly hosted by Ishigaki-jima Observatory and Ishigaki-City. 1,364 people came and enjoyed this program from October 17 to 23.

These activities of NAOJ Ishigakijima Astronomical Observatory greatly contribute to not only observational studies, but also to regional development such as school education, lifelong learning, tourism, and so on, through cooperation with local communities.

9. Public Relations (PR) and Awareness Promotion Activities

(1) Open House Events

On April 13, 2014: the Fifth Open Observatory Event held at the Ibaraki University Center for Astronomy, and NAOJ Mizusawa VLBI Observatory, Ibaraki Station, with approximately 700 visitors.

On July 6: The 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 350 visitors.

On August 10: the Special Open House of VERA Iriki Station was supposed to be jointly held with “The Yaeyama Kogen Star Festival 2014”, but was called off due to a strong typhoon.

On August 16: A mission briefing session by WAKATA Koichi, an astronaut of JAXA (Japan Aerospace Exploration Agency) who stayed on the ISS (International Space Station) as the commander, held as an event related to “Iwate Galaxy Festival 2014”, with approximately 1,000 visitors.

On August 30: “Iwate Galaxy Festival 2014”, open house of the NAOJ Mizusawa Campus, held with 847 visitors.

On October 19: In cooperation with Bisei Astronomical Observatory and Nobeyama Radio Observatory, “The second Japan Starlit Sky Summit” was held in Ishigaki-city, and 350 came to the main meeting places such as a memorial lecture by HASEGAWA Tetsuo (ALMA), 1,364 entered screenings of the planetarium “Wish upon a star of the Southern Island” which were held at the same time (October 17 to 23) in Ishigaki-jima Astronomical Observatory and Ishigaki-city.

On February 15, 2015: “The 14th Star Island” open house event of VERA Ogasawara Station was held, with 213 visitors.

(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 17,021
b) VERA Iriki Observatory 2,000
c) VERA Ogasawara Observatory 7,535
d) VERA Ishigaki-jima Observatory 2,754

e) Ishigaki-jima Astronomical Observatory 12,790

(3) Review of the Contents of Our Website

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

Contents list	Sessions	Internet users	Page Views
Mizusawa VLBI Observatory	23,894	15,247	75,769
VERA Mizusawa Observatory	9,163	6,307	30,829
KIMURA Memorial Museum	1,657	1,313	5,319
VERA Ishigaki-jima Observatory	80,920	51,662	185,037

10. Education

(1) Undergraduate and Graduate Education

The Observatory accepted three graduate students from the University of Tokyo and two from SOKENDAI (Graduate University for Advanced Studies). A student from the University of Tokyo was conferred a Ph.D. and awarded the University of Tokyo President's Prize. Two master's students, one from Tokai University and another from Kagoshima University, were accepted as visiting graduate students and completed master's theses. Undergraduate students from Tohoku University, Okayama University, Yamaguchi University, and Kyushu University were accepted as summer students of SOKENDAI. The University of the Ryukyus and NAOJ began offering this joint course in FY 2009. Classroom lectures at the university took place on August 11, 13, 14, and 15, and observational workshops were held in Ishigaki-jima from August 25 to 28, with a total of 31 participants. A hands-on radio observation program was conducted at the VERA Ishigaki-jima Station and Ishigaki-jima Astronomical Observatory. In addition, staff members at the station visited these universities to deliver lectures.

(2) High School Student Hands-On Events

"The 8th Z-Star Research Team Workshop" was held to use the VERA Mizusawa antenna; five high school students from Iwate prefecture were accepted. A preliminary session was held June 28 and 29, and observations were done August 2 to 4. As a result, students successfully discovered a new maser source. During August 18 to 20, VERA Ishigaki-jima Station and Ishigaki-jima Astronomical Observatory held "The Churaboshi Research Team Workshop" for thirteen high school students from Okinawa, Fukushima, and Fukuoka prefectures. It was organized with support from JSPS. One of the groups detected a new maser source using the VERA Ishigaki-jima antenna. The Observatory supported the SSH (Super Science High School) research activities for a high school in Akita Prefecture using the Mizusawa 20-m antenna.

6. Solar Observatory

The Solar Observatory primarily engages in the operation of solar observational facilities on the west side of Mitaka Campus. 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 development of new observational instruments and 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 completion of 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 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 which enables us to observe two wavelength ranges simultaneously using two cameras has just been installed. Now the new system is under testing, and after its completion, the data acquisition will be conducted more efficiently.

In this fiscal year, concentrated maintenance work for the SFT was done, and some deteriorated parts of the telescope were replaced.

(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 261 days in 2014, from January to December. A huge sunspot, which is the largest one in the last 24 years, appeared in this year. The Hinode project and the Solar Observatory jointly released some related images to the public on November 19.

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 with high temporal resolution, allowing it to more completely capture active phenomena, and a broad dynamic range through a combination of multiple exposure times. This advancement has enabled us to observe many phenomena in recent heightened solar activity, such as flares and prominence eruptions. The observatory also uses the SFT to conduct regular imaging observations in the G-band (430 nm) and continuum wavelengths. 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 coelostat 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 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 also available to the public because 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.

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.

The solar optical observations carried out 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, discussions and on-site inspections have been conducted.

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 Nagoya University between February 16 and 18, 2015.

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, research expert Naomasa Kitagawa replaced a staff member who departed last year. Dr K. Kuzanyan of IZMIR, Russia, started his ten month stay as a JSPS fellow in September 2014.

7. 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) 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 is projected 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 partial number of antennas and full operation commenced in FY 2012. This report describes the progress of the project, which includes 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. The report also describes the progress regarding the ASTE telescope.

1. ALMA Project Progress

Along with the scientific observations, commissioning observations of ALMA have been underway. These include long-baseline observation tests, polarimetric observation tests, and solar observation tests.

In particular, intensive long-baseline observation tests were made from September through November 2014 with an extended antenna configuration of up to 15 km for the verification of equipment performance, new observation methods, and efficient calibration methods. As a result of these test observations, astronomers successfully made the first detailed image of a protoplanetary disk around the young star HL Tau at an extraordinary high resolution of 0.035 arcsec (equivalent to 40000/20 vision). The high sensitivity and resolution of ALMA made it possible to reveal several gaps which are seemingly produced by the gravitational influence of planets forming in the disk. This is a remarkable result which could reshape our understanding of planetary formation theory. Another outstanding result with ALMA was an unprecedentedly sharp image of an asteroid Juno and a lensed galaxy SPD.81, which demonstrated the high potential of ALMA. The data for these results have already been made available on the ALMA Archive, and many papers based on them have been written by astronomers. Following the success of these long-baseline test observations, the maximum baseline will be extended up to 10 km in the ALMA Cycle 3 Call for Proposals for scientific observations that will be scheduled from October 2015.

2. ALMA Open-Use and Scientific Observations

The third round of open-use observations of ALMA commenced in June 2014 with Cycle 2. The details of Cycle 2 include interferometric observations using thirty-four 12-m parabolic antennas, Atacama Compact Array (ACA) observations (interferometric observation with nine 7-m antennas and single-dish observations with two 12-m antennas), six frequency bands (Bands 4 and 8 are added to Bands 3, 6, 7, and 9), a maximum baseline of 1.5 km (for Bands 3 to 7) or 1 km (for Bands 8 and 9), and a maximum of 150 fields of view for mosaic observations and polarimetric observations.

An open call for the fourth round of open-use observations was issued for Cycle 3. The details of Cycle 3 as advertised include interferometric observations using thirty-six 12-m antennas, ACA observations (interferometric observation with ten 7-m antennas and single-dish observations with two 12-m antennas), seven frequency bands (Band 10 is newly added to Bands 3, 4, 6, 7, 8, and 9), a maximum baseline of 10 km (for Bands 3 to 6), 5 km (for Band 7), or 2 km (for Bands 8 to 10) and a maximum of 150 fields of view for mosaic observations and polarimetric observations. The deadline of the public calls for proposals for Cycle 3 is set at 00:00 JST on April 24, 2015. Cycle 3 is scheduled to commence in October 2015.

Open use of ALMA has produced a number of scientific achievements. This section describes some of these focusing mainly on East Asian projects. A research group led by Bunyo Hatsukade at NAOJ observed galaxies hosting gamma ray bursts (GRBs), the brightest explosive phenomenon in the Universe, using ALMA and successfully detected radio emissions from molecular gas for the first time. Also, this observation revealed the spatial distribution of molecular gas and dust, showing that gamma ray bursts occurred in a remarkably dust-rich environment. A research team led by Kazuki Tokuda at Osaka Prefecture University conducted ALMA observations of the gas cloud MC27 in the constellation Taurus and found two starless high-density gas cores and an arc-shaped high-density gas region, which is assumed to be formed by the dynamic gravitational interaction of multiple gas cores that are very close to the initial stage of star formation. A research group led by Junko Ueda at NAOJ observed 37 galaxies that are in their final stages of merger using ALMA and several other radio telescopes. The group found that, among the 30 colliding galaxies from which molecular radio emission have been detected, 24 galaxies have rotating molecular gas disks and half of them have extended gas disks that are larger than the stellar bulges at the galactic centers. This is the first observational evidence showing that mergers of two or more galaxies will lead to the formation of a new galaxy with a gas disk structure at a high rate. A research team led by Shigehisa Takakuwa at the Academia Sinica, Institute of Astronomy and Astrophysics, (ASIAA), Taiwan, observed the baby binary stars L1551NE and found a gas disk surrounding both stars (known as a circumbinary disk) with spiral arms of molecular gas extending from the disk toward the binary stars. This is the first image that shows the twin stars shaking the surrounding circumbinary disk and inducing the gas motion falling onto the twin stars. A research team led by Shuro Takano at NAOJ observed the central part of the spiral galaxy M77 and discovered that organic molecules are concentrated in a region surrounding a supermassive black hole at its center. This result shows that the black hole is surrounded by a large amount of dust and gas which is shielded from X-rays and UV photons. These findings will be a key to understanding the mysterious environment around supermassive black holes. A research group led by Aya Higuchi at Ibaraki University conducted observations of the massive-star forming region IRAS 16547-4247 and revealed the presence of multiple, at least two, gas outflows from a protostar at the center. Also the radio observation results of molecular line emissions of methanol revealed in vivid detail an hourglass structure created by gas outflows spreading outward.

3. Educational Activities and Internship

The NAOJ Chile Observatory held a graduate school guidance session on June 14, 2014. Eight undergraduate students attended the session, engaging in lectures given by teachers and talks with current graduate students.

4. Public Outreach Activities

In April 2014, the NAOJ Chile Observatory hosted a week-long ALMA booth at the Japanese Geoscience Union Meeting in Yokohama. The NAOJ Chile Observatory organized public lecturers and Science Cafe events on 19 occasions in FY 2014 to provide updated information and increase interest in ALMA and its scientific achievements through conversations with a large number of visitors.

The NAOJ ALMA project website published 44 news articles and seven 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 22,000 followers as of the end of FY 2014.

Approximately 50 newspaper/journal articles were posted, reporting scientific discoveries from the Early Science observations and test observations. ALMA was featured in three television programs. In addition to news reports on ALMA's observational achievements, there was a program showing people involved in the ALMA project in depth such as "Fathers Working in the World 6", which effectively increased interests in ALMA and appealed to a mass audience.

As part of the construction film project continuing since FY 2013, the NAOJ Chile Observatory produced a new film showing the development of the receivers at the Advanced Technology Center (ATC) in FY 2014, and filmed interviews with developers of the ACA correlators.

The NAOJ newsletter featured ALMA in the February 2015 issue with an article summarizing the ALMA project and its scientific achievements, including interviews with ALMA staff members stationed in Chile. The series "Bienvenido a ALMA" in which ALMA staff members introduce their work, continues to be featured in the NAOJ newsletter, which is also made public on the ALMA website.

ALMA MUSIC BOX was created by translating the ALMA radio data into music with the support of designers and artists. This work was exhibited in an exhibition titled "THE FAB MIND: Hints of the Future in a Shifting World" from October 2014 through February 2015 at the 21_21 DESIGN SIGHT in Roppongi, Tokyo, which provided a good opportunity for many people who are familiar with design and art to know more about ALMA and its scientific achievements.

5. International Collaboration (committees, etc.)

The ALMA project has various committees, which hold meetings frequently for international collaboration. The ALMA Board has met twice, and the ALMA Scientific Advisory Committee (ASAC) was summoned three times in FY 2014. In addition to these, teleconferences have been held on a near-monthly basis by these committees and the East-Asia ALMA Science Advisory Committee (EASAC). Each working group holds meetings and teleconferences more frequently to maintain close communication in implementing the international project.

6. Workshops and Town Meetings

- June 17 to 18, 2014 NAOJ Mitaka
  ASTE/ALMA Development Workshop
- July 14 to 17, 2014 Jeju, Korea
  EA ALMA Science Workshop
- October 27 to 29, 2014 NAOJ Mitaka
  ALMA/ASTE/Mopra Users Meeting
- December 8 to 11, 2014 Tokyo International Forum
  International Workshop "Revolution in Astronomy with ALMA - the 3rd year -"
- December 13 to 14, 2014 NAOJ Mitaka
  ALMA Postdoc Symposium
- March 5, 2015 Ehime University
  ALMA Cycle 3 Town Meeting
- March 25, 2015 Kogakuin University
  ALMA Cycle 3 Town Meeting
- March 26, 2015 Japan Aerospace Exploration Agency (JAXA) Institute of Space and Astronautical Science
  ALMA Cycle 3 Town Meeting
- April 2, 2015 Kagoshima University
  ALMA Cycle 3 Town Meeting
- April 8, 2015 NAOJ Mitaka
  ALMA Cycle 3 Town Meeting

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

None

8. Research Staff Changes

(1) Hired
- Patricio Sanhueza: project research staff

(2) Departed or transferred

- Hiroshi Nagai: project assistant professor, transferred to the NAOJ Chile Observatory to assume the position of a project associate professor.
- Shinya Komugi: project associate professor, departed to Kogakuin Univeristy to assume the position of an associate professor.
- Hiroko Shinnaga: project associate professor, departed to Kagoshima University to assume the position of an associate professor.
- Chibueze, James: project assistant professor, departed to University Nigeria to assume the position of a lecturer.

9. Main Visitors

- August 5, 2014
  Dr. Kyosuke Nagata, President of University of Tsukuba, visited the Santiago Central Office of the Joint ALMA Office (JAO) and had a meeting with the ALMA Director Pierre Cox.
- November 6, 2014
  Dr. Hiroyuki Takeda, Vice Dean of the School of Science at the University of Tokyo, and others visited the ALMA Operations Support Facility (OSF) and the Array Operations Site (AOS).
- November 26, 2014
  Dr. Kaoru Yamanouchi, Vice Dean of the School of Science at the University of Tokyo, and others visited the ALMA Operations Support Facility (OSF) and the Array Operations Site (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 observation methods for submillimeter astronomy. With ALMA entering its operation phase, ASTE will be engaged mainly to provide observational evidence for strengthening ALMA observation proposals and to pursue developments for the enhancement of ALMA's future performance.

Two public calls were made in FY 2014 for open-use observation proposals for spectroscopic observations in the 345 GHz band: the first call (2014a) was from June to September and the second call (2014b) from October to December. To render support for researchers contributing to the observational performance enhancement of ASTE, the Guaranteed Time Observation (GTO) scheme has been offered since FY 2013, which allows them exclusively to make proposals for GTO slots. A total of 59 proposals for open-use observations and GTO slots had been made including 28 for open use and five for GTO during the first call, and 25 for open use and one for GTO during the second call. These proposals were reviewed by the program subcommittee at the NAOJ Chile Observatory and 38 proposals were subsequently adopted including 20 for open use and five for GTO during the first call, and 12 for open use and one for GTO during the second call. Open-use observations were conducted from the ASTE Mitaka operation room between June 16 and December 19, 2014.

In June 2014, the ASTE/ALMA Development Workshop was held at NAOJ Mitaka Campus to discuss future instruments to improve the observational capability of ASTE and future development for ALMA performance enhancements. In response to a call for proposals for future ASTE instruments made in November 2014, three development proposals were submitted, and subsequently adopted as candidate future instrument development programs for ASTE by the reviewers selected from the Japanese ASAC members.

8. 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), was reinforced this year. Now ATERUI has a theoretical peak performance of 1 Pflops, making it the world's fastest supercomputer for astronomy. The center also continued operation of other computers such as GRAPE-7, GRAPE-DR, and GRAPE-9 which are dedicated to 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 second year of the upgraded astronomical simulation system, which includes the main supercomputers of the open-use computers for this project. The CPUs of the main super computer, Cray XC30, which is installed and operating at Mizusawa VLBI Observatory, have all been updated, 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 from Cray Japan Inc., the center has built the following equipment to aid the open-use operations: a series of dedicated computers for gravitational N-body problems, known as GRAPEs; PC clusters 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 conducted by researchers in Japan and overseas. In particular, the GRAPE system is promoted for its effective open use. The center undertook development, improvement, and maintenance for both the hardware and software of the system this year. One of the major events of this year was the test operation of GRAPE-9. This system has a performance improvement of roughly 10-fold over the current GRAPE-7.

Computational resources are allocated to the XC30, GRAPEs, and minor computational PC clusters in accordance with a formal evaluation process. Their usage and application/results for this year are listed below. The CfCA conducted a survey this year on the number of peer-reviewed papers published in English in FY 2013 on studies that involved the project's open-use computers. It was revealed that 79 papers were published in total in that fiscal year.

Drupal, a content management system introduced for data exchange with users of open-use computers, is presently used for providing information and transmitting various application forms as necessary. The periodical 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 in which the results were obtained by using the center's computers.

One paper was accepted in FY 2013 for payout in FY 2014, while four papers were accepted in FY 2014 for payout in the same year at approximately 400,000 JPY.

□ Statistics on the Cray XC30

Operating hours

- Annual operating hours: 8088.6
- Annual core operating ratio: 88.37 %

Users

- Category S: 1 adopted in the first term, 0 in the second term; total 1
- Category A: 14 adopted at the beginning of the year, 1 in the second term; total 15
- Category B: 56 adopted at the beginning of the year, 9 in the second term; total 65
- Category MD: 13 adopted at the beginning of the year, 3 in the second term; total 16
- Category Trial: 44, annual total
- Category I: 0, annual total

□ Statistics on the GRAPE system

Users

- Category A: 4 adopted at the beginning of the year, 0 in the second term; total 4
- Category B: 6 adopted at the beginning of the year, 3 in the second term; total 9
- Category Trial: 1, annual total

□ Statistics on PC cluster

Operating hours

- Annual operating hours: 8690.0
- Annual job operating ratio: 71.7 %

Total number of users: 39, annual 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, a users' meeting was held to serve as a forum for direct information exchange. Many participated in the meeting, and discussions were fruitful.

□ Cray XC30 workshop for beginning users: August 20, 2014, 6 attendees

□ Cray XC30 workshop for intermediate users: January 19, 2015, 14 attendees

□ IDL visualization workshop: August 21, 2014, 11 attendees

□ AVS visualization workshop: August 22, 2014, 11 attendees

□ N-body simulation Winter School: January 26–28, 2015, 16 attendees

□ Users meeting: January 20-21, 2015, 56 attendees

3. PR Activities

CfCA took part in the special open house of Mizusawa Campus, Iwate Galaxy Festival 2014, held on August 30, 2014. About 600 visitors attended the ATERUI guided tours and experienced a close-up view of the facility. These occasions were featured on local television programs and in newspapers. At the Mitaka Open House held in October 2014, 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 five groups of high school students and companies for tours of the computer room in Mitaka Campus.

In FY 2014, three press releases were issued from CfCA; "The K computer simulation indicates that the neutrino-heating mechanism causes supernova explosions" (April 18, 2014, Tomoya Takiwaki, Assistant Professor at CfCA), "Supercomputer for Astronomy "ATERUI" Upgraded to Double its Speed" (November 13, 2014), and "The K computer figures out the mechanism of electron acceleration" (February 27, 2015, Tsunehiko Kato, Research Expert at CfCA). In addition, the press release from the NAOJ Chile Observatory, "Astronomers Identify Gas Spirals as a Nursery of Twin Stars through ALMA Observation" (December 4, 2014), included the results of calculations by ATERUI (Professor Tomoaki Matsumoto, Hosei University).

Moreover, the results obtained by ATERUI were presented with short articles on the CfCA website. "The Astronomical Herald" published by the Astronomical Society of Japan featured CfCA in Vol.108 No.2 and No.3 in 2015. The introduction of CfCA by Prof. Eiichiro Kokubo and six articles about simulation studies by the CfCA computers appeared in these volumes.

CfCA assisted GOTO Inc. in making the planetarium program "Space Analyzer". This program features supercomputers used for astronomical research, and presents results obtained by ATERUI, GRAPE and K computer. This program was screened at the Kobe Science Museum from September 2014 to March 2015.

A Twitter account @CfCA_NAOJ has been operated to provide information about CfCA. In addition, the Youtube CfCA channel was created as part of the PR activities, and the movies of simulations and the videos for press releases were published through this channel.

4. 4D2U Project

In FY 2014, the 4D2U project added a new member for content development. A movie based on simulations titled "Formation and Evolution of Dark Matter Halos (II. Formation of the Large-Scale Structure of the Universe)" was released on the 4D2U website in March 2015. This content was distributed with 360 degree panoramic video for the first time. Viewing this format with a head mounted display (HMD) provides a realistic experience. The updated versions of the four-dimensional digital universe viewer, "Mitaka," were released in December 2014 (ver.1.2.2), February 2015 (ver.1.2.2a, ver1.2.2b and beta version for Oculus Rift) and March 2015 (ver.1.2.3). These versions of Mitaka included new functions, such as displaying the 3D surface of the Moon and plotting the positions of objects observed by the VERA project. In particular, the beta version for Oculus Rift and version 1.2.3 which can project with the Dome Master format expanded the usage of Mitaka. The imaging speed of Mitaka was made faster and faster every update.

The 4D2U project supported and provided contents for exhibitions held in museums and galleries. For example, "mission[SPACExART]—beyond cosmologies" (Museum of Contemporary Art Tokyo, June 7 to August 31, 2014), "Mystery of the Moon" (Konica Minolta Plaza, July 15 to August 10, 2014) and "Depictions of Space" (Tokyo Dome City Space Museum TeNQ, February 28 to June 28, 2015). In addition, 4D2U demonstrations using the dispatch system were conducted at events held by the Hiroshima Astrophysical Science Center (July 20, and August 22–24, 2014). Local visitors enjoyed special programs to experience the latest astronomy findings through 3D vision. Moreover, 4D2U contents were provided for TV programs, planetarium programs, lecture presentations, books and so on.

In cooperation with the Public Relations Center, the 4D2U project installed a new projection system for the 4D2U Dome Theater. On March 17, 2015 the renewal of the 4D2U Dome Theater was announced on the NAOJ website. The newest movie content "Formation and Evolution of Dark Matter Halos (II. Formation of the Large-Scale Structure of the Universe)" was produced and released for this renewal. Mitaka ver.1.2.2 was developed and installed on the new dome system.

A Twitter account @4d2u has been operated to provide information about 4D2U. In addition, a Youtube channel for 4D2U was created as part of the PR activities, and movie contents of 4D2U can be watched on this channel.

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 the basis for collaboration 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 JICFuS. In particular, the institute engages primarily in computer-aided theoretical research into the 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 ability 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 high-performance computing development of novel algorithms to meet research goals from the perspective of computer specialists. In addition to 'HPCI Strategic Program Field 5 "the origin of matter and the Universe" ', JICFuS has been adopted for 'Research and Development, Application Development of scientific/social issues that require particular attention by the use of POST K-computer' in FY 2014.

In order to implement research plans, Hiroyuki Takahashi and Tomoya Takiwaki (until July) were engaged as project assistant professors, and Tomomhisa Kawashima (from May) was engaged as a project researcher in FY 2014. Takahashi and Kawashima developed a new plasma simulation code to solve basic equations of relativistic radiation magnetohydrodynamics (MHD) based on first principles. By performing global simulations of black hole accretion disks, they revealed that the black holes are able to grow up rapidly via mass accretion. This is closely related to an unresolved issue in astrophysics: how stellar mass black holes grow into supermassive black holes. Takiwaki carried out three-dimensional simulations of core-collapse supernovae using the supercomputer "K." His research is key for various studies within the framework of JICFuS, because supernovae are closely related to elementary particle and nuclear physics. Although the mechanism of supernova explosions is a long-standing enigma that has been debated for more than 60 years, the research into supernovae has progressed considerably through numerical simulations with the most realistic parameters using the K computer.

Representing 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 how to spur 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 computer. Although the center is involved with the JICFuS-led HPCI Strategic Program Field 5 as mentioned in (1), its activity in the HPCI consortium is fundamentally independent. The HPCI consortium is an incorporated association established in April 2012, and the center is currently an associate member able to express views, obtain information, and observe overall trends in the planning: however, it is devoid of voting rights as well as the obligation to pay membership fees. Continuing from last year, a number of conferences and WGs have been held in which participants discuss a next-generation national supercomputing framework to follow the K computer.

This year the budget allocation was officially approved for the development of a next-generation system, called "post-K", by the Ministry of Education, Culture, Sports, Science, and Technology (MEXT). The institutes and groups for its development have been established. Now detailed discussions as to how we develop and use the post-K system have begun in related communities.

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 HPC through participation in this discourse.

6. Contract Staff Transfers

The following staff members were employed on a contract basis in this FY:
(Research experts) Hirotaka Nakayama, Tsunehiko Kato
(Postdoctoral fellows) Shun Furusawa, Tomohisa Kawashima
(Research associates) Yukihiko Hasegawa, Yuji Matsumoto

The following contract staff members departed in this FY:
(Research expert) Tomoya Takiwaki (assistant professor)
(Postdoctoral fellow) Naoki Ishitsu
(Research associates) n/a

9. 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 has 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 elucidate the coronal heating mechanism through a more multifaceted understanding of magnetohydrodynamic (MHD) phenomena occurring in the solar atmosphere. The satellite actually made many 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 corona. The onboard telescopes were developed as part of a wide-ranging international collaboration with assistance from ISAS/JAXA. The 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 regards to 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, including three from the Hinode Science Center (HSC): 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 2014 marks the eighth year since the satellite's launch. Extremely good evaluations were received from the senior review class evaluation committees held at the respective space agencies during FY 2012–2013. These accolades made it possible for the satellite to continue operation for the next few years at its current operational level. The operation of the Focused Mode was conducted in the June and January – February periods of FY 2014 after a test run in January 2014.

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 arcsecond 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 the maintenance of a sound field of view even in the narrow band filter imager system, in which image degradation was detected initially in part of the field of view.

The XRT has the capacity of imaging 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 arcsecond. 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 for the chromosphere, transition region, and coronal plasma thorough 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 observations from the chromosphere and the transition region, located between the photosphere and the corona, to the corona itself.

A mission data processor (MDP) was installed to manage observations and to acquire data via the three telescopes. Coordinated observations using the three telescopes are vital to achieve the scientific goals of the Hinode satellite, in which the MDP plays a crucial oversight role. 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 are primarily downlinked at the Kagoshima station (USC) and at Norway's Svalsat station through collaboration with ESA, allowing for data acquisition during every orbit. Scientific operation was again performed in FY 2014 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 211 days in FY 2014, 68 days of which were for contracted work. Moreover, the contribution rates to the scientific operation of HSC were 24.9 % (domestic) and 15.7 % (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 observation together with other satellites and terrestrial observational equipment, promote joint observations among solar researchers worldwide. As of March 2015, a total of 284 applications have been accepted. In particular, core HOP proposals made by members of the scientific instrument team have became refined over multiple implementations, and systematic observations have yielded extensive results that can be expanded to 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 purpose is to promote rigorous collaborative research between researchers in Japan and abroad by maximizing the scientific outputs gained from the Hinode satellite by providing a suitable environment for analyzing the satellite data, facilitating access to Hinode observational data by distributing the analyzed data, and constructing 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 2014, HSC staff members and students published 14 peer-reviewed papers related to Hinode, bringing the total to 241 papers by the end of March 2015. Cumulatively, a total of 810 peer-reviewed papers have been published on Hinode-related topics. Publication of papers in this category continues at a pace of nearly 100 papers per year, even 8 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 2014, three postdoctoral fellows were engaged as members of HSC, including one project assistant professor, one postdoctoral fellow, and one Japan Society for the Promotion of Science (JSPS) fellow. The project assistant professor (Ishikawa, R.) was hired as an NAOJ assistant professor in June. Hinode Science Meetings for Japanese and international solar researchers are held on a regular basis to promote heliophysical research using the Hinode scientific satellite. The eighth meeting was combined with the "2014 Living With a Star (LWS) science meeting," and took place between November 2 and 6, 2014, in the city of Portland, Oregon (USA). The NASA Marshall Space Flight Center (MSFC) was a co-organizer.

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)
Uitenbork, Han	National Solar Observatory (USA)
Kuhn, Jeffrey	University of Hawaii (USA)

Table 1. Long-Term Visitors.

