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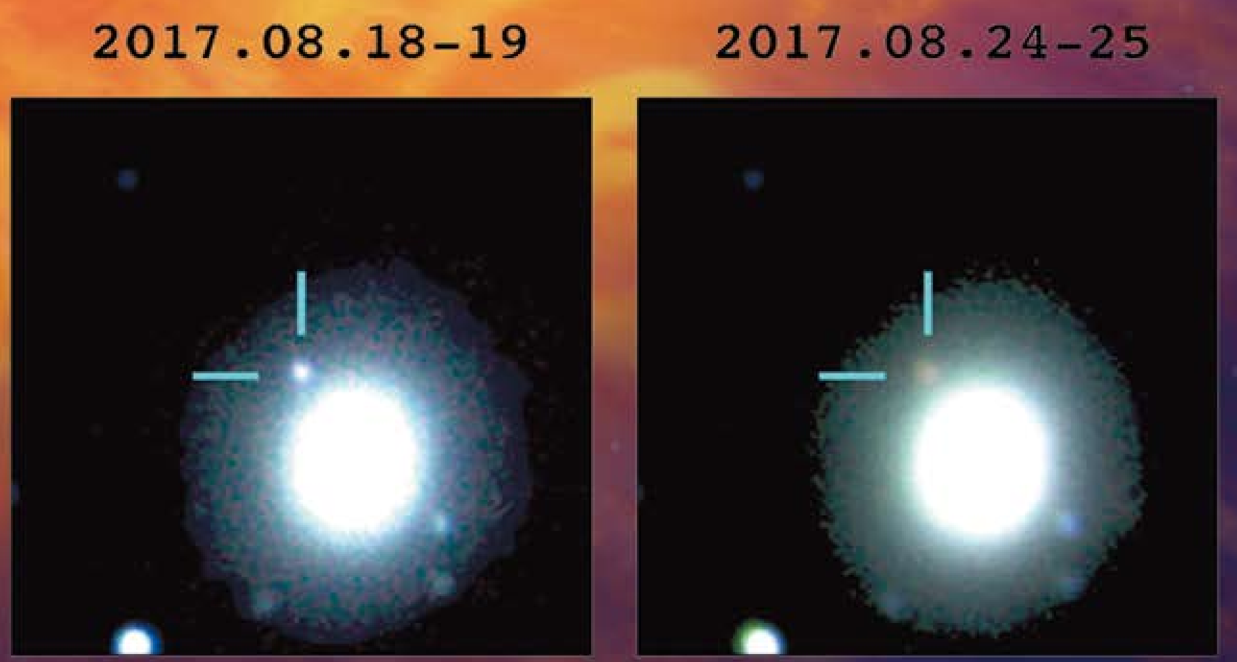

Cover Caption

Artist's impression of the explosion phenomenon (kilonova) accompanying the gravitational wave event GW170817 induced by neutron star merger. The kilonova image detected by the Subaru Telescope and IRSF is shown in the lower right corner. The kilonova emission becomes darker and redder with time.
Credit: NAOJ/Nagoya University

Postscript

Editor Publications Committee
HANAOKA, Yoichiro
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HIROTA, Tomoya
YOSHIDA, Haruo

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

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

Annual Report of the National Astronomical Observatory of Japan

Volume 20, Fiscal 2017

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PREFACE

Saku TSUNETA
Director General of NAOJ

Looking back over the annual report of the National Astronomical Observatory of Japan (NAOJ) for Fiscal Year 2017 (April 2017 – March 2018), we can say that this year saw many important developments in the field of Astronomy. I am pleased to say that NAOJ participated in many of these advancements and discoveries. This year NAOJ was also active developing new instruments to ensure that we will continue to play a major role in world astronomy in the future.

First of course, this year we saw the dawn of a new age of multi-messenger astronomy. The Subaru Telescope detected the electromagnetic counterpart to GW170817, the first recorded gravitational wave produced by the merger of binary neutron stars, which was initially detected by LIGO (Laser Interferometer Gravitational-Wave Observatory) in the United States and Europe's VIRGO in August 2017. Comparing observations of the changes in visible and infrared light over time to numerical simulations helped to finally confirm that rare earth metals such as gold are formed through the process of rapid neutron capture (r-process) in merging neutron stars.

In Japan, NAOJ and the High Energy Accelerator Research Organization are participating in the construction of the Large-scale Cryogenic Gravitational Wave Telescope in Kamioka (Kamioka Gravitational wave detector, KAGRA) led by the Institute for Cosmic Ray Research of the University of Tokyo. KAGRA utilizes the technology and experience gained from NAOJ's TAMA300 300-m laser interferometer gravitational wave detector built in Mitaka Campus in the 1990's. NAOJ was responsible for the basic design of KAGRA, and utilizing the high level engineering skills of the Advanced Technology Center developed a 14-m multilevel ultra-high performance vibration isolator, a transmitted light monitoring system, and also designed and produced baffles to counteract all types of scattered light. NAOJ also established the Kamioka Branch of the Gravitational Wave Project Office and has played a major role in developing KAGRA.

KAGRA hopes to perform joint observation with LIGO and Virgo in the second half of 2019. By joining the world wide gravitational wave detector network, KAGRA will help to improve the localization of gravitational waves sources, as well as greatly improving humanity's gravitational waves observation capabilities. With coordinated follow-up observations by electromagnetic telescopes, expectations for multi-messenger astronomy are very high.

Expectations are also high in radio astronomy. ALMA started the 5th observation cycle (Cycle 5) from October 2017. A total of 1,664 observation proposals were received from all over the world. The total observation time of 4,000 hours using 12-m antennas during Cycle 5 is a substantial increase compared to the 3,000 hours during Cycle 4. This is a credit to the unrelenting efforts of the Joint ALMA Observatory to improve operations. Additionally, for bands 3, 4, and 6 the maximum baseline of 16 km became available, offering unprecedented spatial resolution.

The breakdown of ALMA observation papers by subject is: 23 % "planetary formation", 22 % "interstellar matter/star formation", 22 % "active galaxies", and 33 % miscellaneous areas. Papers utilizing archived data have also been increasing, and now account for 22 % of the total. If we include papers that combine new PI data with archive data, the total rises to 27 %. Japan has been very competitive in publishing research papers using ALMA; it is the nation with the second highest total of papers after the United States.

In 2017, a large number of papers on protoplanetary disks and their varieties were published using ALMA observations. By examining a large number of protoplanetary disks, astronomers hope to better understand the causes of the varieties of exoplanets. Additionally, the discovery of rotating outflows from protostars in Orion has given us a valuable hint to understand protostars and the transport of angular momentum in the disks that surround them.

ALMA has also been contributing to the observation of organic molecules. The organic compound acrylonitrile was discovered in the atmosphere of Saturn's moon Titan. This molecule is thought to be capable of naturally forming membrane-like structures. It is believed that the primeval Earth had an atmosphere similar to Titan's, so this is an important clue to understanding abiogenesis.

Furthermore, observations of a galaxy cluster 9.4 billion light-years away ($z = 1.5$) found that the temperature of the gas in each galaxy decreases for galaxies closer to the periphery of the cluster. This suggests that cold molecular gas belonging to the member galaxies is being stripped off by hot gas from the cluster. This important discovery betters our understanding of the factors contributing to the gradual decline of star formation throughout the Universe since its peak 10 billion years ago.

Last year we reported that ALMA had detected the redshifted 88 μm emission line of ionized oxygen in a distant galaxy discovered by the Subaru Telescope 13.1 billion light-years away ($z = 7.2$). This was the most distant confirmation of oxygen in the Universe. ALMA quickly broke this record with the discovery of oxygen in a galaxy 13.2 billion light-years away ($z = 8.4$), drawing us closer to the epoch of cosmic reionization.

Speaking of the Subaru Telescope, open use at Japan's flagship optical-infrared facility is proceeding well. NAOJ succeeded in creating a wide area three-dimensional map of dark matter using weak gravitational lensing analysis on data from the Hyper Suprime-Cam Subaru Strategic Program (HSC SSP). The scope of this HSC dark matter map is more than 15 times that of previous ones constructed from Hubble Space Telescope data. It provides a detailed picture of the assembly of matter in the Universe over the past 7.5 billion years. Other observations utilizing HSC's ultra-wide field of view discovered a massive cluster of protogalaxies located 12 billion light-years away. Discoveries such as this bring us closer to understanding the composition of the early Universe.

The initial results of the HSC SSP observations were covered in a special edition of the Publications of the Astronomical Society of Japan (PASJ). The data acquired at that time was only about a tenth of the total plan, but its uniqueness enabled the publication of 40 research papers. By 2020, HSC observations are scheduled to cover over 1000 square degrees of the sky with more resolution and depth than ever before. Please watch for future results from HSC.

The Subaru Telescope's next major instrument after HSC, the Prime Focus Spectrograph (PFS), is being developed by a collaboration of seven countries led by Kavli IPMU at the University of Tokyo. PFS is a revolutionary piece of equipment that has approximately 2,400 optical fibers arrayed across a field of view comparable to that of HSC. Light from the sky is directed into four spectrographs, and spectra ranging from 0.38–1.26 μm can be measured simultaneously. Development is being carried out across various institutions, aiming to start scientific observations by 2021. Upon completion, PFS will allow further inquiry into the distance, speed, and chemical composition of the multitude of unidentified celestial bodies captured by HSC. As a result, we expect major progress towards unveiling the mysteries of dark energy, as well as gaining a clearer picture of how galaxies formed throughout the long history of the Universe.

A new exoplanet observation instrument is also under development at the Subaru Telescope. Final adjustments were made at the summit in order for the InfraRed Doppler instrument (IRD) to begin open use in 2018. The Subaru Coronagraphic Extreme Adaptive Optics (SCExAO), which allows for direct observation of exoplanets, and the Coronagraphic High Angular Resolution Imaging Spectrograph (CHARIS) are already available for open use. The development and operation of these instruments are led by the Astrobiology Center, which was established by the National Institutes of Natural Sciences in 2015. In December 2017, the NAOJ Extrasolar Planet Detection Project Office dissolved and relocated to the Astrobiology Center. Progress in not only exoplanet research, but also astrobiology, is expected from coordination between the Astrobiology Center and NAOJ.

At Okayama Astrophysical Observatory, which supported Japan's astronomical research for 57 years, open use observations concluded at the end of 2017. Okayama Astrophysical Observatory served as the cornerstone to elevate Japanese astronomy to the world level during the postwar reconstruction period. It fostered many researchers, and was a driving force behind the very successful Subaru Telescope. In the future, we will shift our focus to the open use for Japanese universities on the Seimei Telescope, Kyoto University's telescope in Okayama Campus. University researchers will assume the operation of the Okayama Astrophysical Observatory telescopes, with support from NAOJ. The Okayama 188-cm Reflector Telescope has produced outstanding achievements, such as discovering over 30 exoplanets. We expect even better results from it in its new role as a dedicated exoplanet telescope.

We also have high hopes for the Thirty Meter Telescope (TMT) Project, a five-nation collaboration between Japan, the United States, Canada, China, and India to construct an extremely large telescope with a 30-meter diameter primary mirror. It is expected to produce groundbreaking results through exploration of terrestrial exoplanets, tracing of the early history of the Universe, identification of dark energy, and other research activities. NAOJ is in charge of some of the key components of TMT, including fabrication of the telescope structure and the primary mirror. The construction site is located on Maunakea on the Island of Hawai'i; however, on-site construction has been suspended for three years, becoming a cause of concern for all involved. Still, design and fabrication of the respective work responsibilities have progressed steadily in Japan, as well as the other countries, throughout the delay in on-site construction.

The State of Hawai'i Board of Land and Natural Resources (BLNR) approved the sublease agreement executed between the University of Hawai'i in charge of the management of the Maunakea lands and the TMT International Observatory (TIO) in July 2014, and in September 2017, granted the Conservation District Use Permit (CDUP) that is required to build in the Maunakea summit area. Lawsuits were filed in response to the BLNR decisions. But the Supreme Court of Hawai'i ruled that there are no problems in the sublease agreement in August 2018, and in October of the same year the court found the CDUP to be valid. Having continuously engaged in a number of dialogues with the community of Hawai'i, we have obtained its greater support and understanding, and are currently proceeding carefully in discussions with stakeholders in Hawai'i to prepare for resuming construction expeditiously.

The scope of astronomy has grown to encompass fields ranging from basic physics to life sciences, making cooperation with physicists, chemists, and biologists vital. University researchers also contribute greatly to the production of research results, as well as to the development of new observational instruments. NAOJ's large-scale observational facilities provide the foundation of an effective dual support system for university researchers. The facilities offer the researchers open use observation time to pursue their own research and also provide a platform for the development of major instrumentation with external funding acquired by the researchers.

There have been concerns about the decline of science in Japan. Eleven of the fourteen fields of natural sciences, which include physics, chemistry, medical science, and materials science, have experienced drops in the number of scientific papers published. And reports have indicated that even the fields that aren't experiencing drops are falling behind the world average. However, astronomy is the only field of study experiencing a growth in scientific articles while also exceeding worldwide averages. Among the fourteen divisions of natural sciences in Japan, Astronomy also has the highest share of papers published worldwide. (Refer to "What price will science pay for austerity?" Nature 543, S10–S15 (23 March 2017), https://dx.doi.org/10.1038/543S10a)

The Subaru Telescope and ALMA have been major milestones in Japanese science. The rapid development of Japanese astronomy, as demonstrated by large-scale observational facilities such as these, acted as a catalyst for new developments and stimulation in Japanese science and research facilities. The remarkable scientific returns enabled by astronomy have increased Japan's international profile, while instilling a sense of national pride, and developing an interest in science among the Japanese people, especially the younger generations. In keeping with its duty as part of the Inter-University Research Institute Corporation, NAOJ will strive to pioneer new technology while proposing and implementing large-scale international collaborative projects dealing with fascinating subjects.

Saku Tsuneta

I Scientific Highlights

(April 2017 – March 2018)

Formation of Close-in Super-Earths by Giant Impacts: Effects of Initial Eccentricities and Inclinations of Protoplanets

MATSUMOTO, Yuji (Academia Sinica)
KOKUBO, Eiichiro (NAOJ)

Nowadays, dozens super-Earths, which are composed rock or ice, are already found in orbits that are close to their stars (e.g., [1]). Recent observations have reveled the orbital eccentricity (e) and orbital inclination (i) distributions of super-Earths [2,3]. We considered how the eccentricities and inclinations of close-in super-Earths are determined in the giant impact stage. These evolve through gravitational scattering and collisions between protoplanets in gas-free environments. The eccentricities are increased by scattering between protoplanets [4], and they are damped by collisions [5]. The collisions tend to occur at the point where their orbits initially crossing since the small scattering cross section of protoplanets in the close-in region. The orbital crossing initially occurs around the apocenter of the inner protoplanet and the pericenter of the outer planet. As a result, the velocity of merged body is about equal to the Kepler velocity.

We studied the effects of the initial e and i of protoplanets on the final orbits of planets formed by giant impacts [6]. We performed N-body simulations of the protoplanet accretion over 500 times. Numerical computations were carried out on the PC cluster at the Center for Computational Astrophysics, NAOJ.

We found that the final eccentricities do not depend on initial eccentricities, when orbits of protoplanets are initially not crossed. While the eccentricities gradually increase with each collision if initial e is small, they gradually decrease when initial e is large. The final planets become similar due to these relaxations.

On the other hand, the initial inclinations are not relaxed. When the initial i is small, the velocity dispersions normal to the disk midplane keep small through scattering, and the final planets have small i. If the initial i is large, collisions do not occur immediately after orbital crossing, since they can collide only in parts of their orbits. Protoplanets experience more scattering until a collision, which make i larger. This is why the merged protoplanets have larger i. And, final inclinations of planets depend on initial inclinations. The eccentricities In large i cases are larger those in small i cases due to more scattering. We found that the inclinations of observed planets are consistent with our results, if protoplanets initially have ~ 10^{-3}–10^{-2} rad inclinations (Figure 1, [6]).

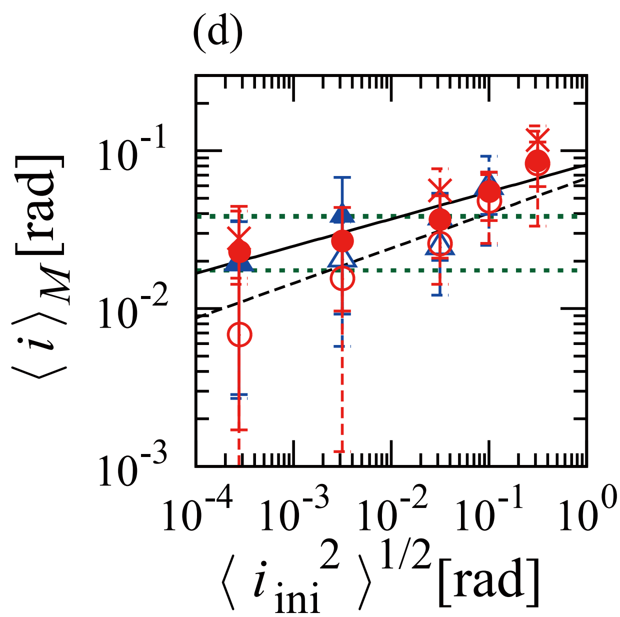

Figure 1: This figure is from the panel (d) of Figure 9 in [6]. The mass-weighted inclination ($\langle i \rangle_M$) is shown as a function of the initial inclination dispersion of protoplanets ($\langle i_{\rm ini}^2 \rangle^{1/2}$). The error bars indicate the standard deviation. The filled symbols are the results of models that initial number of protoplanets is $N_{\rm ini}$ = 16 (models N16), the open symbols are those of models N8, and crosses are those of models N32. The initial eccentricity dispersions are different between red circles and blue triangles. The solid and dashed lines are the fits by the least-squares-fit method for models. The dotted lines shows the mode of the mutual inclination [2,3].

References

[1] Mullally, F., et al.: 2015, *ApJS*, **217**, 31.
[2] Fabrycky, D. C., et al.: 2014, *ApJ*, **790**, 146.
[3] Xie, J. W., et al.: 2016, *P. Natl. Acad. Sci. USA*, **113**, 11431.
[4] Kokubo, E., Ida, S.: 2002, *ApJ*, **581**, 666.
[5] Matsumoto, Y., Nagasawa, M., Ida, S.: 2015, *ApJ*, **810**, 106 .
[6] Matsumoto, Y., Kokubo, E.: 2017, *AJ*, **154**, 27.

Statistical Study of the Magnetic Field Orientation in Solar Filaments

HANAOKA, Yoichiro, SAKURAI, Takashi
(NAOJ)

We have been carrying out full-Sun, full-Stokes spectropolarimetric observations using the He I 1083.0 nm line since 2010. The He I 1083.0 linear polarization signals of solar filaments show the magnetic field in filaments. Figure 1 shows a filament observed in Hα and in He I 1083.0. The linear polarization signals in panel (b) is approximately parallel to the fine structures seen in the Hα image in panel (a), and they are almost aligned. We can define the average direction of the magnetic field, and it deviates clockwise with respect to the filament axis.

We have carried out a statistical study of the average orientation of the magnetic field in filaments with respect to their axes for 438 samples [1]. Figure 2 shows the relation between the latitude and the deviation of the average magnetic field of filament samples. This figure show a clear hemispheric tendency; most filaments in the northern (southern) hemisphere show the clockwise (counterclockwise) deviation of the average magnetic field direction. The deviation angles of the magnetic field from the axes have the peak around 10–30° (the light-green belts in Figure 2). Such a hemispheric tendency has been studied for the chirality of the fine structures in filaments and the magnetic field in prominences, and our results are consistent with them. Therefore, our results confirm the hemispheric tendency of the filament magnetic fileds with the direct measurements of the magnetic field in filaments for the first time.

There is an interesting feature in the filaments which violate the hemispheric tendency; the alignment of the background magnetic field of such filaments is in many cases opposite to that of active regions following the Hale-Nicholson law.

A filament is considered to be located at the bottom of a magnetic flux rope, which often erupts into the interplanetary space as a part of a coronal mass ejection (CME). Therefore, our observation of the filament magnetic field can be used to predict the magnetic field of CME flux ropes, which is the key to investigate their impact to the geomagnetic field.

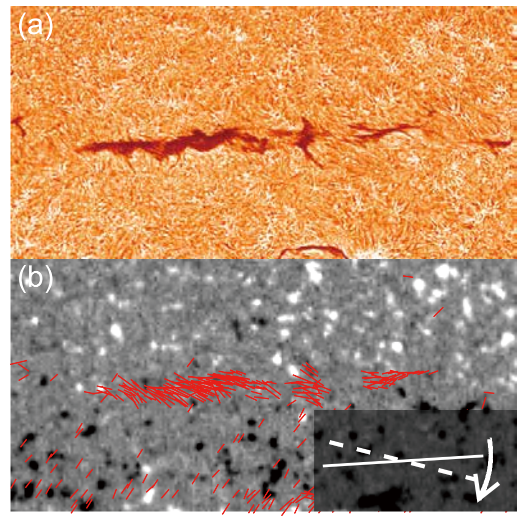

Figure 1: A filament (located in the northern hemisphere) observed on 2014 November 23. The celestial north is to the top. (a) Hα image of the filament and (b) the linear polarization signals (> 0.1 %) represented by red lines drawn on the photospheric magnetogram. At the lower-right corner, the approximate direction of the axis of the filament is shown with a solid line, and the average direction of the linear polarization signals is shown with a dashed line.

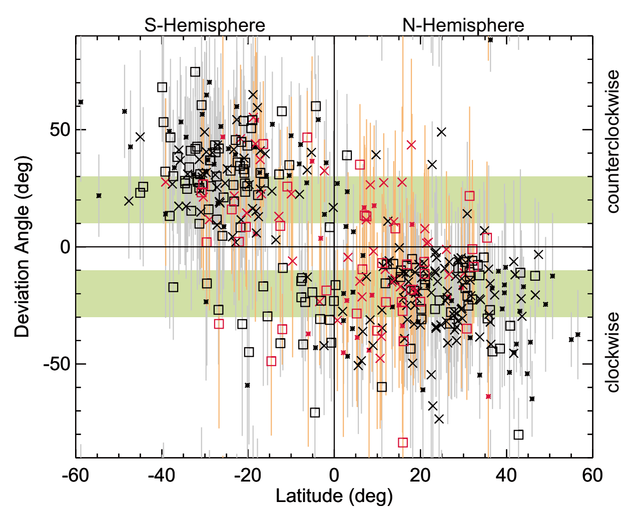

Figure 2: The relation between the latitude of the filaments and their average deviation angle. Black symbols represent filaments in the quiet areas, and red symbols represent those in the active areas. The cross symbols correspond to the filaments with the preceding positive polarity, and the box symbols correspond to the filaments with the preceding negative polarity. The dots show the filaments where the alignment of the polarity cannot be defined clearly. The vertical lines are error bars.

Reference

[1] Hanaoka, Y., Sakurai, T.: 2017, *ApJ*, **851**, 130.

ALMA Reveals a Rotating Dense Molecular Torus in NGC 1068

IMANISHI, Masatoshi, NAKANISHI, Kouichiro, IZUMI, Takuma (NAOJ)
WADA, Keiichi (Kagoshima University)

Active galactic nuclei (AGNs) emit strong radiation from the compact nuclear regions of galaxies. It is widely believed that a mass-accreting supermassive black hole (SMBH) is present at the center, surrounded by toroidally distributed (torus shaped) gas and dust which are thought to be rotating under the gravitational potential of the central SMBH. If this kind of gas and dust torus is present, various observational results of AGNs can naturally be explained (the so-called AGN unified model), so that researchers believe that such a torus is present. However, since the torus is spatially very compact, < 10 pc in physical size or < 0.15 arcsec at the distance of 15 Mpc, its observational understanding is still highly incomplete. Thanks to the advent of ALMA with high spatial resolution observing capability, our understanding of the AGN torus is expected to improve a lot.

NGC 1068 (z=0.0037, distance ~14 Mpc) is a nearby well-studied AGN. From previously revealed spatial distribution of optical ionized gas emission and radio jet, there is a consensus that the torus should be located along the almost east-west direction. ALMA high-spatial-resolution CO J=6–5 observational results were reported, but its dynamical direction is along the almost north-south direction, rather than the expected east-west torus direction. The results are largely different from the classical torus picture.

We have observed NGC 1068, with 0.04 arcsec × 0.07 arcsec resolution, in the HCN J=3–2 (265.89 GHz) and HCO^+ J=3–2 (267.56 GHz) lines, both of which are known to be good dense gas tracers. We have detected east-west oriented dense molecular emission and rotation (Figure 1), as expected. However, the observed rotation is slower than that expected from Keplerian motion dominated by the gravity of the central SMBH. Dense molecular emission and velocity dispersion are asymmetric. We interpret that the dense molecular emission is brighter at the western part of the central mass-accreting SMBH, due to higher turbulence and resulting reduced line opacity. We have also found that dense gas at the eastern (western) part of the torus is redshifted (blueshifted) (Figure 1), while that at the central part of the host galaxy outside the torus, along the torus direction, is counter-rotating (i.e., eastern region is blueshifted and western region is redshifted) (Figure 2), suggesting that some external process happened in the past. This may be the result of a minor galaxy merger [1].

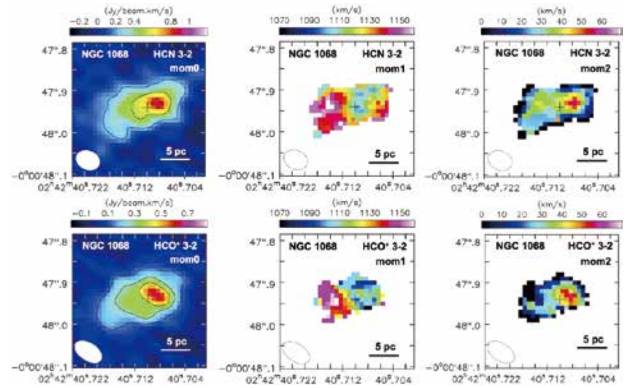

Figure 1: Integrated intensity (Left), intensity-weighted mean velocity (Middle), and intensity-weighted velocity dispersion (Right) maps of the HCN J=3–2 (Top) and HCO^+ J=3–2 (Bottom) emission lines in the torus region with ~10 pc scale around the mass-accreting SMBH (denoted as the "+" mark). Gas at the eastern part (left side of the figures) is redshifted, and that at the western part (right side of the figures) is blueshifted. At the western part, both lines are brighter and velocity dispersion is larger.

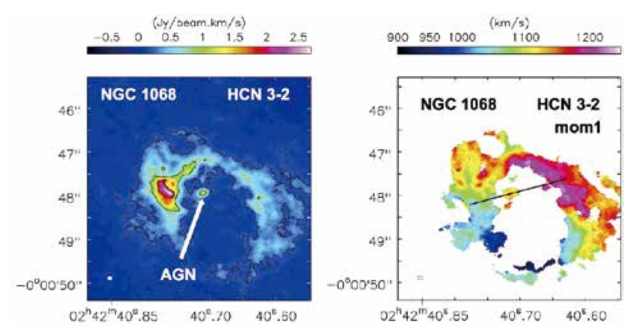

Figure 2: Integrated intensity (Left) and intensity-weighted mean velocity (Right) maps of the HCN J=3–2 emission line at the central ~350 pc region of the host galaxy. The mark "AGN" (in the left panel) corresponds to the torus in Figure 1. Dense molecular gas at the eastern (western) part outside the torus along the torus direction (solid line in the right panel) is blueshifted (redshifted), suggesting counter-rotation of dense gas inside and outside the torus. The HCO^+ line also shows virtually the same properties.

Reference

[1] Imanishi, M., et al.: 2018, *ApJL*, **853**, L25.