10. Gravitational Wave Project Office

The activities of the Gravitational Wave Project Office (GWPO) are focused on the realization of the Large-scale Cryogenic Gravitational-wave Telescope in the Kamioka mine (KAGRA). KAGRA is a gravitational wave detector based on a laser Michelson interferometer with arms 3 km in length that is currently under construction. The project is realized in collaboration with ICRR and KEK in the framework of a MoU about the development of gravitational wave astronomy. According to the plan, the project construction should be completed in 2017 and the first observation run should take place shortly afterwards. KAGRA should join the international network of gravitational wave detectors in the USA and in Europe and contribute to the opening of gravitational wave astronomy. In parallel the GWPO is preparing for KAGRA data analysis and is conducting R&D for future upgrades to KAGRA and for the development of DECIGO.

1. Development of KAGRA

In order to further clarify the role of NAOJ within KAGRA, a MoU with ICRR has been established in FY 2014. According to the MoU the GWPO is responsible for the development of the vibration isolation system (VIS), the auxiliary optics system (AOS), part of the mirror characterization equipment (MIR) and the overall interferometer optical design. In FY 2014 JSPS approved a Specially Promoted Research for the development of KAGRA. Part of the funding was allocated to NAOJ for the development of VIS and AOS. In addition, the GWPO is contributing to the project management, particularly for the activities of the executive office, the system engineering office, the committee for publication control, the publication relation committee and the safety committee. The main achievement at the site in FY 2014 has been the installation of the vacuum system and the beginning of the installation of the interferometer. In order to support on-site activity more efficiently, the GWPO made preparations for a branch at Kamioka which just opened on April 1st 2015.

(1) Vibration Isolation

The vibration isolation system (VIS) is composed of the suspensions required to isolate all the interferometer components from ground vibrations. Fifteen VIS's are required for KAGRA. Four different types of suspensions have been developed at NAOJ for this purpose. During FY 2014 the VIS design has been finalized and construction has been completed for most of the components of initial KAGRA. Some of the development work has been done in collaboration with the Advanced Technology Center (ATC) of NAOJ. In particular, the bottom filters were developed in close collaboration with ATC. We also acquired the first ensemble of four inverted pendulums in collaboration with Nikhef. The first prototype of one complete suspension was assembled to be tested at TAMA. In parallel we started installation of the vibration isolation systems for the input mode-cleaner at the Kamioka site.

(2) Auxiliary Optics System

The auxiliary optics subsystem consists of several kinds of optics including optical baffles, beam dumps, beam reducing telescopes, high quality viewports and the optical local sensors (optical levers) for the mirrors of the interferometer. The installation of 250 pieces of the arm-duct optical baffles, which are designed to reduce noise due to stray light, has been completed in both 3 km long arms of KAGRA. Optical simulations to estimate the stray-light noise with the designed

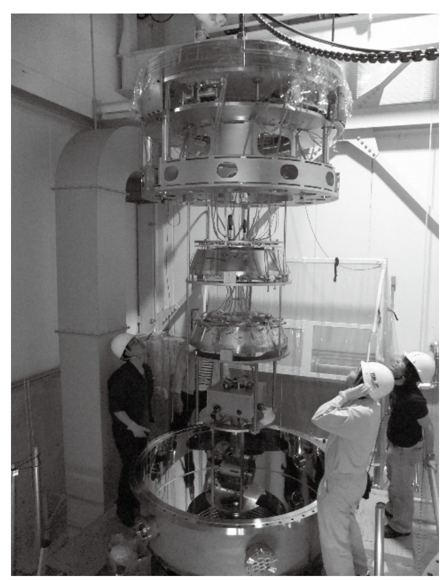

Figure 1: KAGRA construction progress: while the arm ducts are installed at Kamioka, the first full prototype of the vibration isolation system is tested in one of the TAMA vacuum chamber at Mitaka.

optical baffle system in the arm cavities were finished in the last year, and the performance was estimated to fulfill KAGRA's requirement. One of the large baffles (400 mm diameter) should be installed in a cryostat (20 K), and the structure to support such a baffle is being discussed. The beam reducing telescope will sense the tilts of the main cryogenic mirrors in the 3-km arms, making it indispensable for the long-term stability of the interferometer operation. Its conceptual design was finished and some of the required optics were delivered.

(3) Mirrors Development

Sapphire mirrors are the most important optics for KAGRA. Therefore, tests to determine their quality are necessary. NAOJ GWPO already made a scatter-meter for the mirrors. It can measure the total amount of scattering with a level of 1 ppm. In FY 2014, an optical absorption measurement system was introduced in the TAMA experimental room. It has the potential to measure absorption less than 1.5 ppm/cm for the sapphire substrates. Now it is being fine-tuned to improve its stability.

2. Data analysis and theory

(1) Data Analysis Preparation

Based on the approved Grant-in-Aid for Scientific Research on Innovative Areas "New Developments in Astrophysics through Multi-Messenger Observations of Gravitational Wave Sources," preparations for multi-messenger analysis are in progress. To reduce the false alarm rate of the KAGRA detector, a physical environmental monitoring system is necessary. Now the system has been installed in the X-end room at the Kamioka site. The recorded data were analyzed by the KAGRA detector characterization sub-group. The noise veto information will be shared by GW search systems.

(2) Theoretical Research on General Relativity

General-relativistic higher-order perturbation theories have very wide applications for cosmology, black holes, and gravitational waves. Therefore, a framework for general-relativistic higher-order gauge-invariant perturbation theory has been discussed from a general point of view. In 2014 it was shown that the general framework developed by Dr. Kouji Nakamura is applicable to any-order perturbations on an arbitrary background space-time. In addition Dr. Nakamura together with Dr. Masaki Ando also proposed a precise derivation of the resultant response of a rotating torsion bar antenna when acted upon by gravitational waves.

3. R&D

(1) R&D for Upgrades of KAGRA

In parallel with the development of KAGRA, the GWPO continues to carry out an R&D program to prepare future detector upgrades. We seek external funds to support this program. In FY 2014 we completed a cryogenic infrastructure to test optical components for KAGRA at cryogenic temperature. In parallel we started a collaboration with the Institute for Molecular Science to study the quantum behavior of macroscopic objects. For this purpose, a large vacuum chamber was funded by NINS via an intra-institute funding program. Finally we started R&D to study the capabilities of mirrors based on crystalline coatings. The goal is to reduce the thermal noise in precision measurements based on optical cavities such as GW detectors. This project was funded by JSPS. In FY 2014 we also submitted to JSPS a larger scale project hoping to realize frequency dependent squeezed states of light using the TAMA infrastructure.

(2) DECIGO/DPF

In FY 2014 the DECIGO Pathfinder (DPF) proposal, submitted to JAXA for the next scientific mission, was rejected. One of the main reasons was the lack of available manpower since the gravitational-wave community in Japan is concentrating on the construction of KAGRA. However the scientific significance of DECIGO has been recognized by JAXA. So we revised the roadmap to DECIGO.

As a "pathfinder," we will do R&D on the ground and use airplanes to make a free-fall environment to test each unit developed for DECIGO. The revised R&D plan was submitted to JSPS and was approved.

In NAOJ, an interferometric sensor is being developed. In this fiscal year, we made a test bench with balancing masses ("yajirobee") for simulating the test masses to achieve free-fall in some degrees of freedom on the ground. The controllability of the masses are shown experimentally.

4. Education

During FY 2014 one master's student from SOKENDAI and one undergraduate student each from Ochanomizu University and from Tokyo University of Science did their research projects in the GWPO. All of them obtained their degrees. In addition, one PhD student from ICRR is continuing his research at NAOJ to do his thesis on the KAGRA vibration isolation system. The GWPO also hosted one PhD student from Niigata University under the NAOJ research visitor program; an undergraduate student from the USA under the International REU program in Gravitational-Wave physics funded by NSF; and two undergraduate students under the SOKENDAI summer student program. Within the SOKENDAI program we also hosted a master's student from the University of Pisa who then applied and was accepted as a PhD student at the U-Tokyo. The GWPO also contributed to teaching with regular classes given at the Department of Astronomy of U-Tokyo and at Hosei University. Punctual classes were given also at Ochanomizu University, the SOKENDAI summer school and at the department of Engineering of U-Tokyo.

5. Publications, presentations and workshops organization

The office members were authors of 34 publications in international journals and of 11 presentations to international conferences. 30 presentations were also given to conferences in Japan.

During FY 2014 we organized the 6th Korea-Japan workshop that took place at NAOJ on June 20th and 21st, 2014. We also contributed to the organization of the Gravitational Wave Advanced Detector Workshop in Takayama in May 2014.

6. Outreach

KAGRA had a tunnel completion ceremony in July. Following this event, a TV program by NHK featured KAGRA and the office contributed to it. We also had an interview by Mainichi-shinbun about KAGRA yielding a newspaper article in January. The office contributed to the NAOJ open days in October by showing the TAMA facility and the ATC's clean room for assembling KAGRA components to the public. Visits to the TAMA facility were also given to several groups of high school students, college students, and people from private companies.

7. Relationships with industry

We continue the collaboration with a Japanese company aimed at improving the quality of low loss mirrors. In particular, we fabricated an ultra-low loss rigid cavity using the optical contact method. The specification for the reflectance of the mirrors is 99.999 % and the target loss factor is less than 5 ppm. The cavity is now under inspection.

8. Personnel

At the beginning of FY 2014 the project included a total of 14 personnel, including one specially appointed professor, two associate professors (one of which is affiliated with U-Tokyo), five assistant professors (of which one is assigned to ICRR), three engineers, two administrative staffs (shared with the Jasmine project) and one postdoc. During the year one postdoc, one specially appointed researcher, one specially appointed specialist and one research associate joined the team, so that at the end of the year the GWPO had 18 staff members. In addition one PhD student, one master's student and two undergraduate students did their research project in the GWPO. We also hosted a research director from CNRS (France) who visited our office for one-and-a-half months.

11. TMT-J Project Office

The TMT Project is a construction project to build an extremely large telescope with 30 meter aperture through the collaboration of five partner countries comprised of Japan, the United States of America, Canada, the People's Republic of China and the Republic of India. The TMT-J (TMT Japan) Project Office heads the project for NAOJ. In Fiscal Year 2014, an agreement was executed establishing the key project principles and work share assignment for TMT construction. TMT International Observatory was founded for the purpose of construction and operation of TMT and the commencement of the construction of TMT was declared. For its part in the construction, Japan is fabricating the primary mirror segments, designing the telescope structure, and designing/studying science instruments.

At the end of Fiscal Year 2014, 3 Professors, 3 Associate Professors, 1 Chief Research Engineer, 2 Specially Appointed Senior Specialists, 1 Research Administrator Staff, 2 Research Experts, 1 Research Supporter, 1 Public Outreach Official, 1 Specially Appointed Research Staff Member, 1 Specially Appointed Project Research Staff Member, and 2 Administrative Supporters were in full-time positions for the Project Office. In addition, 1 Professor, 4 Associate Professors, and 5 Assistant Professors from the Advanced Technology Center, Subaru Telescope and NAOJ Chile Observatory 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. Commencement of Construction by the TMT Project

The TMT-J Project Office of NAOJ has participated in quarterly TMT Board meetings held since 2007 as well as in the Science Advisory Committee and external review committee meetings to give shape to the international collaboration. By April 2014, this effort led to the execution of agreements by the final authorities of each participating organization that set the key principles and schedules for construction; work share and the basis for observing time allocation; and the establishment of the TMT International Observatory which would assume the role of constructing and operating TMT. In May of the same year, TMT International Observatory (TIO) was incorporated in the USA. At this point, the National Institute of Natural Sciences (NINS), National Astronomical Observatories of Chinese Academy of Sciences, University of California and California Institute of Technology became official members of the project by executing the project agreements. The Department of Science and Technology of India and National Research Council of Canada followed by becoming official members with the approval of the project budget in December of the same year for India and April 2015 for Canada. Along with the 6 members, the Association of Universities for Research in Astronomy joined the project as an Associate Member representing the USA in anticipation of later becoming a full-fledged member. Japan also has a role in leading the international collaboration with a TMT Board Member representing Japan appointed as Vice Chairperson of the TMT International Observatory Board of Governors.

In July of 2014, commencement of construction was declared with the approval of a sublease from the University of Hawai`i to TMT International Observatory for the TMT construction site on the summit of Maunakea and the completion of all paperwork and procedures to use the land for construction. In October, a groundbreaking ceremony was held in Hawai`i and onsite construction commenced.

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 and fabrication of the primary mirror segments and preliminary design of the telescope structure was performed. In Fiscal Year 2014, in addition to domestic progress related to the fabrication of the primary mirror, detailed designs of the telescope structure, and the development of science instruments (explained below), Japan also initiated payments to TMT International Observatory to cover Japan's share of operating expenses that include onsite construction costs.

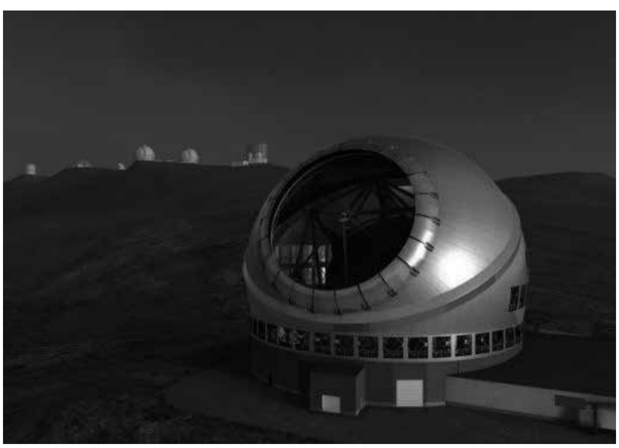

Figure 1: Conceptual image of TMT once constructed.

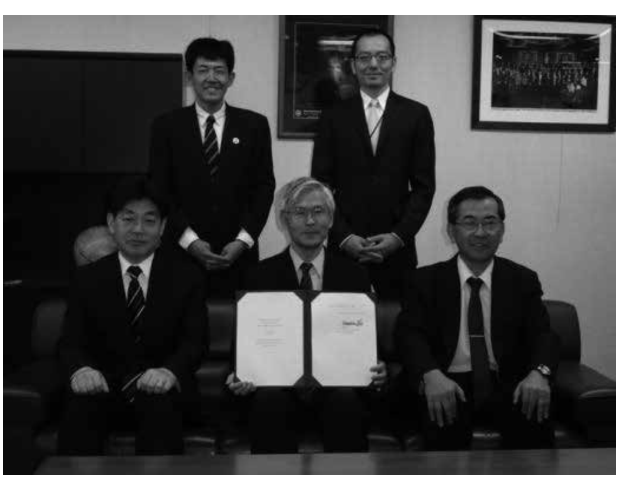

Figure 2: Execution of the TMT agreement by the President of NINS.

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

Japan is officially charged by the executed agreements with responsibility for the design/manufacture of the telescope structure, the primary mirror segments and sections of the science instruments.

(1) Fabrication of the Primary Mirror Segments

The plan for the primary mirror calls for Japan to fabricate all of the segment mirror blanks and to spherically grind the blanks as part of its work share. In 2014, 39 blanks were fabricated, 18 of which were spherically grounded. Because Japan is also in charge of polishing 30 % of the mirror segments, we developed and demonstrated technology with the capacity to mass produce aspherically polished segments. We also performed aspherical grinding on 15 segment blanks.

(2) Design of the Telescope Structure and Its Control System

The plan for the telescope structure is to have the detailed design of the telescope completed in 2 years starting from Fiscal Year 2014, based on the preliminary design from Fiscal Year 2013. The control system of the telescope structure passed its preliminary design review in April 2014, followed by the primary mirror segment exchange mechanism (Segment Handling System) in November, enabling both to continue on to the detailed design phase. In addition, fabrication and evaluation of prototypes are underway for large structures that are difficult to fabricate and require fabrication with extreme precision. In February 2015, the first design review was held for the main telescope structure.

(3) Science Instruments

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

Japan is in charge of fabricating the imaging component for the Infrared Imaging Spectrometer (IRIS). In fiscal year 2014, optical design of the imaging system that will enable the addition of a highly demanded high-contrast optics system and wide-field capability in the imaging system was proposed to the TMT Science Advisory Committee and approved.

For the Wide Field Optical Spectrometer (WFOS), Japan continued its conceptual study from Fiscal Year 2013 in anticipation that it will be placed in charge of the camera system. The availability of high quality large diameter glasses for the camera system was confirmed through investigations.

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

Continued effort is made to reflect the opinions of the community through actions such as the TMT-J Science Advisory Committee (TMT-J SAC). A tool for evaluating science observation performance in the preparation of proposals for scientific research to be undertaken with TMT was proposed by TMT-J SAC and is being developed by the TMT-J Project Office. It has been made internationally available and has been used by many researchers. 14 special feature articles on TMT with a brief overview of the project, current status of construction, and science feasibility studies were published in three special issues of the Astronomical Herald of the Astronomical Society of Japan.

While the Science Advisory Committee of the TMT International Observatory performed a central role in studying the scientific research feasible with TMT, Japan played a major role in the TMT International Science Development Teams (ISDTs) established in 2013 with researchers from Japan participating as conveners in five of the eight science categories.

The TMT Project, particularly the status of Japan's work share, is introduced on the TMT-J Project Office home page. Preparations were made to update the English web page to make information about the progress made on the project by Japan available overseas. TMT Newsletters volumes 40 to 43 were delivered. Public outreach was undertaken by performing lectures all over Japan and through exhibits made available through organizations such as the NINS Symposium and Inter-University Research Institute Symposium. Continued efforts to raise donations for the TMT Project resulted in donations from one corporation and 732 individuals in 2014 (between January and December).

With the support of "Club TMT" formed in 2012 to support the project, TMT was introduced in screenings and lectures at science museums and planetarium all around Japan. About 50 lectures and classes on demand were held for the public.

Public relations/outreach and contributions to workforce development and education were performed by Workforce Pipeline, Education, Public Outreach and Communications (WEPOC), an international study team. In October 2014, WEPOC opened an assembly in Tokyo where outreach activities performed within Japan and at the Subaru Telescope in Hawai`i, as well as Hawai`i instruction courses for high school students that included visits to the Subaru Telescope were introduced. Activities of the assembly also included visits to science museums.

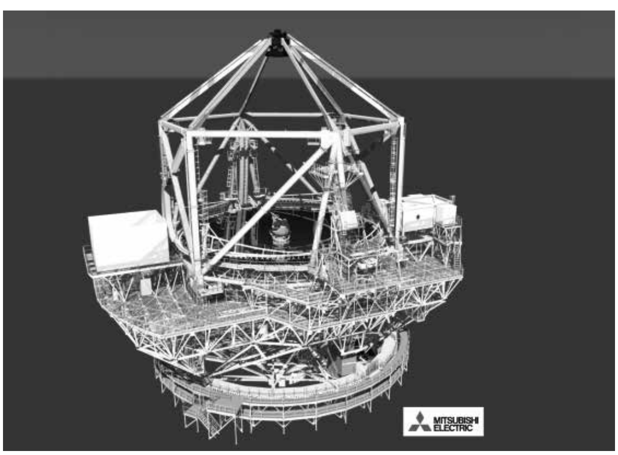

Figure 3: Detailed design of the telescope structure in development.

Figure 4: Aspherical grinding of a primary mirror segment.

12. 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 μ) measurements of 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 2021. 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 2030s. 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 2014

1) Organization of the office

The JASMINE Project Office is composed of four full-time staff members, six staff members with concurrent posts, two postdoctoral fellows, one research associate, one technical associate, and four graduate students. Significant contributions were made by members of the following organizations: the NAOJ Gravitational Wave Project Office; 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 technical experience in onboard data acquisition and the like necessary for the upcoming JASMINE project, achieve scientific results in the study of dynamical structures in the vicinity of the Solar System, and the analysis of star formation based on stellar motions in star formation regions.

The satellite is 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 postponed due to delays in construction work at the Alcantara Space Center launch site in Brazil. On the other hand, the construction of the rocket has been completed, and work on interface adjustment between the rocket and the satellite is in progress. 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. The project has continued to prepare terrestrial communication stations related to satellite operation. 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. The Gaia Project involves observational and analytical methods similar to those of Nano-JASMINE. A Japanese WG led by Ryoichi Nishi of Niigata University continued to engage actively in investigating the scientific results obtained in the future by Nano-JASMINE.

3) Overview of Planning and Developing 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 10–20 μas and proper motions, or transverse angular velocities across the celestial sphere, at 10–50 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 a compact object in a 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 for the ISAS call for small-sized scientific satellite mission proposals. The name and submission requirements were altered in FY 2013; it is now known as Epsilon onboard Space Science Missions. 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. As planning progressed, the full mission proposal was prepared and submitted in February 2014. Although Small-JASMINE was not selected as a final candidate, it should be remarked that the evaluation committee gave Small-JASMINE high scores. Furthermore the evaluation committee suggested a specific needed improvement. To date, we have already promised that Small-JASMINE can make this improvement. We have been making a revised mission proposal in preparation for the next ISAS call for proposals.

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, an identical model 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.

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

The Extra-Solar Planet Detection Project Office (EPO) will manufacture/maintain large-scale instrumentation and develop new technologies and observational methods for exoplanet research. The goal is to make contributions as a center of excellence in this field and promote observations of exoplanets and studies of their formation. The EPO promotes not only instrumentation, but also cutting-edge observational research using these state-of-the-art instruments in collaboration with domestic and international researchers. The science themes are not limited to exoplanets and their formation. They also include brown dwarfs and star/planet formation. The main themes in the last 5 years are:

(1) The development/upgrade/maintenance/operation of the high contrast imager HiCIAO and the promotion of the SEEDS survey project.
(2) The development of the new IR Doppler instrument IRD and planning its observations.
(3) The development of the high contrast instruments SEIT (for TMT) and WACO (for WFIRST, formerly SPICA/SCI and JTPF activities.)
(4) The instrument development and maintenance for smaller telescopes (Okayama/MuSCAT multi-channel optical camera, IRSF/SIRIUS 3-band infrared camera and IRSF/SIRPOL 3-band infrared polarimeter).

In FY 2015, the project consisted of 5 main staff members, 3 joint appointment staff members, and 5 postdocs. There were 36 refereed papers in English, 4 non-refereed papers in English, 14 presentations in English, 1 refereed paper in Japanese, 2 non-refereed papers in Japanese, 5 books in Japanese, and 49 presentations in Japanese.

1. Development of the Subaru next Generation Exoplanet Instruments and Exoplanet Observational Researches

(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 with the 8.2 m Subaru Telescope, which can utilize various differential imaging techniques to distinguish polarization, multi-band observations, and angles. The project started in 2004 and its performance verification was completed in 2009. The main survey of first Subaru Strategic Program SEEDS (Strategic Explorations of Exoplanets and Disks with Subaru) with more than 100 people continued from October 2009 until January 2015, without any serious troubles.

(2) IRD (Infrared Doppler Instrument)

IRD is a high precision (~1 m/s) radial velocity spectrometer working at near-infrared wavelengths. It's 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 (PI: Motohide Tamura). The final manufacturing of the main componets, fiber experiments, laser frenqucy comb, and total asemble are being conducted. Science discussions on habitable planets around M dwarfs are also proceeding.

2. Exoplanet Instrument Developments for Future Space and Ground-Based Telescopes and International Collaborations

(1) WACO (WFIRST-AFTA Coronagraph) and JTPF (Japanese Terrestrial Planet Finder)

These missions aim to directly image and characterize Earth-like planets and super-Earths for signatures of life. As a member of the WACO working group, coronagraph performance tests at the JPL testbed are conducted with collaborators with other Japanese collaborators.

(2) SEIT (Second Earth Imager for TMT)

The aim of the SEIT instrument is direct imaging and characterization with the 30 m telescope TMT. Both technical and science discussions are being conducted, including optical demonstration tests.

3. Science Research, Education, and Outreach

The SEEDS project was successfully completed in January 2015 without any major troubles. In this year, a planet (< 15 Jupiter masses) is confirmed at r ~ 47 au around Herbig Ae star HD100546. The planet is not point-like but extended, probably suggesting the presence of circum-planetary structures. Spiral structures are also detected in the protoplanetary disk.

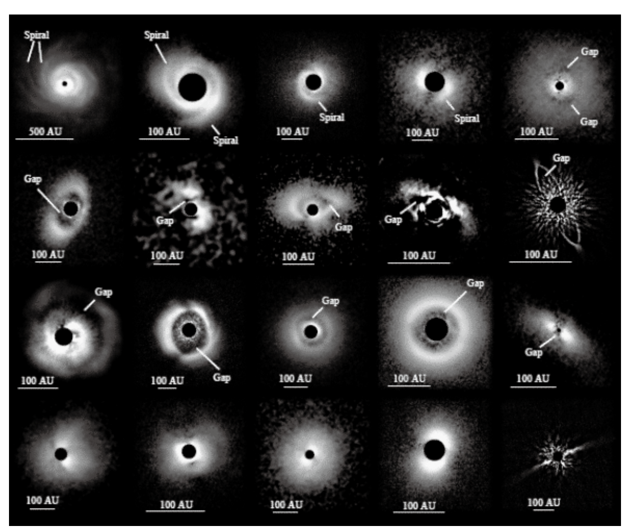

Figure 1: A gallery of protoplanetary and debris disks detected by the SEEDS project in near-infrared wavelengths.

A statistical survey of ~250 SEEDS stars was made and the frequency of stars having objects at 10–100 au around them with masses between 5–70 Jupiter-masses is about 2 %. W. M. Keck Observatory and the Subaru Telescope were used in cooperation for a survey of 120 M stars to search for giant planets.

The SEEDS also directly imaged many protoplanetary disks. It detected scattered light for the first time, which revealed asymmetric structures of the disk around a young star IRS48 (a.k.a. WLY 2–48). A review paper was published on the direct imaging of protoplanetary disks around Herbig Ae stars. An international collaboration using Hubble Space Telescope observations detected about 10 debris disks.

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

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

1. Component Technology Development for Future Lunar/Planetary Exploration Projects

(1) Radio Source for VLBI Observation of Lunar/Planetary Gravity Field:

In 2014, a new lunar gravity field model was publicized based on the recent observations by the GRAIL lunar explorer. The tidal Love number derived from the new gravity model has improved more than expected, and its accuracy exceeds our scientific goal for SELENE-2 VLBI. Therefore, we were required to revise thoroughly our development plan.

i) Analysis of Electric Property and Thermal Tolerance of Macor Antenna

Because financial support from the SELENE-2 mission was terminated when the mission was halted by JAXA, we cancelled fabrication of the Breadboard Model (BBM) for the antenna board. Instead, in the context of future lunar/planetary explorations and component technology development, we investigated the electrical properties of the Macor material that comprises the base substrate of the antenna. We measured the dielectric constant of the base substrate material in relation to changing ambient temperature in a vacuum chamber simulating the environment on the surface of the Moon (−200 °C to +120 °C). The test results have been accepted by a peer-reviewed international journal.

ii) Studies of the Internal Structure of the Moon

Investigation for the elastic and viscous structure of the deep interior of the Moon continued in FY 2014 by combining the selenodetic and seismic data. The expected accuracy of the internal structure based on the accuracy of selenodetic observations was studied quantitatively and submitted to an international journal.

iii) Discussion for Providing Two Beams for the S and X Bands in the 20-m VERA Antenna

Same-beam S-band VLBI observation had been considered for the primary method of differential VLBI observation between the orbiter and the lander. The Vivaldi antenna was selected as the model to be adopted. An antenna element was designed using electromagnetic analysis software, and its shape was optimized. A computer simulation confirmed that the antenna is able to perform at the required performance level.

(2) Development Experiment for Lunar Laser Ranging (LLR)

The distance between the Moon and the Earth can be accurately measured by transmitting a laser from a telescope on Earth to laser retroreflectors that were placed on the lunar surface by the US Apollo missions and Soviet lunar exploration missions and observing the reflected photons, thereby allowing for investigation of lunar rotational variations. Due to the lack of reflectors in the southern hemisphere and the time difference between the two ends of reflector arrays generated by libration, the level of precision has hitherto been insufficient for determining small variations in the process of energy dissipation in the lunar interior.

Aiming to fabricate an LLR retroreflector to be mounted on the lander, material selection and mirror-forming methods were investigated. Preparatory technological development was pursued in conjunction with a tri-party agreement with the Chiba Institute of Technology and Tokyo University of Science, aiming to utilize Ion Beam Figuring (IBF). Monocrystalline silicon and glass ceramics to be used as the mirror material were tested and their stability was verified in a simulated lunar surface environment in a thermal vacuum chamber. Instead of Clearceram-EX, monocrystalline silicon was selected as the best mirror material for thermal-structural and optical analyses.

(3) Development of In Situ Lunar Orientation Measurement (ILOM) Telescope

Research is underway to install an ILOM, which is like a small Photographic Zenith Tube (PZT) telescope, on the lunar surface and to perform high-precision observations of lunar rotational variations to constrain the internal structure of the Moon. Because measurement can be conducted independent from lunar orbital motion, this small telescope is capable of detecting miniscule variations in the rotation of the Moon, allowing us to determine whether or not the lunar core is molten.

The mercury pool developed in FY 2013, which is less susceptible to vibration, was installed in the Breadboard Model (BBM) of the telescope. The imaging performance of the BBM was examined by using an artificial light source; we determined the relationship between variations of the star-image center, ground vibrations, and the inclination of the telescope tube. Also, the frame of the telescope for ground observation was fabricated.

(4) Development of the Laser Altimeter (LIDAR) of Hayabusa 2

i) ranging tests using a flight model, hardware tests using ground support equipment, and accuracy estimation for asteroid surface albedo calculated through the intensity ratio of the transmitted and received lasers.

ii) development of a quick-look software and verification during the integration tests.

iii) theoretical calculation of the size and density of circum-asteroid dust for hardware development.