ALMA Dense Molecular Gas Observations of IRAS 20551−4250

IMANISHI, Masatoshi, NAKANISHI, Kouichiro, IZUMI, Takuma
(NAOJ)

Ultraluminous infrared galaxies (ULIRGs; $L_{IR} > 10^{12} L_{\odot}$) are formed by gas-rich galaxy mergers and are shining brightly in the infrared due to thermal emission from dust heated by deeply buried starbursts and AGNs (= mass-accreting supermassive black holes; SMBHs). Distinguishing the hidden energy sources of ULIRGs is important to understand the star formation and SMBH mass growth during galaxy mergers. Since starbursts and AGNs have different energy generation mechanisms, physical and chemical effects to the surrounding molecular gas should be different. It is expected that starbursts and AGNs can be distinguished based on molecular rotational J-transition line flux ratios at the (almost) dust-extinction-free (sub)millimeter wavelength range.

It has been argued that HCN rotational J-transition line fluxes, relative to HCO^+, are stronger in AGNs than in starbursts. Possible reasons include (a) high HCN abundance in AGNs, and (b) vibrational excitation of HCN by infrared radiative pumping (by absorbing 14 μm photons) and the increase of the rotational J-transition line fluxes at the vibrational ground level due to decay back. IRAS 20551−4250 (z=0.043) is a ULIRG which contains a luminous buried AGN and shows a higher HCN-to-HCO^+ flux ratio than starbursts (Figure 1). Thanks to small molecular line widths, vibrationally excited HCN and HNC emission lines were clearly detected ([1]), so that this ULIRG is a good target to quantitatively estimate the contribution from (b). We have observed this ULIRG at multiple J-transition lines of HCN, HCO^+, and HNC (Figure 2), and obtained the following results. (1) Main to isotopologue molecular line flux ratios at J=3–2 is smaller for HCN than HCO^+ and HNC, due to larger line opacity of HCN. An enhanced HCN abundance is suggested. The intrinsic HCN-to-HCO^+ flux ratios corrected for line opacity in IRAS 20551−4250 will increase, further deviating from starbursts. (2) High-J to J=1–0 flux ratios are higher for HNC than HCN (Figure 3, left), which cannot be explained by collisional excitation. Inclusion of infrared radiative pumping, by putting an AGN at 30–100 pc from molecular gas, can largely explain this result (Figure 3, right). However, the infrared radiative pumping rate is comparable for HCN and HCO^+, so that this is not a main mechanism to enhance the HCN-to-HCO^+ flux ratios [1].

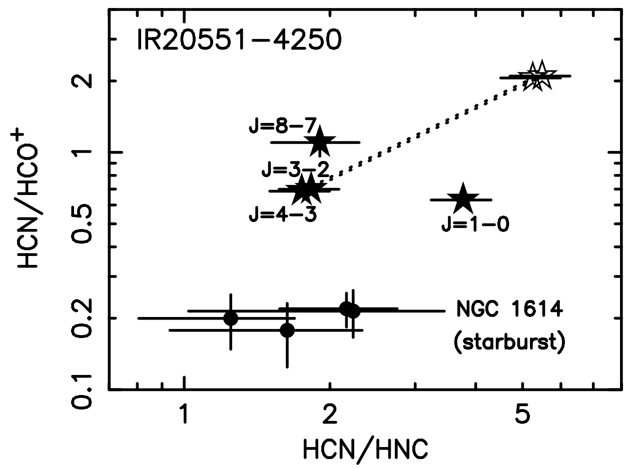

Figure 1: Flux ratios of HCN, HCO^+, and HNC which probe dense molecular gas. In IRAS 20551−4250, the HCN-to-HCO^+ flux ratios at multiple J-transitions (J=1–0, J=3–2, J=4–3, and J=8–7) are higher than that of the starburst galaxy NGC 1614 at J=3–2. For the J=3–2 and J=4–3 lines of IRAS 20551−4250, intrinsic flux ratios corrected for line opacity are also plotted as open stars (connected to the observed ratios by dotted lines).

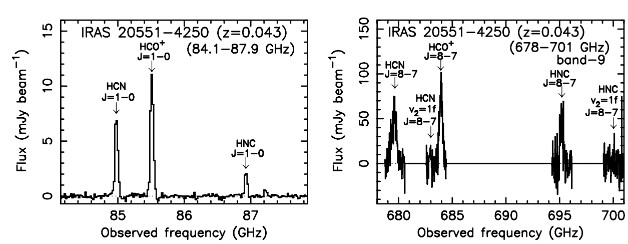

Figure 2: Examples of ALMA spectra. HCN, HCO^+, HNC J=1–0 and J=8–7 emission lines are clearly detected.

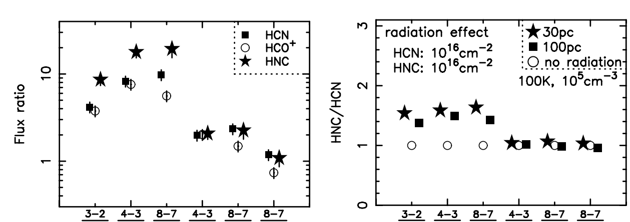

Figure 3: (Left): High-J to low-J flux ratios. High-J to J=1–0 flux ratios are higher for HNC than HCN, which cannot be explained by collisional excitation, based on critical density comparison. (Right): Calculations of molecular line flux ratios in the case of (i) collisional excitation only and (ii) inclusion of infrared radiative pumping by putting an AGN at 30–100 pc from molecular gas. In case (ii), the increase of the high-J to J=1–0 flux ratios is higher for HNC than HCN, because the infrared radiative pumping rate for HNC (by absorbing 21.5 μm photons) is higher than that of HCN.

Reference

[1] Imanishi, M., et al.: 2017, *ApJ*, **849**, 29.

General Relativistic Radiation MHD Simulations of Supercritical Accretion onto a Magnetized Neutron Star: Modeling of Ultraluminous X-Ray Pulsars

TAKAHASHI, Hiroyuki, OHSUGA, Ken
(NAOJ)

Gas accretion onto compact objects such as black holes (BHs) or neutron stars (NSs) is known as one of the most energetic phenomena in the universe. These systems are powered by liberating the gravitational energy through mass accretion, so that the mass accretion rate is an important key parameter determining their activities. In particular, the supercritical accretion, where the accretion rate exceeds the critical rate $\dot{M}_{\rm crit}$ ($\equiv L_{\rm Edd}/c^2$, $L_{\rm Edd}$ and c are the Eddington luminosity and light speed), is of interest since the large amount of gas falls onto central objects. Such energetic phenomena are thought to happen around the black hole since the black hole can swallow the gas and energy.

A recent finding of pulsations in ultraluminous X-ray sources (ULXs) changes the situation. The X-ray pulsation with a period of P = 1.37 s and its time derivative $\dot{P} \simeq -2 \times 10^{-10}$ s s^{-1} has been observed from M82 X-2 [1]. After this notable discovery, X-ray pulsations have been observed in other two ULXs [2,3]. These observational facts indicate that a supercritical accretion happens onto a NS (namely, ULX Pulsar), since the luminosity of these ULX Pulsars highly exceeds the Eddington luminosity for the neutron stars.

In this paper, we, for the first time, performed the General Relativistic Radiation Magnetohydrodynamic (GR-RMHD) simulations of supercritical accretion onto the strongly magnetized neutron star [4]. Figure 1 shows results of GR-RMHD simulations. NS is situated at the origin. Far from the NS, a geometrically thick, supercritical accretion disk is formed. Close to the NS, the accretion disk is truncated around $r = 3R_*$, where R_* = 10 km is the neutron star radius. Inside this radius, the magnetic energy of NS dominates. The gas accretion is prohibited by the magnetic pressure. Alternatively, the angular momentum of the disk gas is efficiently transported to the NS due to the magnetic torque. Then the gas losing angular momentum falls on to the NS along the magnetic field lines. The gravitational energy is liberated by the collision of accreting gas with the NS. Thus, the magnetic pole of NS shines brightly. The angular momentum transport to the NS results in the spin up of NS. The estimated spin up rate in our simulation is about $\dot{P} = -3 \times 10^{-11}$ s s^{-1}, which is quantitatively consistent with the observed value. Thus, our results support the scenario of supercritical accretion onto the NS.

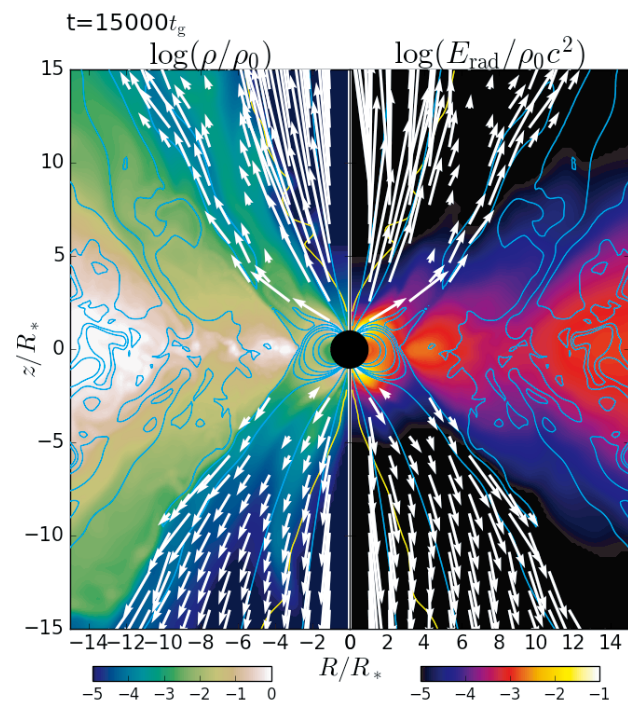

Figure 1: Supercritical accretion onto NS using GR-RMHD simulations. Color shows mass density (left) and radiation energy density (right), and arrows show fluid velocity (left) and radiation flux (right). Contours show magnetic field lines.

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Cyanopolyyne Chemistry in High-Mass Star-Forming Regions

TANIGUCHI, Kotomi, SAITO, Masao
(NAOJ)

Cyanopolyynes ($HC_{2n+1}N$; n=1, 2, 3, ...) are one of the representative carbon-chain series. In general, HC_3N, the shortest member of cyanopolyynes, is detected from starless cores and star-forming cores, while longer cyanopolyynes (i.e., HC_5N and HC_7N) are abundant in starless cores and deficient in star-forming cores.

The chemical composition around young stellar objects (YSOs) is key to the initial chemical condition and/or star formation processes. Figure 1 shows the chemical diversity around YSOs. In low-mass star-forming regions, chemically two types have been found: hot corino (complex organic molecules (COMs)-rich) and warm carbon chain chemistry (WCCC; carbon-chain-rich). The different starless core phases are considered to be a factor to bring the difference between hot corino and WCCC; long and short starless core phases lead hot corino and WCCC, respectively [1]. In high-mass star-forming regions, hot core sources, where COMs are abundant as well as hot corino, have been found, while no counterpart of WCCC source has been confirmed.

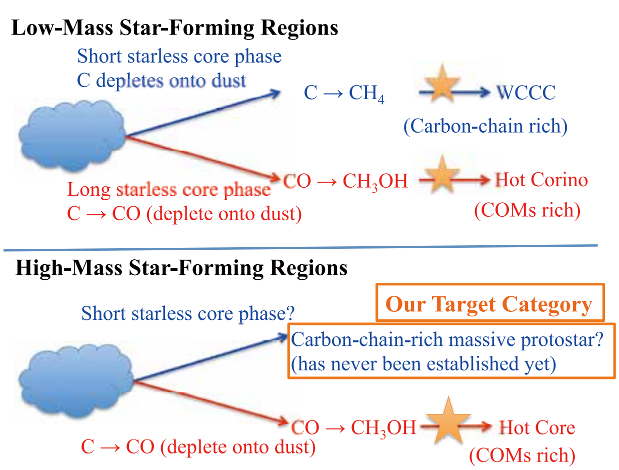

Figure 1: Chemical diversity around YSOs.

We carried out observations of long cyanopolyynes toward four massive young stellar objects (MYSOs; G10.30−0.15, G12.89+0.49, G16.86−2.16, and G28.28−0.36) associated with the 6.7 GHz CH_3OH masers with the Nobeyama 45-m radio telescope and the Green Bank 100-m telescope (GBT) [2]. HC_5N has been detected from all of the four sources and HC_7N has been detected from the three sources except for G10.30−0.15 with the GBT. We also detected the high excitation energy (E_u/k ~ 100 K) lines of HC_5N from the three sources, except for G10.30−0.15, with the Nobeyama 45-m radio telescope. Such high excitation energy lines cannot be detected if HC_5N exists in cold molecular clouds. Therefore, the detection of these lines means that HC_5N exists in the warm gas around MYSOs. We found a possibility of the chemical diversity among MYSOs; G28.28−0.36 shows the highest HC_5N abundance without a thermal CH_3OH line observed with the GBT, while G12.89+0.49 shows the lowest HC_5N abundance with a strong thermal CH_3OH emission line. From the results, G28.28−0.36 seems to be a good candidate of a counterpart of WCCC source in high-mass star-forming regions.

In low-mass star-forming regions, cyanopolyynes are known to be good chemical evolutional indicators (e.g. [3]). On the other hand, the chemical evolution of cyanopolyynes in high-mass star-forming regions was not clear. We carried out survey observations of HC_3N and HC_5N in the 45 GHz band toward 17 high-mass starless cores (HMSCs) [4] and 35 high-mass protostellar objects (HMPOs) [5] with the Nobeyama 45-m radio telescope [6]. We have detected HC_3N from 15 HMSCs and 28 HMPOs, and HC_5N from 5 HMSCs and 14 HMPOs, respectively. From the Kolmogorov-Smirnov test, the HC_3N column density increases from HMSCs to HMPOs, which may imply that HC_3N is newly formed at HMPO stage. In addition, the HC_3N column density tends to decrease with increasing the luminosity-to-mass ratio, which is a physical evolutional indicator. This suggests that HC_3N is destroyed by stellar activities (e.g., UV radiation).

Our studies are on-going projects. Current our conclusion is that cyanopolyynes are good candidates of chemical evolutionary indicators in high-mass star-forming regions.

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Formation Mechanisms of Cyanopolyynes in Low-Mass Starless Cores

TANIGUCHI, Kotomi, SAITO, Masao
(NAOJ)

Cyanopolyynes ($HC_{2n+1}N$; n=1, 2, 3, ...) are one of the representative carbon-chain species. Carbon-chain molecules tend to be abundant in low-mass starless cores and deficient in star-forming cores (e.g., [1]). It is important for understanding of the physical conditions and evolution in early low-mass starless cores to reveal formation mechanisms of carbon-chain molecules. However, the formation mechanisms of carbon-chain species are unclear due to shortage of laboratory experimental data.

One method to investigate formation pathways of carbon-chain molecules is ^{13}C isotopic fractionation, i.e., differences in abundance among the ^{13}C isotopologues. At the cyanopolyyne peak in Taurus Molecular Cloud-1 (TMC-1 CP), the ^{13}C isotopic fractionation of HC_3N was derived to be [$H^{13}CCCN$] : [$HC^{13}CCN$] : [$HCC^{13}CN$] = 1.0:1.0:1.4, and the neutral-neutral reaction of "C_2H_2 + CN" was proposed as the main formation pathway of HC_3N [2]. On the other hand, there is no clear difference in abundance among the five ^{13}C isotopologues of HC_5N. From the results, the ion-molecule reactions of "$C_5H_m^+$ + N" followed by the electron recombination reactions were proposed as the main formation mechanism of HC_5N at TMC-1 CP [3].

We carried out observations of the three ^{13}C isotopologues of HC_3N toward two low-mass starless cores, L1521B and L134N, using the J=5–4 rotational lines in the 45 GHz band with the Z45 receiver installed on the Nobeyama 45-m radio telescope [4]. The abundance ratios of the three ^{13}C isotopologues were derived to be [$H^{13}CCCN$] : [$HC^{13}CCN$] : [$HCC^{13}CN$] = 0.98 (±0.14) : 1.00 : 1.52 (±0.16) and 1.5 (±0.2) : 1.0 : 2.1 (±0.4) (1σ) in L1521B and L134N, respectively. From the ^{13}C isotopic fractionation patterns, the reactions of "C_2H_2 + CN" and "CCH + HNC" were proposed as the main formation pathways of HC_3N in L1521B and L134N, respectively. Figure 1 shows the summary of the main formation pathways of HC_3N in low-mass starless cores. Although these three sources have similar physical conditions ($T \sim 10$ K, $n \sim 10^4$–10^5 cm^{-3}), the proposed main formation pathway in L134N is different from those in L1521B and TMC-1. We conducted a chemical network simulation and found that the CN/HNC abundance ratio may be a key factor to produce the difference in the main formation mechanism of HC_3N among the three cold molecular clouds.

We reported the first detection of $HC_5{}^{15}N$ using the J=9–8 rotational line in the 20 GHz band from TMC-1 CP with the Nobeyama 45-m radio telescope [5]. Its column density was derived to be (1.9 ± 0.5) × 10^{11} cm^{-2} (1σ). Applying the double isotope method, the $^{14}N/^{15}N$ ratio of HC_5N was calculated at 344 ± 53. Using the previous data taken from [6] and [2], we estimated the $^{14}N/^{15}N$ ratio of HC_3N at 257 ± 54, which is lower than that of HC_5N. The difference in the $^{14}N/^{15}N$ ratio between HC_5N and HC_3N is considered to be produced during their formation. Since there are possible mechanisms that ^{15}N concentrates into CN in cold gas, the lower ratio of HC_3N implies that the main formation pathway involves CN. The higher $^{14}N/^{15}N$ ratio of HC_5N suggests that the main formation mechanism involves nitrogen atoms, because the $^{14}N/^{15}N$ ratio in the local interstellar medium is ~440. In summary, the suggested main formation mechanisms from ^{15}N isotopic fractionation are consistent with those suggested from ^{13}C isotopic fractionation [2,3].

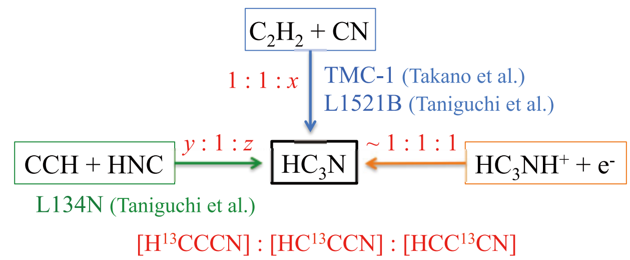

Figure 1: Possible formation mechanisms of HC_3N and the proposed main formation pathways in three cold molecular clouds. Expected ^{13}C isotopic fractionation patterns for each mechanism are shown in red font (discussed in [4] in detail).

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Discovery of H_2O Megamasers in Obscured Active Galactic Nuclei

YAMAUCHI, Aya[1/2], MIYAMOTO, Yusuke[2], NAKAI, Naomasa[3], TERASHIMA, Yuichi[4]
OKUMURA, Taishi[3], ZHOU, Bin[3], TANIGUCHI, Kotomi[2/5], KANEKO, Hiroyuki[2]
MATSUMOTO, Naoko[2/6], SALAK, Dragan[7], NISHIMURA, Atsushi[8], UENO, Saeko[9]

1: JSPS, 2: NAOJ, 3: University of Tsukuba, 4: Ehime University, 5: SOKENDAI, 6: Yamaguchi University, 7: Kwansei Gakuin University, 8: Nagoya University, 9: Kagoshima University

We carried out a survey of H_2O maser emission toward 10 obscured active galactic nuclei (AGNs). The target galaxies were selected from obscured AGNs found by Terashima et al. (2015) [1]. They developed a new method to discover obscured AGNs by utilizing X-ray and infrared data.

We made observations of H_2O maser emission from February to June and December in 2016 using the 45-m telescope of the Nobeyama Radio Observatory.

We newly detected maser features from two AGNs, NGC 1402 and NGC 7738, with a signal-to-noise-ratio (SNR) of above 4, and tentatively detected in NGC 5037 (SNR >3). The isotropic maser luminosities of NGC 1402 and NGC 7738 are $47\,L_\odot$ and $468\,L_\odot$, respectively; they are megamasers (i.e., $\geq 10\,L_\odot$). On the other hand, the isotropic maser luminosity of NGC 5037 is $5\,L_\odot$, which is one order of magnitude smaller than typical luminosities of megamasers.

NGC 7738 shows maser features redshifted and blueshifted from the systemic velocity of the galaxy (Figure 1). Weak features at $V_{\rm LSR} \approx 6573\,{\rm km\,s^{-1}}$ may be systemic velocity features, although SNR is not high enough. Redshifted and blueshifted features are symmetrical with respect to the possible systemic features in velocity. Such symmetrical components are typically seen as water-vapor masers in AGNs, indicating a rotating edge-on disk (its inclination angle is ≈ 90°). Thus the spectrum in NGC 7738 strongly suggests an edge-on maser disk rotating with velocity of $\sim 350\,{\rm km\,s^{-1}}$ (separation between the systemic and the other two features).

NGC 1402 and NGC 7738 have an X-ray spectrum that has a flat continuum and a strong Fe-K emission line, indicating the presence of Compton-thick AGNs in these objects. In the case of NGC 6926, classified as an AGN of the same type by Terashima et al. (2015) [1], H_2O maser emission has already been detected. This type of AGNs may tend to have H_2O maser emission.

Our detection rate of 20 % (2/10) is higher than those of previous surveys (usually several percent). This high detection rate indicates that the selection method is effective.

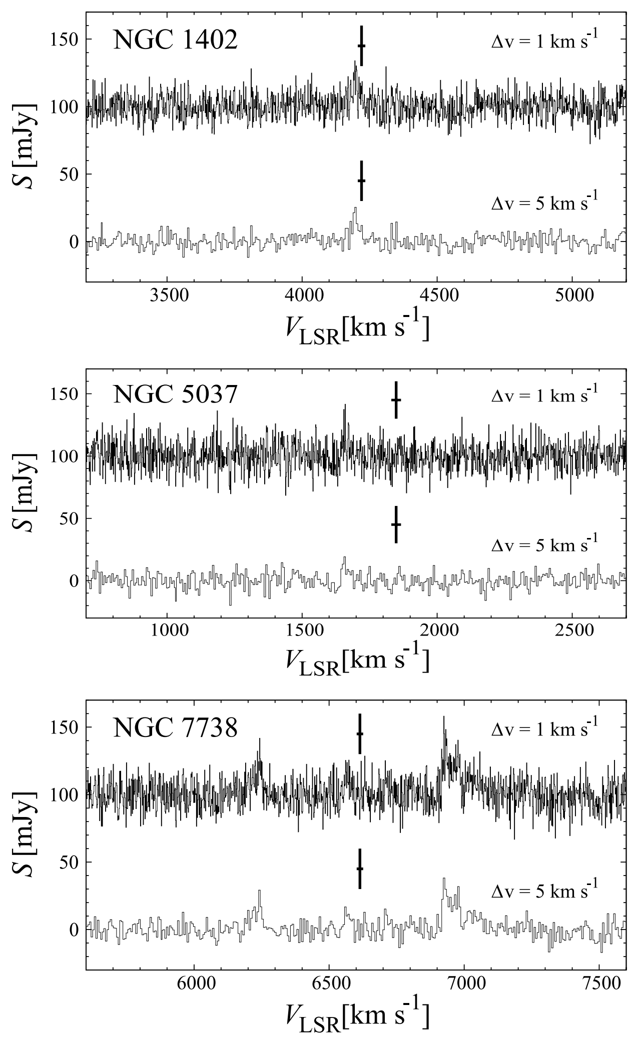

Figure 1: Yamauchi et al. (2017) [2]. The H_2O maser spectra of AGNs (marginally) detected with the 45-m telescope. To make the graph easier to view, the spectra with velocity resolution of $1\,{\rm km\,s^{-1}}$ are plotted 100 mJy above. Vertical and horizontal lines in the spectra indicate the systemic velocities of the galaxies and those errors, respectively.

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Evidence for Higher Black Hole Spin in Radio-loud Quasars

SCHULZE, Andreas[1], DONE, Chris[2], LU, Youjun[3/4], ZHANG, Fupeng[5], INOUE, Yoshiyuki[6]

1: NAOJ, 2: University of Durham, 3: National Astronomical Observatories, Chinese Academy of Sciences, 4: University of Chinese Academy of Sciences, 5: Sun Yat-Sen University, 6: Institute of Space and Astronautical Science JAXA

One of the major unsolved questions on the understanding of the AGN population is the origin of the dichotomy between radio-quiet and radio-loud quasars, i.e. why does the majority of AGN feature only weak core radio emission, while about 10 % of them have powerful relativistic jets with high bulk Lorentz factor. The most promising explanation is provided by the spin paradigm, which suggests radio-loud quasars have higher black hole spin. However, the measurement of black hole spin remains extremely challenging.

To address this question, we proposed a novel approach to probe the mean radiative efficiencies of both populations as direct tracers of black hole spin. For this goal, we used a large well-defined statistical quasar sample drawn from SDSS [1] at $0.3<z<0.8$, separated into radio-loud and radio-quiet quasars. A radio loud quasar is here defined by their radio-to-optical flux density ratio R either above 10 (or above 80). We used the [O III] luminosity as an indirect average tracer of the ionizing continuum in the extreme-UV regime where differences in the SED due to black hole spin are most pronounced. We found that the radio-loud sample shows an enhancement in [O III] line strength by a factor of at least 1.5 compared to a radio-quiet sample matched in redshift, black hole mass and optical continuum luminosity L_{5100} or accretion rate (see Fig. 1).

We do not see evidence that the observed trend is driven by star formation or jet-driven outflows (see e.g. Fig. 2). A remaining uncertainty we cannot fully resolve given current observations lies in our assumption of similar average NLR structures between radio-loud and radio-quiet quasars. However, we find a similar enhancement in both narrow and broad high ionization lines (in particular broad He II λ4686) which suggests that our result is not driven by NLR physics.

We argue that the most plausible explanation for the observed [O III] equivalent width enhancement is an intrinsic difference in ionizing continuum, thus in SED, meaning higher average bolometric luminosities at fixed accretion rate in the radio-loud population. This suggests that the radio-loud quasar population has on average systematically larger radiative efficiencies and therefore higher black hole spin than the radio-quiet population. Assuming a standard average radiative efficiency of 0.1 for radio-quiet quasars (a = 0.67), radio-loud quasars would have an efficiency of 0.15 and thus a = 0.89, which is high but not yet close to maximum spin.

Our results provide new observational support for the black hole spin paradigm [2].

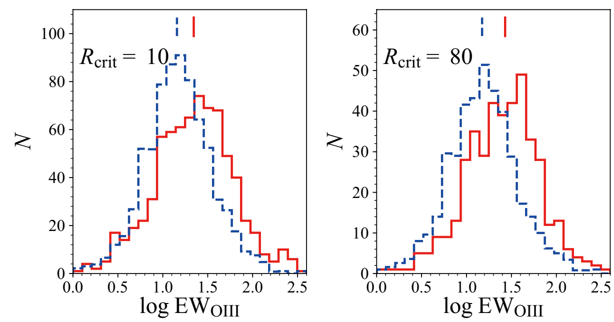

Figure 1: Histogram of [O III] equivalent width for the radio-loud quasar sample (solid red lines) and the matched radio-quiet sample (dashed blue lines), in the left panel for defining radio-loud quasars by a radio loudness parameter $R>10$ and in the right panel using a more conservative threshold $R>80$.