(5) Development of a Ganymede Laser Altimeter (GALA) for the Jupiter Icy Moon Explorer (JUICE) Mission

GALA was officially selected by ESA as one of the JUICE mission payloads following a proposal submission in FY 2012, and the RISE Project Office officially commenced activities as a main GALA-Japan team member. Japan will undertake the development of a receiving telescope as a part of the laser altimeter system.

i) detailed laser link calculations (performance model) to serve as the basis for the hardware design.

ii) deliberation on the specifications for the thermal–structural analysis to be outsourced to a manufacturer.

iii) The RISE Project Office leads the gravity/rotational variation subgroup within the Japanese part of the science team.

3. Educational Activities/PR

Six RISE members delivered lectures on a part-time basis to graduate students at the University of Aizu for two semesters; and two RISE members served as part-time lecturers at Iwate University for a half year each. The office accepted two undergraduate students from Iwate University through an internship program, and one undergraduate student from Kobe University in the summer student program of the Graduate University for Advanced Studies (SOKENDAI).

4. Joint Research/International Collaborations

‘The Memorandum on Basic Issues Concerning Research and Development of Scientific Instruments for Lunar Landing Exploration’ was renewed between members of the RISE Project Office and the Faculty of Engineering at Iwate University in FY 2014. In accordance with this memorandum, joint research into the basic development of a lunar lander/explorer (LLR and ILOM) is conducted by the Faculty of Engineering at Iwate University, with monthly meetings held alternately at Iwate University and NAOJ Mizusawa Campus.

Joint research continues with a group from Kazan Federal University, Russia, which is well respected in theoretical investigation into the internal structure of the Moon, to establish a new theory of lunar rotation, in line with ‘the Memorandum of Understanding for Cooperative Research between Kazan Federal University and National Astronomical Observatory of Japan on VLBI and Astrometrical Observations,’ which was renewed in 2010. A two-day workshop on the internal structure of the Moon was held at Mitaka and Mizusawa Campuses using a Grant-in-Aid for Bilateral Research from the Japan Society for the Promotion of Science. Seventeen Russian scientists attended at this workshop and visited the RISE office in Mizusawa.

15. Solar-C Project Office

The SOLAR-C Project Office engaged in planning the next solar observation satellite project, SOLAR-C, and implemented the preparation of the flight components for the Chromospheric Lyman-Alpha SpectroPolarimeter (CLASP) to be flown on a sounding rocket experiment. In Fiscal Year (FY) 2014 the JAXA SOLAR-C working group (WG) led by Prof. Watanabe submitted the SOLAR-C proposal for the JAXA Strategic Middle-Class Satellite Mission. The CLASP team has executed the assembly and testing of the CLASP flight model in the ATC cleanroom for the flight operation scheduled in the summer of 2015.

1. SOLAR-C Project

SOLAR-C is a planned project which may become Japan's fourth solar observation satellite, after Hinotori, Yohkoh, and Hinode. The plan is to realize the launch in the early years of the 2020s. The project is intended to investigate the solar magnetic plasma activities that influence space weather and space climate around the Earth. The investigations will be the first to involve the chromospheric magnetic-field and achieve high-resolution imaging/spectroscopic observations from space. The themes include major problems in solar research: the heating of the chromospheric/corona, the origin of solar explosive events, and variation in the solar spectral irradiance. The tasks include resolving the fundamental small-scale magnetic structures derived directly or indirectly from the Hinode observations and visualizing the activities and interactions of magnetic structures. SOLAR-C will conduct high-resolution (0.1−0.3 arcsecs) observations of radiance, polarization, and spectroscopy over the outer atmosphere from the photosphere to the corona by using onboard instruments. The instruments for SOLAR-C consist of SUVIT with a 1.4 m aperture for observing the photosphere and chromosphere; EUVST for spectroscopic observation from the chromosphere to the corona; and HCI for capturing images of the transition region and corona. 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 USA and European space agencies and institutions will deal with other major instruments through a large-scale international collaboration.

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, dedicated to the SOLAR-C project. It was promoted to become the SOLAR-C Project Office in FY 2013 as an A-project independent from the Hinode Science Center. It continues the preparatory work for the satellite project with four full-time staff members and 11 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 observation of the hydrogen Lyman-alpha 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 received a prospective development budget for the flight equipment during FY 2013. The payload consists of a far-ultraviolet (FUV) telescope and a spectro-polarimeter to conduct polarization observations which were prepared in Japan, with components contributed by the USA (CCD cameras and control computers) and France (a spherical concave grating). The system then will be mounted on an American sounding rocket for launch in the USA in summer 2015. The Japanese PI is R. Kano, an assistant professor at the NAOJ, who leads postdoctoral fellows and assistant professors to pursue design, instrument development, and testing.

3. Major Activity in FY 2014

The major activity on SOLAR-C in FY 2014 was to make and submit the SOLAR-C mission proposal for the JAXA Strategic Middle-class Satellite Mission. The JAXA SOLAR-C WG helped the European scientists with making another SOLAR-C proposal for the ESA M4 opportunity, which was submitted in Jan 2015 to get development funds for the European contribution. The WG submitted the mission proposal to JAXA in Feb 2015. Both examination outcomes will come in the early part of FY 2015.

The instrument assembly, testing, and calibrations were performed on CLASP for the flight operations in summer 2015. For the installation of components supplied by the USA partner group, the USA scientists and engineers joined the assembly and test activities in Japan. The CLASP project has received significant contributions from the ATC in design, fabrication of necessary components, and testing of some of the flight models.

4. Others

Although the SOLAR-C Project Office is reimbursed by the 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.

T. Kobiki is going to leave the SOLAR-C project at the end of FY 2014 and T. Bando is going to move to another project in May 2015.

16. Astronomy Data Center

1. Introduction

The Astronomy Data Center (ADC) is a central core of computing and archiving for astronomical data and supports scientists around the world through the provision of our wide variety of data center services. In addition, ADC is driving forward research and development programs for future generations of services. Our activity is organized into the DB/DA Project, Network Project, JVO Project, Project for HSC Data Analysis/Archiving Software Development, and the Open-use computer system and service.

2. ADC Report

(1) DB/DA Project

The DB/DA-project conducts research and development on astronomical databases and data analysis. It also opens various astronomical data to researchers and educators (http://dbc.nao.ac.jp/).

SMOKA (http://smoka.nao.ac.jp/) is the core of the DB/DA-project and presents 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). The total amount of opened data is more than 10 million frames (54 TB) as of May 2015. SMOKA contributes to many astronomical products. The total number of refereed papers using SMOKA data is 173.

(2) Network Project

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

1) Upgrading International circuit between Tokyo and Hawai`i: NAOJ operates a high bandwidth network between Hawai`i and Tokyo for transmitting the huge amount of science data from Subaru Telescope. In this year, we upgraded from ATM based 155 Mbps circuit to Ethernet based 1 Gbps circuit. Also we started a NAOJ data center service in Honolulu and the NAOJ network has been connected to the Honolulu Internet exchange (HIX) and the DRF Internet service provider in the United States.

2) Mizusawa 10 Gbps R&D Project: We are continuing R&D for high traffic data transfer architecture for science data exchange on Mizusawa 10 Gbps circuit committed to the NICT JGN-X project. In this year, we made a partnership with Intel and are now implementing "Renjyaku+" which is based on the Intel Data Plane Development Kit. It's able to exchange digital data with an actual transmitting rate over 100 Gbps.

(3) JVO Project

We continued development of JVO portal version 2. We implemented basic functions such as, "Quick Search," "Basic VO Search," "Parallel VO Search." We also implemented functions to display the search progress, to view the search results, and to access data stored on JVOSpace. We added a new feature to the JVO/ALMA data archive which enables users to search data based on the observed frequencies. The JVO/ALMA data archive system was demonstrated at the ASJ meeting held at Yamagata University. A cross identification system was developed to identify the same objects among big catalogs, which enables cross identification from 20 billion records in 10 minutes. VO school was held in January 2015, and three participants learned how to use the JVO portal and several VO tools. The all-sky image data taken by AKARI/FIS have been incorporated into the JVO database system, and they are now accessible with the VO interface.

(4) Project for HSC Data Analysis/Archiving Software Development

This project started in January 2009. The main purpose is to develop the data analysis pipeline and data archiving software for Hyper Suprime-Cam (HSC). Our main efforts are concentrated on the implementation of the software to achieve effective data analysis/archiving by parallel and distributed processing; precise photometric and astrometric calibrations; and correction of various effects originating from the camera system.

The Strategic Survey Program (SSP) using HSC began in March 2014 and we started to have stable large data output (about 300–400 GB per night). We ran the data analysis pipeline software on the data, produced databases storing the results, and released them to the SSP team collaborators twice during the fiscal year (in September 2014 and February 2015). The amount of released data is about 50 TB, the number of image files is 200 thousand, the number of objects listed in the released catalog is about 80 million and the database size is about 2 TB. We've developed various software for getting images or catalog data using the database through web browsers, and they are now operating stably. We are planning to improve the usability and to also add many functions for effective data search/retrieval to accelerate scientific activities based on the released data. The computers/hardware for the data release are in stable operation and software with minimum functions is in the operational phase. Improvements to the functions and new development for the data analysis pipeline software are still essential for achieving the planned accuracies for the calibration/measurement of celestial objects in the images. The on-site data analysis system developed since 2011 is now in the operational phase, and performed well in SSP and open-use observation with observer support tools, such as an observation log viewer, which allows browsing of the data analysis results through a web browser. This is a large contribution towards the smooth operation of the Subaru Telescope.

(5) Open-Use Computer System and Service

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 “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 FY 2014, the total number of users and data requests were 384 users and 31 TB, respectively.

During the course of inter-university research, we also held or supported some workshops on using software and systems. The dates and numbers of participants in FY 2014 were as follows.

1. SOKENDAI summer school, July 31–September 8, 2014, 3 users (Supported)

2. Subaru autumn school 2014, September 24–26, 2014, 12 users

3. ALMA CASA tutorial, October 29, 2014, 32 users (Support)

4. IDL School for FITS analysis, December 9–10, 2014, 12 users

5. *N*-body simulation winter school, January 26–28, 2015, 13 users

6. VO School, February 26–27, 2015, 3 users

7. SQL school, March 3–4, 2015, 7 users

In FY 2014, the schools were held a total of 7 times for 82 users.

3. Others

As part of outreach and promotion activities, 90 issues of “ADC News” were published from No.386 to No.436 in FY 2014. The news was distributed by e-mail to users and appeared on the ADC webpages.

17. 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 for both current on-going astronomy programs and for future programs.

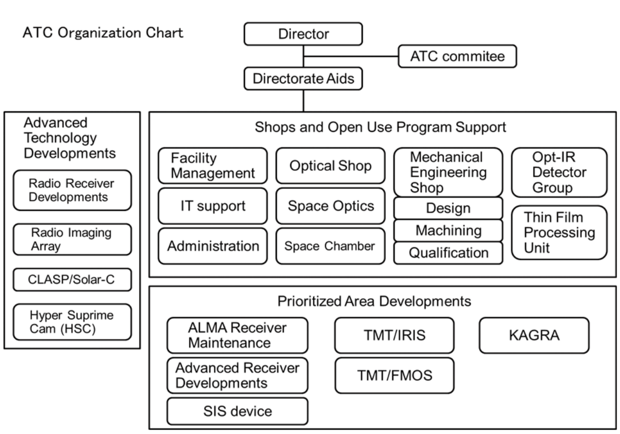

Figure 1: New Organization Chart of ATC from October 2014.

The development of ALMA receivers has been one of the “prioritized area developments,” and their fabrication and shipment were concluded in FY 2013. In FY 2014, some of the receivers with degraded performance were sent back to ATC for maintenance. In the ATC management committee, discussions were held about reorganizing ATC for ALMA receiver maintenance and other development activities. The new ATC organization shown in Figure 1 started in October 2014. ALMA receiver development teams were divided into three groups, which are “ALMA receiver maintenance”, “advanced receiver development,” and “telescope receiver development.” The “telescope receiver development” group works on receiver developments within the common use programs.

The “prioritized area developments” includes instrument development for IRIS, to be used with the Thirty Meter Telescope (TMT), and for the gravitational wave telescope KAGRA. The design and production of equipment have been supported by the mechanical engineering shop (ME shop). Another “prioritized area program,” Hyper Suprime-Cam (HSC), started observations in March 2014.

The “advanced technology developments” includes development for radio imaging arrays, the solar-observing rocket-borne instrument CLASP, and others. CLASP is scheduled to be launched in summer 2015.

The oversight committee of ATC with non-NAOJ members discussed ATC activities on current projects and R&D for future programs. In FY 2014, ATC activities for ALMA receiver development were reviewed and will feedback to ongoing programs such as TMT. R&D programs will be reviewed in FY 2015 accordingly.

2. Workshops and Development Support Facilities

(1) Mechanical Engineering Shop (ME shop)

The aim of the ME shop is to work on design, machining, and evaluation of astronomy instruments, in other word to support astronomy "MONOZUKURI" (fabrication). Three teams for the corresponding functions (design, machining, and evaluation) work efficiently using their advanced skills.

The design team worked hard on structural designs of KAGRA's auxiliary optics subsystem (AOS) and TMT/IRIS's focal plane assembly.

For KAGRA, the following items have been performed:

- Design of mirror mount for BRT (Beam Reducing Telescope)
- Vibration analysis of the BRT structure
- Design, assembly, and evaluation of mirror suspension XYθ traverse mechanism
- Assembly of six 'bottom filters'
- Mechanical design and vibration analysis of Type-Bp mirror suspension
- Vibration analysis and improvement of Type-A mirror suspension

For TMT/IRIS, the following items have been performed:

- Design of atmospheric dispersion corrector (ADC), cold stop, filter exchange mechanism and detector mount
- Test fabrication and evaluation of ADC
- Test fabrication of the filter exchange mechanism
- Vibration test of a kinematic lens cell
- Design and fabrication of a medium-sized cryogenic vacuum chamber.

For other programs, there were the following items:

- Support of HSC on-sight evaluation
- Design of a universal support mechanism for ALMA receivers
- Design of a 4-element horn array and a detector mount.

The machining team worked on KAGRA and TMT/IRIS instrumentation as well as numerous requests from NAOJ and non-NAOJ users. For KAGRA it machined 11 sets of bottom filter parts on schedule; this followed the proto-type machining in the previous year. One of the materials for the bottom filter 'maraging steel' with high stiffness was successfully machined within the required accuracy. In FY 2014, an additional request was received to machine the 'recoil masses' from the material Ti-6Al-4V. After test fabrication of 2 sets of recoil masses, 8 sets were successfully fabricated. For TMT/IRIS, mechanical parts and interfaces for ADC were fabricated after component evaluation feedback, which all serves to help realize cryogenic operation of the instrument. Other machining includes kinematic mounts made of invar for CLASP; a waveguide for the ion-engine of ISAS; and waveguide and horn components for radio imaging array development.

In the field of super-precision machining, work has been done in collaboration with other institutes and upon users' requests for precision machining. In one of the collaborative programs, we performed super-precision milling using single-crystal diamond tools in collaboration with the High Energy Accelerator Research Organization (KEK). The program aimed to achieve efficient machining of a mirror surface for the X-band acceleration disk; test fabrication and evaluation were performed. Another collaborative program was conducted with the Institute for Molecular Science and Nagoya University. This one, which continued from FY 2013, involved machining MgF_2 aspherical lens using a single-crystal diamond tool and was successfully concluded. For submillimeter-wave camera development, wide-band corrugated feed-horns have been fabricated by a milling process, which resulted in good performance, and machining started for a 4-element corrugated feed-horn array.

The ME shop accepted 132 machining or repair requests in FY 2014. With 7 programs carried over from FY 2013, 133 out of 139 programs have been concluded and 6 programs are carried over to FY 2015. There were 7 programs requested from outside NAOJ. The following table shows the requests in FY 2014. (Numbers in the parenthesis show the programs carried over to FY 2015.)

Carried over from FY 2013	7
ATC	23 (3)
HSC	1
TMT/IRIS	10
KAGRA	17 (2)
SOLAR-C/CLASP	36
Solar Observatory	6
Subaru Telescope	1
ALMA	7
ASTE	1
RISE	2
ADC	2
Exo-Planet	13 (1)
JASMINE	4
FOREST	1
Other Divisions	2
Outside NAOJ	
U Tokyo	4
JAXA/ISAS	2
Total	139 (6)

(2) Optical Shop

A. Management and maintenance

- Measuring instrument maintenance (such as daily inspections)
- Technical consulting for users: 67
- Repair and upgrade

Interferometer ZYGO-GPI alignment camera exchange
Solid Spece-3700 repair
Replacement of HEPA filters in the optical shop

B. Open use of measurement instruments (April 2014 - March 2015)
• The number of annual users: 391
ATC internal: 159
NAOJ and the Institute of Astronomy, University of Tokyo: 196
Other organizations: 36
• Use of LEGEX910 (large-scale 3-D measurement machine): 37
ALMA and HSC: 13
Measurement requests to the optical shop: 24
Number of operating days: 50

(3) Optical and Infrared Detector Group

The group supports domestic and foreign instrument groups who use fully-depleted back illuminated CCDs (FDCCD). Since last year, at the request of a domestic group we have upgraded and tested a cryogenic dewar and a cooler for Kyoto3DII camera, a PI instrument of Subaru Telescope. This new camera will operate on the telescope in FY 2015. Furthermore, for foreign instrument groups using FDCCDs, we responded to their requests by e-mail, upgraded the manual on the website, and also conversed with them at conferences. We also attempted to set up an evaluation system for the detectors of the Solar-C project, which will be evaluated in FY 2015.

(4) Thin Film Processing Unit

For the SuMIRe (Subaru Measurement of Images and Redshifts) project, we fabricated wideband anti-reflection coating on the micro-lenses of input optical fibers. The 3500 lenses were coated successfully by high performance multilayer. The lenses are being evaluated at Subaru Telescope.

(5) Space Chamber Shop

The shop supports common use programs that use vacuum chambers and equipment in clean rooms. Major common use programs include usage of the vacuum chamber at the Institute for Molecular Science to evaluate the CLASP instrument using the UVSOR synchrotron facility, as well as usage of the space chamber in the ATC clean room for various thermal analyses under vacuum. The next generation solar observing satellite program, SOLAR-C, used the space chamber for a variety of experiments. Another program, the Wide-field Imaging Surveyor for High-redshift (WISH), used the facility to evaluate cryogenic motors for the filter exchange mechanism. Subaru Telescope used the facility to evaluate optical filters for instruments. Another small vacuum chamber is often used for out-gas measurements, and a thermostatic oven was used for thermal cycle tests of various components.

(6) Facility Management Unit

This unit manages 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 building facilities and equipment, we changed the lighting apparatus from old fluorescent lamps to new LED balls in 5 laboratories and a machine shop. Illumination was largely improved in each laboratory, and in the machine shop it became bright enough for precision machining anywhere in the room. The coolant water circulation facility underwent annual maintenance and the rust was removed from the duct line. However, an accidental break down of the pump occurred and users had to rely on public tap water for a period. All the crane facilities had annual maintenance, and a 4.8-ton crane had an additional check of its load bearing ability. After an inspection by the Labor Standards Inspection Office, it was revealed that four sets of fume hoods did not meet the required ventilation performance for toxic fumes. In addition, one of the fume hoods needed to neutralize fumes from hydrogen fluoride-based solvent, and a so-called Scrubber is to be installed. Most of the organic solvents, oils, and fats are now stored in a separate hazardous material storehouse. In addition, the unit cooperated with a new building under construction for the TMT program which will be completed in FY 2015.

Concerning the laboratory usage including clean rooms, the main users are ATC members, KAGRA, TMT, the Division of Radio Astronomy, HSC, JASMINE, the Division of Optical and Infrared Astronomy, the Exo-planet team, Subaru Telescope, and the SOLAR-C/CLASP team. KAGRA used a clean room in the south building and CLASP used one in the north building. The CLASP team finished instrument evaluation before March 2015, and was prepared to launch from the United States of America in summer 2015.

3. Open Use Programs

In FY 2014, ATC announced and accepted open use programs twice a year. ATC facilities were used for 7 “collaborative development programs” and 30 “facilities use programs.” Information about these programs is presented in “Common use of ATC facilities” with names of the leaders and research titles. Reports from the open use programs are also presented on the ATC homepage.

4. Prioritized Area Developments

(1) ALMA Band 4, 8, 10

In the ALMA project, mass-production of the Band-4, -8, and -10 receiver cartridges (the development of which Japan is responsible for) and their shipment to Chile were completed within FY 2013. In FY 2014, problems occurring at the Chile site were responded to, and in September, while some of the work still remained, the PAS (Provisionary Acceptance on-Site) tests were completed.

The teams “ALMA receiver maintenance”, “advanced receiver development” and “telescope receiver development” have been created by reorganizing the previous receiver development teams for Bands 4, 8, and 10. The purpose of this was to formalize the framework for receiver cartridge maintenance, to be able to broadly apply the technology cultivated through the development of ALMA to other telescope receivers, and to propel forward the development of advanced receivers for the future. Under the strong leadership of the director of ATC, work efficiency has been improved by coordination between teams for appropriate placement of personnel, and by sharing instruments and equipments.

Regarding the ALMA project, the "ALMA receiver maintenance" and "advanced receiver development" teams will continue to be placed in the category of "prioritized area developments." With respect to the maintenance of ALMA receivers, we will steadfastly carry out the maintenance of receiver cartridges for Bands 4, 8, and 10. In addition, with regard to "advanced receiver development," we will push forward with receiver development that supports the future of ALMA, such as wide bandwidth, multi-pixel, and higher frequency receivers. Also, "telescope receiver development" will be placed in the "advanced technology developments" and we will push forward with the development of receivers to be installed in telescopes such as the Nobeyama 45-m Telescope and ASTE.

(2) Hyper Suprime-Cam (HSC)

HSC has been used for the regular science operations since March 24, 2014. This includes both Subaru Strategic Program and normal open-use observation. During FY 2014, the number of nights allocated to HSC program was April: 11 nights, June: 18 nights, September: 16 nights, November: 19 nights, January: 12 nights, March: 19 nights; for a total of 95 nights (including engineering nights). We lost four nights in June due to camera hardware trouble. Several incidents occurred simultaneously including shutter failure due to the battery of the real time clock running out and hardware trouble in the HSC control computers. Because the prime focus is hard to reach, it took more nights to solve all of these problems. In the early part of FY 2014, we had minor troubles with the mechanics of the shutters and the filter exchangers which affected the operation. We had a great deal of supports from ATC engineering staff near the end of 2014, and all of the problematic mechanics were fixed. As a result, most of the troubles never occurred during the last two observing runs in Jan.–March.

Through the engineering runs we confirmed the expected image quality as well as the throughput of the camera. Using the engineering runs, we improved coordination between HSC and the telescope control software to make things run parallel. This enables efficient observation; 90 % of the usable time is now dedicated to science exposures.

We have a couple of left over items for FY 2015 including the investigation and replacement of problematic CCDs, the development of the throughput monitoring system, and a new single lamp flat field system.

(3) IRIS Instrument for TMT

We have been continuing development of the IRIS instrument for the Thirty Meter Telescope (TMT) since 2011.

In the preliminary design phase, which started in March 2013, we proposed an optical design which solves all major problems including (1) optimum field configuration between the imager and spectrographs, (2) optical distortion of an atmospheric dispersion corrector (ADC) in the spectrographs, and (3) application of high contrast optics. The new optics design also achieves 4 times larger field of view than the previous conceptual design with all the requirements satisfied without significant increase in the cost. The design has been approved by the TMT Board. The optical design continued evolving to an all reflective design which is now regarded as a baseline.

We also made good progress in fabricating prototype coatings and filters with higher throughput than ever to realize "high throughput, low wavefront error optics."

(4) Gravitational Wave Telescope KAGRA

We developed KAGRA's auxiliary optics subsystem (AOS) and vibration isolation subsystem (VIS) with the Gravitational Wave Project Office.

For AOS, some of the mechanical design aspects for the large optical baffles are ongoing. There are five kinds of such baffles, and their maximum diameter is around 800 mm. Among them, four kinds of baffles are located inside the two 3-km arms of KAGRA, where gravitational wave signals will be converted to optical signals with high sensitivity. In an interferometric gravitational wave detector, noise contributions due to stray lights are generally determined by the product of the seismic fluctuations of the baffles, their surfaces' blackness, and the coupling factor of stray light to the main beam mode of the interferometer. So the baffles should be designed considering not only the blackness of scattering from the baffle surface but also their mechanical stiffness. For the mechanical design of the baffles, the ME shop is supporting finite element analysis of the structures and helping some discussions on how to assemble and install the system.

In addition, we have designed a beam reducing telescope, which also belongs to KAGRA-AOS. The telescope systems will be located at the end of each 3-km arm of KAGRA to monitor the tilt and shift of the beam line, and to provide feedback signals to the control system. It consists of an optical part, vibration isolation part, and signal processing part. In FY2014 we designed the optical part.

KAGRA-VIS is a suspension system to isolate the mirrors required for the KAGRA interferometer from seismic fluctuation. The system consists of multi-stage isolation filters; the ME shop has manufactured some parts for the seven pieces of the bottom filters, and has also performed assembly work, tests, and packing for delivery. The ME shop has also manufactured two units of recoil masses, which will be suspended to reduce the fluctuations of the mirrors. The recoil masses are made of a special metal, Ti-6Al-4V, because of its nice magnetism and conductivity. Though it was the first time for the ME shop to work with the material, it successfully machined them. The traversers which support most of the suspended parts in vacuum and move around smoothly to place the mirrors as planned, have been designed, assembled, and tested.

5. Advanced Technology Developments

(1) Telescope Receiver Developments

Based on the ALMA receiver developments, the "telescope receiver development" team started its activities, including development of the Nobeyama FOREST receiver and the 345/450 GHz band receiver of the ASTE telescope. We have also pushed forward the basic study of a cryostat for enabling simultaneous use of multiple receiver cartridges. ATC can increase the technology standards of the community by giving feedback using the technologies and knowledge accumulated through development of specific projects, and benefit the technology developments of other projects, universities, and research institutions. It is also important to make the best use of the achievements of the projects.

(2) Radio Imaging Array Development

In collaboration with the University of Tsukuba, Saitama University, KEK, and RIKEN, the MKID (Microwave Kinetic Inductance Detector) group of the Advanced Technology Center is developing superconductive cameras in millimeter and submillimeter wavelengths for the Antarctica terahertz telescope, which observes distant galaxies with a wide field of view, and for LiteBIRD, which detects CMB B-mode polarization.

We had progress in the following areas for development of wide-field-of-view millimeter and submillimeter instruments in FY 2014.

1) Wide field and compact 0.1 K cryogenic system
2) Wide field of view (1 degree) terahertz optics
3) Anti-reflection coated 700 pixels Si lens-array
4) CMB B-mode polarization MKID camera

Tom Nitta, a JSPS Research Fellow for Young Scientists, moved to the University of Tsukuba as an assistant professor starting from April 1, 2015.

(3) Terahertz Intensity Interferometry

Intensity measurements of astronomical sources can be used to realize a type of intensity interferometer known as a Hanbury-Brown and Twiss interferometer. These are based on the quantum optical behavior of thermal photons. To advance this technology in terahertz frequencies, we have started a study on the measurement of intensity correlations and delay times, and their applications to aperture synthesis imaging. In collaboration with Nobeyama Solar Radio Observatory, Nobeyama Radioheliograph was used to measure intensity correlation of solar 17 GHz radiation and successfully measured delay time with a precision less than 10 psec with an integration time of 50 msec. Development of superconducting tunnel junction detectors started to measure terahertz photon pulses, and a concept study of photon counting terahertz interferometry was performed. The development activity was supported by a grant from Matsuo Academic Foundation.

(4) Space Optics

Activities to observe astronomical objects from space by using sounding rockets and science satellites have been pursued to realize future space science missions. In FY 2014, fundamental development was executed for the on-going sounding rocket mission CLASP and for future satellite missions WISH and SOLAR-C. In FY 2013 the CLASP project, which is a mission to observe solar magnetic fields in the chromosphere and transition region via the hydrogen Lyman alpha line at 121.6 nm, entered the phase of preparing the flight instrument. In FY 2014, it moved to the stage of assembling and testing the flight instrument in the ATC clean room. The CLASP spectro-polarimetric capability was finally calibrated by the end of FY 2014 with a UV calibration light source that was developed in ATC. The CLASP payload is to be launched in summer 2015 from a launch site in the USA. For a planned future solar observing satellite mission SOLAR-C, the first prototype component developments have been carried out for the waveplate to modulate the polarization state and for an image slicer optical unit to realize the 2D spectro-polarimetry, in addition to performance evaluation of a near-infrared imaging device. A collaborative study on the contamination control for optical surfaces that are exposed to solar UV illumination has been performed with the JAXA research and development branch.

(5) Near-IR Imaging Sensor Developments

A commercial InGaAs near-infrared image sensor, which is a product of a domestic manufacturer, was evaluated at cryogenic temperatures to improve the readout performance. However, the noise and dark current was still high for astronomical observation. We have designed a low noise CMOS readout integrated circuit to improve the readout performance of the InGaAs image sensors.