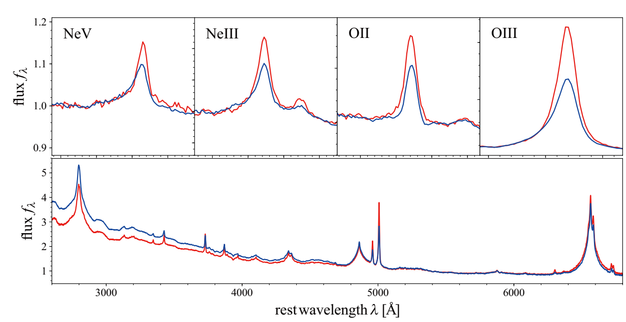

Figure 2: Composite spectra of the radio-loud (red) and matched radio-quiet (blue) quasar sample, where the composite spectra are normalized at 5100 Å, for the full spectrum (lower panel) and several prominent narrow high-ionization lines (upper panels).

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Rotating Starburst Cores in Massive Galaxies at $z = 2.5$

TADAKI, Ken-ichi[1/2], KODAMA, Tadayuki[2/3], NELSON, Erica J.[1], BELLI, Sirio[1]
FÖRSTER SCHREIBER, Natascha M.[1], GENZEL, Reinhard[1/4/5], HAYASHI, Masao[2]
HERRERA-CAMPUS, Rodrigo[1], KOYAMS, Yusei[2], LANG, Philipp[6], LUTZ, Dieter[1]
SHIMAKAWA, Rhythm[3], TACCONI, Linda J.[1], ÜBLER, Hannah[1], WISNIOSKI, Emily[1], WUYTS, Stijn[7]
HATSUKADE, Bunyo[8], LIPPA, Magdalena[1], NAKANISHI, Kouichiro[2/3], IKARASHI, Soh[9]
KOHNO, Kotaro[8/10], SUZUKI, Tomoko L.[3], TAMURA, Yoichi[8], TANAKA, Ichi[2]

1: Max-Planck-Institut für extraterrestrische Physik, 2: NAOJ, 3: Department of Astronomical Science, SOKENDAI (The Graduate University for Advanced Studies), 4: Department of Physics, Le Conte Hall, University of California, 5: Department of Astronomy, Hearst Field Annex, University of California, 6: Max-Planck-Institut für Astronomie, 7: Department of Physics, University of Bath, 8: Institute of Astronomy, The University of Tokyo, 9: Kapteyn Astronomical Institute, University of Groningen, 10: Research Center for the Early Universe, The University of Tokyo

We present spatially resolved ALMA observations of the CO J=3–2 emission line in two massive galaxies at z=2.5 on the star-forming main sequence. Both galaxies have compact dusty star-forming cores with effective radii of R_e=1.3±0.1 kpc and R_e=1.2±0.1 kpc in the 870 μm continuum emission. The spatial extent of star-forming molecular gas is also compact with R_e=1.9±0.4 kpc and R_e=2.3±0.4 kpc, but more extended than the dust emission. Interpreting the observed position-velocity diagrams with dynamical models, we find the starburst cores to be rotation-dominated with the ratio of the maximum rotation velocity to the local velocity dispersion of $v_{max}/\sigma_0 = 7.0^{+2.5}_{-2.8}$ (v_{max}=386^{+36}_{-32} km s^{-1}) and $v_{max}/\sigma_0 = 4.1^{+1.7}_{-1.5}$ ($v_{max} = 391^{+54}_{-41}$ km s^{-1}). Given that the descendants of these massive galaxies in the local universe are likely ellipticals with v/σ nearly an order of magnitude lower, the rapidly rotating galaxies would lose significant net angular momentum in the intervening time. The comparisons among dynamical, stellar, gas, and dust mass suggest that the starburst CO-to-H_2 conversion factor of $\alpha_{CO} = 0.8\,M_\odot$ (K km s^{-1} pc^{-2}) s^{-1} is appropriate in the spatially resolved cores. The dense cores are likely to be formed in extreme environments similar to the central regions of local ultraluminous infrared galaxies. Our work also demonstrates that a combination of medium-resolution CO and high-resolution dust continuum observations is a powerful tool for characterizing the dynamical state of molecular gas in distant galaxies.

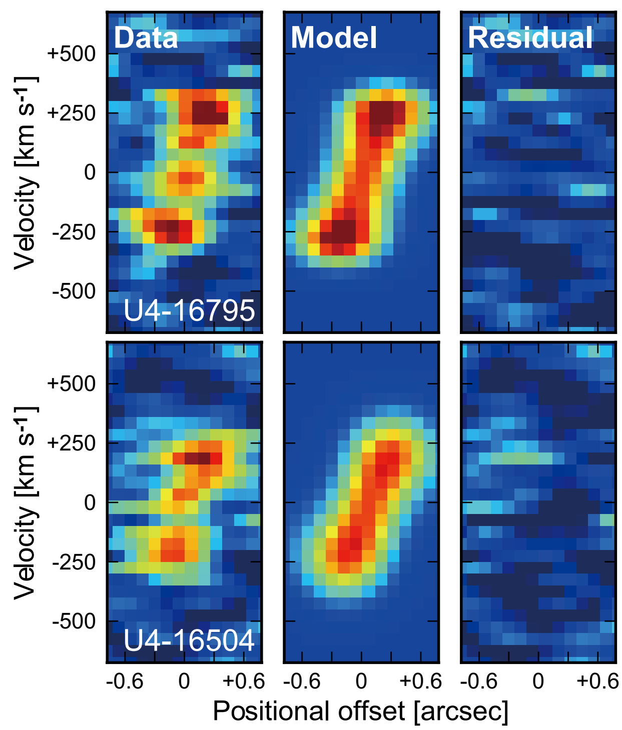

Figure 1: Observed position-velocity diagrams of the CO spectra (left). The middle and right panels show the best-fit dynamical model and the residuals between the data and the model, respectively.

Reference

[1] Tadaki, K. et al.: 2017, *ApJ*, **841**, L25.

First ALMA Observation of a Solar Plasmoid Ejection from an X-ray Bright Point

SHIMOJO, Masumi[1/2], HUDSON, Hugh S.[3/4], WHITE, Stephen M.[5], BASTIAN, Timothy S.[6], IWAI, Kazumasa[7]

1: NAOJ, 2: SOKENDAI, 3: University of Glasgow, 4: UCB, 5: AFRL, 6: NRAO, 7: Nagoya University

Eruptive phenomena such as plasmoid ejections or jets are important features of solar activity and have the potential to improve our understanding of the dynamics of the solar atmosphere. Such ejections are often thought to be signatures of the outflows expected in regions of fast magnetic reconnection. The 304 Å EUV line of helium, formed at around 10^5 K, is found to be a reliable tracer of such phenomena, but the determination of physical parameters from such observations is not straightforward. We have observed a plasmoid ejection from an X-ray bright point simultaneously at millimeter wavelengths with ALMA, at EUV wavelengths with SDO/AIA, and in soft X-rays with Hinode/XRT. This paper reports the physical parameters of the plasmoid obtained by combining the radio, EUV, and X-ray data. We consider three basic working hypotheses to consider. (1) The plasmoid consists of (roughly) isothermal plasma that is optically thick at 100 GHz. (2) The plasmoid consists of isothermal plasma that is optically thin at 100 GHz. (3) The plasmoid consists of multi-thermal plasma. As a result, we conclude that the plasmoid can consist either of (approximately) isothermal ~10^5 K plasma that is optically thin at 100 GHz, or a ~10^4 K core with a hot envelope.

This analysis demonstrates the value of the additional temperature and density constraints that ALMA can provide. In addition, at higher frequencies the spatial resolution of ALMA is close to that achieved with space-borne telescopes such as AIA, providing the ability to spatially resolve the same features at very different wavelengths, and providing complementary physical information.

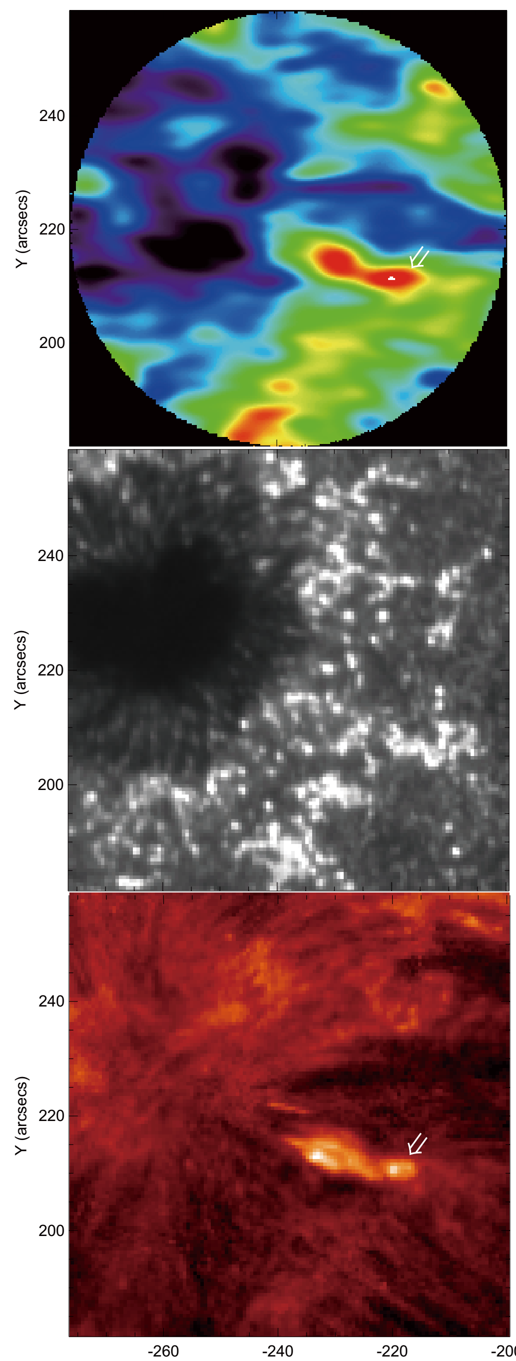

Figure 1: The leading sunspot of active region NOAA12470 observed with ALMA at Band 3 (100 GHz, upper panel), in ultraviolet continuum from the lower chromosphere (AIA1700, middle panel), and the He II transition-region line (AIA304, lower panel). The white arrows indicate an erupted plasmoid.

Reference

[1] Shimojo, M., et al.: 2017, *ApJ*, **841**, L5.

Variation of Solar Microwave Spectrum in the Last Half Century

SHIMOJO, Masumi[1/2], IWAI, Kazumasa[3], ASAI, Ayumi[4], NOZAWA, Satoshi[5]
MINAMIDANI, Tetsuhiro[1/2], SAITO, Masao[1/2]

1: NAOJ, 2: SOKENDAI, 3: Nagoya University, 4: Kyoto University, 5: Ibaraki University

The total solar flux in microwaves, particularly the F10.7 index (total solar flux at 2.8 GHz), is widely used as an indicator of solar activity in the fields of heliophysics and geophysics, because the F10.7 index indicates the variation of solar UV emission in comparison to sunspot number. The time variation in microwaves is traditionally classified into three components based on the timescale of enhancements. The components are a background component from the quiet-Sun, a slowly varying component, and a sporadic (burst) component. The background component is considered to originate from optically thick thermal bremsstrahlung emission from the atmosphere above the upper chromosphere, and the slowly varying component originates in the thermal bremsstrahlung emission of coronal loops above active regions and thermal gyro-resonance emission from strong magnetic field regions, such as sunspots.

In Japan, continuous four-frequency solar microwave observations (1, 2, 3.75 and 9.4 GHz) began in 1957 at the Toyokawa Branch of the Research Institute of Atmospherics, Nagoya University. In 1994 the telescopes were relocated to NAOJ Nobeyama Campus, where they have continued observations up to the present. We analyzed the more than 60 years of solar microwave data from these telescopes. At first, we determined the month that solar activity is most minimum in each solar cycle using the standard deviation of the flux density of the solar microwave. Then, we investigate the microwave spectra of the months, and found that microwave intensities and spectra at the minimums of the latest five cycles were the same every time. In contrast, during the periods of maximum solar activity, both the intensity and spectrum varied from cycle to cycle.

These results show that the average atmospheric structure above the upper chromosphere in the quiet-Sun has not varied for half a century, and suggest that the energy input for atmospheric heating from the sub-photosphere to the corona have not changed in the quiet-Sun despite significantly differing strengths of magnetic activity in the last five solar cycles.

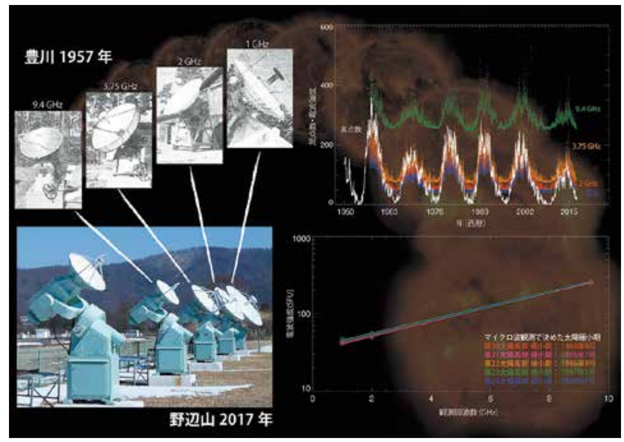

Figure 1: Left: Photos of the antennas at Toyokawa 1957, and Nobeyama 2017. Upper Right: Long-term variation of microwave and sunspot number. Lower Right: The microwave spectra at the solar minima.

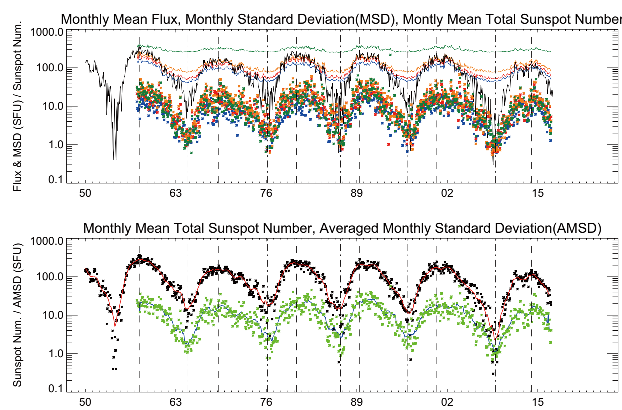

Figure 2: Upper panel: The monthly mean microwave fluxes, the monthly mean total sunspot number (solid lines), and the monthly standard deviations (MSD: asterisk). Lower Panel: The black asterisks indicate the monthly mean total sunspot number, and the red line is the 13-month smoothed monthly total sunspot number. The green asterisks indicate the Averaged MSD, and the blue line is the 13-month smoothed AMSD.

Reference

[1] Shimojo, M., et al.: 2017, *ApJ*, **848**, 62.

Joint Strong and Weak Lensing Analysis of the Massive Cluster Field J0850+3604

WONG, Kenneth C.[1], RANEY, Catie[2], KEETON, Charles R.[2], UMETSU, Keiichi[3]
ZABLUDOFF, Ann I.[4], AMMONS, S. Mark[5], FRENCH, K. Decker[4]

1: NAOJ, 2: Rutgers University, 3: ASIAA, 4: Arizona University, 5: Lawrence Livermore National Laboratory

Gravitational lensing by massive galaxy clusters is a powerful tool to study faint high-redshift galaxies through lensing magnification. Many orbits of *Hubble Space Telescope* (*HST*) time have been dedicated to characterizing such clusters and using them to search for lensed $z \geq 7$ galaxies and determine their contribution to the reionization of the intergalactic medium. The *HST* Frontier Fields program [1] has imaged six of the most massive and well-studied lensing clusters for this purpose. However, cosmic variance is a large source of uncertainty, and exploring new lines of sight for use as cosmic telescopes will be key to addressing this as we move into the era of the *James Webb Space Telescope* (*JWST*).

Several such fields were identified [2] in the Sloan Digital Sky Survey (SDSS) based on their large integrated luminosity density in luminous red galaxies (LRGs), which are tracers of massive structure. Spectroscopic follow-up of a subset of these fields reveal massive structures with large total integrated masses [3]. One of these fields, J085007.6+360428 (hereafter J0850), has archival multi-band imaging from Subaru/Suprime-Cam, which shows a multiply-imaged lensed arc with a photometric redshift of $z \approx 5$. Spectroscopy of the massive cluster at z =0.38 indicates a dynamical mass of $\sim 3 \times 10^{15}\,M_{\odot}$.

Using the Suprime-Cam imaging, we perform a joint weak and strong lensing analysis of J0850 to constrain the mass distribution and magnification properties of this field. We use a color-color selection to identify background galaxies, which we use to measure the reduced shear induced by the foreground cluster. We parameterize the cluster as an elliptical NFW [4] profile and fit it to the shear data. The posterior distributions of the halo parameters are then used as inputs for a forward model that reconstructs the multiply-imaged $z \approx 5$ galaxy. This model includes line-of-sight structure, including a foreground group halo identified in the spectroscopy. The models that reproduce the surface brightness distribution of the arclets are used as our final posterior distribution. We use the surface brightness distribution of the multiple images as constraints since this reveals that one of the images is a rare "fold arc", a highly-magnified image that lies across a lensing critical curve, and that would not be reproduced if only the image positions were used. Portions of this arc can be magnified by over a factor of 1000, making it promising for high-resolution imaging to study features at scales of ≤ 30 pc.

We find a virial mass of $2.93^{+0.71}_{-0.65} \times 10^{15}\,M_{\odot}$ for the cluster. The concentration is typical of halos of similar mass and redshift, indicating that there is no bias toward high concentration as is sometimes seen in lensing-selected samples. The cluster has a large ellipticity of $\varepsilon = 0.53^{+0.09}_{-0.10}$, suggesting that it is an efficient lens (i.e. a high density of multiple images) [5]. The full results are presented in [6]. The high mass of this cluster makes it ideal for future studies of high-z galaxies.

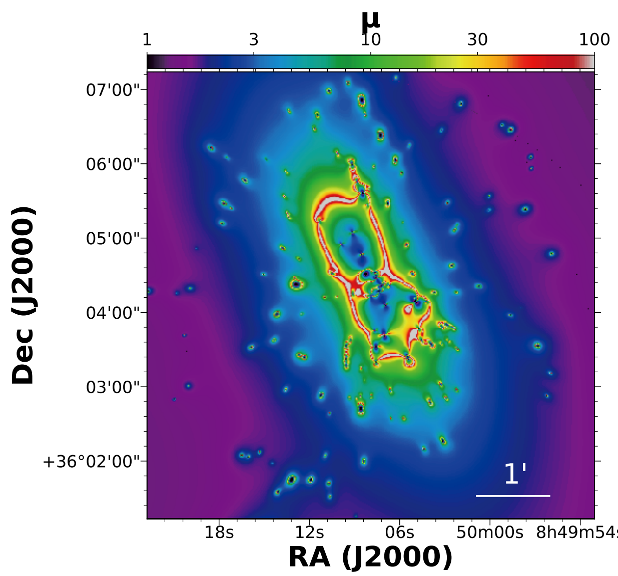

Figure 1: Magnification map for the best mass model of the J0850 field for a source redshift of $z_S = 5.03$, based on our combined lensing analysis. The region shown is 6′ × 6′.

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[2] Ealges, S., et al.: 2010, *PASP*, **122**, 499.
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[4] Wong, K. C., et al.: 2017, *ApJL*, **843**, L35.
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[7] Wong, K. C., et al.: 2015, *ApJ*, **811**, 115.

ALMA Observations of the Gravitational Lens SDP.9

WONG, Kenneth C.[1], ISHIDA, Tsuyoshi[2], TAMURA, Yoichi[3], SUYU, Sherry H.[4/5/6]
OGURI, Masamune[2/7], MATSUSHITA, Satoki[6]

1: NAOJ, 2: University of Tokyo, 3: Nagoya University, 4: MPA, 5: TUM, 6: ASIAA, 7: IPMU

Recent surveys at submillimeter wavelengths have revealed a population of gravitationally lensed dusty star-forming galaxies at $z \sim 2$–7 [1]. By combining the high sensitivity and spatial resolution of the Atacama Large Millimeter/Submillimeter Array (ALMA) with the natural magnification of gravitational lensing, the detailed properties of these galaxies can be studied on spatial scales of tens to hundreds of parsecs. One such system is the gravitational lens H-ATLAS J090740.0–004200 (hereafter SDP.9). SDP.9 was first identified as one of the brightest sources in the Science Demonstration Phase (SDP) of the *Herschel* Astrophysical Terahertz Large Area Survey (H-ATLAS) [2], and consists of a massive early-type galaxy at $z_L = 0.6129$ [3] lensing a background submillimeter galaxy at $z_S = 1.5747$ into a bright arc and small counterimage.

ALMA data on SDP.9 were obtained during Cycle 3 (Program 2015.1.00415.S; PI: K. Wong) [4]. The Band 6 continuum was observed, as well as the CO J=6–5 line. During the observations, 49 12 m antennas were used, and baselines ranged from 84.7 m to 16.2 km with the C36-7 configuration. The total on-source time was 4526 s under stable weather conditions with precipitable water vapors ~0.50 mm.

We find that the source is split into two tangentially elongated arcs, as is suggested by previous SMA observations. The northern arc is less extended than the southern arc, and some clumpy structures are visible in both arcs. We measure the peak intensity and total flux density of each arc in both the continuum and CO maps. Taking the CO line flux integrated across both arcs in each velocity bin, we measure an updated source redshift of $z_S = 1.5747 \pm 0.0002$.

We find no clear emission from the central demagnified image of the lens in the velocity-integrated CO(6–5) map down to a 3σ rms level of 0.0471 Jy km s^{-1}. The central image, which is predicted for non-singular mass distributions, offers a unique probe of the innermost central mass distribution of the lens [5,6], but we are unable to place meaningful constraints for this system.

We model the lens system using constraints from the ALMA imaging and archival *Hubble Space Telescope* (*HST*) imaging with the lens-modeling software GLEE [7]. The velocity gradient in the source galaxy is nearly orthogonal to the elongation of the lensed arcs, making a robust identification of multiple-image pair regions challenging. We find an Einstein radius of $\theta_E = 0.66 \pm 0.01$ arcsec, a slightly steeper than isothermal mass profile slope, and a projected axis ratio of $b/a = 0.68^{+0.05}_{-0.04}$. The lensed image configuration is strikingly different between the *HST* and ALMA data. The *HST* data, which probe the rest-frame optical emission from the source, show a much more symmetric configuration, while the ALMA submillimeter data has the large bright southern arc and the much smaller northern arc. This difference suggests a spatial offset between the stellar component and the gas and dust component of the source galaxy, as has been seen in other lensed submillimeter galaxies at this redshift.

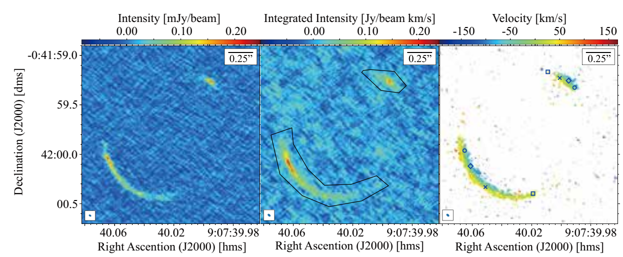

Figure 1: Left: ALMA Band 6 continuum image with Briggs weighting and no tapering. Center: velocity-integrated CO(6–5) intensity map. The black lines indicate the regions used to measure the integrated flux of the arcs. Right: CO(6–5) velocity map. Small symbols represent the conjugate points used for our mass modeling, with symbols of the same shape representing image pairs.

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[1] Negrello, M., et al.: 2010, *Science*, **330**, 800.
[2] Ealges, S., et al.: 2010, *PASP*, **122**, 499.
[3] Bussmann, R. S., et al.: 2013, *ApJ*, **779**, 25.
[4] Wong, K. C., et al.: 2017, *ApJL*, **843**, L35.
[5] Tamura, Y., et al.: 2015, *PASJ*, **67**, 72.
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[7] Suyu, S. H., Halkola, A.: 2010, *A&A*, **524**, A94.

Near-infrared Spectroscopic Observations of Comet C/2013 R1 (Lovejoy) by WINERED: CN Red-system Band Emission

SHINNAKA, Y.[1/2], KAWAKITA, H.[2/3], KONDO, S.[2/3], IKEDA, Y.[2/4], KOBAYASHI, N.[2/5/6], HAMANO, S.[2]
SAMESHIMA, H.[2], FUKUE, K.[2], MATSUNAGA, N.[2/7], YASUI, C.[1/2], IZUMI, N.[1/2], MIZUMOTO, M.[5/7]
OTSUBO, S.[2/3], TAKENAKA, K.[2/3], WATASE, A.[2/3], KAWANISHI, T.[2/3], NAKANISHI, K.[2], NAKAOKA, T.[2/3]

1: NAOJ, 2: Koyama Astronomical Observatory, 3: Kyoto Sangyo University, 4: Photocoding, 5: University of Tokyo, 6: Kiso Observatory, 7: ISAS

Recently nitrogen isotopic ratios ($^{14}N/^{15}N$ ratios) in various astrophysical objects have been investigated by both observational and theoretical studies. From the viewpoint of chemical evolution in molecular cloud and proto-planetary disk, the high ^{15}N-fractionation found in those environments together with comets in the Solar System is quite puzzling. Any chemical evolution models cannot explain the observed high ^{15}N-fractionation of molecules in solid-phase quantitatively, so far.

In the case of CN radical of comets, CN *B-X* violet band at ~388 nm has been observed (e.g., [1]). Observational conditions are often not good for a comet which becomes brighter as it approaches the Sun because this band (which is close to UV region) is significantly affected by telluric extinction. In addition, S/N ratios of CN emission spectra would be worth because of the extinction by dust grains in cometary coma.

Here we report high-resolution near-infrared spectra of CN red-system band (*A-X*) at ~1.1 μm [2]. The red-system band is not severely affected by the telluric extinction compared to the violet-system band. We developed the fluorescence excitation model for CN by solar radiation based on modern spectroscopic studies. We applied the fluorescence excitation models for CN to the observed CN spectra of comet C/2013 R1 (Lovejoy). The spectra were taken by the near-infrared high-resolution spectrograph WINERED mounted on the 1.3-m Araki telescope at the Koyama Astronomical Observatory, Kyoto, Japan on 30 November 2013. Our emission model could reproduce the observed CN red-system band of the comet with a linear combination of a pure fluorescence excitation model for the outer coma region and a fully collisional fluorescence excitation model for the inner coma region (see Figure 1). The observed spectrum is consistent within error-bars with the previous estimates of isotopic ratios in comets; $^{12}C/^{13}C$ of ~90 [1] and $^{14}N/^{15}N$ of ~150 [1,3].

This study was financially supported by JSPS grants (16684001, 20340042, 21840052, 26287028, 13J10504, 15J10864, 16K17669, 16H07323), MEXT Supported Program for the Strategic Research Foundation at Private Universities (S0801061, S1411028) and the Japan-India Science Cooperative Program 2013-2015 and 2016-2018.

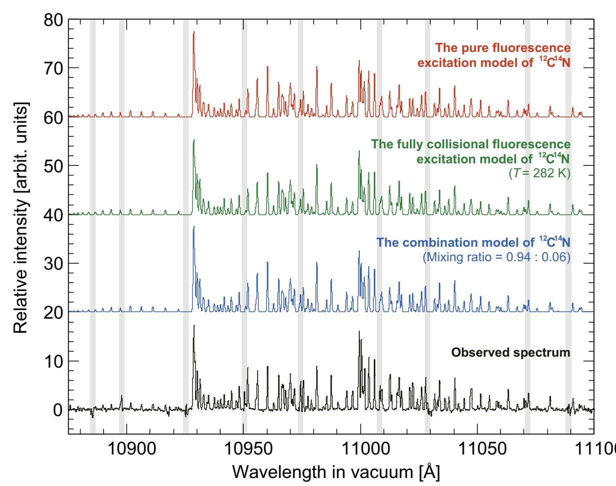

Figure 1: Comparison between synthesized and observed spectra of comet Lovejoy in the CN red-system (0-0) band [2]. The top three spectra are the synthesized spectrum of $^{12}C^{14}N$ based on the pure fluorescence excitation model (red), the fully collisional fluorescence excitation model with T_{rot} of 282 K (green), and the synthesized spectrum of $^{12}C^{14}N$ as a linear combination of the fully collisional fluorescence excitation model and the pure fluorescence excitation model with a mixing ratio of 0.94:0.06 (blue) for the observed conditions of comet Lovejoy. The bottom spectrum (black) is observed emission spectra of comet Lovejoy. The gray vertical bars correspond to the regions of OH sky emission lines.

References

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Suzaku Observations of Heavily Obscured (Compton-thick) Active Galactic Nuclei Selected by Swift/BAT Hard X-Ray Survey

TANIMOTO, Atsushi, UEDA, Yoshihiro (Kyoto University)
KAWAMURO, Taiki (NAOJ)
RICCI, Claudio (Ponticia Universidad Catolica de Chile)
AWAKI, Hisamitsu, TERASHIMA, Yuichi (Ehime University)

To reveal the nature of Compton-thick Active Galactic Nuclei (CTAGNs: $\log N_{\rm H}/{\rm cm}^{-2} \geq 24$) is an important, yet unresolved issue in modern astronomy. CTAGNs are key objects to understand the origin of the co-evolution of Supermassive Black Holes (SMBHs) and their host galaxies. According to a galaxy/SMBH evolutionary scenario, major mergers trigger violent star formation and rapid growth of SMBHs heavily obscured by gas and dust. This leads to the idea that some CTAGNs may be distinct populations from less obscured AGNs. However, it remains an open question whether CTAGNs are intrinsically same objects or not as the rest of AGNs due to observational difficulties in detecting CTAGNs.

We present a uniform broadband X-ray (0.5–100.0 keV) spectral analysis of 12 *Swift*/BAT selected CTAGNs observed with *Suzaku*. We fitted these spectra with the Monte Carlo based AGN torus model [1] (Figure 1). The main results are as follows. (1) Unabsorbed reflection components are commonly observed, suggesting that the tori are clumpy. (2) Almost CTAGNs show small scattering fractions implying a buried AGN nature (Figure 2). (3) Comparison with the results obtained for Compton-thin AGNs [2] (Figure 3) suggests that the properties of these CTAGNs can be understood as a smooth extension from Compton-thin AGNs with heavier obscuration [3].

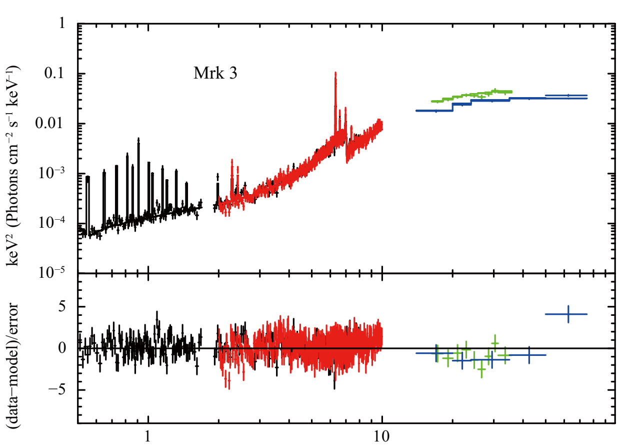

Figure 1: Broadband X-ray spectra. Black and Red: Suzaku/XIS. Green: Suzaku/PIN. Blue: Swift/BAT.

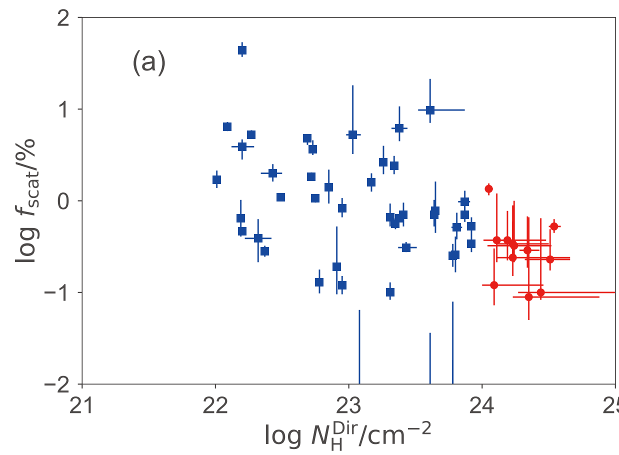

Figure 2: Correlation between hydrogen column density and scattering fraction.

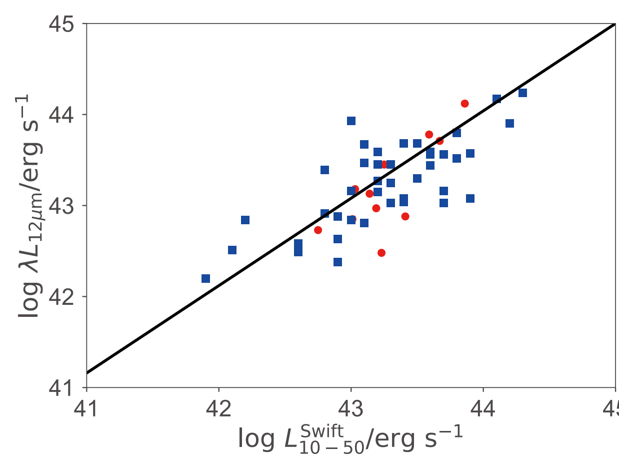

Figure 3: Correlation between the X-ray and infrared luminosities.

References

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[3] Tanimoto, A., et al.: 2018, *ApJ*, **853**, 146.

Superluminous Transients at AGN Centers from Interaction between Black Hole Disk Winds and Broad-line Region Clouds

MORIYA, Takashi (NAOJ)
TANAKA, Masaomi (Tohoku University)
MOROKUMA, Tomoki (University of Tokyo)
OHSUGA, Ken (Tsukuba University)

We propose that superluminous transients that appear at central regions of active galactic nuclei (AGNs) such as CSS100217:102913+404220 (CSS100217) and PS16dtm, which reach near or super-Eddington luminosities of the central black holes, are powered by the interaction between accretion disk winds and clouds in broad-line regions (BLRs) surrounding them. Such transients have been suggested to be a kind of supernova (SN) explosions because of their similarities to Type IIn SNe. However, similar transients preferentially appear in AGN central regions with similar properties. This fact has motivated us to consider a possibility that these transients are related to AGN activities rather than SNe.

If the black hole accretion disk luminosity temporary increases by, e.g., limit-cycle oscillations, leading to a powerful radiatively driven wind, strong shock waves propagate in the BLR. Because the dense clouds in the AGN BLRs typically have similar densities to those found in Type IIn SNe, strong radiative shocks emerge and efficiently convert the ejecta kinetic energy to radiation. As a result, transients similar to Type IIn supernovae can be observed at AGN central regions. Since a typical black-hole disk wind velocity is $\simeq 0.1c$ where c is the speed of light, the ejecta kinetic energy is expected to be $\simeq 10^{52}$ erg when $\simeq 1\,M_\odot$ is ejected. This kinetic energy is transformed to radiation energy in a timescale for the wind to sweep up a similar mass to itself in the BLR, which is a few hundred days. Therefore, both luminosities ($\sim 10^{44}$ erg s^{-1}) and timescales (~100 days) of the superluminous transients from AGN central regions match to those expected in our interaction model. Figure 1 shows a schematic picture of our model to explain the superluminous transients from AGN activities.

If the superluminous transients from AGN centers are related to the AGN activities triggered by limit-cycle oscillations, we expect that the luminosity of the superluminous transients are correlated with the AGN central BH mass as demonstrated in Figure 2. Also, the limit-cycle oscillation repeats in the timescale of decades so the superluminous transients should become bright repeated in the timescale decades or so.

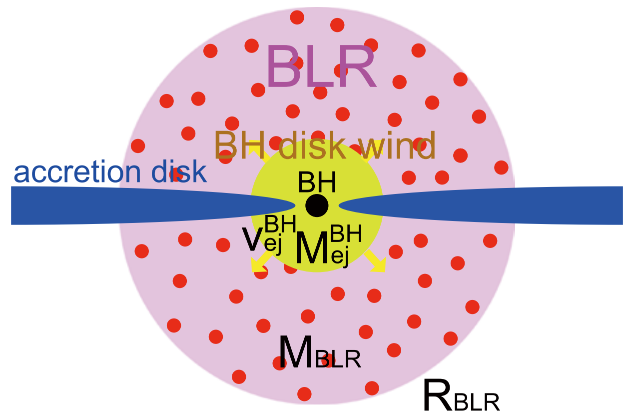

Figure 1: Schematic picture of our BH disk wind model. If the BH accretion disk ejects a wind with $M_{\rm ej}^{\rm BH}$ and $v_{\rm ej}^{\rm BH}$, it is decelerated by the dense clouds in the BLRs (red dots) and its kinetic energy is efficiently converted to radiation [1].

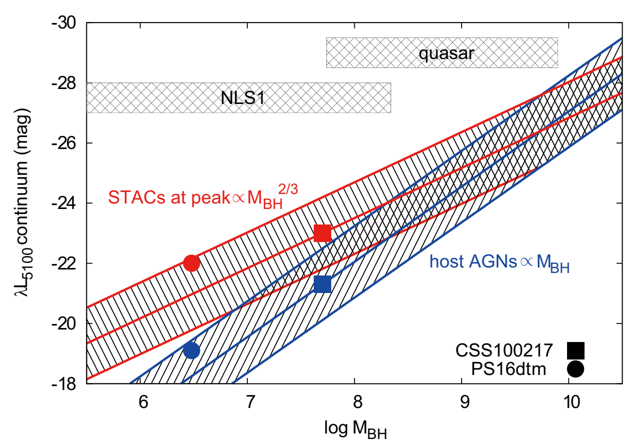

Figure 2: Luminosity estimates of the superluminous transients from AGN centers (STACs) by the BH disk wind model and their host AGNs [1].

Reference

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On the Macroturbulence Model for the Solar Photospheric Velocity Field

TAKEDA, Yoichi (NAOJ)
UENO, Satoru (Hida Observatory of Kyoto University)

In incorporating the effect of atmospheric turbulence in the broadening of spectral lines, the so-called radial-tangential macroturbulence (RTM) model has been widely used for solar-type stars, which was devised from an intuitive appearance of granular velocity field of the Sun. Since this model assumes that turbulent motions are restricted to only radial and tangential directions, it has a special broadening function with notably narrow width due to the projection effect (cf. Figure 1), the validity of which has not yet been confirmed in practice.

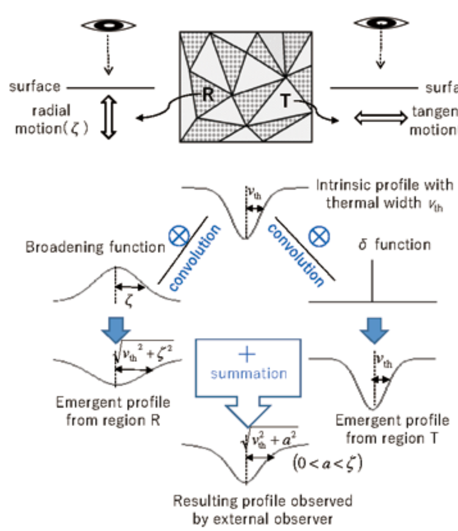

Figure 1: Schematic description of the concept of radial–tangential macroturbulence, which explains why the width of the broadening function is considerably smaller than the actual velocity dispersion.

With an aim to check whether this RTM model adequately represents the actual solar photospheric velocity field, we carried out an extensive study on the non-thermal velocity dispersion along the line-of-sight (V_{los}) at various points of the solar disk based on locally-averaged spectra obtained by the Domeless Solar Telescope at Hida Observatory. By comparing two kinds of theoretical V_{los} vs. θ relations (θ is the angle between the surface normal and the line of sight; i.e., $\theta = 0°$ at the disk center and $\theta = 90°$ at the limb) predicted from the RTM model and the Gaussian macroturbulence (GM) model (Figure 2) with the observed trend (Figure 3), the following conclusion was drawn: The center-to-limb run of V_{los} is simply monotonic with a slightly increasing tendency with θ, which contradicts the specific trend (an appreciable peak at $\theta \sim 45°$) predicted from RTM. This means that RTM is not an adequate model at least for solar-type stars, which would significantly overestimate the turbulent velocity dispersion by a factor of ~2. The classical Gaussian macroturbulence model should be more reasonable in this respect. See [1] for more details of this study.

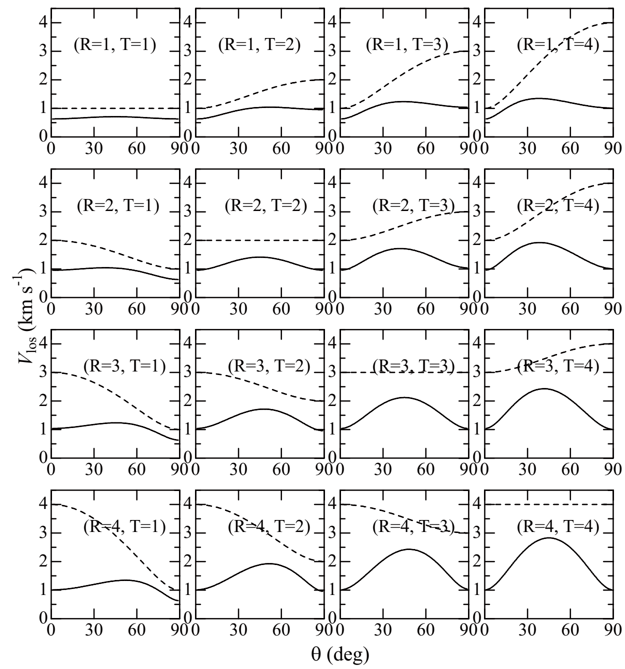

Figure 2: Theoretical V_{los} vs. θ diagram corresponding to RTM (solid line) and GM (dashed line).

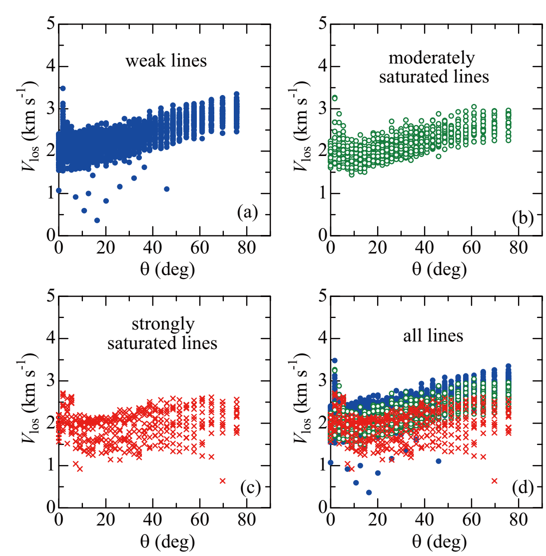

Figure 3: Observed V_{los} vs. θ diagram for each of the line-strength classes.

Reference

[1] Takeda, Y., UeNo, S.: 2017, *PASJ*, **69**, 46.

Testing the Planet-Engulfment Hypothesis as the Origin of Li-rich Giants

TAKEDA, Yoichi, TAJITSU, Akito
(NAOJ)

It is known that a small fraction (~1 %) of red giant stars show unusually strong Li line (indicative of considerably large Li abundance in the photosphere), in marked contrast to normal red giants mostly showing significant depletion of surface Li because of the dilution due to evolution-induced envelope mixing. One of the various mechanisms proposed so far to explain this Li-enhancement is the accretion/swallowing of substellar companion (planets or brown dwarfs) by the red giant star (see [1] and the references therein). This hypothesis can be tested by spectroscopically checking ^{6}Li or Be, which are expected to exist in such cool low-mass companions. That is, if this is the case, we may as well detect ^{6}Li and/or overabundance of Be.

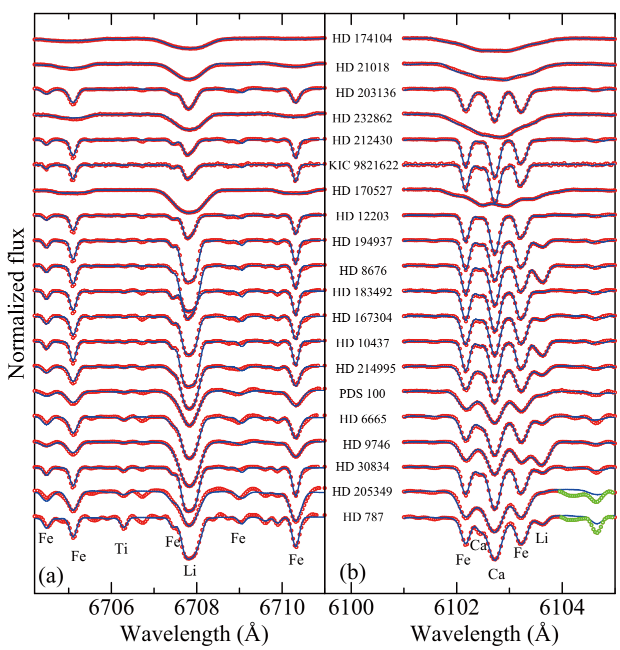

Figure 1: Synthetic spectrum fitting for Li abundance determination.

We recently carried out a compehensive spectroscopic study on 20 Li-rich giants based on the Subaru/HDS spectra and compared their observational characteristics with those of ~300 normal red giants. According to the resulting Li abundances determined by applying the spectrum-fitting method to Li I 6708 and Li I 6104 lines (Figure 1), we could not detect any signature for the existence of ^{6}Li (Figure 2). It was also confirmed from our analysis of Be II 3131 line that Li-rich giants are deficient in Be (just like normal giants) without any sign of enrichment. Consequently, we conclude that the hypothesis of "engulfment of substellar companions" (accretion of unprocessed gas or solid material) is rather unlikely as the origin of Li-rich giants (at least as the major mechanism),

See [2] for more details of this study.

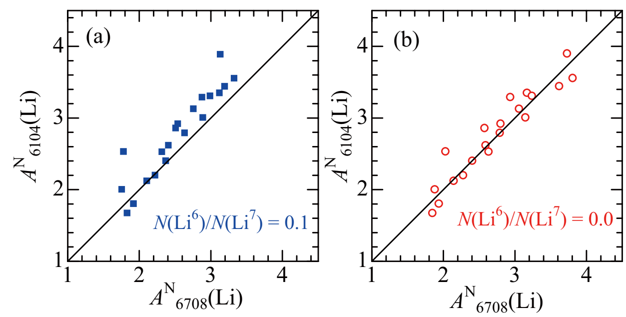

Figure 2: Effect of ^{6}Li/^{7}Li ratio on the A^N_{6104}(Li) vs. A^N_{6708}(Li) correlation.

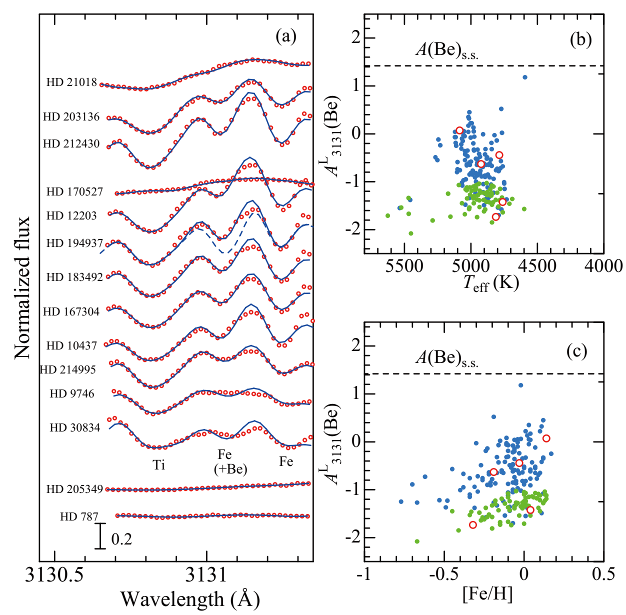

Figure 3: Synthetic spectrum fitting for Be abundance determination, and the resulting Be abundances plotted against T_{eff} and [Fe/H] (small filled circles are normal giants for comparison, where blue and green symbols denote established abundances and upper limits for indeterminable cases, respectively).

References

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[2] Takeda, Y., Tajitsu, A.: 2017, *PASJ*, **69**, 74.

Luminosity Effect of O I 7771–5 Line Strength in Evolved A–F–G Stars

TAKEDA, Yoichi
(NAOJ)
JEONG, Gwanghui, HAN, Inwoo
(KASI, Korea)

Although the strength of O I 7771–5 triplet feature (W_{77}) is known to show a luminosity effect and may be usable for empirical evaluation of absolute magnitude (M_V), our understanding on its behavior is still insufficient. Especially, the validity and applicability limit of various analytical relations proposed so far (which are not necessarily consistent with each other) has yet to be clarified.

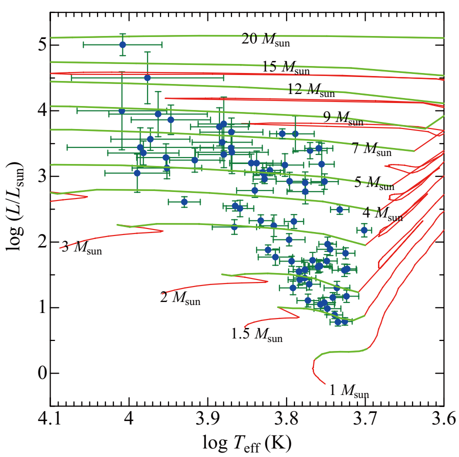

Figure 1: Program stars plotted on the theoretical HR diagram.

With an aim to shed light on this situation, we investigated how W_{77} depends on M_V and other stellar parameters for unbiased sample of 75 evolved A-, F-, and G-type stars of various luminosity classes (subgiants, giants, and supergiants; cf. Figure 1). Based on the high-dispersion spectra obtained with the echelle spectrograph of 1.8 m reflector at Bohyunsan Optical Astronomy Observatory (Korea Astronomy and Space Science Institute), we measured W_{77} for each star by applying the spectrum-fitting technique (cf. Figure 2).

Our results are shown in Figure 3, where we can confirm that W_{77} tends to increase as M_V becomes more luminous. However, the behavior of W_{77} for the whole sample is too complicated to be described by a simple relation. Specifically, distinctly different trends of W_{77} were found for the lower-gravity ($\log g < 2.5$) group of supergiants or bright giants and the higher-gravity ($\log g > 2.5$) group of giants or subgiants. That is, the simple M_V vs. W_{77} formulas proposed by past studies are applicable only to the former group, but not to the latter group showing a totally different tendency. Since these two groups overlap at $0 > M_V > -5$ (i.e., F–G supergiants of the former group and A-type giants of the latter group), special care should be taken in using W_{77} of stars in this M_V range. It is thus recommended to confine only to supergiants of $-5 > M_V > -10$, if one wants to safely make use of the luminosity effect of O I 7771–5 lines.

See [1] for more details of this study.

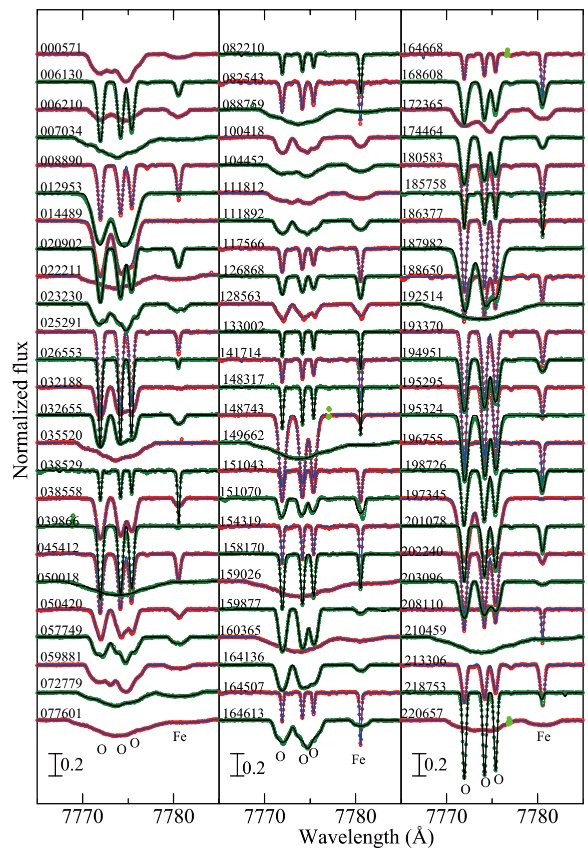

Figure 2: Spectrum fitting in the 7765–7785 Å region.

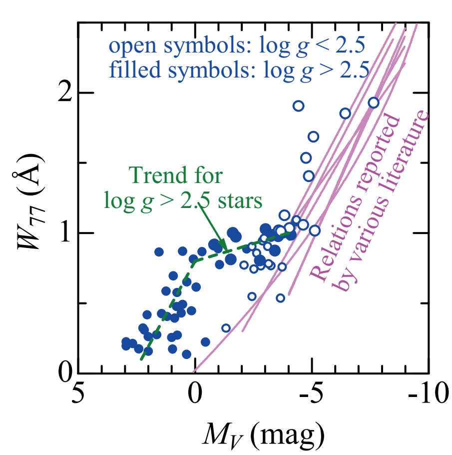

Figure 3: W_{77} vs. M_V relation.

Reference

[1] Takeda, Y., Jeong, G., Han, I.: 2018, *PASJ*, **70**, 8.

Development of Micro-Mirror Slicer Integral Field Unit for Space-borne Solar Spectrographs

SUEMATSU, Yoshinori
(NAOJ)

SAITO, Kosuke, KOYAMA, Masatsugu, ENOKIDA, Yukiya, OKURA, Yukinobu
NAKAYASU, Tomoyasu, SUKEGAWA, Takashi
(Canon Inc.)

Integral field spectroscopy (IFS) is a two dimensional spectroscopy, providing spectra for each spatial direction of an extended two-dimensional field simultaneously. There are three methods to realize the IFS depending on image slicing devices: micro-lenslet arrays, optical fiber bundles, and narrow rectangular image slicer arrays. Basically, the integral field spectroscopy unit (IFU) acts as a coupler between the telescope and the spectrograph by optically reformatting a two-dimensional rectangular field into a quasi-continuous pseudo-slit located at the entrance focal plane of a spectrograph.

The scientific advantages of IFS for studies of localized and transient solar surface phenomena are obvious. From the viewpoint of high-efficiency spectroscopy, wide wavelength coverage, precision spectro-polarimetry, and space application, the image slicer consisting of all reflective optics is the best option among the three. For space instrumentation, small-sized IFU units are advantageous; they demand that the width of the slicing mirrors should be as narrow as an optimal spectrograph slit width (< 100 μm), which is usually difficult to manufacture with glass polishing techniques. In this study, we could successfully applied a Canon's novel technique for high optical performance metallic mirrors of small dimensions.

Keeping in mind a possible application for a future space-borne spectrograph such as SOLAR-C: a next planned Japanese solar space mission, we designed an IFU that utilizes a micro-mirror slicer of 45 arrayed 30-μm-wide metal mirrors and a pseudo-pupil metal mirror array of off-axis conic aspheres re-formatting three pseudo-slits; this design is feasible for optical configuration sharing a spectrograph with a conventional real slit. We manufactured a prototype IFU for evaluation according to the optical design and deposited a protected silver coating on both metal mirrors after its successful space qualification tests.