General purpose data acquisition systems, MESSIA, have been used at several astronomical observatories over the last decade. We have developed a new version by using a circuit board originally developed for Hyper Suprime-Cam. As a final evaluation, we have installed the new system onto an instrument of the KANATA telescope operated by Hiroshima University, and started test observations.

18. 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. The Center is comprised of seven offices and one 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. The activities of each office are reported hereafter.

2. Personnel

In FY 2014, the Public Relations Center was composed of Director Toshio Fukushima and the following staff members: 2 Professors, 1 Associate Professor, 3 Assistant Professor (2 hold concurrent posts), 4 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), 23 Public Outreach Official, 1 Research Supporter, and 2 Administrative Supporter.

Cheung Sze-Leung (Specially Appointed Senior Specialist, IAU Office for Astronomy Outreach); Tatsuya Uzumaki (Public Outreach Official, Outreach and Education Office); Hiroshi Futami (Public Outreach Official, Museum Project Office); and Takaaki Takeda (Public Outreach Official, Museum Project Office) joined the Center on April 1, 2014. Yukiko Shibata (Public Outreach Official, Outreach and Education Office) joined on August 1. Shiomi Nemoto, (Public Outreach Official, Museum Project Office) and Satomi Hatano (Public Outreach Official, Outreach and Education Office) joined on March 1, 2015.

The following members relocated: Tatsuya Uzumaki (Public Outreach Official, September 30); Chisato Ikuta (Assistant Professor, November 30); Mayumi Hori (Chief of the Library, March 31, 2015). The following members retired: Norio Ohshima (Research Engineer); Hideo Fukushima (Research Engineer); Shoichi Itoh (Public Outreach Official); Yukie Baba (Public Outreach Official), Hitoshi Masuzawa (Public Outreach Official); and Yuriko Watanabe (Public Outreach Official).

3. Public Relations Office

The Public Relations Office actively promoted scientific developments produced by various NAOJ Projects including the NAOJ Chile Observatory and the Subaru Telescope. It also promoted the results of joint research projects conducted with universities and other research organizations through press conferences and web releases. In cooperation with the Outreach and Education Office, the Public Relations Office also conducted awareness campaigns for the lunar eclipse, meteor showers and other astronomical phenomena of interest to the public. An internet broadcast of the October 8 total lunar eclipse garnered approximately 30,000 viewers.

(1) Multimedia-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 to the website.

In response to trends in society's use of the internet, the Japanese webpage was updated in August to better accommodate smart phones.

NAOJ e-mail newsletters No. 129–142 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.

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 2015, the number of followers exceeds 47,000.

(2) Publicizing Developments

There were 16 research result announcements (compared to 26 in FY 2013 and 17 in FY 2012.) Information releases were actively presented, totaling 26 articles (Tables 2, 3).

In the perennially popular Astronomy Lectures for Science Journalists program, the title of the 21st lecture was "The Start of Construction for TMT," held before the September 30, 2014 groundbreaking ceremony for the Thirty Meter Telescope

Month	Access counts	Month	Access counts	Month	Access counts
April 2014	576,378	August 2014	1,180,446	December 2014	532,836
May 2014	451,804	September 2014	696,725	January 2015	641,761
June 2014	408,358	October 2014	2,179,203	February 2015	470,296
July 2014	634,310	November 2014	581,852	March 2015	642,456
Total: 8,996,425					

Table 1: Monthly website access statistics for the Public Relations Office website, NAOJ Public Relations Center (April 2014–March 2015).

May 21, 2014	Revealing the Complex Outflow Structure of Binary UY Aurigae
July 7, 2014	Still hot inside the Moon: Tidal heating in the deepest part of the lunar mantle
July 29, 2014	Next-Generation Thirty Meter Telescope Begins Construction in Hawaii
August 18, 2014	Mysterious Space Tornado Formation Process Clarified (Japanese Only)
September 17, 2014	Creating Pancakes using Galaxy Collisions-Violent Origins of Disk Galaxies Probed by Radio Telescopes
November 7, 2014	Revolutionary ALMA Image Reveals Planetary Genesis
November 13, 2014	Supercomputer for Astronomy “ATERUI” Upgraded to Double its Speed
November 19, 2014	Huge Sunspots and their Magnetic Structure observed by “Hinode”
December 4, 2014	Astronomers Identify Gas Spirals as a Nursery of Twin Stars through ALMA Observations
February 26, 2015	ALMA Revealed Surprisingly Mild Environment around a Supermassive Black Hole (Japanese, English release by NAOJ Chile Observatory)
March 31, 2015	ALMA Disentangles Complex Birth of Giant Stars

Table 2: Web releases.

June 3, 2014	Giant Explosion Buried in Dust: ALMA Probes Environment around Gamma Ray Bursts
June 19, 2014	Jupiter’s Moons Remain Slightly Illuminated, Even in Eclipse
July 3, 2014	Dynamical Star-Forming Gas Interaction Witnessed by ALMA
August 8, 2014	A Chemical Signature of First-Generation Very-Massive Stars
February 2, 2015	Classical Nova Explosions are Major Lithium Factories in the Universe

Table 3: Press Conferences.

	Solar info	Lunar info	Ephemeris info	Time	Solar System	Universe	Astronomy	Other	Total
April–June	204	116	45	6	168	65	107	774	1485
July–September	200	284	46	8	150	68	118	995	1869
October–December	230	324	78	3	294	85	125	669	1808
January–March	214	130	71	15	186	74	106	468	1264

Table 4: Telephone inquiries made to the Outreach and Education Office of the NAOJ Public Relations Center (April 2014–March 2015).

(TMT). A total of 37 participants listened ardently to the project progress report and lectures about the key science. The materials used in the lectures where distributed to participants beforehand. We also concentrated on a way to deliver the lectures via the internet for reporters who can’t attend.

(3) Activities as NAOJ’s Public Relations Center

The following activities were pursued in addition to the Center’s regular task of aiding research result releases.

The Public Relations Office produced 6 videos in both English and Japanese to introduce the research activities at NAOJ to a broad public audience. The titles included “Analyzing the Universe at multiple wavelengths,” “Telescope: Going back through the Universe’s History,” and “Research and Education at NAOJ.” As of the end of March 2015, these videos have been viewed a total of approximately 10,000 times.

The Office also helped Projects with their own lectures for the general public. In November it assisted with a lecture introducing the successes of the Subaru Telescope, which celebrated its 15th Anniversary, and the expectations for TMT. This was co-sponsored by Sendai Astronomical Observatory. This was the first time one of these lectures was attempted outside of Tokyo. In December, the Office assisted with lectures presenting the latest results from ALMA.

The Office also and cooperated with documentation and offered exhibit materials and image contents for the large events “Space Expo 2014” (presented by NHK and others) and “Hikari- The Wonder of Light” (presented by the National Museum of Science and Nature and others). Training in photography was offered twice, in June and October, to improve the skills of outreach personnel in each project. In July, Social Networking Service (SNS) training was offered to all NAOJ personnel to elucidate communication using SNS.

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 6,426 telephone inquiries (Table 4) and 141 letters, 69 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, 2 were conducted: “Summer Nights: Let’s Count Shooing Stars, 2014” in August (346 responses) and “Let’s Observe the Total Lunar Eclipse” in October (1,293 responses).

The “Fureai (Friendly) Astronomy” project, in its 5th year, provided events to 51 schools, covering all that applied, with 4,812 pupils in attendance. Many of the responses from the pupils expressed interest in seeing stars or aspiration for becoming astronomers, suggesting that the event was a good opportunity to familiarize the children with astronomy and to inspire them by meeting and learning from astronomers. A total of 42 lecturers participated.

On August 4 (Monday) and 5 (Tuesday) during summer vacation “Summer Vacation Junior Star-Gazing Party + You are Galileo!” events were held for elementary, junior high, and high school students (application required, maximum capacity 50 participants). Including guardians, the number of participants to hear lectures about handcrafting and using telescopes exceeded 100 on both days. There were a total of 217 participants (112 on August 4 and 105 on August 5).

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 18 and 19 with the theme “TMT Challenging the Frontiers of Space.” It was co-hosted by the Institute of Astronomy, 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. Both days were graced with clear skies. Events thrived with 4,768 visitors, the most ever, in attendance. 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 5th International Science Film Festival was co-hosted between August 1 and September 29, with more than 100 participating affiliates. Screenings of science films and other events such as a stamp-collection rally were held at 36 science museums, planetariums, and film theaters in Japan, with more than 1 million people participating. The Kickoff Event (Hiratsuka City Museum) Dome Festa (Hiroshima Children’s Museum) and Closing Event (Koriyama City Fureai Science Center) were held as the core events.

The “NAOJ Tours” cohosted each year with Tamarokuto Science Center were held on Monday, January 5 and Sunday, March 8. These days consisted of a sunspot observation event at the 20-cm Telescope Dome, self-guided tours along the tour course, star chart production, explanations of the theory behind navigation, and a stargazing party at the 50-cm Telescope for Public Outreach. Each day had a total of 40 participants, for a total of 80.

“The 10th Workshop for Popularizing Cutting-Edge Astronomy @ ALMA in Chile” was held at the Chile Observatory focusing on ALMA. A total of 25 researchers and people engaging in education or astronomy promotion took part.

The Office conducted the following events in Mongolia, as part of the “You are Galileo!” project from June 30 to July 6, 2014, in cooperation with the Office of International Relations with support from the Foundation for Promotion of Astronomy. On July 1, a lecture and handmade telescope workshop was held at an elementary school in Byan Ulgi Mongolia with 40 participants. Additionally, a stargazing event was held in a nomad camp with approximately 50 participants. The “1st East Asian Astronomical Education and Outreach Workshop” was held July 3-5, at the National University of Mongolia in the city of Ulaanbaatar. A total of 35 participants from 5 countries (Nepal, Hong Kong, Portugal, Japan and Mongolia) attended.

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 education and outreach, was distributed via the internet to domestic and international users. The Outreach and Education Office cooperated with the Japan Foundation of Public Communication on Science and Technology to produce the “Hikari-zu” (Light Diagram) poster (A1, A2 sizes, both Japanese only).

(3) Community Activities

The “Mitaka Picture Book House in the Astronomical Observatory Forest” welcomed 38,911 visitors in FY 2014. The Outreach and Education Office participated in planning the “Stars and Constellations” (July 2013 – June 2014) and “Picture Books and Space” (July 2014 – June 2015) exhibits. In addition, it cooperated with staff members from the Mitaka City municipal offices and local volunteers for modern and traditional Tanabata celebrations and Moon-Viewing parties. Furthermore, it cooperated on the “Mitaka Picture Book House in the Astronomical Observatory Forest, Picture Book Original Drawings Hallway Exhibit Contest.” The best pieces, “Kimi Ni Mieru Yoni” (“So You Can See” text and pictures by Hiromu Aono) and “Hoshi Miru Ojisan” (“The Man Watching the Stars” text and pictures by Nao Mori), were published with Bun-Shin Publishing as the “Picture Book House in the Astronomical Observatory Forest Compilation Series,” created in NAOJ’s hometown.

The Outreach and Education Office conducted the 6th “Mitaka Solar System Walk” in cooperation with the non-profit organization (NPO) Mitaka Network University Promotion Organization. Held from September 20 to October 26, stamps were placed at 154 shops and 63 facilities, including NAOJ Mitaka Campus and the Mitaka City Municipal Office, for a total of 217 locations around Mitaka. Approximately 15,000 guide-maps/stamp-sheets were distributed, of which 2,665 people turned theirs in for a prize. The total number of stamps was 275,315; the average number of stamps collected was 103 per person. The number of participants who collected all of the stamps was 63. 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 20 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 assisted in presenting Star Sommelier Mitaka, an astronomical guide training course hosted by

Mitaka Network University that provided telescope operation workshops and other related events.

5. Ephemeris Computation Office

The Ephemeris Computation Office 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) The office published the 2015 edition of the Calendar and Ephemeris, the 2015 version of the calendrical section of the Rika Nenpyo, and the 2016 edition of the Reki Yoko (posted in the official gazette on February 2, 2015). In the 2016 Reki Yoko, DE430 is adopted as the standard ephemeris instead of DE405. The internet edition of the Calendar and Ephemeris was also updated to match what was published in the Reki Yoko.

(2) As for the website (http://eco.mtk.nao.ac.jp/koyomi/index.html.en), the contents of the Ephemeris Wiki were expanded and all of the contents were made mobile friendly. The Office cooperated with promotional campaigns again this year. The position of Comet Lovejoy and the radiant points of the Perseids and Geminids meteor showers were published in the Astronomical Information section of the website. Neither the total lunar eclipse nor the New Year's sunrise had good weather, but the page view still exceeded 28 million.

(3) The Japan Association for Calendars and Culture Promotion hosted its 4th General Meeting, the Calendar Presentation Ceremony, and two Symposia on the Traditional Calendar 2033 A.D. Problem.

(4) The Office 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 50th and 51st exhibitions were "Weather Documentation from Towns" and "Star Charts" 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 two full-time and two part-time, handled reports of new astronomical objects and other communications submitted to NAOJ. Lately, about 20 reports per year have been submitted. But this year there was a total of 32 reports including confirmation requests for new celestial object candidates and other reports. The contents were: 12 novae/supernovae, 10 comets (including cometary objects), 8 luminous objects, 1 fixed star, and 1 astronomical phenomena question. Particularly in recent years, there has been an increase in cases where the ghost images of bright stars produced when using a filter to eliminate light pollution have been mistaken for comets. In amongst the many examples reporting an already known comet or a planet as a new object, the report of a supernova in September bares mention. Simultaneous to the discoverer reporting it to NAOJ, it was also reported to Kyushu University's Hitoshi Yamaoka. Hitoshi Yamaoka sent a notice to the International Astronomical Union Central Bureau for Astronomical Telegrams. This event was acknowledged as Supernova 2014cy.

6. Museum Project Office

In FY 2013, the section responsible for managing public access to the facilities was reorganized and the name changed from the Archive Office to the Museum Project Office. Some of these activities are managed in cooperation with the Outreach and Education Office.

(1) Facility Opening Events

Except for the 4 month stoppage from December 2014 to March 2015 to replace worn out equipment, regular showings were held at the 4D2U Dome Theater twice a month (the day before the 2nd Saturday and the 4th Saturday) as in previous years. Advance reservations were required. The 15 events this year attracted 1,359 participants. An additional 54 group screenings were held with 1,543 participants, and 69 tours were organized with 622 participants.

Regular stargazing parties held with the 50-cm Telescope for Public Outreach were scheduled the same days as 4D2U theater screenings. 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 5,161 participants.

A total of 19,754 people visited the Mitaka Campus Visitors' Area in FY 2014. We conducted 197 tours for 5,992 guests, including 60 workplace visits by schools. There were also 357 media interviews granted. So that diverse guests can enjoy the open facilities, we developed English, Chinese, Korean, and Spanish versions of the "NAOJ Mitaka Campus Guidebook." We also produced an "NAOJ Mitaka Campus Workbook" with questions elementary students can find the answers to while touring the facilities.

Guided tours of Mitaka Campus began in June 2011 as part of the Archive Office/Open House initiative. Each tour is conducted on an advance booking basis for a group of 20 participants. Tours are organized into two courses: the "South Course" focusing on Registered Tangible Cultural Heritage offered on the 1st Tuesday and 2nd Sunday of the month and the "North Course" focusing on Important Cultural Heritage and Geodesy-related sites held on the 3rd Tuesday and 4th Sunday. The Office accommodated 422 people during the tours. In addition, we created the "Mitaka Campus Guided Tour Handbook" and distributed it to the participants.

(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. The Office also established the basic concept for the NAOJ Museum (tentative name) including both facility opening efforts and archive works.

On April 25, 2014, seven historically important buildings in NOAJ Mitaka Campus became Registered Important Cultural Properties: the Repsold Transit Instrument Housing, Housing of Gautier Meridian Circle, First Meridian Mark Building of Gautier Meridian Circle, Second Meridian Mark Building of Gautier Meridian Circle, Old Library and its Warehouse, Gatehouse, and the Front Gate. This brings the total number of Registered Important Cultural Properties to 10.

Guide Volunteers were registered from among the graduates of the "NAOJ Guide Volunteer Training Course" sponsored by NPO Mitaka Network University Promotion Organization (refereed to below as Mitaka Network University) in FY 2013. Mitaka Network University held the 2nd "NAOJ Guide Volunteer Training Course." Four people enrolled, graduated, and were registered as NAOJ Guide Volunteers.

7. Library Unit

In addition to the normal work of collecting and sorting scientific journals and books focusing on astronomy and offering them to students and researchers inside and outside of NAOJ, the Library continued to digitalize important documents and open the data to the public. Also the library collection was checked and the catalog of contents was maintained.

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. 249– No.260 (April 2014–March 2015)
- Annual Report of NAOJ Vol. 26, Fiscal 2012 (Japanese)
- Annual Report of NAOJ Vol. 16, Fiscal 2013 (English)
- Annual Report of NOAJ Vol. 15 Supplement Fiscal 2012 (English)

In FY 2014, in addition to normal operations, the Publications Office tried to strengthen its ability to reach international readers. First of all, it produced the "Annual Report of NAOJ Vol. 15 Supplement Fiscal 2012" completing the translation of the Japanese Version. Likewise, English Volume 16 was also a complete translation. NAOJ News also started producing feature articles and series related to internationalization. (The September edition's theme was international education and outreach. The 1st installment of the 'NAOJ Foreign Staff Interviews' series appeared in the December edition.) The Office investigated the possibility of producing an international edition of the Rika Nenpyo. In daily work, to support the outreach activities of various Projects through NAOJ News, special editions focusing on feature series were systematically produced. Extra copies were printed and given to the relevant Project's outreach personnel. The special edition themes were: "Museum" (April), "Library" (June), "TMT" (August), "Vapor Deposition Techniques" (January), and "ALMA" (February). From now, we plan to develop and share NAOJ News articles so that they can be used as a source of content for each Project's outreach activities. To this end, we promote close cooperation to produce comprehensive, fundamental articles. To facilitate this flow, we are reediting various levels of articles issued by the Publications Office to construct integrated NAOJ public relations, outreach, and education contents (and a basic platform for these). At the same time, we are in the process of producing a digital book based on the last 12 years of articles from the "Annual Report of NAOJ Research Highlights" as a prototype for promoting the digitalization and integration of published contents. In addition to periodicals, the Office produced the 2015 calendar "Historical Observational Instruments of NAOJ." This is the 10th calendar produced since 2005. 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 "Rika Nenpyo, Chronological Scientific Tables."

9. International Astronomical Union Office for Astronomy Outreach

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 by the Public Relations Center Outreach and Education Office. Cheung Sze-Leung started work as the Outreach Coordinator in April. Since then the OAO has been located in a new office within the Public Relations Center: the IAU Office for Astronomy Outreach. IAU OAO is responsible for IAU's international outreach activities, in cooperation with the Outreach and Education Office and others. In FY 2014 it primarily conducted the work for the International Year of Light 2015 "Cosmic Light" and the NameExoWorlds Contest.

"The Globe at Night – Sky Brightness Monitoring Network Users Workshop" was held January 7-9, 2015 at NAOJ Mitaka Campus. There were a total of 30 attendees from Hong Kong, the Republic of Korea, Taiwan, Nepal, Mongolia, the Republic of the Philippines, and Japan.

19. Division of Optical and Infrared Astronomy

1. Overview

The Division of Optical and Infrared Astronomy oversees the Okayama Astrophysical Observatory, the Subaru Telescope (C Project), the TMT-Japan Project Office, the Gravitational Waves Project Office (B Projects), the JASMINE Project Office, and Extrasolar Planet Detection Project Office (A Projects). The primary purpose of the division is facilitating and invigorating projects and individual research through personnel exchanges to place researchers in environments more suitable for their individual projects. While pursuing seminal observational and developmental research, the division launches new projects as necessary to further these goals. 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 the Subaru Telescope facility engaging in open use, and universities and research institutes in Japan, focusing on developmental research into new instruments and observational research. This concept was developed when the Subaru Telescope was constructed.

Almost all NAOJ members in optical- and infrared-related fields have positions in the division and engage in either the division or A, B, or C Projects. At times, they may also have affiliated positions in many other projects. The division and the various projects carry equal weight in organizational terms. The primary staff of the Division of Optical and Infrared Astronomy in FY 2014 consisted of one professor, one associate professor, three assistant professors, one specially-appointed assistant professor and two JSPS research fellows.

The division coordinates educational, research, and administrative activities for all research divisions and projects except for the Gravitational Wave, JASMINE, and TMT-Japan (TMT-J) projects. The TMT-J project has come to an expansive stage in which the telescope fabrication has been started. In tandem with this progress, personnel transfer occurs often within the Optical and Infrared Astronomy Division. The division plays an increasingly important role in coordinating between the Subaru Telescope and TMT-J projects. The division as a whole maintains and operates facilities to support research; e.g., a mailing list server for the Mitaka offices of the Subaru Telescope, TMT-J, Extrasolar Planet Detection, and Gravitational Wave Project Offices; and a web server for members of the Mitaka offices of the Subaru Telescope, TMT-J, and Extrasolar Planet Detection Project Offices, as well as graduate students in the division.

The remainder of this report will focus on the research projects conducted by full-time members 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; objects within the Solar System; structures around late-type stars; and the search for exoplanets. A rapid change in the shape of the plasma tail of Comet Lovejoy (C/2013 R1) was analyzed. Observations of extended ionized objects in nearby galaxies and clusters of galaxies were performed, and the data is now being analyzed. The search for extrasolar planets continued using direct imaging methods.

Research in other areas is also in progress, including astronomical phenomena based on old ephemerides and other documents, and statistical research into automatic identification of AGN using public astronomical archive data and astronomical databases.

As part of the research using astronomical archive data, statistical research into stripped gas from galaxies in clusters was performed. Other research undertaken was on the host galaxies of AGN using SDSS imaging/spectroscopy data.

(2) International Cooperative Observational Research

The division also engages in international collaborative studies with overseas researchers. Research on star formation in the outer parts of nearby galaxies, and on low surface brightness dwarf galaxies were conducted with a US researcher. The site survey in western Tibet for constructing a telescope also continues in cooperation with the National Astronomical Observatory of China (NAOC).

3. Subaru Telescope-Related Observational Instrument Development

The division searched for planetary candidates using the HiCIAO infrared coronagraph, and implemented hardware and software improvements for direct imaging and observation of protoplanetary discs. The division analyzed the relation between the real seeing conditions and the environment in the Subaru Telescope's enclosure using a computational fluid dynamics' model provided by other institutions.

In relation to the data archive, the division joins the file-system-based technology WG convened by the Society of Scientific Systems to explore the possibilities for overcoming difficulties arising from storage expansion. For this purpose, guidelines for assessment and analysis of storage system capability were investigated and reported.

4. Operational Support for the 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, and management of open-use-related travel expenses, and promoting PR activities for the Subaru Telescope. The division also gives support to the management of data analysis systems in collaboration with the Astronomy Data Center. Moreover, the division also supports the Subaru Autumn Schools co-hosted with the Subaru Telescope and the Astronomy Data Center, and Subaru Telescope observation classes.

5. Research Environment Maintenance

The division manages the printers and rented multifunction photocopiers in the Mitaka Subaru Building, teleconferencing systems on the second and third floors, sub-networks, and data backup servers for the Subaru Telescope Mitaka office as part of its efforts to maintain the research environment. The division assisted in replacing a UPS battery, updating shared storage for the Subaru Telescope Mitaka office, and setting up computers for newcomers. The teleconferencing system and the web server were replaced. The contents of the division homepage were renewed. An office migration was performed to meet a request from the TMT-J office.

6. Planning of the Next-generation Large-Scale Project

The Division of Optical and Infrared Astronomy is engaged in planning large post-Subaru projects in optical and infrared astronomy such as TMT and the JASMINE series. A framework for collaboration between ISAS and NAOJ also needs to be established.

A study group on next-generation large disk and computing systems was launched with KEK, which will handle voluminous data in five to ten years in the future. Discussions revolve around archival hardware and software 10 years in the future to serve as an astronomical database for the next-generation observational instruments and TMT succeeding the Subaru Telescope.

7. PR, Outreach, and Discovery of New Astronomical Objects

The division cooperates with the Public Relations Center in supporting PR/outreach activities, such as publications and press conferences on Subaru Telescope research results and discoveries of new astronomical objects. An active participant in a special public event held at Mitaka (Mitaka Open House Day), the Division of Optical and Infrared Astronomy provided mini-lectures and exhibits and planned projects appealing to elementary and junior high school students such as magnet puzzles.

8. Educational Activities

The Division of Optical and Infrared Astronomy provides postgraduate education to 19 graduate students from the Graduate University of Advanced Studies, the University of Tokyo, the Tokyo University of Agriculture and Technology, Tokyo Institute of Technology, Nihon University, and International Christian University.

Division staff members made active contributions to seminars and self-directed studies. The division participated in the “Fureai (Friendly) Astronomy” project, dispatching lecturers to various elementary and junior high schools around the country to provide pupils with opportunities to become familiar with and appreciate astronomy.

20. Division of Radio Astronomy

The Division of Radio Astronomy oversees Nobeyama Radio Observatory, Mizusawa VLBI Observatory, RISE Lunar Exploration Project, and NAOJ Chile Observatory operating the Atacama Large Millimeter/submillimeter Array (ALMA) and 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 among themselves. 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/electronic devices, which cause 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 USA 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 optical pollution from artificial light sources is an obstacle in optical observation, artificial radio interference generated by the electrical/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 that unique capability, 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 2014, 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 necessitate an operator license because it is operated at low-levels and wide bandwidths. Additionally, there has been a rapid increase in demand for higher frequencies. For example, 76 and 79 GHz automotive radar 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. The radio astronomy observations have been given priority in a number of frequency bands within the range of 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. In terrestrial radio applications, 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; and 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 Observatory will cause deterioration in its observation results, or rather tend to make its observations impossible in the near future. Radio astronomy observations in the 60 GHz band are not common because of the high rate of absorption in the atmosphere. Albeit in fact, the 60 GHz system must be watched closely in its second harmonics in terms of adverse effects on CO observations in the 115 GHz band.

(3) International Activities

The ITU' Radio Regulations (RR), which allocates radio frequencies to wireless applications, are revised once every three to four years in the World Radiocommunication Conference (WRC). The most recent meeting was WRC-12, held in February 2012. The RR include frequency bands in which radio astronomy observation is prioritized. Preparatory conferences need to be held in Geneva annually in preparation for the upcoming WRC-15 to discuss necessary matters for the revision of the RR. 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. It has also contributed to opinion-forming through its regular attendance at the Asia/Pacific Region (APG) meetings in preparation for WRC-15, as a delegate representing Japan. In FY 2014, the subcommittee pursued the protection of radio astronomy frequency bands through participation in the ITU-R WP7D meetings held in Geneva in May and October and the ITU-R WP1A meeting held in Geneva in June. The subcommittee also has participated in the APG meetings held in Australia in June 2014 and in Thai in February 2015, in addition to other relevant meetings and conferences.

(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 in relation to societal and technological trends.

Several examples of the interference problems discussed in section (2) above are given below. One example is the advent of UWB wireless applications, used in positioning and tracking material flow in manufacturing and logistics industries. The applications in the UWB frequency band induce interference in VLBI geodetic observations to detect movement of the plates in plate tectonics. Although this band is not under RR protection, it is vital from the perspective of predicting earthquakes and is the subject of special consideration by the MIC. 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. A wider scale of distribution is predicted for 76 GHz and 79 GHz band automotive radars, which just emerged in the market. Of particular concern are the possible effects of interference from these radars on the 45-m Radio Telescope at the Nobeyama Radio Observatory, which engages in observations of spectral-lines of deuterated compounds and other molecules in interstellar matter. The observations with the 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.

The 23 GHz band is deployed for emergency wireless communications at times of natural disasters that lead to a breakdown of CATV networks. Ammonia molecular lines (RR-protected band) overlap with the 23 GHz band due to redshifts from the expansion of the Universe. An additional point for consideration is that the 1.6 GHz band may be of important use at times of natural disasters for satellite-based mobile communications rather than terrestrial wireless communications. The MIC performed as a mediator in discussions regarding interference issues caused by satellite phones using geostationary and non-geostationary (orbiting) satellites, and an agreement on usage conditions was concluded between the parties: service providers which create the interference and the Radio Astronomy Frequency Subcommittee representing the radio astronomical observatories, bearing in mind the importance of the emergency use of satellite phones at times of natural disasters.

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. The filter is currently under development in NHK Science & Technology Research Laboratories based on a series of discussions at NAOJ Mitaka Campus. PLC utilizing home power lines affects radio astronomy observations in low-frequency bands below 30 MHz. A petition against unduly hasty introduction of PLC was submitted to the MIC jointly with ASJ and the Society of Geomagnetism and Earth, Planetary and Space Sciences. A press conference was organized to raise broad public awareness of the relevant facts. 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 the trends 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.

Moreover, the subcommittee engages in making applications to the MIC, requesting frequency protection of 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.

21. 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, the Solar-C Project Office, and the Nobeyama Solar Radio Observatory, and conducts research on the Sun in close liaison with these respective projects. The operation of the Nobeyama Radioheliograph was transferred to the Solar-Terrestrial Environment Laboratory of Nagoya University, and the Nobeyama Solar Radio Observatory was closed at the end of fiscal year 2014 (March 2015). Shin Toriumi has been appointed as an NAOJ fellow and joined the division in April. The graduate students supervised by the staff of the above-mentioned projects also belong to the division. All the permanent staff of these projects are 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, 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 Radioheliograph at Nobeyama and the Solar Flare Telescope and other telescopes in the Mitaka campus. In addition, the division 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 Toriumi published three papers in refereed journals as lead author. They are (1) on the formation and flare activity of delta-type sunspots derived from a combination of data analysis and numerical simulation, (2) on the detection of horizontal flows on the surface of the Sun prior to the emergence of magnetic flux from below, and (3) a review article on the flux emergence phenomenon presented at the 7-th Hinode Symposium. He also has been promoting collaborative research with international partners.

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 organizer was M. Shimojo.

2. Educational Activities

The teaching staff of the division supervised three graduate students from the University of Tokyo and two from the Graduate University for Advanced Studies (SOKENDAI). Among them Anjali John Kaithakkal of SOKENDAI obtained a Ph.D. in September.

The division, in cooperation with Kyoto University and Nagoya University, supported the annual research-experience tour for undergraduate students; about ten students visited solar-related research organizations and experienced the latest research in the field.

3. International Cooperation

Y. Katsukawa succeeded Y. Suematsu as 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.

22. Division of Theoretical Astronomy

1. Overview

The Division of Theoretical Astronomy (DTA) aimed at achieving internationally outstanding research accomplishments both in quality and quantity for the following four goals which were set by the NAOJ Board, and engaged in research activities for FY 2014 accordingly:

- Advance world class cutting-edge theoretical research.
- Pursue theoretical astronomy research, particularly in areas that utilize NAOJ supercomputers or large-scale observational instruments to give further insight into their newest developments.
- 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 structure of the Universe in terms of formation and evolution processes; dynamics; and the physical state of matter. This research spans astronomy and astrophysics from the early Universe to galaxies, stars, planetary formation, activities of compact objects, and plasma phenomena. 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 an influential 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 observational facilities of 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. It also leads research activities in various related fields of astronomical science. The division started a new series of DTA symposia and organized two meetings in 2014 entitled "Formation and evolution of planets in star forming regions and in the environment of star clusters" and "Activity and magnetic properties of compact astronomical objects."

2. Current Members and Transfers

In FY 2014, the dedicated faculty of the Division of Theoretical Astronomy included two professors, two associate professors, and four assistant professors. Another 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, including two NAOJ postdoctoral fellows and one JSPS fellow; one EACOA fellow; and one administration associate who gave full support to all activities of the division. Among them Takaya Nozawa and Yasuhiro Hasegawa were appointed project assistant professor and EACOA fellow in April and September 2014, respectively. Takahiro Kudoh, an assistant professor, was promoted to associate professor and moved to Nagasaki University.

3. Research Results

The publication category IV research papers 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: 64
- Papers in English (conference proceedings, non-reviewed Papers, etc.): 38
- Reports in English (talks at international conferences): 70
- Reports in Japanese (talks at national meetings, etc.): 84

Some of the research results are presented as the research highlights listed at the beginning of this report. The following highlights include research in which the division members took leading roles:

- Discovery of Dramatic Optical Variability in a Possible Radio-Loud Narrow-Line Seyfert 1 Galaxy (Masaomi Tanaka, et al.)
- High-speed Fluid Dynamics in Magnetic Reconnection in a Low-β Plasma (Seiji Zenitani)
- Formation of Carbon Grains in Red-supergiant Winds of Very Massive Population III Stars (Takaya Nozawa, et al.)
- Origins of Large Amounts of Dust Grains and Unusual Extinction Curves in High-redshift Dusty Quasars (Takaya Nozawa, et al.)
- Opacity of fluffy dust aggregates (Akimasa Kataoka, et al.)
- The initial mass function of star clusters (Michiko Fujii)
- Polarization Structure of Magnetically Supported Molecular Filaments (Kohji Tomisaka)
- Neutrino Oscillation and Nucleosynthesis in Core-Collapse

Supernova Explosion (Toshitaka Kajino, et al.)
- Cosmological solutions to the Big-Bang Lithium problem: Big-bang nucleosynthesis with photon cooling X-particle decay and a primordial magnetic field (Toshitaka Kajino, et al.)
- Supernova Nucleosynthesis of ^{26}Al and Nuclear Structure of ^{26}Si (Toshitaka Kajino, et al.)
- The in-medium effects on the neutrino reaction in dense matter (Toshitaka Kajino, et al.)
- Induced Amino Acid Chirality From Strong Magnetic Fields in Interstellar Environments (Toshitaka Kajino, et al.)
- Asymmetric Neutrino Emission from Magnetized Proto-Neutron Stars: Effects of Absorption Cross-Sections in Iso-entropical Conditions (Toshitaka Kajino, et al.)
- Revised Big-Bang Nucleosynthesis with Exotic Dark Matter Particles: Detailed Quantum Mechanical Calculation (Toshitaka Kajino, et al.)
- Supernova Relic Neutrinos and the Supernova Rate Problem: Analysis of Uncertainties and the role of Failed Supernovae (Toshitaka Kajino, et al.)
- Neutrino Magnetic Moment, CP Violation and Flavor Oscillations in Matter (Toshitaka Kajino, et al.)
- Sterile neutrino oscillations in core-collapse supernova simulations (Toshitaka Kajino, et al.)

The following research results were released on Division's website (http://th.nao.ac.jp/) as research highlights:

- Stochastic electron acceleration during spontaneous turbulent reconnection in a strong shock wave (Tsunehiko Kato, et al.)
- Shocking structure in a supersonic reconnection jet (Seiji Zenitani)
- The initial mass function of star clusters (Michiko Fujii)
- The world's most extensive simulation of the Milky Way galaxy (Michiko Fujii)
- Revealing Large Amounts of Dust and Unusual Extinction Curves in the Early Universe (Takaya Nozawa, et al.)
- Discovery of a Blue Star at the Location of Supernova 2011dh (Takaya Nozawa, et al.)
- Formation of Carbon Grains in Very Massive Primordial Stars (Takaya Nozawa, et al.)
- Two- and Three-dimensional Neutrino-hydrodynamics simulations of Core-collapse Supernovae (Tomoya Takiwaki, et al.)
- Opacity of fluffy dust aggregates (Akimasa Kataoka, et al.)
- Cosmological solutions to the Lithium problem: Big-bang nucleosynthesis with photon cooling, X-particle decay and a primordial magnetic field (Toshitaka Kajino, et al.)
- A New Production Mechanism for Ultra-High-Eneregy Cosmic Ray (UHECR) Neutrinos (Toshitaka Kajino, et al.)

4. Educational Activities

The lecture subjects are listed below to supplement Section III on activities for research and educational adjunct lecturership at the universities and graduate schools:

Toshitaka Kajino: Special lectures on cosmology and nuclear astrophysics at the Graduate School of Hokkaido University; 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.

Takahiro Kudoh: Space and Earth science at the University of Electro-Communications.

Eiichiro Kokubo: Planetary science at the University of Tokyo; special lectures on planetary formation theory at the Graduate School of Kyoto University; introduction of planetary formation at Ryukyu University.

Fumitaka Nakamura: Astronomy investigation at the Graduate University for Advanced Studies.

Takashi Hamana: Geology at the Tokyo University of Agriculture and Technology.

Haruo Yoshida: Gravitational mechanics at the Graduate University for Advanced Studies.

Toshitaka Kajino delivered a Super Lecture entitled "Birth of the Universe, Life and Intelligence and the Future" in SSH-Korea Joint Symposium held at Kashiwazaki Senior High School in Niigata. Kohji Tomisaka and Takahiro Kudoh led a group of undergraduate students in visiting actual research sites during the Summer Student event of the Graduate University of Advanced Studies.

5. 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:

Michiko Fujii: "Spiral galaxies made by gravitational force" at Science Live Show Universe.

Takashi Hamana: "Dark matter and dark energy in Space" at Asahi Culture Center Yokohama.

Toshitaka Kajino: "Origin of the elements in the cosmos; The birth of the Universe and its mysterious connection with life" at the meeting of 1953 class union of the University of Tokyo.

Eiichiro Kokubo: "New travelogue to the Solar System" at Ikebukuro Community College, "The Earth in the Universe" at Mitaka City College, "Hometown of planets" and "New world – exo-planets discovered" at Asahi Culture Center Kyoto and Shinjyuku, "Origin of the Solar System" at Gunma Prefecture Observatory, "Origin of the Earth and Moon" at Sakae China-Japan Center.

Ken Ohsuga: "Computational approach to black holes" at Asahi Culture Center, Yokohama.

Masaomi Tanaka: "Supernova explosions and the origin of elements" at Asahi Culture Center Shinjyuku.

6. International Collaborations

Toshitaka Kajino performed duties of the following posts: editorial board member for the UK Institute of Physics "Journal of Physics G"; review panel member of the European Science Foundation Euro GENESIS Project; 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). Eiichiro Kokubo served as a member of the Organizing Committee of the IAU's Extrasolar Planets Commission.

The Division of Theoretical Astronomy played leading roles in organizing the following international conferences:

- The First NAOJ-ECT* International Workshop on "Nuclear Physics and Astrophysics of Neutron-Star Mergers and Supernovae and the Origin of R-Process Elements," Trento in Italy, Sept. 8 - 12 in 2014. This international workshop was held based upon the agreement made between the NAOJ and ECT*, both signing the Memorandum of Understanding mediated through the Division of Theoretical Astronomy. This agreement encompasses the scientific advancement in border areas between astronomy and astro-, nuclear-, particle-, and condensed-matter physics by promoting an exchange of scientists and postgraduate students for international conferences, joint research projects, and university education programs in mutual collaboration.
- NAOJ-RIKEN Joint HPCI Workshop on "Physics of Neutron Stars and Supernova Explosions," RIKEN Wako in Japan, Dec. 16 - 20 in 2014.
- NAOJ-Beihang University Joint International Workshop on Cosmology and Nuclear Astrophysics, Beijing in China, Jan. 20 - 23 in 2015.

7. Awards

Takeshi Inoue received a 2014 Research Encouragement Award of the Astronomical Society of Japan. Akimasa Kataoka was awarded the President's Prize and Nagakura Research Encouragement Prize of The Graduate University of Advanced Studies. Seiji Zenitani was elected an Excellent Reviewer of 2014 for the Journal of Earth, Planets and Science (EPS) of the Society of Geomagnetism and Earth Planetary and Space Sciences. A journal paper written by Toshio Suzuki and Toshitaka Kajino 2013, J. Phys. G40, 083101 was selected as a highlight of 2013.

8. 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, the NAOJ budget for guest visitors, and others. The main international visitors of FY 2014 to the division are listed below:

Akif B. Balantekin, (University of Wisconsin–Madison, US)
Myung-Ki Cheoun, (Soongsil University, South Korea)
Cemsinan Deliduman, (Mimar Sinan Fine Arts University, Turkey)
Yamac Deliduman, (Mimar Sinan Fine Arts University, Turkey)
Kyungsik Kim, (Korea Aerospace University, Republic of Korea)
Motohiko Kusakabe, (Korea Aerospace University, Republic of Korea)
Man Hoi Lee, (University of Hong Kong, China)
Grant J. Mathews, (University of Notre Dame, USA)
Steven Rieder, (University of Groningen, Netherland)
Chung-Yoel Ryu, (Hanyang University, South Korea)
Edwin L. Turner, (Princeton University, USA)
Toshiya Ueta, (University of Denver, USA)
Ghil-Seok Yang, (Hangyang University, Republic of Korea)

23. Office of International Relations

The Office of International Relations strives in promoting autonomous research activities by planning and implementing strategies for NAOJ's international research efforts characteristic to the institution as a whole. It also supports efforts to strengthen the foundation for expanded internationalization.

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 for international partnerships.

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. The office gathers and accumulates necessary and practical information for arranging agreements and contracts with overseas universities or research institutions, including precautions and problem solving, by means of conducting consultations or investigations on individual cases and provides such information as required. The Office of International Relations also offers advice and consultations, and responds to inquiries on a case-by-case basis. Other matters handled by the office include signing agreements and memoranda for international collaborations and addressing export security control issues in relation to overseas joint research projects.

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 August 17, 2014 at Daejeon, Korea. The four institutions forming EACOA are NAOC (China), KASI (Korea), ASIAA (Taiwan), and NAOJ (Japan). The office also issued a public call for the EACOA postdoctoral fellowship program for 2015. In addition, it presented NAOJ's projects and research results by displaying an exhibit at the IAU Asia-Pacific Regional Meeting held on August 18 – 22 at Deajeon, Korea. Furthermore, the office supported the activities of the IAU Office for Public Outreach. The Office of International Relations also cooperated with EACOA member organizations in supporting the activities of the IAU Office for Astronomy Development (OAD) in the East Asia region.

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 to organizations or individuals for contact as appropriate, coordinating between organizations and gathering relevant information.

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. This involved consultation on visa applications and other procedures as well as general issues in relation to their stays in Japan to help ensure a pleasant experience. The office started to run a new support service called "Support Desk" providing general information useful for everyday activities. Japanese language lessons for newly arrived non-Japanese speaking staff members and students were also conducted.

5. Assistance in International Partnerships Involving Japanese Research Organizations

The Office of International Relations helps 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. The collaboration with the Office of International Relations at NINS yielded a workshop for international joint research associates in which the office was involved from the planning stages to the preparation of a manual for hosting international researchers and in giving English-language master seminars to various NINS organizations.

III Organization

1. Organization

- Advisory Committee for Research and Management
- Director General
  - Vice-Director General (on General Affairs)
  - Vice-Director General (on Finance)
  - Director of Engineering
  - Director of Research Coordination
  - Projects
    - (C Projects)
      - Subaru Telescope
      - Okayama Astrophysical Observatory
      - Nobeyama Radio Observatory
      - Nobeyama Solar Radio Observatory
      - Mizusawa VLBI Observatory
      - Solar Observatory
      - NAOJ Chile Observatory
      - Center for Computational Astrophysics
      - Hinode Science Center
    - (B Projects)
      - Gravitational Wave Project Office
      - TMT Project Office
    - (A Projects)
      - JASMINE Project Office
      - Extrasolar Planet Detection Project Office
      - RISE Project
      - SOLAR-C Project Office
  - Centers
    - Astronomy Data Center
    - Advanced Technology Center
    - Public Relations Center
  - Divisions
    - Division of Optical and Infrared Astronomy
    - Division of Radio Astronomy
    - Division of Solar and Plasma Astrophysics
    - Division of Theoretical Astronomy
  - Research Enhancement Strategy Office
    - Research Evaluation Support Office
  - Office of International Relations
  - Human Resources Planning Office
  - Safety and Health Management Office
  - Engineering Promotion Office
  - Administration Department

2. Number of Staff Members

		(2015/3/31)
Regular Employees		
Director General		1
Research and Academic Staff		158
	Professor	29
	Executive Engineer	0
	Associate Professor	36
	Chief Research Engineer	11
	Assistant Professor	62
	Research Associate	0
	Research Engineer	20
Engineering Staff		37
Administrative Staff		55
Research Administrator Staff		8
Employees on Annual Salary System		63
Fixed-term Employees		
Full-time Contract Employees		79
Part-time Contract Employees		148

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

4. Research Departments

Projects

C Projects

Subaru Telescope

Director	Arimoto, Nobuo
Professor	Arimoto, Nobuo
Professor	Iye, Masanori
Professor	Mizumoto, Yoshihiko
Professor	Ohashi, Nagayoshi
Professor	Usuda, Tomonori
Associate Professor	Aoki, Wakou
Associate Professor	Hayashi, Saeko
Associate Professor	Ichikawa, Shin-ichi
Associate Professor	Iwata, Ikuru
Associate Professor	Kashikawa, Nobunari
Associate Professor	Kodama, Tadayuki
Associate Professor	Nomaru, Junichi
Associate Professor	Takato, Naruhisa
Associate Professor	Takeda, Yoichi
Associate Professor	Terada, Hiroshi
Chief Research Engineer	Yutani, Masami
Assistant Professor	Hayano, Yutaka
Assistant Professor	Imanishi, Masatoshi
Assistant Professor	Komiyama, Yutaka
Assistant Professor	Minowa, Yosuke
Assistant Professor	Okita, Hirofumi
Assistant Professor	Pyo, Tae-soo
Assistant Professor	Shirasaki, Yuji
Assistant Professor	Yagi, Masafumi
Research Engineer	Tazawa, Seiichi
Chief Engineer	Kurakami, Tomio
Chief Engineer	Namikawa, Kazuhito
Chief Engineer	Negishi, Satoru
Chief Engineer	Omata, Koji
Chief Engineer	Tamura, Tomonori
Engineer	Sato, Tatsuhiro
Specially Appointed Research Staff	Tadaki Kenichi
Postdoctoral Fellow	Yabe, Kiyoto
Research Expert	Yamanoi, Hitomi
Research Supporter	Schramm, Malte
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	Kobayashi, Hideki
Manager	Seto, Yoji
General Affairs Section	
Chief	Kobayashi, Hideki
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	Castro, Timothy
RCUH	Clergeon, Christophe
RCUH	Cook, David
RCUH	Currie, Thayne
RCUH	Doi, Yoshiyuki
RCUH	Doughty, Danielle
RCUH	Elms, Brian
RCUH	Endo, Banri
RCUH	Fabricius, Maximilian
RCUH	Ferre, Mateu Anna
RCUH	Ferreira, James
RCUH	Finet, Francois
RCUH	Formanek, Keiko
RCUH	Frayser, Suzanne
RCUH	Fujiwara, Hideaki
RCUH	Fujiyoshi, Takuya
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
RCUH	Kudo, Tomoyuki
RCUH	Kyono, Eiji
RCUH	Lemmen, Michael
RCUH	Leonard, Alex
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, Tetsuro
RCUH	Ono, Yoshito
RCUH	Otsuka, Masaaki
RCUH	Otsuki, Noriko
RCUH	Oya, Makoto
RCUH	Park, Hong Soo
RCUH	Pathak, Prashant
RCUH	Ramos, Lucio
RCUH	Roth, Noriko
RCUH	Saito, Yuriko
RCUH	Shimakawa, Rythm
RCUH	Shubert, Kiaina
RCUH	Singh, Garima
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
RCUH	Walawender, Joshua
RCUH	Weber, Mark
RCUH	Williams, Joshua
RCUH	Winegar, Tom
RCUH	Wung, Matthew
RCUH	Yamazaki, Kohei
RCUH	Yeh, Sherry (Chia-Chen)

Hyper Suprime-Cam

Director	Miyazaki, Satoshi
Associate Professor	Takata, Tadafumi
Assistant Professor	Furusawa, Hisanori
Assistant Professor	Komiyama, Yutaka
Assistant Professor	Nakaya, Hidehiko
Specially Appointed Assistant Professor	Tanaka, Masayuki
Chief Engineer	Kamata, Yukiko
Chief Engineer	Uraguchi, Fumihiro
Postdoctoral Fellow	Okura, Yuki
Research Expert	Kawanomoto, Satoshi
Research Expert	Koike, Michitaro
Research Expert	Mineo, Sogo
Research Expert	Yamada, Yoshihiko
Administrative Supporter	Uekiyo, Hatsue

Okayama Astrophysical Observatory

Director	Izumiura, Hideyuki
Associate Professor	Izumiura, Hideyuki
Associate Professor	Ukita, Nobuharu
Chief Research Engineer	Koyano, Hisashi
Assistant Professor	Yanagisawa, Kenshi
Specially Appointed Assistant Professor	Kambe, Eiji
Engineer	Tsutsui, Hironori
Postdoctoral Fellow	Fukui, Akihiko
Research Expert	Kuroda, Daisuke
Research Expert	Maehara, Hiroyuki
Research Supporter	Kamiya, Koki
Research Supporter	Shimizu, Yasuhiro
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	Iwashita, Hiroyuki
Chief Research Engineer	Kanzawa, Tomio
Assistant Professor	Ishizuki, Sumio
Assistant Professor	Oshima, Tai
Assistant Professor	Takano, Shuro
Assistant Professor	Umemoto, Tomofumi
Specially Appointed Assistant Professor	Minamidani, Tetsuhiro
Research Engineer	Mikoshiba, Hiroshi
Senior Engineer	Miyazawa, Kazuhiko
Chief Engineer	Handa, Kazuyuki
Chief Engineer	Miyazawa, Chieko
Engineer	Nishitani, Hiroyuki
Engineer	Wada, Takuya
Postdoctoral Fellow	Morokuma, Kana
Specially Appointed Research Staff	Nishimura, Atsushi
Specially Appointed Research Staff	Takekoshi, Tatsuya
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	Naito, Akihiko
Consultant	Saito, Yasufumi
Research Assistant Staff	Mizuno, Izumi

Administration Office

Deputy Manager	Otsuka, Tomoyoshi

General Affairs Section

Chief	Otsuka, Tomoyoshi
Administrative Supporter	Kikuchi, Kikue
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	Sasaki, Hiroaki
Chief	Shimizu, Hidetoshi
Staff	Kobayashi, Kazuhito
Administrative Supporter	Kodaira, Toshiko
Administrative Supporter	Takasawa, Mitsue
Administrative Supporter	Tokui, Chisato

Nobeyama Solar Radio Observatory

Director	Hanaoka, Yoichiro
Professor	Shibasaki, Kiyoto
Chief Research Engineer	Kawashima, Susumu
Assistant Professor	Shimojo, Masumi
Senior Engineer	Shinohara, Noriyuki
Postdoctoral Fellow	Iwai, Kazumasa
Administrative Supporter	Shinkai, Hisako
Administrative Supporter	Takemura, Miwako

Mizusawa VLBI Observatory

Acting Director	Takami, Hideki
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	Hagiwara, Yoshiaki
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	Fukushima, Hideo
Research Engineer	Ishikawa, Toshiaki
Research Engineer	Oshima, Norio
Research Engineer	Suzuki, Shunsaku
Engineer	Shizugami, Makoto
Engineer	Ueno, Yuji
Postdoctoral Fellow	Matsumoto, Naoko
Postdoctoral Fellow	Sawada, Satoko
Specially Appointed Research Staff	Kim, Jeoung Sook
Specially Appointed Research Staff	Nagayama, Takumi
Specially Appointed Research Staff	Tazaki, Fumie
Specially Appointed Research Staff	Wu, Yuanwei
Specially Appointed Senior Specialist	Miura, Mitsuo
Research Expert	Hanayama, Hidekazu
Research Expert	Kanaguchi, Masahiro
Research Expert	Oyama, Tomoaki
Technical Expert	Funayama, Hiroshi
Technical Expert	Kuji, Seisuke
Technical Expert	Miyaji, Takeshi
Administrative Expert	Oikawa, Shinichi
Research Supporter	Asakura, Yu
Research Supporter	Isono, Yoko
Research Supporter	Matsukawa, Yuki
Research Supporter	Yamashita, Kazuyoshi
Research Supporter	Yamauchi, Aya
Administrative Supporter	Komori, Akiyo
Administrative Supporter	Yoshihara, Keiko

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	Koseki, Tatsuya
Administrative Supporter	Sasaki, Mie
Administrative Supporter	Takahashi, Yumi

Ishigakijima Astronomical Observatory

Head	Miyaji, Takeshi
Associate Professor	Agata, Hidehiko

Research Engineer	Fukushima, Hideo
Research Engineer	Oshima, Norio
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
Professor	Shibasaki, Kiyoto
Associate Professor	Hanaoka, Yoichiro
Associate Professor	Suematsu, Yoshinori
Chief Engineer	Shinoda, Kazuya
Postdoctoral Fellow	Otsuji, Kenichi
Research Expert	Kitagawa, Naomasa
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	Asayama, Shinichiro
Associate Professor	Iono, Daisuke
Associate Professor	Kiuchi, Hitoshi
Associate Professor	Kosugi, George
Associate Professor	Mizuno, Norikazu
Associate Professor	Ohishi, Masatoshi
Associate Professor	Okuda, Takeshi
Specially Appointed Associate Professor	Kawamura, Akiko
Specially Appointed Associate Professor	Komugi, Shinya
Specially Appointed Associate Professor	Nagai, Hiroshi
Specially Appointed Associate Professor	Shinnaga, Hiroko
Chief Research Engineer	Kawashima, Susumu
Chief Research Engineer	Kikuchi, Kenichi
Chief Research Engineer	Watanabe, Manabu
Assistant Professor	Espada Fernandez, Daniel
Assistant Professor	Ezawa, Hajime
Assistant Professor	Hiramatsu, Masaaki
Assistant Professor	Hirota, Akihiko
Assistant Professor	Kamazaki, Takeshi
Assistant Professor	Matsuda, Yuichi
Assistant Professor	Nakanishi, Kouichiro
Assistant Professor	Oshima, Tai
Assistant Professor	Sawada, Tsuyoshi
Assistant Professor	Shimojo, Masumi
Assistant Professor	Sugimoto, Masahiro
Assistant Professor	Takahashi, Satoko
Assistant Professor	Umemoto, Tomofumi
Specially Appointed Assistant Professor	Akiyama, Eiji
Specially Appointed Assistant Professor	Chibueze, James Okwe
Specially Appointed Assistant Professor	Erik, Muller
Specially Appointed Assistant Professor	Hatsukade, Bunyo
Specially Appointed Assistant Professor	Saigo, Kazuya
Research Engineer	Ashitagawa, Kyoko
Research Engineer	Nakazato, Takeshi
Senior Engineer	Kobiki, Toshihiko
Senior Engineer	Nakamura, Kyoko
Chief Engineer	Kato, Yoshihiro
Specially Appointed Research Staff	Ao, Yiping
Specially Appointed Research Staff	Herrera Contreras, Cinthya Natalia
Specially Appointed Research Staff	Kurono, Yasutaka
Specially Appointed Research Staff	Miura, Rie
Specially Appointed Research Staff	Sanhueza Nunez, Patricio Andres
Specially Appointed Research Staff	Ueda, Junko
Specially Appointed Senior Specialist	Fukui, Hideharu
Specially Appointed Senior Specialist	Kawasaki, Wataru
Specially Appointed Senior Specialist	Kobayashi, Tsuyoshi
Specially Appointed Senior Specialist	Kuniyoshi, Masaya
Specially Appointed Senior Specialist	Matsui, Takayuki
Specially Appointed Senior Specialist	Morita, Eisuke
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
Research Expert	Fujimoto, Yasuhiro

Research Expert	Inoe, Norio
Research Expert	Ishimaru, Fumiaki
Research Expert	Kawakami, Shinnosuke
Research Expert	Nakamura, Koji
Research Expert	Noma, Naoko
Research Expert	Nukatani, Sorahiko
Research Expert	Sakuma, Naoko
Research Expert	Shibuya, Masaru
Research Expert	Tomimuro, Hisashi
Research Expert	Yasui, Takashi
Administrative Expert	Kamada, Masako
Research Supporter	Kusuno, Kozue
Research Supporter	Uchida, Ayako
Research Supporter	Yamazaki, Toshitaka
Administrative Supporter	Kono, Izumi
Administrative Supporter	Matsunaga, Choko
Administrative Supporter	Saito, Naoko
Administrative Supporter	Sakurai, Junko
Administrative Supporter	Uchida, Rena
Research Assistant Staff	Onishi, Kyoko
AUI Staff	Gabriela Krapivka Flores
AUI Staff	Joaquin Collao
AUI Staff	Lorena Toro
AUI Staff	Maria Angelica Ramos
AUI Staff	Nicolas Silva
AUI Staff	Oscar Mendez
AUI Staff	Veronica Gareca

Administration Department

Manager	Yamaguchi, Takahiro

General Affairs Section

Chief	Tsukano, Satomi

Accounting Section

Chief	Yamaguchi, Takahiro
Staff	Hiramatsu, Naoya

Center for Computational Astrophysics

Director	Kokubo, Eiichiro
Professor	Kokubo, Eiichiro
Professor	Tomisaka, Kohji
Assistant Professor	Inoe, Tsuyoshi
Assistant Professor	Ito, Takashi
Assistant Professor	Kudo, Takahiro
Assistant Professor	Ohsuga, Ken
Assistant Professor	Tanaka, Masaomi
Specially Appointed Assistant Professor	Takahashi, Hiroyuki
Specially Appointed Assistant Professor	Takiwaki, Tomoya
Specially Appointed Research Staff	Furusawa, Shun
Specially Appointed Research Staff	Kawashima, Tomohisa
Postdoctoral Fellow	Ishitsu, Naoki
Research Expert	Kato, Tsunehiko
Research Expert	Nakayama, Hirotaka
Research Expert	Narazaki, Yayoi
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
Professor	Shibasaki, Kiyoto
Specially Appointed Professor	Kuhn, Jeffrey Richard
Specially Appointed Professor	Uitenbroek, Han
Associate Professor	Hara, Hirohisa
Associate Professor	Sekii, Takashi
Associate Professor	Suematsu, Yoshinori
Assistant Professor	Ishikawa, Ryoko
Assistant Professor	Kano, Ryohei
Assistant Professor	Katsukawa, Yukio
Assistant Professor	Kubo, Masahito
Assistant Professor	Shimojo, Masumi
Research Engineer	Bando, Takamasa
Specially Appointed Research Staff	Antolin, Patrick
Technical Expert	Inoe, Naoko
Research Supporter	Nakada, Yuichiro