It demonstrated that the final optical quality of the IFU is sufficiently high for a visible light spectrograph. Each slicer micro-mirror is 1.58 mm long and 30 μm wide with the micro-roughness is less than 1 nm rms and edge sharpness is less than 0.2 μm even after the reflective coating and mirror tilt errors were less than the required accuracies. As to the pseudo-pupil mirrors, the micro-roughness was less than 1.27 nm rms and the surface figure accuracy was less than 59 nm PV. Tilt errors around the x-axis of all surfaces were less than 4.6 arcsec and those around the y-axis of all the surfaces were less than 2.3 arcsec, which are less than the requirement (7.7 arcsec). We confirmed that the pseudo pupils were projected as designed and the re-arranged slicer images were focused by the pseudo-pupil mirrors as three pseudo slits at a distance 200 mm away (see Figure 1).

We also presented a concept of a field lens placed at the slit plane that changes the diverging beam from the pseudo-pupil mirrors to a telecentric beam into a spectrograph. The field lens needs to have a high index larger than 2. Off-the-shelf ZnSe-made cylindrical lenses which are close to the optical design were used and successfully verified the optical performance.

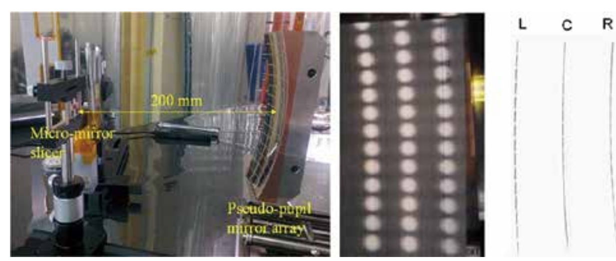

Figure 1: Set up of micro-mirror slicer IFU (left), footprint at pseudo-pupil mirror array of F/24 beams arising from the slicer (middle), and image on a camera of the re-arranged slicers through the ZnSe cylindrical field lens (right), confirming that all the metal mirrors were fabricated as designed.

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Stellar Stream and Halo Structure of the Andromeda Galaxy Revealed by Subaru Hyper Suprime-Cam

KOMIYAMA, Yutaka[1], CHIBA, Masashi[2], TANAKA, Mikito[2], TANAKA, Masayuki[1], KIRIHARA, Takanobu[3]
MIKI, Yohei[4], MORI, Masao[5], LUPTON, R. H.[6], GUHATHAKURTA, P.[7], KALIRAI, J. S.[8], GILBERT, K.[8]
KIRBY, E.[9], LEE, M. G.[10], JANG, I. S.[10], SHARMA, S.[11], HAYASHI, Kohei[1]

1: NAOJ, 2: Tohoku University, 3: Chiba University, 4: University of Tokyo, 5: Tsukuba University, 6: Princeton University, 7: UCO Lick, 8: STScI, 9: Caltech, 10: SNU, 11: Sydney

The halos of galaxies preserve fossil records of galaxy formation through hierarchical assembly and past accretion events. The halo of the Andromeda galaxy (M31) is a complementary target to the Milky Way as it can be observed in perspective from the center to the halo. However, the detail of the M31 halo is still vailed due to its large distance.

We have carried out a wide and deep survey for 9.2 deg^2 field in the north-west (NW) halo of the Andromeda galaxy (M31) using Hyper Suprime-Cam on the Subaru Telescope. Our survey goes deep enough to probe red clump (RC) stars, which are numerous and make distinct feature in the color-magnitude diagram, and allows us to investigate the detailed structure and the stellar population of the NW Stellar Stream which is known to exist in this field.

From the distance estimate based on the RC magnitude, it is likely that the NW Stream is located ~70 kpc behind the main body of M31. A numerical simulation incorporating this distance estimate sets a strict constraint on the orbit of the NW Stream. The detailed structure of the NW Stream which is traced by the number density distribution of RC stars is revealed. The cross-sectional shape of the stream is well represented by a Gaussian with FWHM of 25 arcmin (5.7 kpc), with a slight skew to the south-west direction. The shape along the stream is revealed to be complicated: in addition to a significant gap, numbers of bumps and dips are found along the stream (see Figure 1). It is expected that future numerical simulation which reproduces the orbit and the shape of the NW Stream will reveal the nature of the NW Stream as well as the properties of the halo of M31.

We also found a distinct stellar population other than that comprising the NW Stream in the south part of our survey field from the analysis of the color-magnitude diagram. This finding suggests that a substructure which is more extended and diffuse than the NW Stream do exist in our survey field. Follow-up observations are necessary to address the nature of this diffuse substructure.

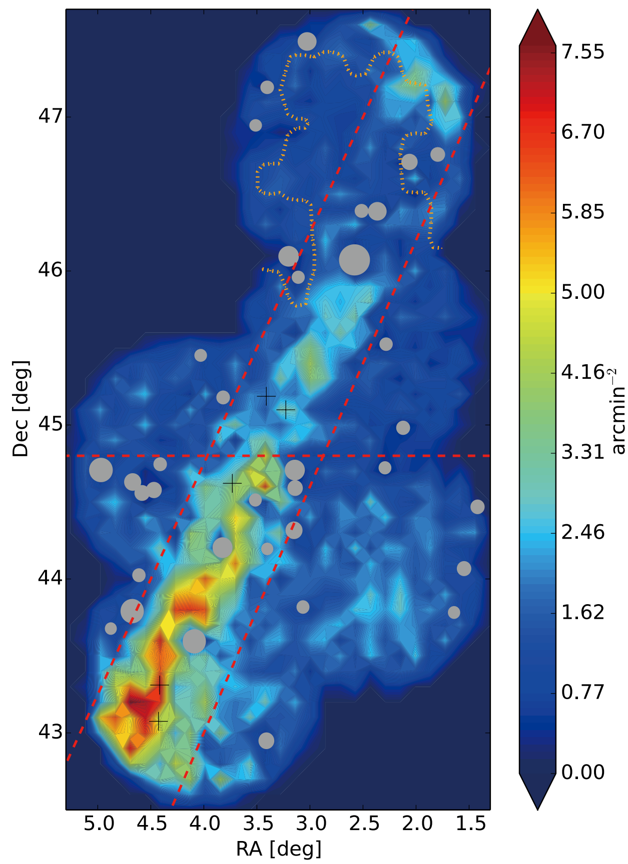

Figure 1: The number density distribution of RC stars. The number density decreases from the south-east to the north-west and a significant gap is also found. The diffuse substructure suggested in the text is seen as a diffuse hump of number density at the south-west part outside the stream. The gray circles represent the masked regions by bright stars and the crosses represent globular clusters which are suggested to be associated with the NW Stream.

Reference

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Extended Ionized Gas out of Galaxies in the Leo Cluster (Abell 1367)

YAGI, Masafumi, YOSHIDA, Michitoshi, KOMIYAMA, Yutaka, KASHIKAWA, Nobunari
(NAOJ)

GAVAZZI, Giuseppe
(University of Milano-Bicocca)

OKAMURA, Sadanori
(Hosei University)

In clusters of galaxies, the relative motion of member galaxies to the hot gas of the cluster produces a ram pressure. The ram pressure strips gas from galaxies, and sometimes the gas stripped out of the galaxy gets ionized by some mechanism to be detected as an Hα emitting cloud. We observed a part of the Virgo cluster and the Coma cluster, in Hα narrow-band, and B, and R broad-bands of the Subaru Suprime-Cam to study such intergalactic ionized gas (e.g., [1,2]). We then executed a systematic survey of the Leo cluster (Abell 1367) with an Hα filter for redshift z=0.022 of the Suprime-Cam [3].

By the survey, we detected six new extended ionized gas clouds in addition to three galaxies with known gas tails (CGCG 097-073, CGCG 097-079, CGCG 097-087; [4]), and one of the new clouds was confirmed to have much longer tail by a follow-up observation [5]. Remarkable objects compared to the previous studies were the clouds which show no relation to the galaxies; “Orphan clouds” (Figure 1 top). Other clouds known so far show the connection to the galaxy from which the gas came from (parent galaxies). Meanwhile, no parent candidates are found at least within 85 kpc from the orphan clouds, and any member galaxies around the region show no sign of stripping toward the orphans. The orphan clouds brought to us new mysteries; from where the gas came, and how the ionization is maintained in ~30 kpc.

Another discovery was that the galaxy group which is infalling onto the cluster (Blue Infalling Group; BIG; [6]) has an ionized gas tail more than 300 kpc long. The length is about twice longer than known before [7]. The apparence of the tail indicates a helical shape. We presented a hypothesis that the tail originated not from the intragroup gas but from each galaxy, and the helical shape corresponds to the motion of the galaxy around the barycenter of the group while the gas had been stripped by the ram-pressure by the cluster gas. We also found sign of star formation in a limited region of the BIG tail (Figure 1 bottom).

Future spectroscopic observation will enable us to set constraints on the motion, the metallicity, and the ionization mechanism of the gas, and to estimate the age and the mass of the star-forming regions. We will try to understand the evolution of the gas in the cluster and the effect of the stripping on the evolution of the galaxies deeply and comprehensively.

Figure 1: Intergalactic ionized gas clouds in the Leo cluster. NB671(Hα;red), R(green), B(blue) three color composite. With the color assignment, ionized clouds is shown in red, and starforming region is in magenta. Yellow bars at the bottom-left indicate 10 kpc. (top) Orphan clouds, which show no connection to galaxies. (bottom) Star-forming regions (green circles) in the tail of the blue infalling group (BIG).

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Dynamics of Porous Dust Aggregates and Gravitational Instability of Their Disk

MICHIKOSHI, Shugo (Kyoto Women's University)
KOKUBO, Eiichiro (NAOJ)

Planetesimals are building blocks of planets. The terrestrial planets and the cores of gas giants are considered to be formed by the collisional accretion of planetesimals. In a protoplanetary disk, small dust grains grow to planetesimals. It is not yet understood how dust grains grow into planetesimals, because this process must overcome various obstacles.

Recent studies on the dust growth showed that the icy dust aggregates formed by coagulation are not compact but significantly porous. The internal density of dust aggregates is much smaller than the material density, which is $\sim 10^{-5}\ \mathrm{g\,cm^{-3}}$. A compression mechanism is necessary to form compact planetesimals. In the final stage of the dust growth, the dust aggregates are compressed by the self-gravity [1].

In the previous paper, we considered the final stage of the evolution of icy dust aggregates [2]. We investigated the dynamics of dust aggregates and obtained their random velocity. We found that, for a reasonable range of turbulence strength, the porous dust disk becomes gravitationally unstable as the dust aggregates evolve through self-gravity compression. In the previous paper, we adopted the MMSN model and assumed an isotropic velocity dispersion and an equilibrium random velocity. In this work, we extend the previous work and adopt a more general disk model and a more precise dynamical model. We considered the self-gravity, mutual collisions, aerodynamic drag, turbulent stirring, and scattering due to gas and calculated the eccentricity and inclination. From them we calculated the Toomre's Q and Roche criterion to examine the gravitational instability (GI) [3].

In the standard model, we found that the GI condition is finally satisfied when $\alpha \lesssim 4 \times 10^{-4}$. Next, we assumed the general parameters and checked whether GI occurs. Figure 1 shows the example of the results. The GI is more tend to occur for larger f_g, where f_g is the normalized disk mass. Thus, the upper limit of α for the GI exists, and it depends on the disk parameters.

Considering the simple approximations, we derived the critical α value analytically

$$\alpha < \alpha_{\mathrm{cr}} = 5.30 \times 10^2 \frac{a^2 \Sigma_{\mathrm{d}}^3}{\eta C_{\mathrm{D}} M_* \Sigma_{\mathrm{g}}^2}. \quad (1)$$

where a is the distance from the central star, C_{D} is the gas drag coefficient, M_* is the central star mass, η is the gas pressure gradient parameter, Σ_{d} is the dust surface density, Σ_{g} is the dust surface density. Figure 1 shows this estimate, which well agrees with the numerical result. This critical α formula is consistent with that derived in the previous work.

We found that if the turbulence is not strong ($\alpha \lesssim 10^{-3}$), the GI takes place. The GI accelerates the planetesimal formation significantly.

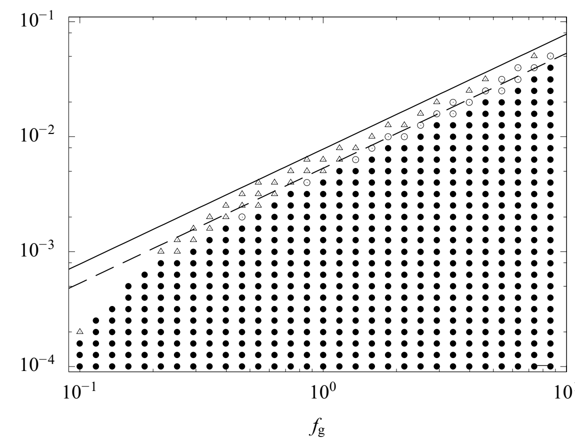

Figure 1: Parameter region for the GI on the normalized disk mass f_g and the turbulent strength α plane. The filled circle points show the cases where the GI takes place. The triangles show the cases where the GI does not take place. The open circles show the cases where the GI does not take place when the non-equilibrium effect is considered. The solid line represents the estimates of the critical α. The dashed line represents the other estimate.

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Gaia DR1 Evidence of Disrupting the Perseus Arm

BABA, Junichi
(NAOJ)

The origin of spiral arms in disk galaxies has been hotly debated since 1960s. There are two different theories of spiral arms in terms of lifetimes and rotational behaviour [1]. The quasi-stationary "density wave" theory characterises spirals as rigidly rotating, long-lived wave patterns (i.e., $\gtrsim$ 1 Gyr) [2]. On the other hand, the "dynamic spiral" theory suggests spiral arms are differentially rotating, transient, recurrent patterns on a relatively short time scale (i.e., ~100 Myr) [3].

In this study [4], we investigated kinematics of 77 Cepheid variables around the Perseus arm in the Milky Way galaxy, taking advantage of the accurately measured distances of Cepheids and the proper motions from Gaia Data Release 1. We found that both the Galactocentric radial ($U_{\rm pec}$) and rotation ($V_{\rm pec}$) velocities of these Cepheids are correlated with their distances from the locus of the Perseus arm (Fig. 1a), as the trailing side is rotating faster (Fig. 1c) and moving inward (Figs. 1b) compared to the leading side. We also found a negative vertex deviation for the Cepheids on the trailing side in contrast to the positive vertex deviation in the solar neighborhood (Fig. 1d).

We compared these observational trends with our N-body/hydrodynamics simulations based on a static density-wave spiral scenario and those based on a transient dynamic spiral scenario. Although our comparisons are limited to "qualitative" trends, they favor a conclusion that the Perseus arm is in the disruption phase of a transient arm. We will further test the disruption phase scenario of the Perseus arm with the future Gaia data releases, and compare more sophisticated simulations.

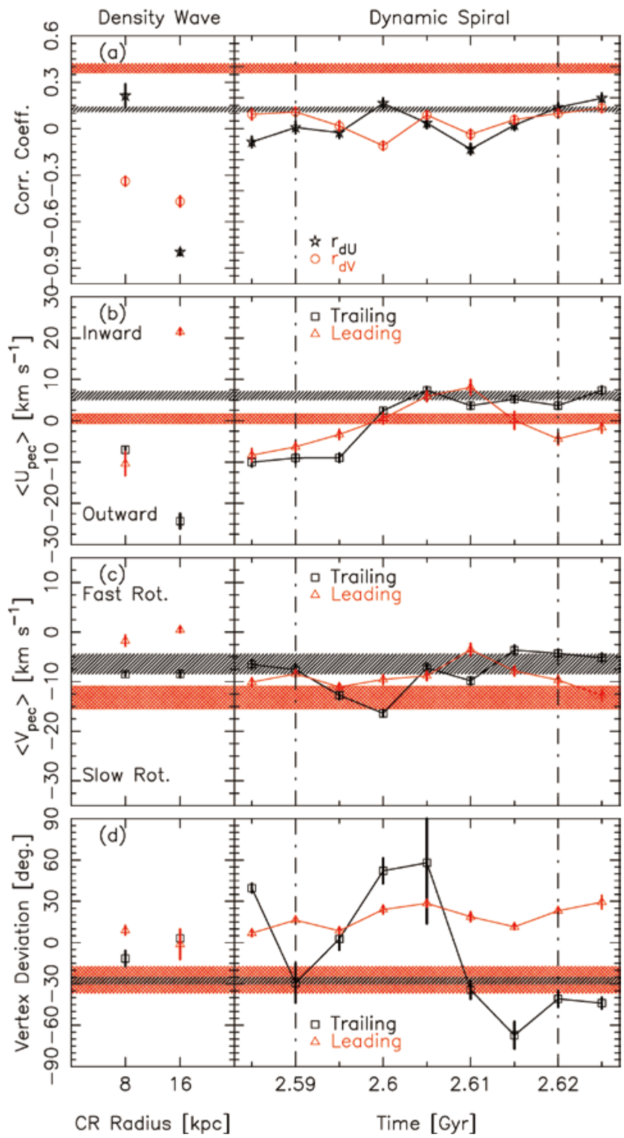

Figure 1: Comparison between the models and the observed kinematics of Cepheids in terms of correlations of $d_{\rm Per}$–$U_{\rm pec}$ and $d_{\rm Per}$–$V_{\rm pec}$ (panel a), mean $U_{\rm pec}$ (panel b), mean $V_{\rm pec}$ (panel c) and the vertex deviation (panel d). Horizontal shaded areas in black and red indicate the observed values. The model results are shown with the open symbols with error bars. Note that the left side of the panels shows the "Density Wave" model results for two different co-rotation (CR) radius values, whereas in the right side the "Dynamic Spiral" model results are presented as a function of time.

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Properties of Galaxies around AGNs in the HSC Wide Survey

SHIRASAKI, Yuji (NAOJ/SOKENDAI) AKIYAMA, Masayuki (Tohoku University) NAGAO, Tohru (Ehime University) TOBA, Yoshiki (ASIAA)

HE, Wanqiu (Tohoku University) OHISHI, Masatoshi, MIZUMOTO, Yoshihiko, MIYAZAKI, Satoshi (NAOJ/SOKENDAI)

NISHIZAWA, J. Atsushi (Nagoya University) USUDA, Tomonori (NAOJ/SOKENDAI)

The ubiquity of super massive black holes (SMBHs) at the centers of galaxies has been recognized from the observation of nearby galaxies. The mechanism of the evolution of SMBHs is however still an open question. Accretion in a secular mode caused by gravitational instability inside a galaxy is one of the mechanism to deliver the gas content into the SMBH. The bright quasi-stellar objects (QSOs) is thought to be maintained by the accretion induced by external processes such as galaxy interactions and/or mergers. Different accretion modes can be the source of feeding SMBH.

We examined the environment of active galactic nuclei (AGNs) to investigate the relevance of the external process to the evolution of SMBHs with masses larger than $10^8\,M_\odot$ [1]. We used the data of the Hyper Suprime-Cam Subaru Strategic Program (HSC-SSP, S15b) for deriving galaxy samples, and the SDSS QSO catalog from which mass of the SMBHs was obtained using the empirical formula relating the emission line width and continuum luminosity to the black hole (BH) mass. The total number of AGN samples used here is 5,345, and those samples cover the redshift range of 0.6–3.0 and the BH mass range of 10^8–$10^{10}\,M_\odot$. This is the first opportunity to investigate the environment of AGNs up to 3.0, which covers the era of the peak of star formation and mass accretion rate for SMBHs, in unprecedented statistics.

Figure 1 shows the distribution of over density of galaxies with a given absolute magnitude at projected distances of 0.2–2.0 Mpc from AGNs relative to those at 7.0–9.8 Mpc. The measured distributions (markers and dashed lines) indicate over density at a bright end against the expectations calculated from the luminosity function obtained in literature (solid lines). It is known that more luminous galaxies tend to be more clustered than less luminous galaxies. According to the SDSS survey and the Subaru deep survey, the auto-correlation length of luminous ($< M_*$: break point of the luminosity function) galaxies is at most $10\,h^{-1}$ Mpc. The auto-correlation length estimated from the over density measured in this work amount to $40\,h^{-1}$ Mpc if we assume that there is no correlation between the distribution of AGNs and the luminous galaxies observed around the AGNs. To resolve the discrepancy from the previous results, we need to think of the association between the AGNs and the luminous galaxies. This indicates that there is an activity which induces star formation and feeding SMBHs beyond $> 10^8\,M_\odot$ in multiple galaxies concurrently at several Mpc scale. We also obtained the indication that the environment of AGNs with larger BH mass has tendency to have larger red galaxy fraction. Those result indicate that the mechanism to evolve the SMBH beyond $10^8\,M_\odot$ is related with the large scale phenomena such as a collision between clusters and/or groups of galaxies.

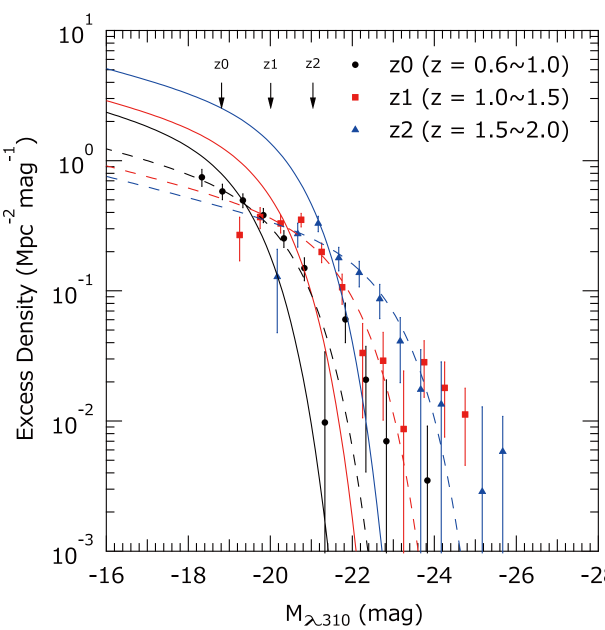

Figure 1: Absolute magnitude distributions of galaxies measured by subtracting the distribution at projected distance from AGNs r_p = 7.0–9.8 Mpc from that at 0.2–2.0 Mpc (markers). Detection efficiency (completeness) of galaxies was corrected. Solid lines represents the distribution expected from the luminosity function measured in literature. Dashed lines are the Schechter function fitted to the observation. The arrows indicate 90 % detection limit.

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Small Jupiter Trojans Survey with the Subaru/Hyper Suprime-Cam

YOSHIDA, Fumi
(Chiba Institute of Technology/Kobe University)
TERAI, Tsuyoshi
(NAOJ)

Jupiter Trojans (JTs) are asteroids that share the orbits with Jupiter and make swarms near the Lagrangian points L4 (leading) or L5 (trailing) of Jupiter. They are a major small-body population located in the middle region between the main belt asteroids (MBAs) and trans-Neptunian objects (TNOs). Recent dynamical models suggest that JTs have formed between/beyond the outer planet regions and were captured into Jupiter's co-orbital region during the dynamical instability phase induced by planetary migration. Investigation of the origin and evolution of JTs is useful for understanding the radial mixing processes of small bodies in that phase.

Here, we focus on the size frequency distribution (SFD) of JTs as a tracer of their origin, but it remains uncertain in the small size range. The SFD includes two kinds of information regarding the accumulation process and collisional evolution process in the large and small size ranges, respectively. These are important clues for the formation region of JTs. Owing to the large aperture of the Subaru Telescope, we detected the smallest sized JTs obtained by the present ground-based telescopes, and investigated the detail SFD of small JTs, which is characterized by the impact strength properties.

We performed an asteroid survey covering ~26 deg^2 of sky area near the Jupiter L4 point using the Hyper Suprime-Cam attached to the Subaru Telescope and detected 631 JTs [1]. The detection limit is 24.4 mag in r band, which is corresponding to ~2 km in diameter assuming a geometric albedo of 0.07 [2]. Considering the detection limit and heliocentric distance of each object, we selected 481 objects as the unbiased sample. The number of sample is more than three times larger than that of the previous surveys [3,4]. We found that the SFD exhibits a single-slope power law over the diameter range of ~2 km to ~10 km and has no feature such as a break and roll-over, though the previous surveys reported a broken power-law or double power-law slopes in the similar size range. The best-fit power-law index of the absolute magnitude distribution $N(H) \propto 10^{\alpha H}$, where H is absolute magnitude, is estimated to be $\alpha = 0.37 \pm 0.01$. This value is consistent with that of the faint end slope presented by Wong & Brown (2015) [4].

Combining the cataloged L4 JTs and our survey, we finally show the entire SFD of L4 JTs down to 2 km in diameter (see Figure 1). We confirmed that JTs' SFD has a power-law transition at diameter of ~10 km but does not show a "wavy" structure which is significantly seen in that of MBAs. This indicates a discrepancy in the impact strength properties between JTs and MBAs, suggesting that these two populations have different composition/collisional evolution. Therefore, it is likely that they originated from different formation regions.

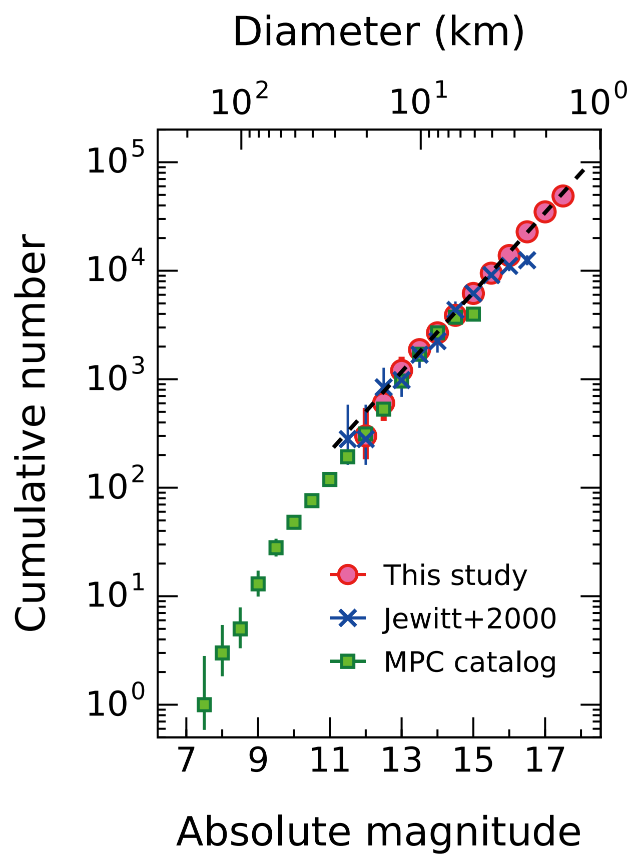

Figure 1: Cumulative SFDs of L4 JTs combined with the data from the Minor Planet Center catalog (squares), Jewitt et al. (2000) [5] (crosses), and this work (circles). The dashed line shows the best-fit power law of our data.

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Multi-band Photometry of Trans-Neptunian Objects in the Subaru Hyper Suprime-Cam Survey

TERAI, Tsuyoshi (NAOJ)
YOSHIDA, Fumi (Chiba Institute of Technology/Kobe University)
OHTSUKI, Keiji (Kobe University)
LYKAWKA, Patryk Sofia (Kindai University)

TAKATO, Naruhisa, HIGUCHI, Arika, ITO, Takashi, KOMIYAMA, Yutaka, MIYAZAKI, Satoshi
(NAOJ)

WANG, Shiang-Yu
(ASIAA)

Trans-Neptunian objects (TNOs), a small body population orbiting beyond the Neptune, have been known to exhibit a diversity in visible color, which is likely to reflect their formation environment. The color distribution of TNOs is helpful to study the formation and evolution of small bodies in the outer region at the early stage of our solar system.

We performed a visible multi-band photometry of TNOs [1] using the data acquired by the Subaru Telescope with Hyper Suprime-Cam (HSC) through the Subaru Strategic Program survey [2]. From the five broad-band (g, r, i, z, and Y) imaging data covering ~500 deg^2 of sky within ± 30° of ecliptic latitude, we identified 30 known TNOs. Based on the dynamical classification scheme presented by Lykawka and Mukai (2007) [3], these objects are classified into the four dynamical groups: 13 cold classical, 6 hot classical, 7 scattered, and 4 resonant populations. Our color measurements showed that the hot classical and scattered populations with orbital inclination (I) of $I > 6°$ (hereinafter, "high-I population") share similar color distributions, while the cold classical population with $I < 6°$ (hereinafter, "low-I population") contains a more amount of reddish objects in the short wavelength range compared to the high-I population. In addition, we confirmed a significant anti-correlation between g-r/r-i colors and inclination in the high-I population as previous studies pointed out.

We also found that the sample objects are separated into two swarms in the g-i vs. eccentricity (e) plot (see Figure 1), i.e., the red/low-e and neutral/high-e groups. Although most of the high-I objects are contained in the neutral/high-e group, four of them are located in the red/low-e region. This fact suggests that the high-I objects consist of two sub-populations, which could provide a useful clue for better understanding the dynamical evolution history of TNOs in the early solar system.

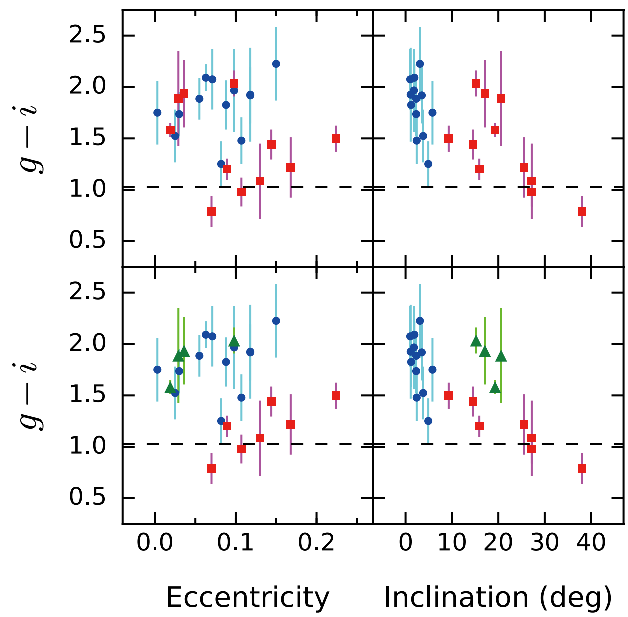

Figure 1: Top: g-i color vs. eccentricity/inclination of the low-I (circles) and high-I (squares) populations. The dashed lines show the solar color. Bottom: The same plot as the top panels, but the red high-I objects are marked with triangles.

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Disentangling the Circumnuclear Disk of Centaurus A with ALMA: An Inner Molecular Ring, Nuclear Shocks and the CO to warm H_2 Interface

ESPADA, Daniel[1/2], MATSUSHITA, Satoki[3], MIURA, Rie E.[1], ISRAEL, Frank P.[4], NEUMAYER, Nadine[5] MARTIN, Sergio[6/7], HENKEL, Christian[8/9], IZUMI, Takuma[10], IONO, Daisuke[1/2], AALTO, Susanne[11] OTT, Jürgen[12], PECK, Alison B.[13], QUILLEN, Alice C.[14], KOHNO, Kotaro[10]

1: NAOJ, 2: Graduate University for Advanced Studies, 3: Academia Sinica, Institute of Astronomy & Astrophysics, 4: Sterrewacht Leiden, Leiden University, 5: Max Planck Institute for Astronomy, 6: Joint ALMA Observatory, 7: European Southern Observatory, 8: Max-Planck-Institut für Radioastronomie, 9: King Abdulaziz University, Saudi Arabia, 10: The University of Tokyo, 11: Chalmers University, 12: National Radio Astronomy Observatory, 13: Gemini Observatory, 14: University of Rochester

We present the distribution and kinematics of the molecular gas in the circumnuclear disk (CND, 400 pc × 200 pc [1]) of Centaurus A with resolutions of ~5 pc (0ʺ.3) and shed light onto the mechanism feeding the Active Galactic Nucleus (AGN) using CO(3–2), HCO^+(4–3), HCN(4–3), and CO(6–5) observations obtained with ALMA [2]. Multiple filaments or streamers of tens to a hundred parsec scale exist within the CND, which form a ring-like structure with an unprojected diameter of 162 pc × 108 pc and a position angle $PA \simeq 155°$. Inside the nuclear ring, there are two leading and straight filamentary structures with lengths of about 30–60 pc at $PA \simeq 120°$ on opposite sides of the AGN, with a rotational symmetry of 180° and steeper position-velocity diagrams, which are interpreted as nuclear shocks due to non-circular motions. Along the filaments, and unlike other nearby AGNs, several dense molecular clumps present low HCN/HCO^+(4–3) ratios (< 0.5). The filaments abruptly end in the probed transitions at $r \simeq 20$ pc from the AGN, but previous near-IR H_2(J=1–0)S(1) maps show that they continue in an even warmer gas phase (T ~ 1000 K), winding up in the form of nuclear spirals, and forming an inner ring structure with another set of symmetric filaments along the N–S direction and within $r \simeq 10$ pc. The molecular gas is governed primarily by non-circular motions, being the successive shock fronts at different scales where loss of angular momentum occurs, a mechanism which may feed efficiently powerful radio galaxies down to parsec scales.

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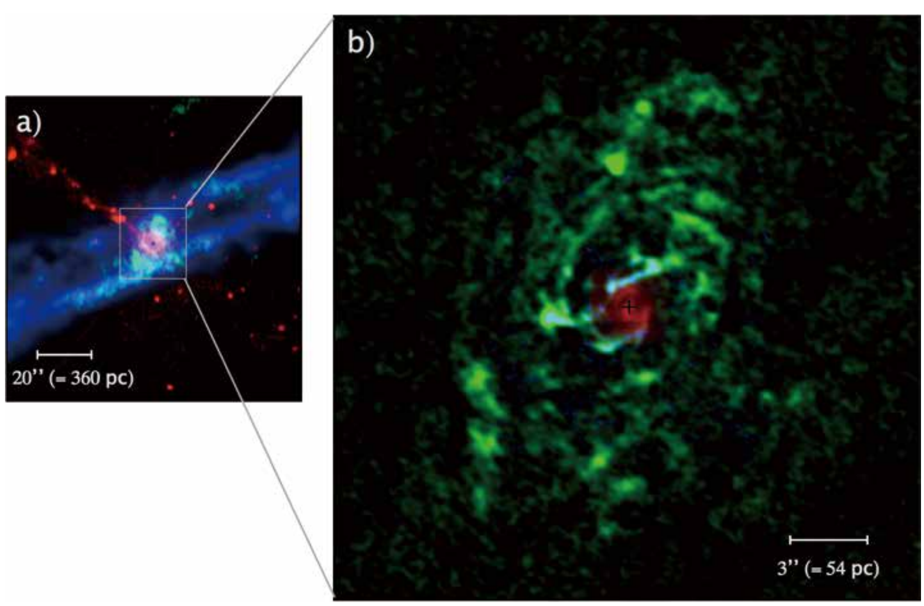

Figure 1: Kiloparsec to parsec scale view of the molecular disk of Cen A (NGC 5128): **a)** Integrated CO(2–1) emission map (green) observed using the Submillimeter Array (SMA, [1]). The circumnuclear disk is just perpendicular to the X-ray/radio jet (red, Chandra). A more extended molecular gas component in form of spiral arms [3] is seen. **b)** Composite image of the CND of Cen A including the ALMA CO(3–2) (green) and CO(6–5) (blue) integrated intensity maps, as presented in [2]. The distribution of molecular hydrogen as traced by the H_2 line (red) is mostly contained within a field of view of 54 pc. The cross sign in the center of the image shows the AGN position.

Supernova Nucleosynthesis Enhanced by Collective Neutrino Oscillations

SASAKI, Hirokazu (University of Tokyo)
KAJINO, Toshitaka (NAOJ/Beihang University/University of Tokyo)
TAKIWAKI, Tomoya (NAOJ)
HAYAKAWA, Takehito (QST)
PHELIVAN, Yamac (Mimar Sinan Fine Arts University)
BALANTEKIN, Baha (University of Wisconsin Madison)

Neutrinos are produced inside high energy astrophysical sites such as core-collapse supernovae, neutron star mergers and the early universe. Neutrino spectra can be affected by inner materials and neutrino themselves. Therefore, we can reveal properties of astrophysical phenomena by observing emitted neutrinos.

In core-collapse supernovae, energetic neutrinos are emitted from a proto-neutron star after the core-bounce. Non-linear neutrino flavor transitions called "collective neutrino oscillations" [1] are induced by coherent scatterings of self-interacting neutrinos outside the proto-neutron star. Collective neutrino oscillations transform the spectra of all neutrino species. Such modified neutrino spectra could change reaction rates of electron antineutrino absorptions on free protons, which is expected to affect νp process nucleosynthesis [2]. However, contributions from neutrino flavor transitions on such nucleosynthesis are still unknown.

In this work [3], we study the impact of collective neutrino oscillations on the νp process nucleosynthesis by combining realistic three flavor multiangle simulations with network calculations. Fig. 1 shows antineutrino spectra after collective neutrino oscillations. The energetic electron antineutrinos are produced in normal neutrino mass hierarchy (Fig. 1a). On the other hand, flavor transitions are highly suppressed owing to multiangle effects in inverted neutrino mass hierarchy (Fig. 1b). As shown in Fig. 2, the abundances of p-nuclei are enhanced by collective neutrino oscillations up to 10^4 times in normal mass hierarchy, which reflects the increased $\bar{\nu}_e$ flux in Fig. 1a. Our results imply the necessity of collective neutrino oscillations for the precise nucleosynthesis in neutrino-driven winds and also help understand the origin of solar-system isotopic abundances of molybdenum 92, 94 and ruthenium 96, 98.

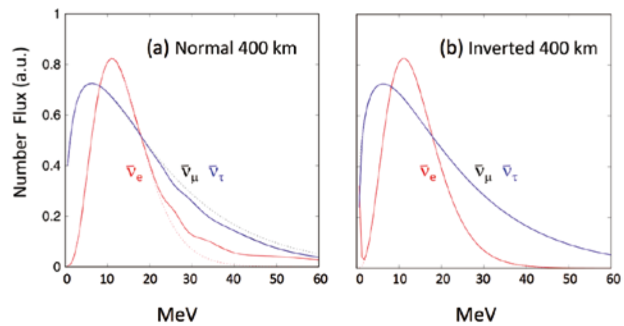

Figure 1: Antineutrino spectra after collective neutrino oscillations. Fig. 1a(b) represents the case of normal (inverted) neutrino mass hierarchy, respectively. The dotted lines are corresponding to initial spectra.

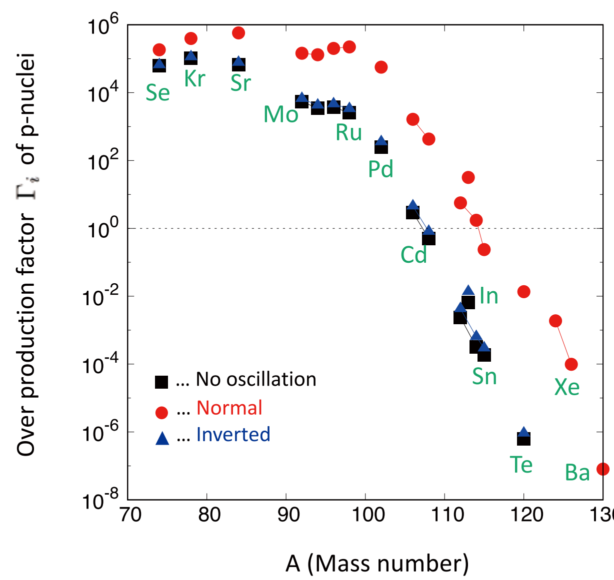

Figure 2: Nuclear abundances of p-nuclei (^{74}Sr, ^{78}Kr, ..).

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On the Disappearance of a Cold Molecular Torus around the Low-luminosity Active Galactic Nucleus of NGC 1097

IZUMI, Takuma[1], ESPADA, Daniel[1], IMANISHI, Masatoshi[1], NAKANISHI, Kouichiro[1], KOHNO, Kotaro[2]
FATHI, Kambiz[3], HATZIMINAOGLOU, Evanthia[4], DAVIES, Ric[5], MARTIN, Sergio[6/4], MATSUSHITA, Satoki[7]
SCHINNERER, Eva[8], AALTO, Susanne[9], ONISHI, Kyoko[10], TURNER, Jean L.[11], MEIER, David S.[12]
WADA, Keiichi[13], KAWAKATU, Nozomu[14], NAKAJIMA, Taku[15]

1: NAOJ, 2: University of Tokyo, 3: Valhallav, 4: ESO, 5: MPIE, 6: JAO, 7: ASIAA, 8: MPIA, 9: Chalmers University, 10: Ehime University, 11: UCLA, 12: NMIMT, 13: Kagoshima University, 14: Kure National Institute of Technology, 15: Nagoya University

The unified scheme of active galactic nuclei (AGNs) postulates that the existence (type-1) or absence (type-2) of a broad line region depends on the viewing angle of an optically and geometrically thick dusty/molecular torus [1]. However, the physical origin of the high-velocity dispersion or the vertical height of a torus is still being debated. At the circumnuclear ~ 10–100 pc scales, energy feedback from supernova explosions and radiation-driven outflows from the AGN itself can be candidate mechanisms [2,3].

In order to study the torus properties in more detail, we used the Atacama Large Millimeter/Submillimeter Array to map the CO(3–2) and the underlying continuum emissions around the type-1 low-luminosity active galactic nucleus (LLAGN; bolometric luminosity < 10^{42} erg s^{-1}) of NGC 1097 at ~10 pc resolution [4]. These observations revealed a detailed cold gas distribution within a ~100 pc of this LLAGN (Figure 1a). In contrast to the luminous Seyfert galaxy NGC 1068, where a ~7 pc cold molecular torus was recently revealed [5], a distinctively dense and compact torus is missing in our CO(3–2) integrated intensity map of NGC 1097, at its AGN location. Based on the CO(3–2) flux, the gas mass of the torus of NGC 1097 would be a factor of ~ 2–3 less than that found for NGC 1068 by using the same CO-to-H_2 conversion factor, which implies less active nuclear star formation and/or inflows in NGC 1097, i.e., an energy source to support the torus thickness would be missing in this LLAGN. To better confirm this view, we performed a dynamical modeling of the CO(3–2) velocity field to decompose the rotation component (V_{rot}) and dispersion component (σ) with tilted-rings (Figure 1b). We then found that NGC 1097 hosts a geometrically thinner torus than NGC 1068, indeed, as reflected by the σ/V_{rot} ratio (a surrogate of the disk aspect ratio; Figure 1c). Although the physical origin of the torus thickness remains unclear, our observations support a theoretical prediction that geometrically thick tori with high opacity will become deficient as AGNs evolve from luminous Seyferts to LLAGNs.

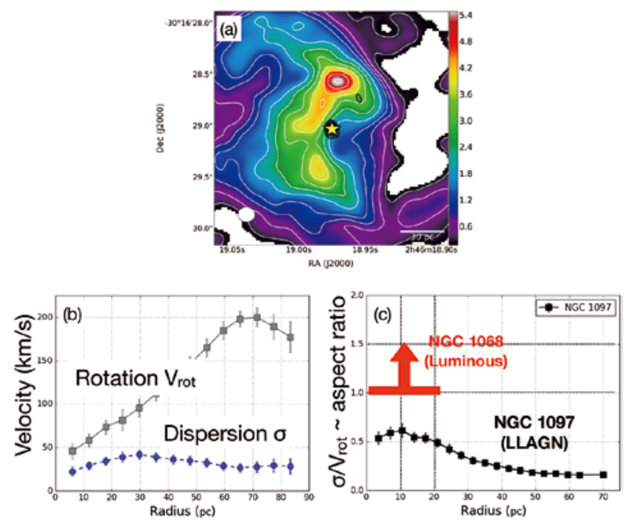

Figure 1: (a) Global spatial distribution of the CO(3–2) integrated intensity in the central ~130 pc of NGC 1097. The central star marks the AGN location. No clear gas concentration was found at the AGN position, indicating the deficit of the molecular torus. (b) Radial profiles of the rotation velocity (V_{rot}; squares) and the velocity dispersion (σ; circles) derived from the CO(3–2) line data with tilted-ring models. (c) Radial profiles of the σ/V_{rot} ratio derived from the CO(3–2) line of NGC 1097. The ratio of NGC 1097 is well smaller than that of the luminous AGN of NGC 1068.

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Molecular Gas Fraction in Interacting Galaxies in Early and Mid Stage Using $^{12}CO(J = 1\text{–}0)$ Mapping Observations

KANEKO, Hiroyuki[1], KUNO, Nario[2], IONO, Daisuke[1/3], TAMURA, Yoichi[4]
TOSAKI, Tomoka[5], NAKANISHI Koichiro[1/3], SAWADA Tsuyoshi[1/6]

1: NAOJ, 2: University of Tsukuba, 3: The Graduate University for Advanced Studies, 4: Nagoya University, 5: Joetsu University of Education, 6: Joint ALMA Observatory

Galaxy interactions play an important role on galaxy evolution. An enhancement of infrared luminosity has been observed from interacting galaxies, meaning that star formation activity is enhanced during the galaxy interaction. However, the detailed mechanism of this phenomena is still unknown. Since molecular gas is a fuel of star formation, it is important to understand how molecular gas is affected through an interaction event for revealing the interaction-induced star formation in interacting galaxies.

We previously have discovered the molecular gas distributions for four interacting galaxies in early and mid stage by mapping observations of $^{12}CO(J = 1\text{–}0)$ emission line with the Nobeyama 45-m radio telescope [1]. Molecular gas distributions are different from atomic gas and stellar distributions: they are not concentrated to their centre of progenitors compared with isolated galaxies. This fact suggests that physical properties of molecular gas is affected even at the beginning of the interaction.

In order to inquire detailed effects onto molecular gas by the interaction, we investigate global molecular gas fraction $f_{\rm mol}^{\rm global}$, which is defined as

$$f_{\rm mol}^{\rm global} = \frac{M_{\rm H2}}{M_{\rm total}}, \quad (1)$$

where $M_{\rm H2}$ and $M_{\rm total}$ are molecular gas and total gas (a sum of molecular gas and atomic gas) mass of the galaxy, respectively. We find that the global molecular gas fraction for interacting galaxies is significantly higher than isolated galaxies, implying the conversion from atomic gas to molecular gas by the interaction.
We further derive local molecular gas fraction $f_{\rm mol}$. $f_{\rm mol}$ is expressed by the following equation:

$$f_{\rm mol} = \frac{\Sigma_{\rm H2}}{\Sigma_{\rm total}}, \quad (2)$$

where $\Sigma_{\rm H2}$ and $\Sigma_{\rm total}$ are the surface density of molecular gas and total gas, respectively. Figure 1 shows $f_{\rm mol}$ distributions for four target interacting galaxies. All interacting systems illustrate complex $f_{\rm mol}$ distributions, while an isolated galaxy has a $f_{\rm mol}$ peak at the galactic centre and $f_{\rm mol}$ decreases with an increase of radius. In order to investigate how these distributions achieved, we perform theoretical model fitting based on [2]. Following the failure of the fitting, we include a new term representing external pressure to the original model. Our new model successfully explains the observed $f_{\rm mol}$–$\Sigma_{\rm total}$ relations. We conclude that higher molecular gas fraction in interacting galaxies is achieved efficient conversion from atomic gas to molecular gas which is by high external pressure. The molecular gas produced through this process may be an ingredient of active star formation in interacting galaxies [3].

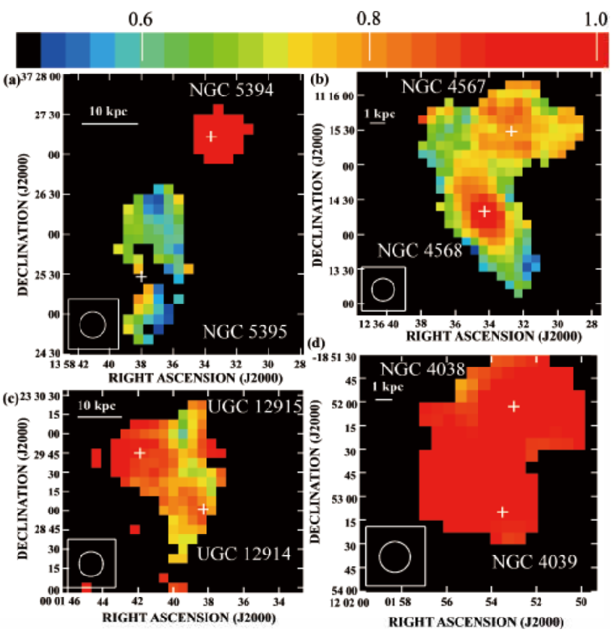

Figure 1: Local molecular gas fraction $f_{\rm mol}$ for four target interacting galaxies.

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Searches for New Milky Way Satellites from the Subaru/HSC Survey: Discovery of Cetus III

HOMMA, Daisuke (NAOJ) CHIBA, Masashi (Tohoku University) OKAMOTO, Sakurako, KOMIYAMA, Yutaka, TANAKA, Masayuki (NAOJ)

TANAKA, Mikito (Hosei University) ISHIGAKI, Miho N. (Kavli IPMU, WPI) HAYASHI, Kohei (University of Tokyo) ARIMOTO, Nobuo (Seoul University)

GARMILLA, Jose A., LUPTON, Robert H., STRAUSS, Michael A. (Princeton University) MIYAZAKI, Satoshi (NAOJ)

WANG, Shiang-Yu (ASIAA) MURAYAMA, Hitoshi (Kavli IPMU, WPI)

The current standard theory of structure formation in the universe, Λ model, predicts that a Milky Way (MW)-sized host halo is surrounded by hundreds to thousands of subhalos. However, this prediction is in conflict with the observed number of only ~50 MW satellites. This is the missing satellites problem, which is one of the unresolved issues related to ΛCDM models. One of the possible solutions to the missing satellites problem is that we are still undercounting the population of fainter or more distant satellites in the MW due to various observational biases. Motivated by this, we have started a systematic search for new MW satellites in the course of the Subaru Strategic Program (SSP) using Hyper Suprime-Cam (HSC), and have already discovered an extremely faint satellite candidate, Virgo I, from the early survey data [1].

We report here the discovery of the second new MW satellite candidate, Cetus III, from the first two years of HSC-SSP data [2]. It is estimated that an absolute magnitude of Cetus III is $M_V \sim -2.4$ mag and a heliocentric distance is ~250 kpc in the direction of the constellation Cetus. The areas where we have discovered Cetus III and Virgo I have been previously surveyed by SDSS, but they are beyond the detection limit of SDSS (Fig. 1), Therefore, the Subaru/HSC is able to discover yet unidentified faint or distant satellites owing to its wide and deep survey and is very effective for the search of missing satellites.

Based on ΛCDM models, we will discover about 10 satellites in the completed HSC-SSP survey over ~1400 deg^2 (Fig. 2). Now we have disovered 2 new satellites (Cetus III, Virgo I) from first two years data (~300 deg^2 covered), the frequency of discovery (1 satellite per 100~200 deg^2) is so far consistent with the prediction of ΛCDM models. In the near future, we expect to find more new satellites, and then the completion of HSC-SSP survey will provide important insights into the nature of dark matter and galaxy formation theory by comparing the results of obserbation such as the number and the spatial distribution of satellites with those of ΛCDM models.

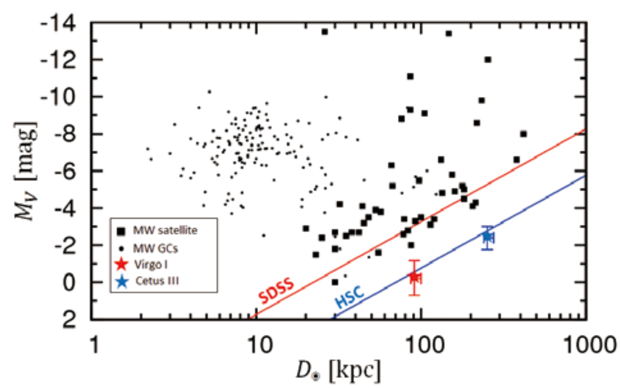

Figure 1: The relation between M_V and heliocentric distance for stellar systems. Dots denote globular clusters in the MW and filled squares denote the MW satellites. The red and blue lines indicate the detection limits of SDSS and HSC, respectively.

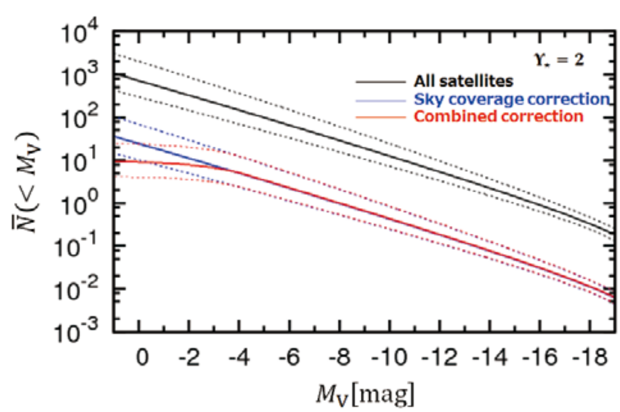

Figure 2: Black solide line denotes the cumulative luminosity function of visible satellites in the MW-sized halo calculated from ΛCDM models. Blue solid line considers the correction only for the sky coverage of the HSC-SSP survey (~1400 deg^2). In addition, red solid line considers the corrections for the detection limit of HSC-SSP survey.

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Detection of Rotating Outflow Driven by a High-mass Protostar Candidate Orion KL Radio Source I

HIROTA, T., HONMA, M.
(NAOJ/SOKENDA)

MACHIDA, M. N., MATSUSHITA, Y.
(Kyushu University)

MOTOGI, K., MATSUMOTO, N.
(Yamaguchi University)

KIM, M. K.
(NAOJ/KASI)

BURNS, R. A.
(JIVE)

In star-formation processes, in particular for high-mass stars, it is still unclear how surrounding matters can accrete onto central protostars. One of the unresolved problems is to understand transfer of angular momentum from the accreting matters, which has been regarded as "angular momentum problem". From a theoretical point of view, outflows and jets are predicted to play essential roles in the transfer of angular momentum. However, observational evidences for this phenomenon are still limited even for nearby low-mass protostars until very recent progress, and little quantitative studies have been presented for high-mass stars.

We carried out observations of the nearest high-mass protostar candidate in Orion KL (420 pc), Radio Source I using ALMA, and detected a rotating outflow ejected from a circumstellar disk. Observations were done in ALMA cycle 2, and the high spatial resolution of 0.1 arcseconds was achieved at band 8, 400–500 GHz. A rotational transition of the ^{18}O isotopologue of silicon monoxide (Si^{18}O) reveals the outflow showing a clear signature of the velocity gradient perpendicular to the outflow axis (Figure 1). It is consistent with that of the circumstellar disk traced by the high excitation (vibrationally excited) water (H_2O) line. Considering the equilibrium of the centrifugal force and gravity, the mass of the central object is estimated to be 8.7 $M_{\odot}$. The outflow traced by the Si^{18}O line is launched at > 10 au radii from the central object, and the outward velocity of the outflow is estimated to be 10 km s^{-1} based on a 3D model. These outflow parameters are consistent with the theoretical model of the magneto-centrifugal disk wind as a driving mechanism of the outflow observed in the high-mass protostar candidate Orion KL Source I. Our results suggest that the outflow driven by the magneto-centrifugal disk wind would play an essential role for angular momentum transfer in high-mass star-formation processes.