B Projects

Gravitational Wave Project Office

Director	Flaminio, Raffaele
Specially Appointed Professor	Flaminio, Raffaele
Associate Professor	Aso, Yoichi
Affiliated Associate Professor	Ando, Masaki
Specially Appointed Associate Professor	Barsuglia, Matteo
Assistant Professor	Akutsu, Tomotada
Assistant Professor	Takahashi, Ryutaro
Assistant Professor	Tatsumi, Daisuke
Assistant Professor	Ueda, Akitoshi
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	Nakamura, Koji

Administrative Supporter	Kondo, Mihoko
Administrative Supporter	Yoshizumi, Mizuho

Secondment (to The University of Tokyo)

Assistant Professor	Oishi, Naoko

TMT Project Office

Director	Usuda, Tomonori
Professor	Iye, Masanori
Professor	Takami, Hideki
Professor	Usuda, Tomonori
Professor	Yamashita, Takuya
Associate Professor	Aoki, Wakou
Associate Professor	Kashikawa, Nobunari
Associate Professor	Kodama, Tadayuki
Associate Professor	Kosugi, George
Associate Professor	Miyazaki, Satoshi
Associate Professor	Takato, Naruhisa
Associate Professor	Terada, Hiroshi
Specially Appointed Associate Professor	Packham, Christopher Charles
Chief Research Engineer	Miyashita, Takaaki
Assistant Professor	Hayano, Yutaka
Assistant Professor	Imanishi, Masatoshi
Assistant Professor	Sugimoto, Masahiro
Assistant Professor	Suzuki, Ryuji
Assistant Professor	Yagi, Masafumi
Postdoctoral Fellow	Hashimoto, Tetsuya
Postdoctoral Fellow	Wanajo, Shinya
Specially Appointed Research Staff	Harakawa, Hiroki
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	Rusu, Cristian Eduard
Public Outreach Official	Tajima, Toshiyuki
Administrative Supporter	Haranaka, Miyuki
Administrative Supporter	Yamaguchi, Chiyu

A Projects

JASMINE Project Office

Director	Gouda, Naoteru
Professor	Gouda, Naoteru
Professor	Kobayashi, Yukiyasu
Associate Professor	Hanada, Hideo
Associate Professor	Takato, Naruhisa
Assistant Professor	Araki, Hiroshi
Assistant Professor	Noda, Hirotomo
Assistant Professor	Tsujimoto, Takuji
Assistant Professor	Yano, Taihei
Chief Research Engineer	Tsuruta, Seiitsu
Research Engineer	Asari, Kazuyoshi
Specially Appointed Research Staff	Shirahata, Mai
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
Specially Appointed Professor	Ojha, Devendra Kumar
Associate Professor	Izumiura, Hideyuki
Assistant Professor	Kotani, Takayuki
Assistant Professor	Morino, Junichi
Assistant Professor	Nakajima, Tadashi
Assistant Professor	Nishikawa, Jun
Assistant Professor	Suto, Hiroshi
Specially Appointed Assistant Professor	Narita, Norio
Specially Appointed Research Staff	Kandori, Ryo
Specially Appointed Research Staff	Omiya, Masashi
Research Expert	Kusakabe, Nobuhiko
Research Supporter	Kurokawa, Takashi
Research Assistant Staff	Oya, Masato

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
Postdoctoral Fellow	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

Associate Professor	Hara, Hirohisa
Associate Professor	Suematsu, Yoshinori
Assistant Professor	Ishikawa, Ryoko
Assistant Professor	Kano, Ryohei
Assistant Professor	Katsukawa, Yukio
Assistant Professor	Kubo, Masahito
Research Engineer	Bando, Takamasa
Senior Engineer	Kobiki, Toshihiko
Chief Engineer	Shinoda, Kazuya
Specially Appointed Research Staff	Narukage, Noriyuki
Technical Expert	Inoe, Naoko
Administrative Supporter	Fujiyoshi, Marie

Centers

Astronomy Data Center

Director	Ohishi, Masatoshi
Professor	Kokubo, Eiichiro
Professor	Mizumoto, Yoshihiko
Associate Professor	Ichikawa, Shin-ichi
Associate Professor	Kosugi, George
Associate Professor	Nomaru, Junichi
Associate Professor	Ohishi, Masatoshi
Associate Professor	Shibata, Katsunori
Associate Professor	Takata, Tadafumi
Assistant Professor	Furusawa, Hisanori
Assistant Professor	Ito, Takashi
Assistant Professor	Kano, Ryohei
Assistant Professor	Oe, Masafumi
Assistant Professor	Shimojo, Masumi
Assistant Professor	Shirasaki, Yuji
Assistant Professor	Takano, Shuro
Research Engineer	Inoe, Goki
Engineer	Fukui, Asami
Specially Appointed Research Staff	Higuchi, Yuichi
Specially Appointed Research Staff	Kawaguchi, Toshihiro
Specially Appointed Research Staff	Yoshida, Tessei
Specially Appointed Research Staff	Zapart, Christopher Andrew
Research Expert	Abe, Miki
Research Expert	Asano, Eiji
Research Expert	Furusawa, Junko
Research Expert	Isogai, Mizuki
Research Expert	Nakajima, Kimihiko
Research Expert	Nakane, Makiko
Research Expert	Tanaka, Nobuhiro
Research Supporter	Fujikawa, Makiko
Research Supporter	Noda, Sachiyo
Administrative Supporter	Aida, Kanako
Administrative Supporter	Ishii, Yuko
Research Assistant Staff	Suzuki, Taiki

JVO Project

Head	Mizumoto, Yoshihiko
Associate Professor	Ohishi, Masatoshi
Assistant Professor	Shirasaki, Yuji

Advanced Technology Center

Director	Noguchi, Takashi
Professor	Noguchi, Takashi
Professor	Takami, Hideki
Associate Professor	Hara, Hirohisa
Associate Professor	Iwata, Ikuru
Associate Professor	Matsuo, Hiroshi
Associate Professor	Miyazaki, Satoshi
Associate Professor	Sekimoto, Yutaro
Chief Research Engineer	Okada, Norio
Assistant Professor	Akutsu, Tomotada
Assistant Professor	Kano, Ryohei
Assistant Professor	Kojima, Takafumi
Assistant Professor	Nakaya, Hidehiko
Assistant Professor	Suzuki, Ryuji
Specially Appointed Assistant Professor	Gonzalez Garcia, Alvaro
Research Engineer	Fujii, Yasunori
Research Engineer	Fukushima, Mitsuhiro
Research Engineer	Iizuka, Yoshizo
Research Engineer	Noguchi, Motokazu
Research Engineer	Sato, Naohisa
Senior Engineer	Kubo, Koichi
Senior Engineer	Takahashi, Toshikazu
Chief Engineer	Fukuda, Takeo
Chief Engineer	Ikenoue, Bungo
Chief Engineer	Inata, Motoko
Chief Engineer	Ito, Tetsuya
Chief Engineer	Iwashita, Hikaru
Chief Engineer	Kamata, Yukiko
Chief Engineer	Kaneko, Keiko
Chief Engineer	Miyazawa, Chieko
Chief Engineer	Obuchi, Yoshiyuki
Chief Engineer	Tamura, Tomonori
Chief Engineer	Uraguchi, Fumihiro
Chief Engineer	Waseda, Koichi
Postdoctoral Fellow	Karatsu, Kenichi
Engineer	Mitsui, Kenji
Engineer	Tsuzuki, Toshihiro
Specially Appointed Research Staff	Dominjon, Agnes Micheline
Specially Appointed Research Staff	Narukage, Noriyuki
Research Expert	Furutani, Akio
Research Expert	Iwakuni, Mikio
Research Expert	Kamada, Chiyoshi
Research Expert	Karatsu, Miki
Research Expert	Konuma, Mika
Research Expert	Matthias, Kroug
Research Expert	Saito, Sakae
Research Expert	Soga, Tomio

Research Expert	Takahashi, Yasuo
Research Expert	Uemizu, Kazunori
Technical Supporter	Hayashi, Ritsuko
Technical Supporter	Kano, Mitchell Senei
Technical Expert	Kumagai, Kazuyoshi
Technical Expert	Nishino, Tetsuo
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
Assistant Professor	Hiramatsu, Masaaki
Assistant Professor	Ikuta, Chisato
Assistant Professor	Soma, Mitsuru
Research Engineer	Fukushima, Hideo
Research Engineer	Katayama, Masato
Research Engineer	Oshima, Norio
Research Engineer	Sasaki, Goro
Chief Senior Engineer	Matsuda, Kou
Engineer	Nagayama, Syogo
Chief	Hori, Mayumi
Specially Appointed Senior Specialist	Cheung, Sze-Leung
Specially Appointed Senior Specialist	Lundock, Ramsey Guy
Research Expert	Komiyama, Hiroko
Research Expert	Ono, Tomoko
Research Expert	Takata, Hiroyuki
Research Expert	Usuda-Sato, Kumiko
Research Supporter	Kume, Kaori
Public Outreach Official	Baba, Yukie
Public Outreach Official	Endoh, Isao
Public Outreach Official	Fujita, Tokiko
Public Outreach Official	Futami, Hiroshi
Public Outreach Official	Hatano, Satomi
Public Outreach Official	Ishikawa, Naomi
Public Outreach Official	Ishizaki, Masaharu
Public Outreach Official	Itoh, Shoichi
Public Outreach Official	Iwashiro, Kuninori
Public Outreach Official	Koike, Akio
Public Outreach Official	Kubo, Maki
Public Outreach Official	Masuzawa, Hitoshi
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	Takeda, Takaaki
Public Outreach Official	Udzumaki, Tatsuya
Public Outreach Official	Watanabe, Yuriko
Administrative Supporter	Aoki, Makiko
Administrative Supporter	Noguchi, Sayumi

Public Relations Office

Head (2014 Dec.1-)	Hiramatsu, Masaaki
Head (-2014 Nov.30)	Ikuta, Chisato
Engineer	Nagayama, Syogo
Specially Appointed Senior Specialist	Lundock, Ramsey Guy
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
Public Outreach Official	Fujita, Tokiko
Public Outreach Official	Hatano, Satomi
Public Outreach Official	Ishikawa, Naomi
Public Outreach Official	Ishizaki, Masaharu
Public Outreach Official	Itoh, Shoichi
Public Outreach Official	Masuzawa, Hitoshi
Public Outreach Official	Naito, Seiichiro
Public Outreach Official	Ohgoe, Osamu
Public Outreach Official	Shibata, Yukiko
Public Outreach Official	Udzumaki, Tatsuya

Museum Deliberation Office

Head	Oshima, Norio
Associate Professor	Agata, Hidehiko
Research Engineer	Sasaki, Goro
Chief Senior Engineer	Matsuda, Kou
Research Expert	Usuda-Sato, Kumiko
Public Outreach Official	Baba, Yukie
Public Outreach Official	Endoh, 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
Public Outreach Official	Watanabe, Yuriko

Ephemeris Computation Office

Head	Katayama, Masato
Chief Senior Engineer	Matsuda, Kou
Public Outreach Official	Endoh, Isao

Library

Chief	Hori, Mayumi
Public Outreach Official	Kubo, Maki
Public Outreach Official	Oguri, Junko

Publications Office

Head	Fukushima, Toshio
Vice-Head	Fukushima, Hideo
Research Expert	Takata, Hiroyuki
Public Outreach Official	Iwashiro, Kuninori
Public Outreach Official	Kubo, Maki

Office for Astronomy Outreach of the IAU

Head	Agata, Hidehiko
Specially Appointed Senior Specialist	Cheung, Sze-Leung
Public Outreach Official	Shibata, Yukiko

General Affairs Office

Head	Matsuda, Kou
Administrative Supporter	Aoki, Makiko
Administrative Supporter	Noguchi, Sayumi

Divisions

Division of Optical and Infrared Astronomy

Director	Mizumoto, Yoshihiko
Professor	Arimoto, Nobuo
Professor	Gouda, Naoteru
Professor	Iye, Masanori
Professor	Kobayashi, Yukiyasu
Professor	Mizumoto, Yoshihiko
Professor	Ohashi, Nagayoshi
Professor	Sekiguchi, Kazuhiro
Professor	Usuda, Tomonori
Professor	Yamashita, Takuya
Associate Professor	Aoki, Wakou
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	Nomaru, Junichi
Associate Professor	Sasaki, Toshiyuki
Associate Professor	Takato, Naruhisa
Associate Professor	Takeda, Yoichi
Associate Professor	Terada, Hiroshi
Associate Professor	Ukita, Nobuharu
Chief Research Engineer	Koyano, Hisashi
Chief Research Engineer	Miyashita, Takaaki
Chief Research Engineer	Yutani, Masami
Assistant Professor	Akutsu, Tomotada
Assistant Professor	Hayano, Yutaka
Assistant Professor	Imanishi, Masatoshi
Assistant Professor	Komiyama, Yutaka
Assistant Professor	Kotani, Takayuki
Assistant Professor	Minowa, Yosuke
Assistant Professor	Morino, Junichi
Assistant Professor	Nakajima, Tadashi
Assistant Professor	Nishikawa, Jun
Assistant Professor	Okita, Hirofumi
Assistant Professor	Pyo, Tae-soo
Assistant Professor	Soma, Mitsuru
Assistant Professor	Suto, Hiroshi
Assistant Professor	Takahashi, Ryutaro
Assistant Professor	Tatsumi, Daisuke
Assistant Professor	Tomono, Daigo
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	Ishizaki, Hideharu
Research Engineer	Tazawa, Seiichi
Research Engineer	Torii, Yasuo
Chief Engineer	Kurakami, Tomio
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 Staff	Toshikawa, Jun

Secondment (to The University of Tokyo)

Assistant Professor	Ohishi, Naoko

Division of Radio Astronomy

Director	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	Asayama, Shinichiro
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	Iwashita, Hiroyuki
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	Espada Fernandez, Daniel
Assistant Professor	Ezawa, Hajime

Assistant Professor	Hagiwara, Yoshiaki
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	Miyoshi, Makoto
Assistant Professor	Nakanishi, Kouichiro
Assistant Professor	Noda, Hirotomo
Assistant Professor	Oshima, Tai
Assistant Professor	Sawada, Tsuyoshi
Assistant Professor	Sugimoto, Masahiro
Assistant Professor	Sunada, Kazuyoshi
Assistant Professor	Takahashi, Satoko
Assistant Professor	Takano, Shuro
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, Shunsaku
Senior Engineer	Kobiki, Toshihiko
Senior Engineer	Miyazawa, Kazuhiko
Senior Engineer	Nakamura, Kyoko
Chief Engineer	Handa, Kazuyuki
Chief Engineer	Kato, Yoshihiro
Chief Engineer	Miyazawa, Chieko
Engineer	Nishitani, Hiroyuki
Engineer	Shizugami, Makoto
Engineer	Ueno, Yuji
Engineer	Wada, Takuya
Research Expert	Tatsuzawa, Kaichi
Research Supporter	Okayasu, Rikako

Division of Solar and Plasma Astrophysics

Director	Sakurai, Takashi
Professor	Sakurai, Takashi
Professor	Shibasaki, Kiyoto
Professor	Watanabe, Tetsuya
Associate Professor	Hanaoka, Yoichiro
Associate Professor	Hara, Hirohisa
Associate Professor	Sekii, Takashi
Associate Professor	Suematsu, Yoshinori
Assistant Professor	Ishikawa, Ryoko
Assistant Professor	Kano, Ryohei
Assistant Professor	Katsukawa, Yukio
Assistant Professor	Kubo, Masahito
Assistant Professor	Shimojo, Masumi
Specially Appointed Assistant Professor	Toriumi, Shin
Research Engineer	Bando, Takamasa
Senior Engineer	Shinohara, Noriyuki
Chief Engineer	Shinoda, Kazuya

Division of Theoretical Astronomy

Director	Tomisaka, Kohji
Professor	Kokubo, Eiichiro
Professor	Tomisaka, Kohji
Professor	Yoshida, Haruo
Specially Appointed Professor	Turner, Edwin Lewis
Associate Professor	Kajino, Toshitaka
Associate Professor	Nakamura, Fumitaka
Assistant Professor	Hamana, Takashi
Assistant Professor	Inoe, Tsuyoshi
Assistant Professor	Kudo, Takahiro
Assistant Professor	Tanaka, Masaomi
Specially Appointed Assistant Professor	Fujii, Michiko
Specially Appointed Assistant Professor	Fujimoto, Keizo
Specially Appointed Assistant Professor	Nozawa, Takaya
Specially Appointed Assistant Professor	Sotani, Hajime
Specially Appointed Assistant Professor	Zenitani, Seiji
Administrative Supporter	Izumi, Shioko
Administrative Supporter	Kano, Kaori
Research Assistant Staff	Kataoka, Akimasa

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	Suematsu, Sayaka
Specially Appointed Senior Specialist	Yamamiya, Osamu

Research Evaluation Support Office

Director	Watanabe, Junichi
Specially Appointed Senior Specialist	Hori, Kuniko

Office of International Relations

Director	Sekiguchi, Kazuhiro
Professor	Sekiguchi, Kazuhiro
Research Expert	Komiyama, Hiroko
Research Expert	Yoshida, Fumi

Administration Office

Deputy Manager/Senior Specialist	Onishi, Tomoyuki
International Academic Affairs Section	
Chief	Kikkawa, Hiroko
Administrative Supporter	Ito, Yoshihisa
Administrative Supporter	Momma, Yoko

Human Resources Planning Office

Director	Yamamiya, Osamu
Specially Appointed Senior Specialist	Suematsu, Sayaka

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
Information Technology Specialist	
Specialist	Yoshikawa, Ikuko
Personnel Accounting Specialist	
Specialist	Kikuchi, Jinichi
General Affairs Section	
Chief	Yoshikawa, Ikuko
Staff	Takada, Miyuki
Staff	Yamafuji, Yasuto
Staff	Yoshimura, Tetsuya
Vehicle Driver	Amemiya, Hidemi
Administrative Expert	Murakami, Sachiko
Administrative Expert	Noguchi, Koki
Administrative Supporter	Kobayashi, Kayo
Administrative Supporter	Odate, Noriko
Administrative Supporter	Seki, Kumi
Personnel Section	
Chief	Yamanochi, Mika
Staff	Isozaki, Yuka
Staff	Takai, Tetsuya
Payroll Section	
Chief	Kikuchi, Jinichi
Staff	Furukawa, Shinichiro
Specially Appointed Senior Specialist	Yamamoto, Chieko
Administrative Supporter	Aiba, Narukazu
Employee Section	
Chief	Yamaura, Mari
Staff	Kawashima, Ryota
Research Support Section	
Chief	Sato, Yoko
Staff	Matsukura, Koji
Staff	Okubo, Kazuhiko
Administrative Supporter	Aka, Shizuno
Administrative Supporter	Okuda, Yutaka
Administrative Supporter	Takeuchi, Kaori
Administrative Supporter	Torii, Makiko

Child Care Leave

Staff	Goto, Michiru
Staff	Ouchi, Kaori

Financial Affairs Division

Manager	Nemoto, Nobuyuki
Senior Specialist	Miura, Norio
External Funding Specialist	
Specialist	Miura, Susumu
Audit Specialist	
Specialist	Yamamoto, Shinichi
Administrative Supporter	Amano, Hiroshi
Administrative Supporter	Kawano, Chie

Administrative Supporter	Sato, Chieko
Administrative Supporter	Shioyama, Erika
Administrative Supporter	Urushibata, Kozue
Administrative Supporter	Yasuda, Masako

General Affairs Section

Chief	Miura, Susumu
Staff	Mizokawa, Yuko
Administrative Supporter	Kono, Midori
Administrative Supporter	Okada, Kazuko

Budget Section

Chief	Fujiwara, Kenichi
Staff	Katou, Masahiro
Staff	Yokota, Banri
Administrative Supporter	Matsubara, Michiko

Asset Management Section

Chief	Miura, Norio
Senior Staff	Sato, Kanako

Purchase Validation Center

Senior Staff	Sato, Kanako
Administrative Supporter	Nakagomi, Kimitoshi
Administrative Supporter	Nishimura, Misako
Administrative Supporter	Taniai, Tomoko
Administrative Supporter	Tanigaki, Yukio

Accounting Division

Manager	Hyuga, Tadayuki

Contract Specialist

Specialist	Chiba, Yoko

Accounting Section

Chief	Sukigara, Yuji
Senior Staff	Chiba, Satoko
Administrative Supporter	Kobayashi, Rina
Administrative Supporter	Nagasawa, Fumi
Administrative Supporter	Okada, Junko

Procurement Section

Chief	Chiba, Yoko
Staff	Kayamori, Shinji
Staff	Sakamoto, Misato
Staff	Sugimoto, Naomi
Administrative Expert	Sato, Masako
Administrative Supporter	Murai, Chikako
Administrative Supporter	Takano, Ayako
Administrative Supporter	Uchida, Shimako

Facilities Division

Manager	Ono, Kazuo
Administrative Expert	Asada, Tsuneaki

General Affairs Section

Chief	Yamada, Tomohiro
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
2014/4/1	Namiki, Noriyuki	Hired	Division of Radio Astronomy (RISE Project), Professor	(Chiba Institute of Technology)
2014/4/1	Aso, Yoichi	Hired	Division of Optical and Infrared Astronomy (Gravitational Wave Project Office), Associate Professor	(The University of Tokyo)
2014/4/1	Kikuchi, Kenichi	Hired	Division of Radio Astronomy (NAOJ Chile Observatory), Chief Research Engineer	
2014/4/1	Okita, Hirofumi	Hired	Division of Optical and Infrared Astronomy (Subaru Telescope), Assistant Professor	
2014/6/1	Ishikawa, Ryoko	Hired	Division of Solar and Plasma Astrophysics (Hinode Science Center), Assistant Professor	(Hinode Science Center, Specially Appointed Assistant Professor)
2014/8/1	Sakamoto, Seiichi	Hired	Division of Radio Astronomy (NAOJ Chile Observatory), Professor	(Japan Aerospace Exploration Agency)
2014/8/1	Kotani, Takayuki	Hired	Division of Optical and Infrared Astronomy (Extrasolar Planet Detection Project Office), Assistant Professor	
2014/11/30	Ikuta, Chisato	Resigned	(Japan Aerospace Exploration Agency)	Public Relations Center, Assistant Professor
2014/12/31	Tomono, Daigo	Resigned		Division of Optical and Infrared Astronomy (Subaru Telescope), Assistant Professor
2015/3/31	Kudoh, Takahiro	Resigned	(Nagasaki University)	Division of Theoretical Astronomy, Assistant Professor
2015/3/31	Hagiwara, Yoshiaki	Resigned	(Toyo University)	Division of Radio Astronomy (Mizusawa VLBI Observatory), Assistant Professor
2015/3/31	Takano, Shuro	Resigned	(Nihon University)	Division of Radio Astronomy (Nobeyama Radio Observatory), Assistant Professor
2015/3/31	Fukushima, Hideo	Resigned		Public Relations Center, Research Engineer
2015/3/31	Iye, Masanori	Retired		Division of Optical and Infrared Astronomy (TMT Project Office), Professor
2015/3/31	Shibasaki, Kiyoto	Retired		Division of Solar and Plasma Astrophysics (Nobeyama Solar Radio Observatory), Professor
2015/3/31	Sasaki, Toshiyuki	Retired		Division of Optical and Infrared Astronomy, Associate Professor
2015/3/31	Yutani, Masami	Retired		Division of Optical and Infrared Astronomy (Subaru Telescope), Chief Research Engineer
2015/3/31	Koyano, Hisashi	Retired		Division of Optical and Infrared Astronomy (Okayama Astrophysical Observatory), Chief Research Engineer
2015/3/31	Oshima, Norio	Contract Expired		Public Relations Center, Research Engineer

2014/10/1	Iwashita, Hiroyuki	Promoted	Division of Radio Astronomy (Nobeyama Radio Observatory), Chief Research Engineer	Division of Radio Astronomy (Nobeyama Radio Observatory), Research Engineer
2015/3/1	Honma, Mareki	Promoted	Division of Radio Astronomy (Mizusawa VLBI Observatory), Professor	Division of Radio Astronomy (Mizusawa VLBI Observatory), Associate Professor

Engineering Staff

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2014/4/1	Sato, Tatsuhiro	Hired	Division of Optical and Infrared Astronomy (Subaru Telescope), Engineer	
2015/3/1	Nishitani, Hiroyuki	Hired	Division of Radio Astronomy (Nobeyama Radio Observatory), Engineer	

2014/8/1	Shinohara, Noriyuki	Promoted	Division of Solar and Plasma Astrophysics (Nobeyama Solar Radio Observatory), Senior Engineer	Division of Solar and Plasma Astrophysics (Nobeyama Solar Radio Observatory), Chief Engineer
2014/8/1	Kubo, Koichi	Promoted	Advanced Technology Center, Senior Engineer	Advanced Technology Center , Chief Engineer
2014/8/1	Kobiki, Toshihiko	Promoted	Division of Radio Astronomy (NAOJ Chile Observatory), Senior Engineer	Division of Radio Astronomy (NAOJ Chile Observatory), Chief Engineer
2014/8/1	Takahashi, Toshikazu	Promoted	Advanced Technology Center, Senior Engineer	Advanced Technology Center , Chief Engineer
2014/8/1	Nakamura, Kyoko	Promoted	Division of Radio Astronomy (NAOJ Chile Observatory), Senior Engineer	Division of Radio Astronomy (NAOJ Chile Observatory), Chief Engineer
2014/9/1	Matsuda, Kou	Promoted	Public Relations Center, Chief Senior Engineer	Public Relations Center, Senior Engineer

Administrative Staff

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2014/4/1	Sasaki, Tsuyoshi	Hired	Administration Department, General Manager	(Iwate University)
2014/4/1	Harada, Eiichiro	Hired	Administration Department General Affairs Division, Manager	(National Institutes for the Humanities)
2014/4/1	Nemoto, Nobuyuki	Hired	Administration Department Financial Affairs Division, Manager	(Ministry of Education, Culture, Sports, Science and Technology)
2014/4/1	Sukigara, Yuji	Hired	Administration Department Accounting Division Accounting Section, Chief	(Tokyo Gakugei Univerisity)
2014/4/1	Hayashigura, Koji	Hired	Administration Department Facilities Division Maintenance Section, Staff	(The University of Tokyo)
2014/8/1	Shimizu, Hidetoshi	Hired	Nobeyama Radio Observatory Administration Office Accounting Section, Chief	(Shinshu University)
2014/8/1	Isozaki, Yuka	Hired	Administration Department General Affairs Division Personnel Section, Staff	
2014/8/1	Kayamori, Shinji	Hired	Administration Department Accounting Division Procurement Section, Staff	
2015/2/1	Yokota, Banri	Hired	Administration Department Financial Affairs Division Budget Section, Staff	
2015/3/1	Takai, Tetsuya	Hired	Administration Department General Affairs Division Personnel Section, Staff	

2014/7/31	Sasaki, Hiroaki	Resigned	(Shinshu University)	Nobeyama Radio Observatory Administration Office Accounting Section, Chief
2014/7/31	Kobayashi, Hideki	Resigned	(Kochi University)	Subaru Telescope Administration Department, Administrative Manager
2014/12/15	Kato, Masahiro	Resigned		Administration Department Financial Affairs Division Budget Section, Staff
2015/3/31	Kikuchi, Jinichi	Resigned	(The University of Tokyo)	Administration Department General Affairs Division, Specialist
2015/3/31	Miura, Susumu	Resigned	(Tokyo Gakugei Univerisity)	Administration Department Financial Affairs Division General Affairs Section, Chief
2015/3/31	Hori, Mayumi	Resigned	(The University of Tokyo)	Public Relations Center, Library Section, Chief
2015/3/31	Okubo, Kazuhiko	Resigned	(The Graduate University for Advanced Studies)	Administration Department General Affairs Division Research Support Section, Staff

2015/3/31	Hyuga, Tadayuki	Retired		
2015/3/31	Ono, Kazuo	Retired		

2014/8/1	Seto, Yoji	Promoted	Subaru Telescope Administration Department, Administrative Manager	Office of International Relations Administration Office, Chief
2014/8/1	Onishi, Tomoyuki	Promoted	Administration Department General Affairs Division, Deputy Manager	Administration Department Accounting Division, Specialist
2014/8/1	Chiba, Yoko	Promoted	Administration Department Accounting Division Procurement Section, Chief	Administration Department Accounting Division Procurement Section, Senior Staff
2014/8/1	Yamamoto, Shinichi	Promoted	Administration Department Financial Affairs Division, Specialist	NAOJ Chile Observatory Administration Department Financial Section, Senior Staff
2014/10/1	Chiba, Satoko	Promoted	Administration Department Accounting Division Accounting Section, Senior Staff	Administration Department Accounting Division Accounting Section, Staff

Employee on Annual Salary System

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2014/4/1	Kawamura, Akiko	Hired	NAOJ Chile Observatory, Specially Appointed Associate Professor	
2014/4/1	Chibueze, James Okwe	Hired	NAOJ Chile Observatory, Specially Appointed Assistant Professor	(NAOJ Chile Observatory, Specially Appointed Research Staff)
2014/4/1	Gonzalez Garcia, Alvaro	Hired	Advanced Technology Center, Specially Appointed Assistant Professor	
2014/4/1	Toriumi, Shin	Hired	Division of of Solar and Plasma Astrophysics, Specially Appointed Assistant Professor	
2014/4/1	Nozawa, Takaya	Hired	Division of Theoretical Astronomy, Specially Appointed Assistant Professor	
2014/4/1	Tadaki, Kenichi	Hired	Subaru Telescope, Specially Appointed Research Staff	
2014/4/1	Higuchi, Yuichi	Hired	Astronomy Data Center, Specially Appointed Research Staff	
2014/4/1	Zapart, Christopher Andrew	Hired	Astronomy Data Center, Specially Appointed Research Staff	