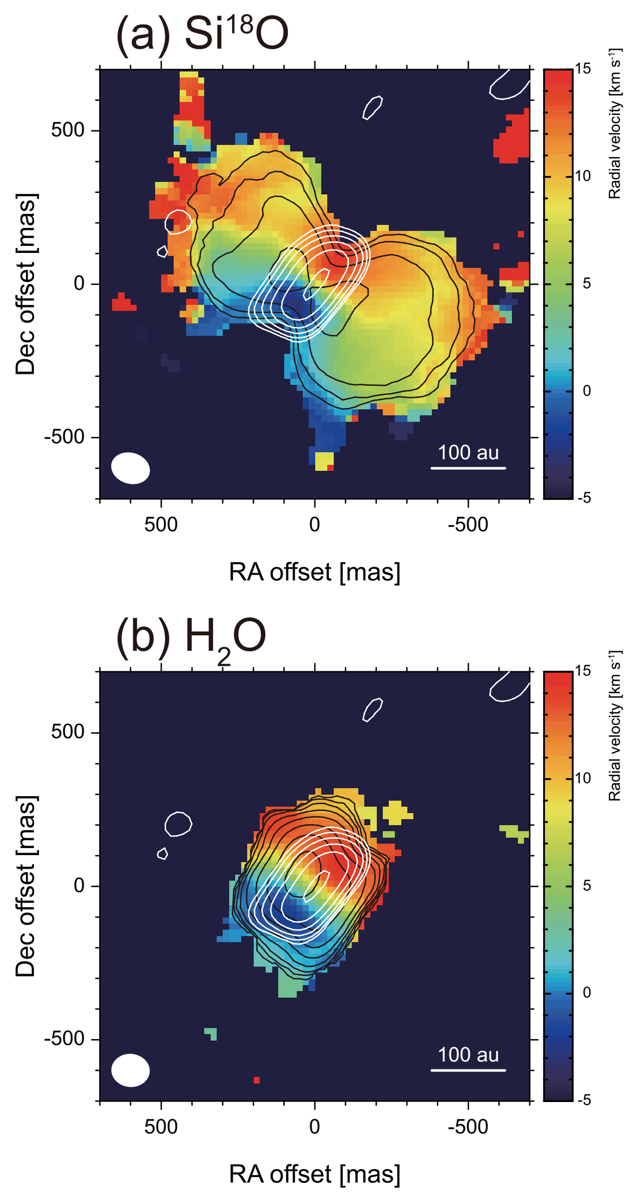

Figure 1: (a) ALMA band 8 continuum emission tracing the disk (white contours), integrated intensity and radial velocity maps of the ^{18}O isotopologue of silicon monoxide (Si^{18}O) line at 484 GHz, showing the outflow driven from the disk (black contours and color scale, respectively). (b) Same as (a) but for the high excitation (vibrationally excited) water (H_2O) line at 463 GHz, tracing the hot rotating gas disk.

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Evolutionary Phases of Gas-rich Galaxies in a Galaxy Cluster at $z = 1.46$

HAYASHI, Masao (NAOJ)
KODAMA, Tadayuki (Tohoku University)
KOHNO, Kotaro, YAMAGUCHI, Yuki (University of Tokyo)
TADAKI, Ken-ichi (NAOJ)
HATSUKADE, Bunyo (University of Tokyo)
KOYAMA, Yusei, SHIMAKAWA, Rhythm[1] (NAOJ)
TAMURA, Yoichi (Nagoya University)
SUZUKI, L. Tomoko[2] (Tohoku University)

Gas content of galaxies is one of fundamental quantities directly related to the star-formation activities in galaxies. Since it is expected that star-forming galaxies in high-z galaxy clusters grow to massive early-type galaxies in the local Universe, the cluster galaxies' gas content should allow us to better understand the quenching mechanisms of galaxies in dense environments.

We conducted a survey of molecular gas in galaxies in the XMMXCS J2215.9-1738 cluster at $z = 1.46$ with ALMA. We have detected emission lines from 17 galaxies within a radius of R_{200} from the cluster center, in Band 3 data with a coverage of 2.33 arcmin^2. The lines are all identified as CO $J = 2$–1 emission lines from cluster members at $z \sim 1.46$ by their redshifts and the colors of their optical and near-infrared counterparts. This is the largest sample of CO emission-line galaxies associated with a $z > 1$ galaxy cluster to date.

The spatial distribution of galaxies with CO(2–1) detected suggests that they disappear from the very center of the cluster (Figure 1). The phase-space diagram showing relative velocity versus cluster-centric distance indicates that the gas-rich galaxies have entered the cluster more recently than the gas-poor star-forming galaxies and passive galaxies located in the virialized region of this cluster (Figure 2). The results imply that the galaxies have experienced ram-pressure stripping and/or strangulation during the course of infall towards the cluster center and then the molecular gas in the galaxies at the cluster center is depleted by star formation. Refer to [1] for further discussion.

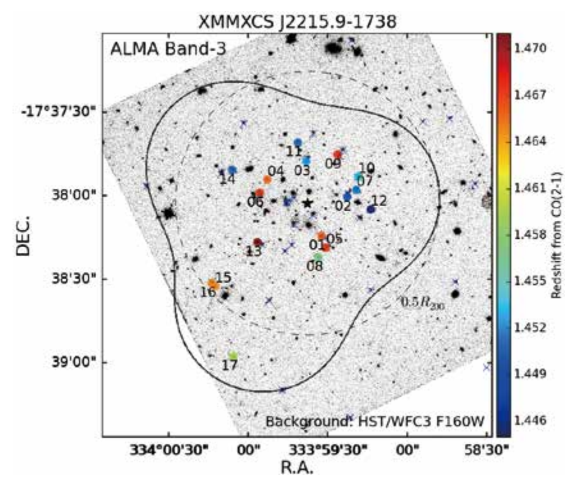

Figure 1: Spatial distribution of galaxies with CO(2–1) line detected which are shown by filled circles. The solid curve shows a region where the ALMA Band 3 data are available. The cross symbols show the [O II] emitters associated with this cluster [2]. A star symbol shows a cluster center [3]. The dashed circle shows the cluster-centric radius of $0.5R_{200}$ [4].

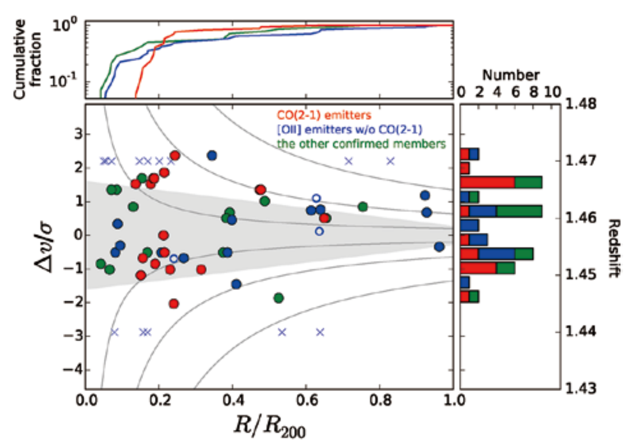

Figure 2: Phase-space diagram showing the relative line-of-sight velocities as a function of cluster-centric distance. Red circles show the CO(2–1) emitters. Blue symbols show the [O II] emitters without CO(2–1) detection. Green circles show the other spectroscopically confirmed cluster members [4,2]. The gray region shows a virialized area defined by [5]. The gray lines show the curves of constant $v \times R$ values [6]. (right panel) Redshift histograms of spectroscopically confirmed galaxies. (upper panel) Cumulative fraction of the number of galaxies as a function of radius from the cluster center.

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[1] (UCO/Lick Observatory) as of the publication date
[2] (NAOJ) as of the publication date

Morphological Evidence for a Past Minor Merger in the Seyfert Galaxy NGC 1068

TANAKA, Ichi, YAGI, Masafumi
(NAOJ)
TANIGUCHI, Yoshiaki
(The Open University of Japan)

NGC 1068 is one of the archetypical Type-2 Seyfert galaxies in the local Universe. Thanks to its close proximity (~15 Mpc) and nearly face-on configuration, many observational studies have been done about the galaxy.

There are two major hypotheses on how the Seyfert-type Active Galactic Nuclei (AGNs) are triggered. One mechanism attributes to the internal secular process, where the galactic disk generates the non-axisymmetric structure (e.g., bars) which efficiently removes the angular momentum of the circulating gas to dump it to the center. NGC 1068 indeed has the bar structure in the center. However, it is also known that the axis of the dust torus around the central Supermassive Blackhole (SMBH) is nearly perpendicular to the rotation axis of the galactic disk. Such misalignment between the central dust torus and the disk of host galaxy is often observed among Seyfert galaxies. Explaining the mis-alignment is not so easy for the triggering scenario by secular evolution.

The other hypothesis is the external trigger such as mergers. On this standpoint, Taniguchi (1999) proposed the AGN unification model by mergers. They discussed that all Seyfert AGN activities were triggered by the minor merger of the *nucleated* (= with the SMBH at its center) satellite galaxy [1]. When a satellite is merged to the main galaxy, most of its body will be destroyed by the tidal field of the main galaxy. However, if it is nucleated, its core with a SMBH can survive and go into the center of the main galaxy to merge with the host SMBH. During the sinking process, the gravitational interaction can violently disturb the gas near the center of the main galaxy, which will lead to the AGN activity. As the angle of the dust torus and the narrow line region around the SMBH is basically determined by the orbit of the sinking satellite, its correlation with the rotation axis of the main disk would be weak as observed. However, no previous studies ever detected the morphological sign of the minor merger around NGC 1068.

We thought that the sign of minor merger might still remain at the very outer part of the host galaxy, due to its longer dynamical timescale. We observed NGC 1068 by Subaru in late 2016. Using the deep optical data by Hyper Suprime-Cam (HSC) and Suprime-Cam, we have discovered the very faint signatures of the past tidal interaction for the first time [2]. This is shown in the top panel of the Figure 1. There are two very faint (> 27 mag arcsec^{-2}: *r* band AB) spurs near the north and the south of the main disk. Their morphology suggests that they are a part of the loop (see the insets at right of the Fig. 1[top]). Such stream structure can be made by the minor merger occurred several Gyrs ago. And also, there are the intriguing structures on the faint outer disk. The bottom panel of fig.1 is the contrast-enhanced image of the outer disk structure. The one-arm structure ("Banana") as well as the "ripple" on the other side are clearly visible. Such structures are also shown to be made by the past minor merger event several Gyr ago by the simulations (see discussions in Tanaka et al. 2017 for more).

Our findings are consistent with the proposed idea by Taniguchi (1999). We recently started the new imaging survey for faint tidal signature on Seyferts by HSC. We will expand the sample size to see how minor merger is important to trigger the Seyfert activity.

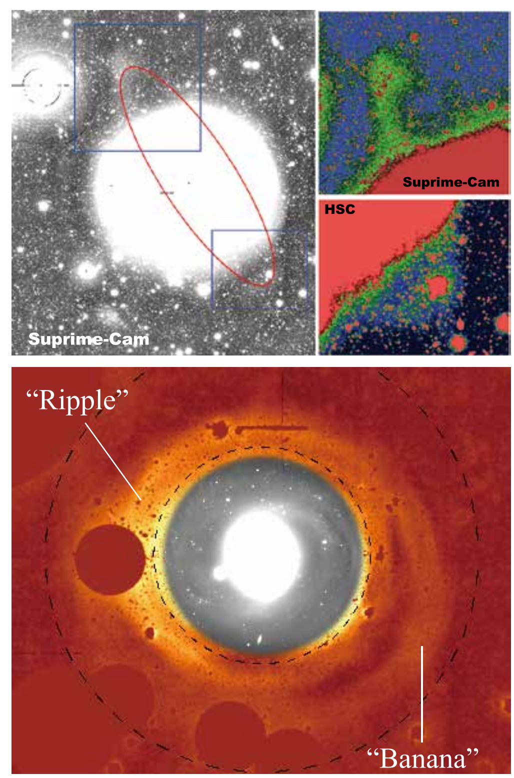

Figure 1: [Top] The discovered diffuse signatures around NGC 1068 by Subaru. Their morphology apparently resembles a part of a loop which could be the tidal stream (see the right two panels). The image size is 19′ × 21′. [Bottom] The contrast-enhanced view of the faint outer disk of NGC 1068. The single-arm structure ("Banana") and the ripple-like feature ("Ripple") are seen. See the ref. [2] for more detail.

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A Universal Correlation between Star Formation Activity and Molecular Gas Properties across Environments

KOYAMA, Shuhei[1], KOYAMA, Yusei[2], YAMASHITA, Takuji[1], MOROKUMA, Kana[3], MATSUHARA, Hideo[3/4]
NAKAGAWA, Takao[3], KODAMA, Tadayuki[5], HAYASHI, Masao[2], SUZUKI, Tomoko[5]
TADAKI, Kenichi[2], TANAKA, Ichi[2], SHIMAKAWA, Rhythm[2], YAMAMOTO, Moegi[4]

1: Ehime University, 2: NAOJ, 3: ISAS/JAXA, 4: SOKENDAI, 5: Tohoku University

In the local universe, it is well known that the fraction of early-type galaxies increases with local galaxy density, while that of late-type galaxies decreases [1]. This strong correlation between galaxy properties and environment suggests that the environment plays an important role in shaping the nature of individual galaxies. It is believed that accelerated galaxy growth and/or efficient quenching of star formation in high-density environments could explain the environmental difference, but the physical causes (or mechanisms) responsible for the environmental effects are still unclear.

In this study, we focused on the environmental impacts on molecular gas properties as the origin of environmental effect, and investigated the environmental dependence of the relation between star formation activity and molecular gas content. The galaxy sample were selected from SDSS DR7 spectroscopic data. We defined the galaxy environment based on the local number density of galaxies, which is expressed as

$$\Sigma_5 = \frac{5}{\pi D_{p,5}^2}\,[\mathrm{Mpc}^2] \qquad (1)$$

$$\rho_5 = \frac{\Sigma_5}{\langle \Sigma_5 \rangle} \qquad (2)$$

where $D_{p,5}$ is the projected comoving distance to the fifth-nearest neighbor galaxy within a redshift slice of $\Delta z = \pm 0.003$, and $\langle \Sigma_5 \rangle$ is the median density measured within the same redshift slice. As shown in Figure 1, we divided the sample into five environmental bins (D1–D5). We selected six to seven galaxies uniformly from D1–D5 and estimated the molecular gas mass by the CO(1–0) observations with NRO 45 m telescope. Further, by combining our sample and the COLDGASS data [2], which is the extragalactic CO survey with IRAM 30 m telescope, we could construct the CO catalog to cover a wide range in environment.

This allows us to conduct the first systematic study of environmental dependence of molecular gas properties in galaxies from the lowest- to the highest-density environments in the local universe. As a result, we confirmed that f_{H_2} have strong positive correlation with the SFR offset from the star-forming main sequence (ΔMS) and, most importantly, we found that these correlations are universal across all environments (Figure 2). This result demonstrated that star formation activity within individual galaxies is primarily controlled by their molecular gas content, regardless of their global environment [3].

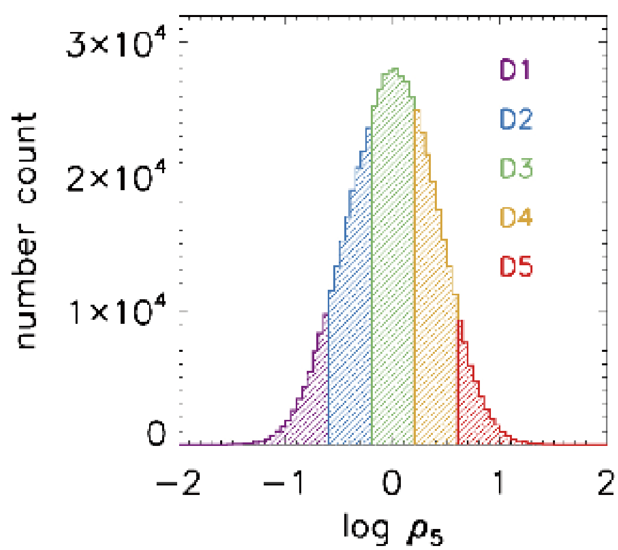

Figure 1: The distribution of ρ_5 for SDSS sample. Our definition of D1–D5 environment bins are shown with different color shades.

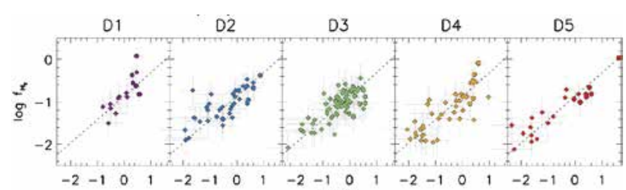

Figure 2: ΔMS–f_{H_2} relation for each environmental bin. For comparison, we show the best-fitting result for D3 bin as gray dotted lines in all of the panels.

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An Optically Faint Quasar Survey at z~5 in the CFHTLS Wide Field: Estimates of the Black Hole Masses and Eddington Ratios

IKEDA, Hiroyuki (NAOJ)
NAGAO, Tohru, KAJISAWA, Masaru (Ehime University)
MATSUOKA, Kenta (University of Firenze)
KAWAKATU, Nozomu (NIT, Kure College)
AKIYAMA, Masayuki (Tohoku University)
MIYAJI, Takamitsu (UNAM)
MORKUMA Tmoki (University of Tokyo)

In order to understand the evolution of supermassive black holes (SMBHs), many quasars have been discovered up to $z\sim7$ by the various quasar surveys (e.g., [1]). Utilizing these quasar sample, the black hole mass ($M_{\rm BH}$) and Eddington ratio ($L/L_{\rm Edd}$) of SMBHs have been measured with a wide range of redshift so far. As for the high redshift, $M_{\rm BH}$ of SMBHs have been measured from the single-epoch virial estimators [2] and then $L/L_{\rm Edd}$ of SMBHs also have been measured. Utilizing these physical parameters, a number of studies for the growth history of the SMBHs have been investigated so far [3]. However, previous studies have been limited mostly to luminous quasars which are likely to be high $L/L_{\rm Edd}$ objects and the mechanism of SMBH formation is still unclear, due to the lack of the faint quasars at high redshift. Some $z\sim5$ faint quasar surveys have been carried out and the faint side of the QLF at $z\sim5$ has been derived [4]. While a large sample of faint quasars at $z\sim5$ have been constructed, the achieved signal-to-noise (S/N) ratio of the spectra is not sufficient to derive $M_{\rm BH}$. Therefore we focus on the public database of CFHT legacy survey (CFHTLS; [5]) to discover faint quasars with high S/N ratio of their spectra. Among the CFHTLS-Wide fields (~145 deg^2), we specifically focus on a ~6 deg^2 area that is covered also by the United Kingdom Infrared Telescope (UKIRT) Infrared Deep Sky Survey (UKIDSS; [6])-Deep Extragalactic Survey (DXS) to select faint quasars effectively. Utilizing these photometric data, we select nine photometric candidates and identify three $z\sim5$ faint quasars, one $z\sim4$ faint quasar, and a late-type star. Since two faint quasar spectra show C IV emission line without suffering from a heavy atmospheric absorption, we estimate $M_{\rm BH}$ and $L/L_{\rm Edd}$ of them. The inferred $\log M_{\rm BH}$ are 9.04 ± 0.14 and 8.53 ± 0.20, respectively. In addition, the inferred $\log L/L_{\rm Edd}$ are -1.00 ± 0.15 and -0.42 ± 0.22, respectively. If we adopt that $L/L_{\rm Edd}$ = constant or $\propto (1+z)^2$, the seed black hole masses ($M_{\rm seed}$) of our $z\sim5$ faint quasars are expected to be $>10^5 M_\odot$ in most cases (Figure 1). We also compare the observational results with a mass accretion model where angular momentum is lost due to supernova explosions [7]. Accordingly, $M_{\rm BH}$ of the $z\sim5$ faint quasars in our sample can be explained even if $M_{\rm seed}$ is $\sim10^3 M_\odot$. Since $z\sim6$ luminous quasars and our $z\sim5$ faint quasars are not on the same evolutionary track, $z\sim6$ luminous quasars and our $z\sim5$ quasars are not the same populations but different populations, due to the difference of a period of the mass supply from host galaxies [8].

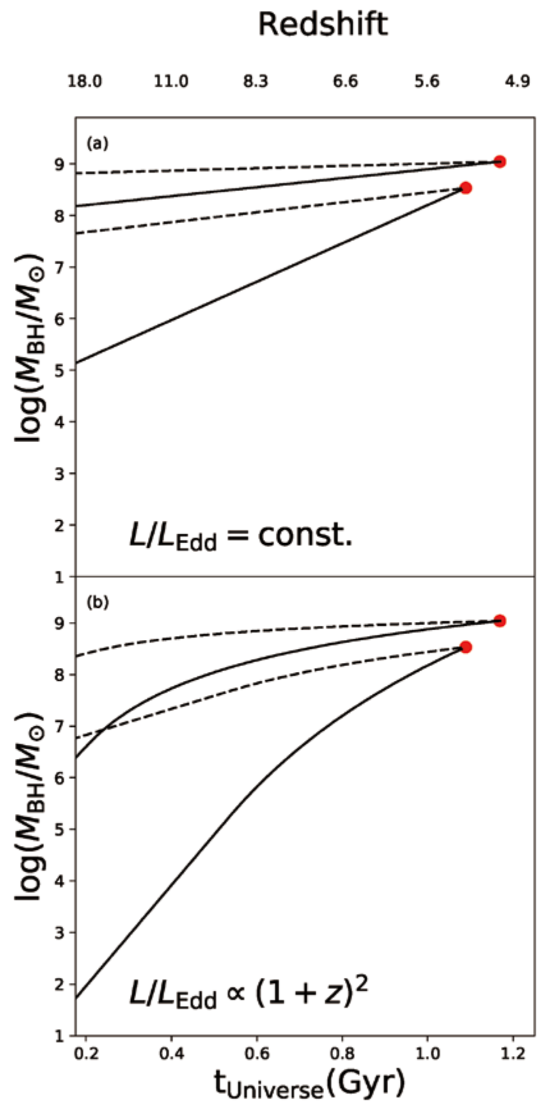

Figure 1: Evolutionary tracks of the SMBHs in our sample. Upper and lower panels show $M_{\rm BH}$ vs. $t_{\rm Universe}$. Solid and dashed lines show the evolutionary tracks for η=0.1 and η=0.3, respectively.

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Pilot KaVA (KVN and VERA Array) Monitoring of the M87 Jet

HADA, Kazuhiro, KINO, Motoki (NAOJ)
PARK, Jongho (SNU)
KaVA AGN Science Working Group (https://radio.kasi.re.kr/kava/about kava.php)

Very long baseline radio interferometer (VLBI) is a powerful tool for observing nonthermal radio sources in the Universe. In particular, VLBI plays a key role in studying relativistic jets in active galactic nuclei (AGN), since the high-resolution capability allows us to directly access the scales of jet formation and acceleration.

The KVN and VERA Array (KaVA) is the first regularly operated international VLBI network in East Asia, consisting of a total of 7 radio telescopes. A feature of KaVA is that the array operates for a quasi-full year. This offers an ideal opportunity to monitor the structural evolution of relativistic jets via detailed multi-epoch observations.

In order to promote early science with KaVA, here we focused on the active galaxy M87. M87 is a giant radio galaxy located at the center of the Virgo cluster and one of the nearest AGN jets. Thus we can directly resolve scales of initial jet formation very close to the black hole by using VLBI.

From December 2013 to June 2014, we performed KaVA 22 GHz monitoring observations of the M87 jet at intervals of 2–3 weeks. In Figure 1 we show multi-epoch KaVA images of M87 obtained by this program. We successfully acquired high-quality jet images at many epochs. As a result, we discovered that the jet speed gradually transitions from subluminal to superluminal motions around distances of several hundred Schwarzschild raii (Rs) to thousands of Rs from the black hole. The observed location of the superluminal motions is much closer to the jet base than that seen in previous studies. This suggests that the efficient acceleration of the jet is already started from much closer to the black hole than previously thought.

This initial result demonstrates that KaVA is indeed a powerful instrument for studying relativistic jets. We will further continue our monitoring of M87 by KaVA or EAVN to reveal more detailed velocity fields of this jet.

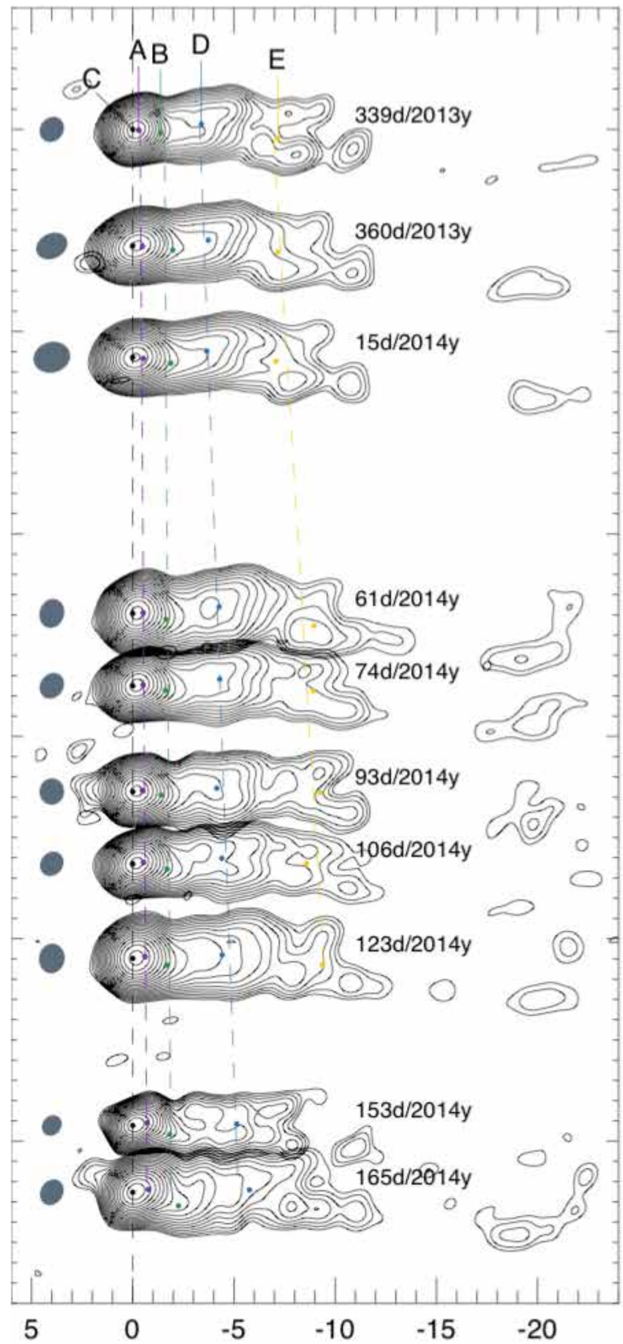

Figure 1: Multi-epoch KaVA 22 GHz images of the M87 jet obtained between January 2013 and June 2014 [1].

Reference

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The Shortest Periodic and Flaring Activity of the 6.7 GHz Methanol Maser in the Intermediate-mass Protostar G 014.23–00.50

SUGIYAMA, Koichiro, HONMA, Mareki, UCHIYAMA, Mizuho, HACHISUKA, Kazuya, MATSUMOTO, Naoko
(NAOJ)

NAGASE, Katsura, YONEKURA, Yoshinori, MOMOSE, Munetake, YASUI, Yasutaka, SAITO, Yu
(Ibaraki University)

MOTOGI, Kazuhito, FUJISAWA, Kenta
(Yamaguchi University)

To statistically investigate the periodic flux variability of methanol masers at 6.7 GHz around protostars [1], we have initiated a single-dish monitor project using the Hitachi 32-m radio telescope since 30 December 2012 [2]. Target sources consist of 442 methanol masers, declination of which is upper than −30 deg. Here, we report the shortest periodic and flaring flux variability of the 6.7 GHz methanol maser newly detected in the intermediate-mass protostar G 014.23–00.50 via the monitor until 21 January 2016 [3].