2014/4/1	Harakawa, Hiroki	Hired	TMT Project Office, Specially Appointed Research Staff	
2014/4/1	Nishimura, Atsushi	Hired	Nobeyama Radio Observatory, Specially Appointed Research Staff	
2014/4/1	Furusawa, Shun	Hired	Center for Computational Astrophysics, Specially Appointed Research Staff	
2014/4/1	Shirahata, Mai	Hired	JASMINE Project Office, Specially Appointed Research Staff	
2014/4/1	Cheung, Sze Leung	Hired	Public Relations Center, Specially Appointed Senior Specialist	
2014/4/1	Shimoda, Takanobu	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2014/4/1	Kobayashi, Tsuyoshi	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2014/4/1	Morita, Eisuke	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2014/4/1	Sugimoto, Kanako	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2014/4/1	Kawasaki, Wataru	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2014/4/1	Matsui, Takayuki	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2014/4/1	Yamada, Masumi	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2014/5/1	Sugiyama, Motokuni	Hired	TMT Project Office, Specially Appointed Senior Specialist	
2014/5/1	Kawashima, Tomohisa	Hired	Center for Computational Astrophysics, Specially Appointed Research Staff	
2014/5/1	Kawaguchi, Toshihiro	Hired	Astronomy Data Center, Specially Appointed Research Staff	
2014/5/19	Wu, Yuanwei	Hired	Mizusawa VLBI Observatory, Specially Appointed Research Staff	
2014/6/1	Zeidler, Simon	Hired	Gravitational Wave Project Office, Specially Appointed Research Staff	
2014/7/1	Sotani, Hajime	Hired	Division of Theoretical Astronomy, Specially Appointed Assistant Professor	
2014/7/15	Omiya, Masashi	Hired	Extrasolar Planet Detection Project Office, Specially Appointed Research Staff	
2014/9/1	Sanhueza Nunez, Patricio Andres	Hired	NAOJ Chile Observatory, Specially Appointed Research Staff	
2014/9/1	Barton, Mark Andrew	Hired	Gravitational Wave Project Office, Specially Appointed Research Staff	
2014/10/1	Minamidani, Tetsuhiro	Hired	Nobeyama Radio Observatory, Specially Appointed Assistant Professor	(Nobeyama Radio Observatory, Specially Appointed Research Staff)
2014/10/1	Yamada, Ryuhei	Hired	RISE Project, Specially Appointed Research Staff	
2014/10/1	Tazaki, Fumie	Hired	Mizusawa VLBI Observatory, Specially Appointed Research Staff	
2014/10/1	Kuniyoshi, Masaya	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2014/10/1	Zang, Liangjian	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2014/11/1	Ueda, Junko	Hired	NAOJ Chile Observatory, Specially Appointed Research Staff	
2014/11/1	Hirata, Naoatsu	Hired	Gravitational Wave Project Office, Specially Appointed Senior Specialist	

2014/11/1	Nagai, Hiroshi	Hired	NAOJ Chile Observatory, Specially Appointed Associate Professor	(NAOJ Chile Observatory, Specially Appointed Assistant Professor)
2015/1/1	Yamamoto, Chieko	Hired	Administration Department General Affairs Division, Specially Appointed Senior Specialist	
2015/2/1	Saito, Motoi	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	

2014/5/31	Ishikawa, Ryoko	Resigned	(Division of Solar and Plasma Astrophysics (Hinode Science Center), Assistant Professor)	Hinode Science Center, Specially Appointed Assistant Professor
2014/7/31	Takiwaki, Tomoya	Resigned		Center for Computational Astrophysics, Specially Appointed Assistant Professor
2014/8/31	Komugi, Shinya	Resigned		NAOJ Chile Observatory, Specially Appointed Associate Professor
2014/9/30	Tadaki, Kenichi	Resigned		Subaru Telescope, Specially Appointed Research Staff
2014/9/30	Minamidani, Tetsuhiro	Resigned	(Nobeyama Radio Observatory, Specially Appointed Assistant Professor)	Nobeyama Radio Observatory, Specially Appointed Research Staff
2014/10/31	Nagai, Hiroshi	Resigned	(NAOJ Chile Observatory, Specially Appointed Associate Professor)	NAOJ Chile Observatory, Specially Appointed Assistant Professor
2014/11/30	Shinnaga, Hiroko	Resigned	(Kagoshima University)	NAOJ Chile Observatory, Specially Appointed Associate Professor
2015/1/31	Chibueze, James Okwe	Resigned		NAOJ Chile Observatory, Specially Appointed Assistant Professor
2015/3/31	Miura, Rie	Resigned	(NAOJ Chile Observatory, Specially Appointed Assistant Professor)	NAOJ Chile Observatory, Specially Appointed Research Staff
2015/3/31	Herrera Contreras, Cinthya Natalia	Resigned	(NAOJ Chile Observatory, Specially Appointed Assistant Professor)	NAOJ Chile Observatory, Specially Appointed Research Staff
2015/3/31	Kawaguchi, Toshihiro	Resigned		Astronomy Data Center, Specially Appointed Research Staff

2015/3/31	Kandori, Ryo	Contract Expired		Extrasolar Planet Detection Project Office, Specially Appointed Research Staff
2015/3/31	Nagayama, Takumi	Contract Expired	(Mizusawa VLBI Observatory, Specially Appointed Senior Specialist)	Mizusawa VLBI Observatory, Specially Appointed Research Staff
2015/3/31	Yamaguchi, Takahiro	Contract Expired	(Office of International Relations, Specially Appointed Senior Specialist)	NAOJ Chile Observatory Administration Department, Specially Appointed Senior Specialist

Research Administrator Staff

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2014/4/1	Chapman, Junko	Hired	Research Enhancement Strategy Office, TMT Project Office, Specially Appointed Senior Specialist	
2014/4/1	Hori, Kuniko	Hired	Research Enhancement Strategy Office, Research Evaluation Support Office, Specially Appointed Senior Specialist	
2014/4/1	Lundock, Ramsey Guy	Hired	Research Enhancement Strategy Office, Public Relations Center, Specially Appointed Senior Specialist	
2014/4/1	Chiba, Kurazo	Hired	Research Enhancement Strategy Office, Engineering Promotion Office, Specially Appointed Senior Specialist	

2014/4/1	Fukui, Hideharu	Hired	Research Enhancement Strategy Office, NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2014/10/1	Miura, Mitsuo	Hired	Research Enhancement Strategy Office, Mizusawa VLBI Observatory, Specially Appointed Senior Specialist	

2014/9/30	Suematsu, Sayaka	Resigned		Research Enhancement Strategy Office, Human Resources Planning Office, Specially Appointed Senior Specialist

Foreign Visiting Researcher

Name	Period	Affiliated Institute
Kuhn, Jeffrey Richard	2014/5/27 ~ 2014/6/20 2014/9/11 ~ 2014/9/20	University of Hawaii (U.S.A)
Ojha, Devendra Kumar	2014/6/9 ~ 2014/7/8	Tata Institute of Fundamental Research (India)
Turner, Edwin Lewis	2014/9/4 ~ 2014/10/31 2015/2/5 ~ 2015/3/5	Princeton University (U.S.A)
Uitenbroek, Han	2014/4/7 ~ 2014/5/16	National Solar Observatory (U.S.A)
Barsuglia, Matteo	2014/5/19 ~ 2014/6/30	Centre National de la Recherche Scientifique (France)
Packham, Christopher Charles	2014/6/4 ~ 2014/8/13	The University of Texas at San Antonio, UTSA (U.S.A)

In the Research and Academic Staff personel list, we only listed reassignments from Engineering Staff.
In the Engineering 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

	Kajita, Takaaki	The University of Tokyo
○	Kusano, Kanya	Nagoya University
	Momose, Munetake	Ibaraki University
	Murakami, Izumi	National Institute for Fusion Science
	Nakagawa, Takao	Japan Aerospace Exploration Agency
	Ohta, Kouji	Kyoto University
	Okumura, Sachiko	Japan Women's University
	Sugita, Seiji	The University of Tokyo
	Umemura, Masayuki	University of Tsukuba
	Yamada, Toru	Tohoku University

From NAOJ

	Arimoto, Nobuo	Subaru Telescope
	Gouda, Naoteru	JASMINE Project Office
	Hasegawa, Tetsuo	NAOJ Chile Observatory
	Kobayashi, Hideyuki	Mizusawa VLBI Observatory
	Noguchi, Takashi	Advanced Technology Center
	Sakurai, Takashi	Solar Observatory
	Takami, Hideki	Advanced Technology Center
	Tomisaka, Kohji	Division of Theoretical Astronomy
	Usuda, Tomonori	TMT Project Office
●	Watanabe, Junichi	Public Relations Center

● Chairperson ○ Vise-Chairperson
Period: April 1, 2014 – March 31, 2016

8. Professors Emeriti and Staffs Emeriti

Professor Emeritus (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

Professor Emeritus (Tokyo Astronomical Observatory)

Akabane, Kenji
Moriyama, Fumio
Kozai, Yoshihide

IV Finance

Revenue and Expenses (FY2014)

(Unit: ¥1,000)

Revenue	Budget	Final Account	Budget − Final Account
Management Expenses Grants	13,273,727	13,897,144	−623,417
Facilities Maintenance Grants	2,382,752	2,241,797	140,955
Subsidy Income	88,999	81,356	7,643
Miscellaneous Income	41,378	61,071	−19,693
Industry-Academia Research Income and Donation Income	653,223	258,288	394,935
Reversals of Reserves for Specific Purposes	1,574	4,209	−2,635
Total	16,441,653	16,543,865	−102,212
Expenses	Budget	Final Account	Budget − Final Account
Management Expenses	13,316,679	13,600,573	−283,894
Employee Personnel Expenses	3,535,534	3,433,737	101,797
Operating Expenses	9,781,145	10,166,836	−385,691
Facilities Maintenance Expenses	2,401,752	2,268,797	132,955
Subsidy Expenses	69,999	54,356	15,643
Industry-Academia Research Expenses and Donation Expenses	653,223	250,458	402,765
Total	16,441,653	16,174,184	267,469
Revenue-Expenses	Budget	Final Account	Budget − Final Account
	0	369,681	−369,681

V KAKENHI (Grants-in-Aid for Scientific Research)

1. Series of Single-year Grants for FY 2014

Research Categories	Number of Selected Projects	Budget (thousand yen)		
		Direct Funding	Indirect Funding	Total
Scientific Research on Innovative Areas (Research in a proposed research area)	8	97,500	29,250	126,750
Scientific Research (S)	3	60,600	18,180	78,780
Scientific Research (A)	10	76,800	23,040	99,840
Scientific Research (B)	1	2,100	630	2,730
JSPS Fellows	8	9,100	2,730	11,830
Research Activity start-up	2	1,600	480	2,080
Publication of Scientific Research Results	1	1,000	0	1,000
Total	33	248,700	74,310	323,010

2. Multi-year Fund for FY 2014

Research Categories	Number of Selected Projects	Budget (thousand yen)		
		Direct Funding	Indirect Funding	Total
Scientific Research (C)	14	16,705	5,012	21,717
Challenging Exploratory Research	2	2,000	600	2,600
Young Scientists (B)	18	15,878	4,763	20,641
Total	34	34,583	10,375	44,958

3. Partial Multi-year Fund for FY2014

Research Categories	Number of Selected Projects	Budget (Series of Single-year Grants) (thousand yen)			Budget (Multi-year Fund) (thousand yen)		
		Direct Funding	Indirect Funding	Total	Direct Funding	Indirect Funding	Total
Scientific Research (B)	4	8,900	2,670	11,570	2,600	780	3,380
Young Scientists (A)	2	8,600	2,580	11,180	5,000	1,500	6,500
Total	6	17,500	5,250	22,750	7,600	2,280	9,880

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	43 (0)	2 Institutes
		188cm Reflector Telescope (Normal Program)	24	155 (4)	12 Institutes, 2 Countries
		188cm Reflector Telescope (Student Program)	1	30 (0)	3 Institutes
	Subaru Telescope		128	422 (60)	77 Institutes, 14 Countries
	Solar Observatory		*	*	*
	Nobeyama Radio Observatory	45-m telescope (General Proposal)	29	188 (64)	46 Institutes, 11 Countries
		45-m telescope (Education Program)	0	0	
		45-m telescope (Short Program)	9	70 (15)	18 Institutes, 5Countries
		45-m telescope (Back-up Program)	1	9 (2)	3 Institutes
	Nobeyama Solar Radio Observatory		34	150 (107)	40 Institutes, 15 Countries
	Mizusawa VLBI Observatory	VERA	18	114 (46)	19 Institutes, 7 Countries
	Astronomy Data Center		384	384 (54 at foreign institutes)	83 Institutes, 15 Countries, Total amount of requested data 31 TB
	Center for Computational Astrophysics		198	198	47 Institutes, 9 Countries
	Hinode Science Center		125	125 (42)	46 Institutes, 14 Countries
	Advanced Technology Center	Facility Use	30	139	58 Institutes
		Joint Research and Development	7	52	15 Institutes
	NAOJ Chile Observatory	ALMA	196	1,846 (1,511)	227 Institutes, 34 Countries
		ASTE	32	209 (44)	21 Institutes, 10 Countries
		Mopra	20	161 (36)	22 Institutes, 12 Countries
Joint Development Research			9		8 Institutes
Joint Research			2		2 Institutes
Research Assembly			17		12 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 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, 2014 - March 31, 2015 *April 1, 2014 - July 31, 2014

Name	Position at NAOJ	Affiliated Institute	Host Project/Center/Division
Onishi, Toshikazu	Visiting Professor	Osaka Prefecture University	NAOJ Chile Observatory
Sakamoto, Seiichi*	Visiting Professor	Japan Aerospace Exploration Agency	NAOJ Chile Observatory
Fujisawa, Kenta	Visiting Professor	Yamaguchi University	Mizusawa VLBI Observatory
Momose, Munetake	Visiting Professor	Ibaraki University	NAOJ Chile Observatory
Imai, Hiroshi	Visiting Associate Professor	Kagoshima University	Mizusawa VLBI Observatory
Iwata, Takahiro	Visiting Associate Professor	Japan Aerospace Exploration Agency	RISE Project
Oka, Tomoharu	Visiting Associate Professor	Keio University	NAOJ Chile Observatory
Kotake, Kei	Visiting Associate Professor	Fukuoka University	Center for Computational Astrophysics
Takahashi, Keitaro	Visiting Associate Professor	Kumamoto University	Division of Radio Astronomy
Hagino, Kouichi	Visiting Associate Professor	Tohoku University	Division of Theoretical Astronomy
Hirata, Naru	Visiting Associate Professor	The University of Aizu	RISE Project
Masuda, Satoshi	Visiting Associate Professor	Nagoya University	Nobeyama Solar Radio Observatory
Yonekura, Yoshinori	Visiting Associate Professor	Ibaraki University	Mizusawa VLBI Observatory
Asaki, Yoshiharu	Visiting Research Fellow	Japan Aerospace Exploration Agency	NAOJ Chile Observatory
Oshima, Akitoshi	Visiting Research Fellow	Chubu University	Center for Computational Astrophysics
Kurayama, Tomoharu	Visiting Research Fellow	Teikyo University of Science	Mizusawa VLBI Observatory
Naruse, Masato	Visiting Research Fellow	Saitama University	Advanced Technology Center

JSPS (Japan Society for the Promotion of Science) Postdoctoral Research Fellows

Name	Research Subject	Host Researcher
Ishikawa, Shinnosuke	Study of solar flare particle acceleration with high-sensitivity and high-resolution X-ray imaging spectroscopic observations	Suematsu, Yoshinori
Niino, Yuu	Probing Cosmic Star Formation at High Redshifts via Afterglows and Host Galaxies Gamma-Ray Bursts	Kashikawa, Nobunari
Hada, Kazuhiro	Probing a relativistic jet in a supermassive black hole with high-resolution radio monitoring observations	Homma, Mareki
Ueda, Junko	Unveiling the evolution of merging galaxies from the formation of cold molecular gas disks	Iono, Daisuke
Sakai, Nobuyuki	Outer Rotation Curve of the Galaxy with VERA	Honma, Mareki
Nitta, Tomu	Development of a superconducting 1000 pixels camera for the antarctic submillimeter telescope	Sekimoto, Yutaro
Nomura, Mariko	Three Dimensional Radiation Hydrodynamic Calculations of Outflows from Accretion Disks and Studies of Absorption Lines in Active Galactic Nuclei	Osuga, Ken
Hayashi, Masao	Formation and evolution of elliptical galaxies revealed by internal structures of growing progenitors in galaxy clusters	Kodama, Tadayuki

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 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 field, in an environment with the most advanced observational instruments and supercomputers, as researchers who work at forefront of world-class research; experts who carry out the 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 five-year doctoral course)
Three (per year in 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 who also have the needed theoretical and creative aptitude 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 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 FY2012, 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 2014, the Department of Astronomical Science accepted four students in the Basic Course and four 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 February 10 to 13, 2015, as well as the 2014 Summer Student program at Mitaka, Mizusawa, Nobeyama and Hawaii 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 (2015/3/31)

Chair of the Department of Astronomical Science	1
Optical and Near Infrared Astronomy Course	
Professors	10
Associate Professors	13
Lecturer	1
Assistant Professors	10
Radio Astronomy Course	
Professors	6
Associate Professors	8
Assistant Professors	18
General Astronomy and Astrophysics Course	
Professors	8
Associate Professors	11
Assistant Professors	15
Total	101

(6) Graduate Students (30 students)

1st year (3 students)

Name	Principal Supervisor	Supervisor	Thesis
Sasahira, Rinko	Osuga, Ken	Tanaka, Masaomi	The co-evolution of galaxies and black holes
Michiyama, Tomonari	Iono, Daisuke	Kodama, Tadayuki	Observing Starburst Galaxies Using ALMA
Yamamoto, Moegi	Kodama, Tadayuki	Iwata, Ikuru	The peak epoch of galaxy formation explored by SWIMS-18 survey

2nd year (5 students)

Name	Principal Supervisor	Supervisor	Thesis
Okutomi, Koki	Aso, Yoichi	Flaminio, Raffael	Research for sensitivity improvement of gravitational wave detectors
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	Study of exoplanets and brown dwarfs from optical and infrared observations

3rd year (9 students)

Name	Principal Supervisor	Supervisor	Thesis
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	Kuno, Nario	Observational study toward 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
Kobayashi, Hiroshi	Osuga, Ken	Tomisaka, Koji	Radiation Hydrodynamic Study of Gas Flow Around Black-Holes
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 properties and environmental dependence of galaxies at their peak epoch of formation
Suzuki, Taiki	Oishi, Masatoshi	Saito, Masao	Research on Organic Molecules in the Universe

Suzuki, Tomoko	Kodama, Tadayuki	Iono, Daisuke	Galaxy anatomy at the peak epoch of galaxy formation

4th year (5 students)

Name	Principal Supervisor	Supervisor	Thesis
Aoki, Sumire	Arimoto, Nobuo	Kodama, Tadayuki	Origin of Morphology of Elliptical Galaxies
Saito, Yuriko	Imanishi, Masatoshi	Hayashi, Saeko	Investigating the supermassive black hole to spheroidal stellar mass ratio at z~3
Matsuzawa, Ayumu	Iguchi, Satoru	Saito, Masao	Research of absorbing plasma around SMBH of M87 by cm and mm wavelength
Oh, Daehyeon	Aoki, Wako	Takami, Hideki	A study of extrasolar planets and their formation sites based on infrared observations
Giono, Gabriel	Suematsu, Yoshinori	Hara, Hirohisa	Study of Optical Tests in Ly-α for CLASP Instrumentation

5th year (8 students)

Name	Principal Supervisor	Supervisor	Thesis
Imase, Keisuke	Kodama, Tadayuki	Kashikawa, Nobunari	Near-Infrared Spectroscopic Observation of Broad Line Regions in Nearby Active Galactic Nuclei"
Kaithakkal, Anjali John	Suematsu, Yoshinori	Watanabe, Tetsuya	Study of Solar Spectro-polarimetry and Magnetic Reversal of the Sun's Poles
Kataoka, Akimasa	Tomisaka, Koji	Nakamura, Fumitaka	Theoretical modeling of the structure evolution of dust aggregates in the early stage of planet formation
Sako, Nobuharu	Watanabe, Tetsuya	Sekii, Takashi	Obsservational Investigation of Short-Lived Activity Creation Processes in the Solar Atmosphere
Shino, Nagisa	Honma, Mareki	Shibata, Katsunori	Testing the formation scenario of massive stars by CH3OH maser
Toshikawa, Jun	Kashikawa, Nobunari	Kodama, Tadayuki	Observational study on high-z clusters
Min, Cheul Hong	Honma, Mareki	Shibata, Katsunori	Research for a symbiotic star using VERA
Sukom, Amnart	Hayashi, Saeko	Izumiura, Hideyuki	Study of star and planetary formation process and the exoplanets based on infrared observations

Research Student (1 student)

Name	Supervisor	Thesis
Yang, Yongzhang	Hanada, Hideo	Research of the interior of the moon and the planet based on an application of rotation theory

2. Education and Research Collaboration with Graduate Schools

Name	Affiliated Institute	Supervisor	Thesis
Isoe, Mari	The University of Tokyo	Kokubo, Eiichiro	Theoretical Study of Planet Formation
Ito, Yuta	The University of Tokyo	Gouda, Naoteru	Galactic structure and evolution
Kimura, Yasuhisa	The University of Tokyo	Hara, Hirohisa	Studies on sub-arcsecond transition-region structures at the footpoints of coronal loops in the active-region plage
Kuramochi, Kazuki	The University of Tokyo	Kobayashi, Hideyuki	Millimeter VLBI studies on astronomical observation with the KVN and VERA Array and the VERA
Kuwahara, Sho	The University of Tokyo	Mizuno, Norikazu	The Study of Star Formation and Interstellar Medium in the Galactic Plane
SHU, Shibo	The University of Tokyo	Sekimoto, Yutaro	Development of MKID camera
Okada, Takashi	The University of Tokyo	Sekimoto, Yutaro	The development of submm-camera for observing CMB
Kasuga, Megumi	The University of Tokyo	Hara, Hirohisa	An observational study on coronal heating through investigation of photospheric properties at the footpoints of coronal loops
Kato, Yuta	The University of Tokyo	Mizuno, Norikazu	Herschel Protocluster Survey
Sakai, Daisuke	The University of Tokyo	Kobayashi, Hideyuki	Study for revealing dynamics in the Galactic Center region with VLBI
Tezuka, Kenjiro	The University of Tokyo	Gouda, Naoteru	Resolving degeneracy with regard to gravitational microlensing by astrometry
Baba, Fuko	The University of Tokyo	Hara, Hirohisa	A case study of energy transfer in the chromosphere with IRIS and Hinode
Hirai, Yutaka	The University of Tokyo	Kajino, Toshitaka	Chemodynamical evolution of dwarf galaxies
Lee, Minju	The University of Tokyo	Kawabe, Ryohei	Environmental effects on galaxy evolution from the JVLA continuum observation towards a protocluster 4C23.56
Aso, Yusuke	The University of Tokyo	Ohashi, Nagayoshi	Formation and growth of protoplanetary disks
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	Starburst and SMBH Formation in Merging Galaxies
Shibagaki, Shota	The University of Tokyo	Kajino, Toshitaka	r-process nucleosynthesis
Shibata, Takashi	The University of Tokyo	Kokubo, Eiichiro	Study of Planet Formation
Sekiguchi, Sigeyuki	The University of Tokyo	Sekimoto, Yutaro	Development of MKID camera for wide field millimeter-wave observations
Tagawa, Hiromichi	The University of Tokyo	Gouda, Naoteru	The study of merge process of primal galaxy black holes with the dynamical friction by gas
Koyamatsu, Shin	The University of Tokyo	Ohashi, Nagayoshi	Formation and Evolution of Protoplanetary Disks
Sekine, Masakazu	The University of Tokyo	Sekimoto, Yutaro	Development of Bi-layer MKID camera
Hara, Takuji	The University of Tokyo	Gouda, Naoteru	Construction of a galactic dynamical model with astrometric data
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	The effects of stellar feedbacks on the molecular cloud formation in the Large Magellanic Cloud
Akiyama, Kazunori	The University of Tokyo	Kobayashi, Hideyuki	Millimeter VLBI studies on the innermost region of AGNs with the KVN and VERA Array and the Event Horizon Telescope
Kiyokane, Kazuhiro	The University of Tokyo	Mizuno, Norikazu	Research of kinematic structure of low-mass star formation process with Radio telescope
Fujii, Akihiko	The University of Tokyo	Kokubo, Eiichiro	Theoretical study on the formation and the evolution of spatial structure in dense planetary rings
Kasai, Miho	Toho University	Matsuo, Hiroshi	Establishment of stable operation of SIS photon detectors
Kubo, Daiki	Toho University	Matsuo, Hiroshi	Experimental studies on readout electronics for SIS photon detectors
Takano, Akihiro	Kobe University	Ohashi, Nagayoshi	Radio Observations of Star Forming Regions

3. Commissioned Graduate Students

Doctoral Course	Affiliated Institute	Period	Supervisor	Thesis
Ono, Yoshito	Tohoku University	2014/4/1 ~ 2015/3/31	Iwata, Ikuru	Verifications of Multi-Object AO system using RAVEN
Oya, Masahito	Nihon University	2014/4/1 ~ 2015/3/31	Watanabe, Junichi	Development of Interferometer for direct observations of exoplantets
Sekiguchi, Takanori	The University of Tokyo	2014/4/1 ~ 2015/3/31	Flaminio, Raffaele	Development of Vibration Isolation System for Large-Scale Cryogenic Gravitational Wave Telescope KAGRA
Mizuno, Izumi	Kagoshima University	2014/4/1 ~ 2015/3/31	Saito, Masao	Polarization calibration method for single-dish radio observations.

Master's Course	Affiliated Institute	Period	Supervisor	Thesis
Kurahashi, Takuya	Meisei University	2014/4/1 ~ 2015/3/31	Iono, Daisuke	Observing Distant Galaxies Using the NRO 45m and ALMA
Okuyama, Yasushi	Tokyo University of Agriculture and Technology	2014/4/1 ~ 2015/3/31	Watanabe, Junichi	Development of precise spectrograph and studies of exoplanets
Kajita, Satoshi	Tokai University	2014/4/1 ~ 2015/3/31	Watanabe, Tetsuya	Study of non-thermal particles in the precursory phenomena of solar flares
Kawauchi, Kiyoe	Tokyo Institute of Technology	2014/4/1 ~ 2015/3/31	Aoki, Wako	The high resolution transmission spectroscopy of the Earth atmosphere using the lunar eclipse data
Sato, Kazuma	Tokyo University of Agriculture and Technology	2014/4/1 ~ 2015/3/31	Watanabe, Junichi	High Contrast Optics for direct observations of exoplanets
Taniguchi, Kotomi	Toho University	2014/4/1 ~ 2015/3/31	Saito, Masao	^{13}C isotopic fractionation of HC_5N in TMC-1
Nakahara, Satomi	Kagoshima University	2014/4/1 ~ 2015/3/31	Honma, Mareki	VLBI multi-epochs observations of the low-luminosity AGN M84
Aoki, Misa	International Christian University	2014/10/1 ~ 2015/3/31	Aoki, Wako	Origins of r-process studied by chemical abundances of metal-poor stars with Subaru/HDS
Sunaga, Naoki	Shizuoka University	2014/10/1 ~ 2015/3/31	Kajino, Toshitaka	High Energy Astrophysics Phenomena and the Origin of Elements

4. Degrees Achieved with NAOJ Facilities

Name	Degree	Thesis
Sako, Nobuharu	Doctor of Philosophy, SOKENDAI	Statistical Study of X-ray Jets using Hinode/XRT
Anjali John Kaithakkal	Doctor of Philosophy, SOKENDAI	A Study on the Photospheric Polar Magnetic Patches of the Sun
Kataoka, Akimasa	Doctor of Philosophy, SOKENDAI	Planetesimal Formation via Fluffy Dust Aggregates
Toshikawa, Jun	Doctor of Philosophy, SOKENDAI	Growth History of Galaxy Clusters Traced by Protoclusters at $z \sim 3$– 6
Imase, Keisuke	Master of Science, SOKENDAI	Near-Infrared Spectroscopic Observation of Broad Line Regions in Nearby Active Galactic Nuclei

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 season (December 28–January 4)

Visitors: 19,754

Open facilities: Observatory History Museum (65-cm Telescope Dome), 20-cm Telescope Dome, Solar Tower Telescope, Exhibition Room, Repsold Transit Instrument Housing, Astronomical Instruments Museum, Gautier Meridian Circle, Old Library

[Regular Star Gazing Party]

Dates: Friday before second Saturday; fourth Saturday

Visitors: 5,161 (23 events)

Open facility: 50-cm Telescope for Public Outreach

[Special Open-House Event] Mitaka Open House Day

Dates: October 24 (Fri), 2014, 14:00–19:00
October 25 (Sat), 2014, 10:00–19:00

Topic: TMT Challenging the Frontiers of Space

Visitors: 4,768

This event is jointly sponsored by NAOJ, the University of Tokyo School of Science Institute of Astronomy, and the SOKENDAI Department of Astronomical Science. 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 University of Tokyo Institute of Astronomy ("Seeing the Universe in Infrared – The Advancing TAO Telescope Project" Kentaro Motohara, Associate Professor at the University of Tokyo [in Japanese]) and NAOJ ("The Search for Planets and Life Outside the Solar System" Edwin L. Turner – Professor at Princeton University [in English with simultaneous Japanese translation]; "At Last! Construction Starts for the Thirty Meter Telescope" Masanori Iye, Professor at SOKENDAI [in Japanese]).

Both days benefited from clear weather, helping attendance reach a record high. In addition to the opening of facilities normally closed to the public, interactive displays and mini-lectures, there were also games and quizzes popular with children to engage a wide range of ages.

* Custom group tours (Dantai Kengaku), 4D2U Theater showings, and Guided Tours were also offered. Refer to the Public Relations Center report for details.

2. Mizusawa Campus

[Open year-round]

Dates: April to March (except for New Year season), 9:00–17:00 daily

Visitors: 17,021

Open facilities: Kimura Hisashi Memorial Museum, VERA 20-m antenna, 10-m VLBI antenna

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.

Date: August 16 (Sat.), 2014, 17:00–20:00 (Pre-event)
August 30 (Sat.), 2014, 10:00–16:00 (Exhibition)

Visitors: Approximately 1,000 (Pre-event) , 847(Exhibition)

[Special Open Day] Held as part of Iwate Galaxy Festival 2014 (Hours: 10:00–21:00)

As a pre-event for the Iwate Galaxy Festival, a mission de-briefing session by JAXA astronaut Koichi Wakata was held during Part 1 of the Special Open House Day. Here he spoke about his activities in the six months he spent on the International Space Station as its first Japanese commander.

Part 2 featured "the Special Lecture on Space" panel with Koichi Wakata, Mareki Honma (Associate Professor in Mizusawa VLBI Observatory), and Koji Matsumoto (Associate Professor in the RISE Project).

Like last year, the Open Day was co-hosted with Ihatov Space Action Center/the Oshu Space and Astronomy Museum (OSAM: Yugakukan) and the city of Oshu. The Open Day included strong involvement by the local community, such as a performance by a marching band from a local elementary school at the opening, workshop corners run by local university students, and others.

NAOJ offered tours of the 20-m parabolic antenna, a commemorative photo booth, plastic bottle rockets, a quiz game, guided tours of the Kimura Hisashi Memorial Museum, and exhibits explaining the research highlights of VERA, RISE and CfCA projects.

In the Kimura Hisashi Memorial Museum, special guided tours named "Kimura Hisashi Memorial Museum guided tour" and "the guided tour of the stars tonight" held by the Young Astronauts Club - Japan Mizusawa Z- Chapter were well received.

Open Day events also included a special lecture by Shogo Tachibana, Associate Professor of Hokkaido University, entitled "Hayabusa-2 —a dream in the Age of Discovery of the Solar System—". This talk was given to a full house, with a good atmosphere.

OSAM (Yugakukan) offered such attractions as "Science's Mystery" experiments, scientific performances by a scientist, and a workshop by internship students. Due to bad weather, a lecture about the stars was held instead of the stargazing party, to close the festival with great success.

Iriki: VERA Iriki Station

[Open year-round]

Dates: April to March (except for New Year season)

Visitors: Approximately 2,000

[Special Open Day]

Date: August 10 (Sun.), 2014, 10:00–21:00

This year's special open house event was canceled due to a typhoon.

Ogasawara: VERA Ogasawara Station

[Open year-round]

Dates: April to March (except for New Year season)

Visitors: 7,535

[Special Open Day]

Date: February 15 (Sun.), 2015, 10:00–17:00

Visitors: 213

A special open house event was held again this year under the name "Star Island 14". Like last year, the free shuttle buses were appreciated by the visitors. The number of visitors was more than 200. NAOJ offered such attractions as exhibits about the research results of VERA, RISE and Okayama Astrophysical Observatory projects, mystery experiment corners and quiz games, as well as a 4D2U digital planetarium show, which was very popular among visitors. On February 14, NAOJ also cooperated in a stargazing session hosted by the local astronomy club. It was held in favorable weather conditions, and the event was an unprecedented success. Space lectures were also given by Sawada from the Mizusawa VLBI Observatory and Yamada from the RISE Project at the Ogasawara Visitor Center on the night of February 15.

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: 2,754

[Special Open day]

Dates: August 3 (Sun.), 2014, 10:00–17:00

Visitors: 264

Held in conjunction with the Star Festival of the Southern Island.

As in previous years, attractions included antenna tours, Purikura (photo booth stickers), merchandise, commemorative lectures, and exhibits.

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 weekdays (19:00–22:00), two 30-minute sessions per evening (four in August)

4D2U screening: from 15:00 to 15:30 every day that the observatory is open

Visitors: 12,790 (877 during the Star Festival of the Southern Island)

Open facilities: Murikabushi 105-cm optical/infrared telescope, Hoshizora Manabi no Heya (featuring the 4D2U "four dimensional digital universe"), interior of observation dome (including exhibits of astronomical images)

The "Hoshizora Manabi no Heya", constructed adjacent to the observatory in 2013 by the city of Ishigaki, was very popular, welcoming 3,488 guests.

[Star Festival of the Southern Island 2014]

Dates: August 2 (Sat.) to August 10 (Sun.), 2014

Visitors: 10,950

This year is the 13th anniversary of both the completion of VERA Ishigaki-jima Station and the Star Festival of the Southern Island. Approximately 8,000 visitors attended the dimmed-light stargazing event even though it was cloudy.

In addition, the first meteorite exhibition in Okinawa prefecture was held in cooperation with the Nayoro Municipal Astronomical Observatory. The number of visitors was 754. And 734 people visited the annual planetarium show (from August 7 to 10).

The activities at Ishigaki-jima Astronomical Observatory boosts regional promotion like school education, lifelong learning and sightseeing. The cooperation agreement between NAOJ and the Tourism Association of the city of Ishigaki has been finalized concluded. And it is widely recognized that 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

[Regular Open]

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: 48,837

Open facilities: 45-m Radio Telescope, Nobeyama Millimeter Array, Nobeyama Radioheliograph, etc. (just viewing)

[Open House Day]

Date: August 23 (Sat), 2014, 9:30–16:00

Visitors: 2,698

The Nobeyama branch was crowded with 2,698 visitors on the 2014 Open House Day. The theme of the Day was "Radio Astronomy, from Nobeyama to the World!" Like every year, we had two lectures on the theme, which attracted large audiences. One was "From Nobeyama to the World: 45 years of Solar Radio Astronomy" by Dr. Hiroshi Nakajima (NAOJ). The other was "The Radio Universe: Results From Nobeyama and ALMA in South America" by Prof. Ken'ichi Tatematsu (NAOJ). We had some established events such as touch the main reflector panel of 45-m Radio Telescope, radio detector handicrafts, short lectures, and a stamp rally. In addition, the antenna handicrafts and original calendar events by NRO alumni, other project staff members, and volunteers took place. Also the participation of the Nagano Pref. PR character, ARUKUMA, made Nobeyama more festive on that day.

[Jimoto Kansha Day (Thanks Day for the locals)]

Date: November 8 (Sat), 2014, 13:30–19:00

Visitors: 65

The local people have said that they have difficulty participating in the the Open House Day, which occurs during the farming season and they do not have a clear understanding of what we (not only NRO but also Tsukuba and Shinshu Universities) study in Nobeyama. In response 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. We had an introduction lecture from each institute and a guided tour of the NRO. In addition, we tried a star gazing party, which was not held due to bad weather. We got a sense of achievement from the event, hearing a comment "This is the first time I've known what they study here."

4. Okayama Campus

Okayama Astrophysical Observatory

[Open year-round]

Dates: 9:00–16:30 daily

Visitors: 10,867

Open facilities: Window view of 188-cm reflecting telescope

[Special Open House]

Date: August 30 (Sat), 2014, 9:30–16:30

Visitors: 632

The special open house event for FY 2014 was co-hosted with the Okayama Astronomical Museum on August 30 (Sat).

We had two special lecture at 188cm reflecting telescope in the dome. The first lecture, by NAOJ vice-director general Junichi Watanabe, was "Why deviate?

Predicting comets. - Comet ISON as an example -". The second lecture, by Professor Tetsuya Nagata of Kyoto University, was "Kyoto University 3.8-m telescope, the start of construction". The two lectures attracted nearly 140 audience members. The lectures were broadcast over the Internet with assistance from the Public Relations Center. The always-popular tours of the main mirror of the 188-cm reflecting telescope were conducted in the morning and afternoon with maximum capacities of 120 participants. The exhibition of the 50-cm reflecting telescope was conducted in two Tokyo Institute of Technology students. Planetarium showings, solar observations by 15-cm telescope, astronomy-related crafts, constellation/astronomy bingo, and an astronomy quiz rally were held at the Okayama Astronomical Museum. We think many visitors enjoyed themselves. The special open house event was co-hosted with 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 the Asakuchi City Board of Education for their considerable assistance in arranging complimentary shuttle bus service between the Observatory and Kamogata Station on the JR San'yo Main Line.

[Special Stargazing Party]

Date: April 4 (Sat), 2014, 18:00–22:15

Visitors: 92

159 applications for 519 applicants were received.

Date: November 1 (Sat), 2014, 17:00–21:15

Visitors: 78

121 applications for 328 applicants were received.

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. Due to rain, both of the special stargazing parties conducted facility tours instead.

5. Subaru Telescope

[Summit Facility]

Dates open for public tour: 99 (these dates are listed in the public tour program page at the Subaru Telescope's web site, the tour was suspended in December due to the telescope work)

Public tour visitors: 559

Special tour visitors: 111visits, 717 visitors

As some special tours were conducted during public tour programs, the total number of actual visitors was 1,252.

[Base Facility]

Special tour visitors: 41 visits, 451 visitors

[Public information]

Primary means of public information is posting at the official website http://subarutelescope.org

- Science results from the Subaru Telescope – 10 Japanese and 11 English articles
- Depicting special activities or making announcement on CfA, recruitment – 24 Japanese and 21 English articles

Supplemented by the social media via official accounts such as Twitters, Facebook page, and YouTube – 197 Japanese and 138 English posting

- 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)

1. Gave a lecture at the Subaru Telescope's base facility in Hilo

2014

May 29: Subaru Telescope staff gave a lecture at the Subaru Telescope's base facility in Hilo for the "Senior University Net".

June 10: Subaru Telescope staff gave a lecture at the Subaru Telescope's base facility in Hilo for the "Higashi Hiroshima Chamber of Commerce" and "Japanese Chamber of Commerce and Industry in Hawaii".

June 26: Subaru Telescope staff gave a lecture at the Subaru Telescope's base facility in Hilo for the NASA Explorer Team (teachers from Key Penninsula Middle School).

July 21: Subaru Telescope staff gave a lecture at the Subaru Telescope's base facility in Hilo for the Ritsumeikan High School students from Kyoto and Waiakea High School students in Hilo.

July 25: Subaru Telescope staff gave a lecture at the Subaru Telescope's base facility in Hilo for the Sumoto High School students from Hyogo.

August 12: Subaru Telescope staff gave a lecture at the Subaru Telescope's base facility in Hilo for the junior high school students from Nago City of Okinawa.

August 22: Subaru Telescope staff gave a lecture at the Subaru Telescope's base facility in Hilo for the Kawagoe High School students from Saitama.

September 12: Subaru Telescope staff gave a lecture at the Subaru Telescope's base facility in Hilo for the Tokyo City University students.

September 16: Subaru Telescope staff gave a lecture at the Subaru Telescope's base facility in Hilo for the Toho University students.

September 23: Subaru Telescope staff gave a lecture at the Subaru Telescope's base facility in Hilo for the Sapporo Nihon University Senior High School students from Hokkaido.

September 26: Subaru Telescope staff gave a lecture at the Subaru Telescope's base facility in Hilo for the University of Ryukyus students.

October 8: Subaru Telescope staff gave a lecture at the Subaru Telescope's base facility in Hilo for the Masuda High School students from Shimane.

October 13: Subaru Telescope staff gave a lecture at the Subaru Telescope's base facility in Hilo for the Meijo University High School students from Aichi.

October 17: Subaru Telescope staff gave a lecture at the Subaru Telescope's base facility in Hilo for the Namiki High School students from Ibaraki.

November 10: Subaru Telescope staff gave a lecture at the Subaru Telescope's base facility in Hilo for the Kunori Gakuen High School students from Yamagata.

November 13: Subaru Telescope staff gave a lecture at the Subaru Telescope's base facility in Hilo for the Group from Germany (MPIA, "Sterne und Weltraum").

December 2 & 3: Subaru Telescope staff gave a lecture at the Subaru Telescope's base facility in Hilo for the Senri High School students from Osaka.

2015

January 5: Subaru Telescope staff gave a lecture at the

Subaru Telescope's base facility in Hilo for the Wakimachi High School students from Tokushima.

January 8: Subaru Telescope staff gave a lecture at the Subaru Telescope's base facility in Hilo for the Seisho High School students from Nara.

January 27: Subaru Telescope staff gave a lecture at the Subaru Telescope's base facility in Hilo for the Sanbonmatsu High School students from Kagawa.

March 6: Subaru Telescope staff gave a lecture at the Subaru Telescope's base facility in Hilo for the Iiyama-Kita High School students from Nagano.

March 8: Subaru Telescope staff gave a lecture at the Subaru Telescope's base facility in Hilo for the Ritsumeikan High School students from Kyoto and Waiakea High School students in Hilo.

March 10: Subaru Telescope staff gave a lecture at the Subaru Telescope's base facility in Hilo for the Ritsumeikan Uji High School students from Kyoto.

2. Remote presentation

2014

May 22 & 23: Subaru Telescope staff gave a presentation via remote conferencing system from the Subaru Telescope's base facility in Hilo to the Nagoya City Museum in Aichi.

June 17: Subaru Telescope staff gave a presentation via remote conferencing system from the Subaru Telescope's base facility in Hilo to Izumo High School in Shimane.

June 27: Subaru Telescope staff gave a presentation via remote conferencing system from the Subaru Telescope's base facility in Hilo to the DNA Expedition Service Lab/ Seodaemun Museum of Natural History in Korea.

July 3: Subaru Telescope staff gave a presentation via remote conferencing system from the Subaru Telescope's base facility in Hilo to the Masuda City for its Science Town event in Shimane.

July 11: Subaru Telescope staff gave a presentation via remote conferencing system from the Subaru Telescope's base facility in Hilo to Tokyo Mirai University in Tokyo.

July 22 & 29: Subaru Telescope staff gave a presentation via remote conferencing system from the Subaru Telescope's base facility in Hilo to University of Ryukyus in Okinawa.

July 25: Subaru Telescope staff gave a presentation via remote conferencing system from the Subaru Telescope's base facility in Hilo to the Saji Astro Park in Saji City of Tottori.

July 28: Subaru Telescope staff gave a presentation via remote conferencing system from the Subaru Telescope's base facility in Hilo to Wakayama Shin-ai High School in Wakayama.

August 1: Subaru Telescope staff gave a presentation via remote conferencing system from the Subaru Telescope's base facility in Hilo to the Galaxity in Adachi Ward of Tokyo.

September 5: Subaru Telescope staff gave a presentation via remote conferencing system from the Subaru Telescope's base facility in Hilo to the Galaxity in Adachi Ward of Tokyo.

September 6: Subaru Telescope staff gave a presentation via remote conferencing system from the Subaru Telescope's base facility in Hilo to the Science Museum in Tokyo for its "Universe" live show.

December 5: Subaru Telescope staff gave a presentation via remote conferencing system from the Subaru Telescope's base facility in Hilo to Arakawa 3rd Junior High School in Tokyo.

3. Lectures, demonstrations, workshops etc. in the vicinity

2014

July 21-25: Subaru Telescope staff provided astronomy workshop during the Pacific Astronomy and Engineering Summit (including high school students from Japan, U.S.A, Canada, China, and India).

September 13-14: Subaru Telescope staff gave a lecture and panel discussion at the HawaiiCon in Waikoloa.

November 15: Subaru Telescope staff made a presentation at the Office of Mauna Kea Management talk for volunteers at Hale Pohaku.

2015

January 24: Subaru Telescope staff provided astronomy four workshop during the Onizuka Science Day at the University of Hawaii at Hilo.

February 7: Subaru Telescope staff gave a lecture for the Universe Tonight at Visitor Information Station, Maunakea.

March 1-5: For the Journey through the Universe program, Subaru Telescope staff went to 26 classes in local public schools and delivered presentations, hands-on experiences, and other demonstrations.

4. Lectures in Japan

2014

April 2: Subaru Telescope staff gave a lecture at the.Nanbu Iryo Center in Okinawa.

April 4: Subaru Telescope staff gave a lecture at the.Nago City Museum in Okinawa.

May 19: Subaru Telescope staff gave a lecture at the.Ishima Junior High School in Tokushima.

June 7: Subaru Telescope staff gave a lecture at the.Asahi Culture Center in Yokohama.

June 26: Subaru Telescope staff gave a lecture at the.Tohodai Elementary School in Osaka.

July 16: Subaru Telescope staff gave a lecture at the University of Ryukyus in Okinawa.

September 19: Subaru Telescope staff gave a lecture at the. Mitaka 5th Elementary School in Tokyo.

November 15: Subaru Telescope staff gave a Special public lecture at Sendai Astronomical Observatory in Miyagi.

2015

February 12: Subaru Telescope staff gave a lecture at the. Seibudai Niiza Junior High School in Saitama.

March 14: Subaru Telescope staff gave a lecture at the. Across in Fukuoka.

March 15: Subaru Telescope staff gave a lecture at the. Kokura High School in Fukuoka.

March 16: Subaru Telescope staff gave a lecture at the Kokura Junior High School Attached to Fukuoka University of Education in Fukuoka.

5. Others

2014

April 26: Subaru Telescope staff participated in Merrie Monarch Festival Parade with observatory group of Mauna Kea and interacted with local community.

May 3: Subaru Telescope staff provided a big 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.

2015

January 27: Subaru Telescope staff made presentation about the Subaru Telescope at the Onizuka Science Day event at the University of Hawaii at Hilo and interacted with hundreds of families in the local community.

March 1: Subaru Telescope staff provided an exhibition with many hands-on activities about the Subaru Telescope at‘Imiloa Astronomy Center’s open house and interacted with hundreds of families in the local community.

6. Media coverage

Japanese 28, English 8

IX Overseas Travel

Research and Academic Staff Overseas Travel

(Including employees on annual salary system)

category / country/area	Business Trip	Training	Total
Korea	50	0	50
China	16	0	16
Hong Kong	0	0	0
Taiwan	14	0	14
Malaysia	0	0	0
Singapore	0	0	0
Thailand	1	0	1
Philippines	0	0	0
Indonesia	0	0	0
Other areas in Asia	6	0	6
UK	4	0	4
Italy	15	0	15
Germany	23	0	23
France	15	0	15
Russia	18	0	18
Other areas in Europe	39	0	39
USA	100	0	100
Canada	27	0	27
Hawaii	76	0	76
Guam, Saipan	0	0	0
Australia	2	0	2
Other areas in Oceania	0	0	0
Mexico	1	0	1
Brazil	0	0	0
Other areas in South and Central America *	40	0	40
Middle East	5	0	5
Africa	4	0	4
others	0	0	0
Total	456	0	456

* Most travelers to South and Central America went to Chile.

X Award Winners

Award Recipients	Affiliated Division	Job Title	Award	Date
Sakurai, Takashi	Division of Solar and Plasma Astrophysics	Professor	Japan Geoscience Union Fellow	1 May, 2014
Sekiguchi, Kazuhiro	Division of Optical and Infrared Astronomy, Office of International Relations	Professor	Diploma of Honor, Mongolian Academy of Sciences	29 May, 2014
Watanabe, Junichi	Public Relations Center	Vice-Director General, Professor	Diploma of Honor, Mongolian Academy of Sciences	29 May, 2014
Agata, Hidehiko	Public Relations Center	Associate Professor	Diploma of Honor, Mongolian Academy of Sciences	29 May, 2014
Honma, Mareki	Mizusawa VLBI Observatory	Associate Professor	National Institutes of Natural Sciences Young Researcher Award, 2014	15 June, 2014
Hada, Kazuhiro	Mizusawa VLBI Observatory	JSPS Postdoctoral Fellow	Inoue Research Award for Young Scientists, 2014	4 February, 2015
NAOJ Chile Observatory Advanced Technology Center			NAOJ Director General Prize (Research and Education Category)	17 March, 2015
Honma, Mareki	Mizusawa VLBI Observatory	Professor	The PASJ Excellent Paper Award, 2014	19 March, 2015
Inoe, Tsuyoshi	Division of Theoretical Astronomy	Assistant Professor	The ASJ Young Astronomer Award, 2014	19 March, 2015

XI Library, Publications

1. Library

Number of books in each library (2015/3/31)

	Japanese Books	Foreign Books	Total
Mitaka	16,849	45,368	62,217
Okayama	220	3,318	3,538
Nobeyama	1,222	6,260	7,482
Mizusawa	4,942	18,067	23,009
Hawaii	1,512	4,170	5,682
Total	24,745	77,183	101,928

Number of journal titles in each library (2015/3/31)

	Japanese Journals	Foreign Journals	Total
Mitaka	622	774	1,396
Okayama	4	18	22
Nobeyama	16	82	98
Mizusawa	659	828	1,487
Hawaii	18	18	36
Total	1,319	1,720	3,039

2. Publication

Here we list continuing publications produced by NAOJ in FY 2014.
The data is based on publications delivered to the libraries.

Mitaka

01) Report of the National Astronomical Observatory of Japan, Vol. 16, 2 issues
02) Annual Report of the National Astronomical Observatory of Japan (in Japanese), no. 25, 2013, 1 issue
03) Annual Report of the National Astronomical Observatory of Japan (in English), vol. 15, Fiscal Year 2013, 1 issue
04) Annual Report of the National Astronomical Observatory of Japan (in English), vol. 15, Supplement, Fiscal 2012, 1 issue
05) National Astronomical Observatory Reprint, No. 2548–2650, 103 issues
06) Calendar and Ephemeris, 2015, 1 issue
07) NAOJ News, No. 249–260, 12 issues
08) Guide to the National Astronomical Observatory of Japan (Japanese), 1 issue
09) Guide to the National Astronomical Observatory of Japan (English), 1 issue
10) Chronological Scientific Tables, 2015, 1 issue

XII Important Dates

April 1, 2014 – March 31, 2015

2014	
4 April	Spring 2014 Special Stargazing Party held at Okayama Astrophysical Observatory, with 92 visitors in attendance (out of 519 applicants).
13 April	Fifth Open Observatory event held at the Ibaraki University Center for Astronomy and the NAOJ Mizusawa VLBI Observatory Ibaraki Station, with approximately 700 visitors in attendance.
26 April	Subaru Telescope staff participated in Merrie Monarch Festival Parade with observatory group of Mauna Kea and interacted with the local community.
3 May	Subaru Telescope staff provided a big 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.
2 June ~ 6 June	Radio Astronomy Observation training held at Nobeyama Radio Observatory for Undergraduate Students with 12 participants
28 June ~ 29 June	Pre-event workshop held for 5 high school students scheduled to attend the Eighth Z-star Research Team event using the radio telescope at the VERA Mizusawa station to search for masers, to improve the understanding of the participants.
6 July	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 350 visitors in attendance.
21 July ~ 25 July	Subaru Telescope staff provided astronomy workshop during the Pacific Astronomy and Engineering Summit (including high school students from Japan, U.S.A, Canada, China, and India).
28 July ~ 1 August	Facility Guide Week for Educational Organization was carried out at Nobeyama Campus.
1 August ~ 28 September	Fifth International Festival of Scientific Visualization—Connecting with Others Through Science—held with over 1 million visitors attending during the festival period.
2 August ~ 4 August	Eighth Z-star Research Team event held for high school students from Iwate Prefecture, including tsunami-struck areas, with 5 participants attending. The team succeeded in detecting a water-maser signal from an astronomical object.
2 August ~ 10 August	The Southern Island of Star Festival 2014 held together with a special open house event at the VERA Ishigaki-jima Station and Ishigaki-jima Astronomical Observatory with approximately 10,950 visitors to the whole Star Festival. Events included an astronomical observation party at the Ishigaki-jima Astronomical Observatory, attended by 877 visitors; and a special public opening of the VERA Station attended by 264 visitors.
4 August ~ 5 August	"Summer Break Junior Astronomical Classes + You are Galileo" held in Mitaka.
10 August	The special open house of VERA Iriki station was scheduled to be held jointly with the Yaeyama Kogen Star Festival 2014, but was canceled due to a typhoon.
16 August	A mission debriefing session by JAXA astronaut Koichi Wakata was held as a pre-event of Iwate Galaxy Festival 2014, a special open house day of Mizusawa campus. There were approximately 1,000 visitors in attendance.
18 August ~ 20 August	Chura-boshi Research Team workshop for high school students in Okinawa Prefecture, Fukushima Prefecture and Fukuoka Prefecture held at VERA Ishigaki-jima Station and Ishigaki-jima Astronomical Observatory, with 21 participants in attendance. One team using radio-waves discovered 1 masers. A second team using visible light observations with the Murikabushi telescope discovered 2 asteroids.
23 August	Open House day of Nobeyama Campus. There were 2,698 visitors for this event.
30 August	Iwate Galaxy Festival 2014, a special open house day of Mizusawa campus, held with 847 visitors in attendance.
30 August	Special open house event held at Okayama Astrophysical Observatory, with 632 visitors in attendance.
30 September	The 21th Astronomy Lecture for Science Reporters "The Start of Construction for TMT" held, with 37 participants in attendance. The event was also broadcast over the internet for reporters who could not attend.
19 October	The second "Third-term Election of the Japanese Stars, Starry Sky Summit" was held in Ishigaki-shi through cooperation between the Beautiful Star Astronomical Observatory of Biseicho, Ihara-shi, Okayama and Nobeyama Radio Observatory. 350 guests entered the main event area, were the program included a memorial event (in honor of Tetsuo Hasegawa, ALMA). 1,364 guests attended the planetarium show "Wish upon the Starry Island" which was shown simultaneously (October 17–23) at Ishigaki-jima Astronomical Observatory and Ishigaki-shi.

24 October ~ 25 October	Mitaka Open House Day held, with 4,768 visitors in attendance.
1 November	Fall 2014 Special Stargazing Party held at Okayama Astrophysical Observatory, with 78 visitors in attendance (out of 338 applicants).
8 November	“Jimoto Kansha Day (Thanks Day for the locals)” was held with Tsukuba and Shinshu Universities at Nobeyama Campus. There were 65 local participants.
15 November	The NAOJ/Subaru Telescope lecture meeting 2014 “Subaru Telescope: Looking to Space” held in Sendai Astronomical Observatory Kato Kosaka Hall with 147 visitors in attendance.
25 November	A ceremony for FY 2014 continuous service recognition held. 11 NAOJ staff members were recognized: Kazuhiro Sekiguchi, Junichi Nomaru, Naruhisa Takato, Hidehiko Agata, Yutaro Sekimoto, Hirohisa Hara, Kazuyoshi Sunada, Takuji Tsujimoto, Makoto Miyoshi, Ryutaro Takahashi, Koji Omata.
7 December	A NAOJ lecutre meeting “Cool Univserse: Tracing Our Roots with ALMA” held in Tokyo International Exchange Center, Plaza Heisei, International Conference Hall with 196 visitors in attendence
8 December ~ 11 December	291 astronomers (182 astronomers from 21 overseas countries) gathered and discussed the latest research results by ALMA at The “Revolution in Astronomy with ALMA 3rd Year”, which was held at the Tokyo International Forum hosted by NAOJ.

2015

27 January	Subaru Telescope staff made presentation about the Subaru Telescope at the Onizuka Science Day event at the University of Hawaii at Hilo and interacted with hundreds of families in the local community.
15 February	Star Island 14 open house event of VERA Ogasawara Station held, with 213 visitors in attendance (more than the average year).
1 March ~ 5 March	For the Journey through the Universe program, Subaru Telescope staff went to 26 classes in local public schools and delivered presentations, hands-on experiences, and other demonstrations.
30 March	A ceremony for FY 2014 continuous service recognition for retiring staff members held. 9 staff members were recognized: Masanori Iye, Norio Oshima, Kazuo Ono, Hisashi Koyano, Toshiyuki Sasaki, Kiyoto Shibasaki, Tadayuki Hyuga, Hideo Fukushima, Masami Yutani.

XIII Publications, Presentations

1. Refereed Publications

Aartsen, M. G., et al. including **Flaminio, R.**, **Fujimoto, M. K.**: 2014, Multimessenger search for sources of gravitational waves and high-energy neutrinos: Initial results for LIGO-Virgo and IceCube, *Phys. Rev. D*, **90**, 102002.

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Angeloni, R., et al. including **Helminiak, K. G.**, **Tamura, M.**: 2014, The VVV Templates Project Towards an automated classification of VVV light-curves. I. Building a database of stellar variability in the near-infrared, *A&A*, **567**, A100.

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