The 6.7 GHz methanol maser in G 014.23–00.50 shows seven spectral components at V_{lsr} = 20.98–25.30 km s^{-1}. We newly detected characteristic flux variability in only one of them at V_{lsr} = 25.30 km s^{-1}, those are flaring and periodic one. The flaring activities were detected via comparing to non-detection durations below the detection limit ($3\sigma \sim 0.15$ Jy in the case of an integration with all the data in each observational date). Their time-scale of the flux rising was typically a few days or shorter (21 hrs at the shortest) and the ratio of the peak flux density was more than 180 in comparison with a quiescent phase (Figure 1). The periodicity of these flaring activities was also detected with the period of 23.9 ± 0.1 days, which has persisted in at least 47 cycles (Figure 2). This period is the shortest one observed in masers at around intermediate-/high-mass protostars so far.

We conclude that the flaring and intermittent periodic (the period of 23.9 days) flux variability detected in only one spectral component might be explained by a periodic change in the flux of seed photons or a periodic variation of the dust temperature via an extra heating source of a shock formed in the colliding-wind binary model [4], in which the orbital semi-major axes of the binary are 0.26–0.34 au.

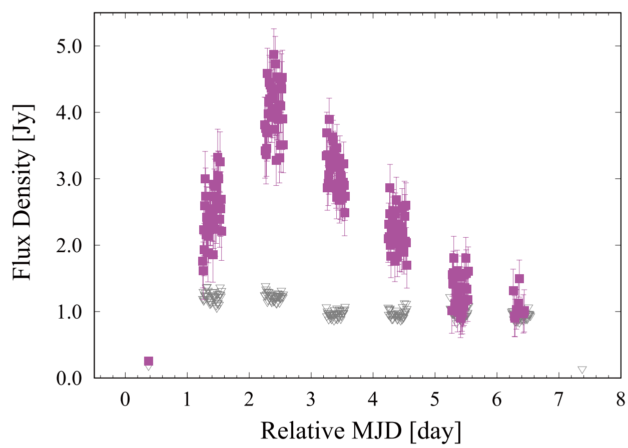

Figure 1: Example of the flaring activities detected at V_{lsr} = 25.30 km s^{-1}. The horizontal axis is observational dates relative to the reference date of 8 September 2015.

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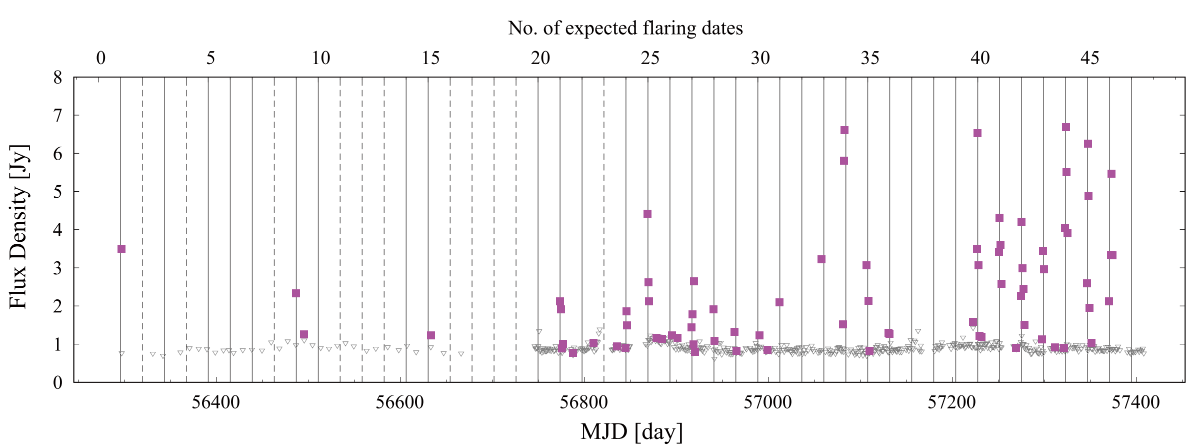

Figure 2: Periodic flux variation detected at V_{lsr} = 25.30 km s^{-1}. Solid and dashed vertical lines show the expected flaring dates with and without observational data.

Polarization Calibration of the Chromospheric Lyman-Alpha SpectroPolarimeter (CLASP) for a 0.1 % Polarization Sensitivity in the VUV Range

GIONO, G., ISHIKAWA, R., NARUKAGE, N., KANO, R., KATSUKAWA, Y., KUBO, M.
BANDO, T., HARA, H., SUEMATSU, Y.
(NAOJ)

WINEBARGER, A., KOBAYASHI, K., CIRTAIN, J. (MSFC/NASA)
CHAMPEY, P. (University of Alabama)
AUCHÈRE, F. (CNRS)

TRUJILLO BUENO, J., ASENSIO RAMOS, A. (IAC)
ŠTĚPÁN, J. (ASCR)
BELLUZZI, L. (IRSL&KIS)

MANSO SAINZ, R. (MPS)
ISHIKAWA, S., TSUNETA, S., SHIMIZU, T., SAKAO, T. (ISAS/JAXA)
De PONTIEU, B. (LMSAL)

ICHIMOTO, K. (Kyoto University)
CARLSSON, M. (University of Oslo)
CASINI, R. (HAO/NCAR)
GOTO, M. (NIFS)

The Chromospheric Lyman-Alpha SpectroPolarimeter (CLASP) is a sounding rocket instrument designed to measure for the first time the linear polarization of the hydrogen Lyman-α line at 121.6 nm. The instrument was successfully launched on 3 September 2015 and observations were conducted at the solar disc center and close to the limb during the five-minutes flight. The disc center observations are used to provide an in-flight calibration of the instrumental polarization. The derived in-flight instrumental polarization is consistent with the spurious polarization levels determined during the pre-flight calibration (Giono et al., 2016) and a statistical analysis of the polarization fluctuations from solar origin is applied to ensure a 0.014 % precision on the instrumental polarization (Figure 1). The combination of the pre-flight with the in-flight polarization calibrations provides a complete picture of the instrument response matrix, and a proper error transfer method is used to confirm the achieved polarization accuracy. As a result, the unprecedented 0.1 % polarization accuracy of the instrument in the vacuum ultraviolet is ensured by the polarization calibration.

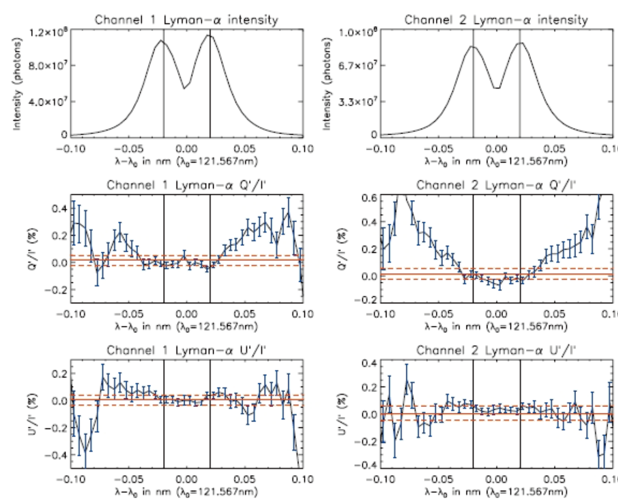

Figure 1: Stokes I', Q'/I' and U'/I' profiles obtained at disc center for a full slit spatially summed and three polarization-modulator rotations temporal summing, for both orthogonal polarization channels. Horizontal red solid lines show the expected spurious polarization offsets from the pre-flight calibration, with red dashed lines showing the $\pm 1\sigma$ error. Vertical black solid lines show the line core (i.e. ± 0.02 nm around the line center). Error bars shown in blue on the polarization signals indicate the noise (1σ), including the photon noise, the read-out noise, and the error due to the residual polarization from the Sun for the full slit spatially summed. By applying a statistical analysis of the polarization fluctuations from solar origin, a 0.014 % precision on the instrumental polarization is ensured.

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Strong Magnetic Field Generated by the Extreme Oxygen-rich Red Supergiant VY Canis Majoris

SHINNAGA, Hiroko (Kagoshima University)
CLAUSSEN, Mark, J. (NRAO)
YAMAMOTO, Satoshi (The University of Tokyo)
SHIMOJO, Masumi (NAOJ)

Evolved stars experience high mass-loss rates forming thick circumstellar envelopes (CSEs). The circumstellar material is made of the result of stellar nucleosynthesis and, as such, plays a crucial role in the chemical evolution of galaxies and the universe. Since asymmetric geometries of CSEs are common, and with very complex structures for some cases, radiative pressure from the stars can explain only a small portion of the mass-loss processes; thus the essential driving mechanism is still unknown, particularly for high-mass stars. Here we report on magnetic field measurements associated with the well-known extreme red supergiant (RSG), VY Canis Majoris (VY CMa). We measured the linear polarization and the Zeeman splitting of the SiO $v=0$, $J=1$–0 transition, using a sensitive radio interferometer. The measured magnetic field strengths are surprisingly high; their upper limits range between 150 and 650 Gauss within 530 AU (~80 R_*) of the star. The field strength of lower limit is expected to be at least ~10 Gauss based on the high degree of linear polarization. Since the field strengths are very high, the magnetic field must be a key element in understanding the stellar evolution of VY CMa as well as the dynamical and chemical evolution of the complex CSE of the star. M-type supergiants, with large stellar surface, were thought to be very slow rotators. This would seem to make a dynamo in operation difficult and would also dilute any fossil magnetic field. At least for VY CMa, we expect that powerful dynamo processes must still be active to generate the intense magnetic field [1].

The CSE of VY CMa has exceptionally strong SiO lines - most of them are masers - in many rotational transitions in multiple vibrational states, along with strong H_2O maser emission [2], over a wide range of energy levels, up to ~7,000 K for SiO and ~7,800 K for H_2O. Furthermore, many SiO lines associated with the CSE are highly polarized, both in circular [3] and linear polarization ([1] and references therein), from a few percent up to $\gtrsim$ 60 % in linear polarization. This high degree of polarization is even detected in low rotational transitions in the ground vibrational state [4], which is usually of thermal origin, as the $v=0$, $J=1$–0 and 2 energy levels are only 2 K and 6 K above ground, respectively.

Zeeman effect in SiO $v=0$, $J=1$–0 emission was detected for the first time from an astronomical object. Along with well-ordered magnetic field pattern measured with high degree of linear polarization, the observational results presented here strongly indicates that this enigmatic O-rich RSG VY CMa has a very intense magnetic field of from 10 Gauss up to 150–650 Gauss. Future observations will further constrain the magnetic field strengths to understand the physics of high mass-loss rate and the stellar evolution of high-mass stars just before supernova explosion.

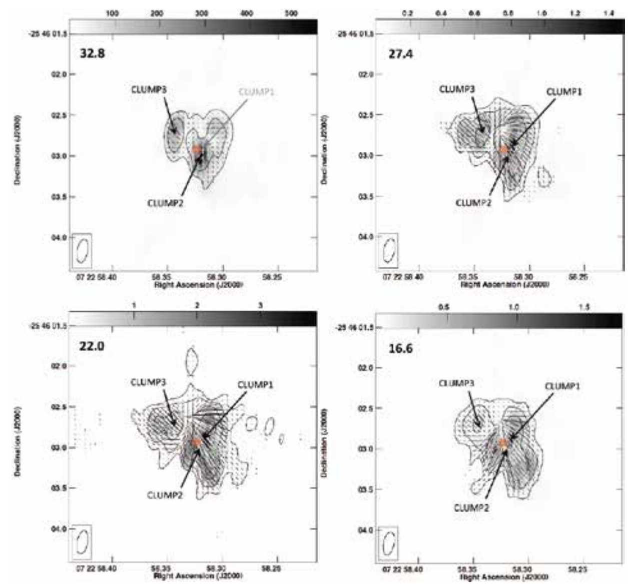

Figure 1: Channel maps of SiO $v=0$, $J=1$–0 emission (contours drawn at (9, 27, 81, 243, 729) times of 1σ noise level of 6.8×10^{-3} Jy/beam; 0.″29 x 0.″12 beam size) with polarization vectors (black/white bars) measured with the VLA. V_{lsr} is written on the top left corner of each panel. The polarized intensity unit (grey scale) of the top left panel and that of the rest panels are in mJy/beam and in Jy/beam, respectively. Polarization vectors are plotted when the signal-to-noise ratio for intensity is above 8 sigma. Each clump and the stellar location ([2]; orange circle, measured with ALMA) are noted.

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Big-Bang Lithium Problem, and Effects of Long-Lived Negatively Charged Massive Particles on Primordial Nucleosynthesis

KUSAKABE, Motohiko, MATHEWS, Grant J.
(University of Notre Dame)

KAJINO, Toshitaka
(NAOJ/University of Tokyo/Beihang University)

CHEOUN, Myung-Ki
(Soongsil University)

We reviewed the big bang nucleosynthesis (BBN) model including a long-lived negatively charged massive particle, i.e., X^- [1]. The mass of the X^-, m_X, is assumed to be much larger than the nucleon mass. This model provides a reason why observed ^{7}Li abundances of metal-poor stars are smaller than that predicted in the standard BBN (SBBN) model [2]. Since the primordial ^{9}Be abundance can be larger than that of the SBBN model, the existence of the X^- particle can be tested by future observations of ^{9}Be in metal-poor stars [3].

The ^{7}Be nuclei are destroyed via a recombination with the X^- followed by a radiative proton capture, i.e., $^7\mathrm{Be}(X^-, \gamma)^7\mathrm{Be}_X(p, \gamma)^8\mathrm{B}_X$ [2]. Since the primordial ^{7}Li nuclei predominantly originate from ^{7}Be nuclei produced during BBN, this ^{7}Be destruction reduces the primordial ^{7}Li abundance. Rates for recombination of ^{7}Be and X^- were calculated accurately, and the dominant transition is the d-wave → 2P for $m_X \gtrsim 100$ GeV [3].

Figure 1 shows the energy level diagram of $^7\mathrm{Be}_X$ for $m_X = 1$ TeV [1]. Red and blue arrows show the three important transitions in the nonresonant recombination reaction, while purple and green arrows show decays of the two main resonances into bound states of $^7\mathrm{Be}_X^*$ (of the nuclear excited state) in the resonant reaction.

Based on the detailed reaction network calculations of BBN, the most realistic constraints on the X^- particle were derived [3]. Parameter regions for the solution to the ^{7}Li problem were identified: the X^- to baryon ratio is $Y_X \gtrsim 0.04$ and the lifetime is $\tau_X \sim (0.6–3) \times 10^3$ s. Using this result, possible candidates of X^- particle are considered [1]. One candidate is a slepton, i.e., a supersymmetric partner of lepton, and the other is a Kaluza-Klein (KK) leptons, i.e., excited states of leptons realized in extra-dimensional models [4]. We focus on the situation that the slepton can only decay into the gravitino, and the KK leptons can only decay into the KK graviton.

The thermal relic abundance of the long-lived stau [5] can be consistent with the parameter region for the ^{7}Li reduction if the stau mass is $\mathcal{O}(1)$ TeV. In addition, the lifetime of the sleptons [4] can be close to $\sim 10^3$ s if the masses of sleptons and the gravitino are of order TeV.

The slepton decay induces nonthermal nucleosynthesis and gravitino production. Constraints from electromagnetic energy injection at the decay and the gravitino energy density [5] lead to a very narrow parameter region. This region for the ^{7}Li problem is available for a selectron and a smuon. However, the stau has a certain hadronic branching ratio at the decay [4]. Hadronic energy injection is heavily constrained [6], and the interesting parameter region is excluded in the stau scenario.

Similarly, a solution to the Li problem exists for the cases of KK electron and muon, while it does not exists for the case of the KK tau [1].

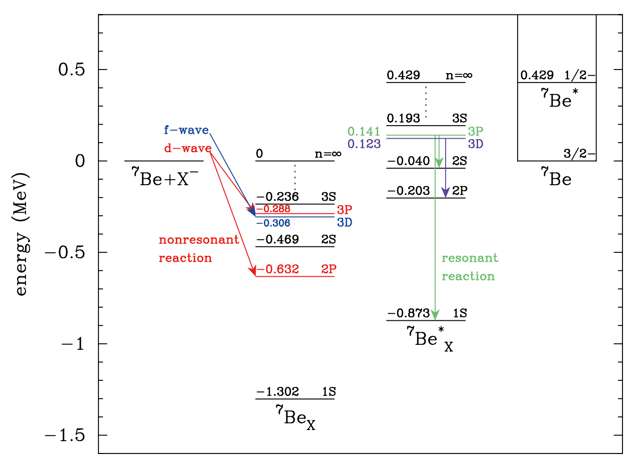

Figure 1: The energy level diagram of the exotic atom $^7\mathrm{Be}_X$ for $m_X = 1$ TeV [1]. Red and blue arrows show the three important transitions in the nonresonant recombination reaction. Purple and green arrows show decays of the two main resonances into atomic bound states of $^7\mathrm{Be}_X^*$ (of the nuclear excited state ^{7}Be*) in the resonant reaction.

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Big Bang Nucleosynthesis and Modern Cosmology

MATHEWS, Grant J., KUSAKABE, Motohiko (University of Notre Dame)
KAJINO, Toshitaka (NAOJ/University of Tokyo/Beihang University)

Big bang nucleosynthesis (BBN) is the testing ground upon which many cosmological models must ultimately rest [1]. A key quantity for BBN is the baryon-to-photon number ratio η which is constrained from observations of cosmic microwave background (CMB) radiation.

A popular explanation for the flat universe and the near isotropy of CMB comes from an epoch of rapid inflation in the early universe. In some special kind of inflationary model which involves non-minimal coupling between matter and gravity, the universe makes a transition from an inflation driving potential to a dark energy producing quintessence. BBN study can put a significant constraint on this model as the nonminimal couplings lead to an excess energy density in gravity waves which alter the predicted light element abundances [2].

In addition, a large extra-dimension affects the dynamics of the universe and BBN. In a Randall-Sundrum II braneworld cosmology, the cosmic expansion rate for a 3-space embedded in a higher dimensional space can be written with a simple equation including additional terms to that of the 3-space dimensional case. The modified term includes the dark radiation term that scales as a^{-4} with a the scale factor of the universe. Because of this scaling almost similar to that of normal radiation, it can significantly alter the fit to BBN abundances and the CMB, and hence, can be constrained [3].

Figure 1 shows the latest constraint on the dark radiation in the ρ_{DR}/ρ vs. η plane [3]. Here, ρ_{DR} is the energy density of the dark radiation, and ρ is the total energy density of relativistic particles. Dark and light shaded region are the allowed region from observations of the primordial D and He abundances, respectively. Contour lines show the 1, 2 and 3σ confidence limits from fits to the CMB power spectrum. Some papers refer to invisible relativistic particles including neutrinos as dark radiation. However, they are completely different from extra-dimensional dark radiation. The former clumps in the universe while the later does not. Their effects on the CMB temperature fluctuation are then different [3].

Many papers have considered the possibility that BBN could constrain a first-order quantum chromodynamics transition. However, a large effect on BBN from the transition is probably not possible since results from lattice gauge theory seems to rule out a first-order transition at low baryon density. Nevertheless, the possibility of baryon inhomogeneities during BBN arising from other mechanisms remains a viable possibility [4].

A time dependence of fundamental constants in an expanding universe appears in theories that attempt to unify gravity and other interactions. BBN is sensitive to variations in the the average light quark mass. A re-evaluation of the effects on BBN from the quark mass variation was performed taking into account an independent evaluation of the resonant ^{3}He(d,p)^{4}He reaction rate based upon the forward and reverse reaction dependence on the quark mass. The newer abundance constraints narrow the range of possible variations in the quark mass, and the deduced range is consistent with less than a 0.7 % variation in the averaged quark mass [5].

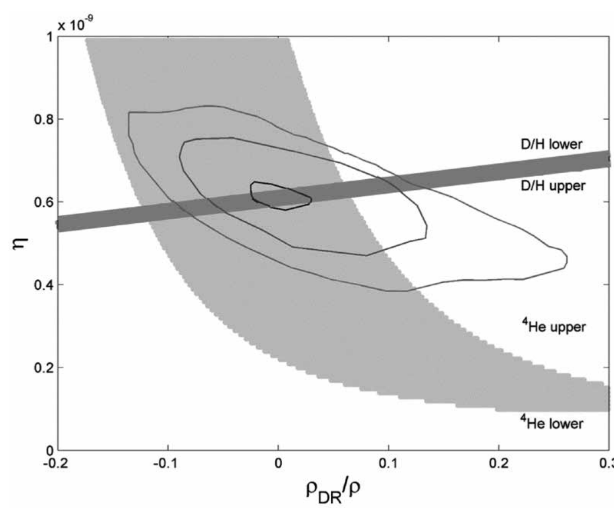

Figure 1: The calculated constraint on the dark radiation in the parameter plane of ρ_{DR}/ρ and η [3], where ρ_{DR} is the energy density of the dark radiation, and ρ is the total energy density of relativistic particles. Dark and light shaded region are the allowed regions from observations of the primordial D and He abundances, respectively. Contour lines delineate the 1, 2 and 3σ confidence limits from fits to the CMB power spectrum.

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The New Hybrid BBN Model with the Photon Cooling, X Particle, and the Primordial Magnetic Field

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

The Big bang nucleosynthesis theory accurately reproduces the abundances of light elements in the Universes, except for ^{7}Li abundance. Calculated ^{7}Li abundance with the baryon to photon ratio fixed by the observations of the cosmic microwave background (CMB) is inconsistent with the observed lithium abundances on the surface of metal-poor halo stars, and this problem is called "^{7}Li problem". Previous studies proposed to resolve this ^{7}Li problem include photon cooling (possibly via the Bose-Einstein condensation of a scalar particle), the decay of a long-lived X particle (possibly the next-to-lightest supersymmetric particle), or an energy density of a primordial magnetic field (PMF) [1,2].

We then used a maximum likelihood analysis to constrain the parameters of the X particles and the energy density of the PMF by the observed abundances of light elements up to Li (Fig. 1) [3].

As a result, we obtained allowed ranges for the X-particle parameters and find that the new hybrid model with a PMF gives the better likelihood than that without a PMF (Table 1:) [3].

We discussed the degeneracy between the parameters of the X particle and the PMF. Since the X particle parameters are mainly limited by the D and $^{7}\$$Li abundances, while the PMF energy density is mainly limited by the ^{4}He abundance, we found that the parameters of the PMF and the X particle have no significant degeneracies [3].

We also discussed the effective number of neutrino species $N_{\rm eff}$ with our new hybrid model. Since the constraint on $N_{\rm eff}$ from the CMB observations is different from the $N_{\rm eff}$ value in our hybrid model which is consistent with the observed light elements, it is difficult to directly compare these two $N_{\rm eff}$ values. We will report a new limit on $N_{\rm eff}$ derived by taking into account analyses of both BBN and the CMB simultaneously in our future work [3].

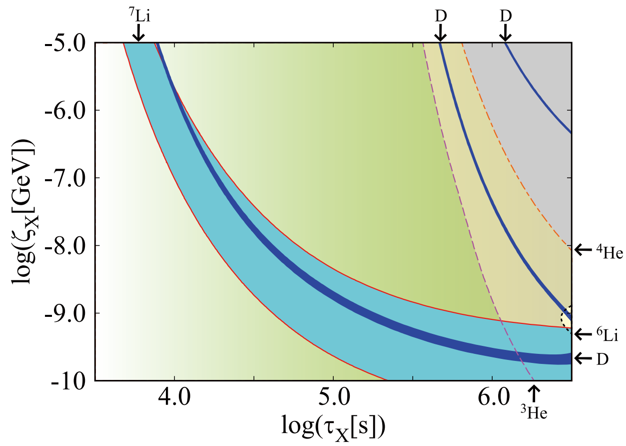

Figure 1: Allowed region in the (τ_X, ζ_X) plane by the observational constraints on the light element abundances for $\eta = 4.57 \times 10^{-10}$ and $B = 1.89\,\mu$G. The curves denote the allowed regions derived from observational limits on the primordial elemental abundances. The narrow dark band and the region bounded by the solid curves (color version: blue and aqua regions) show the 2σ (95 %) confidence limits determined from the observed abundances of D and ^{7}Li, respectively. Dashed, dot-dashed and dotted curves (color version: purple, orange and black curves) are the 2σ (95 %) confidence limits determined from the upper limits on the ^{3}He, ^{4}He and ^{6}Li abundances.

Table 1: Agreement with observed light element abundances for the four models considered here.

Model	γ-cooling	X	PMF	γ-cooling +X+PMF
Nuclide				
Y_p	✓	✓	✓	✓
D/H	-	✓	✓	✓
^{3}He/H	✓	✓	✓	✓
^{7}Li/H	?	-	-	✓
^{6}Li/H	✓	✓(high)	✓	✓(high)

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PENTACLE: Parallelized Particle-particle Particle-tree Code for Planet Formation

IWASAWA, Masaki (RIKEN)
OSHINO, Shoichi (NAOJ)
FUJII, Michiko (The University of Tokyo)
HORI, Yasunori (Astrobiology Center/NAOJ)

Terrestrial planets (Earth and Venus), solid core of gas planets (Jupiter and Saturn) and ice planets (Uranus and Neptune) form through collisions and coagulation between planetesimals (km-sized rocky and icy clumps). The accumulation process of planets is controlled by gravitational interactions between the celestial bodies. According to previous studies, planetary accretion has a two-staged growth mode [1,2]: (i) "runaway growth stage" in which planetesimals grow rapidly and (ii) "oligarchic growth stage" in which larger planetesimals, the so-called protoplanets, continue to slowly grow at orbital separations of several Hill radii. Today, the theoretical framework of these planetary growth process is widely accepted for the standard formation scenario of not only the solar system but also extrasolar planetary systems discovered in recent years. However, past studies on planet formation assumed "extremely large planetesimals" (about 1 / 10th of the planet size) and planetary embryos at the initial state because of the limited number of particles used in *N*-body calculations. According to previous studies on time evolution of the size distribution in a swarm of planetesimals, a typical size of a planetesimal is 1–10 km in radius, which are two orders of magnitude larger than ones assumed in previous studies and observed asteroids such as Itokawa with ~1 km in diameter. In fact, planetary accretion in a swarm of small planetesimals can may not follow the conventional oligarchic growth (e.g. [3]). Thus, it is necessary to develop a new approach that can handle such small planetesimals, namely, at least 100 million of particles in *N*-body simulations for planet formation.

In this research [4], we have newly developed a large scale *N*-body simulation code for planet formation. This code is named PENTACLE, it is freely available on GitHub. In the past planetary *N*-body simulations, it was difficult to calculate such that the number of particles exceeds 100 thousand due to limitation of calculation speed. In the *N*-body calculation, the cost of gravity computation of $O(N^2)$ per time integral of particle motion occurs (100,000 gravity calculations / 1 step for 10,000 particles). In a collisionless system which close encounters of particles do not occur, e.g., a large-scale structure of the universe, *N*-body calculations using about 2 trillion particles have been done [5]. This is because the computation cost is kept to $O(N \log N)$ by the tree method which calculates efficiently gravity forces from distant particles and the number of steps required for time integration of particle motion can be reduced. On the other hand, in the "collisional system" where close encounters of particles happen, e.g., star cluster and planetary system, dynamical evolution of the system should be calculated using short time steps (enormous number of steps). Therefore, about 100,000 particles in the collisional system are the limits of the number of particles that can be computed.

Figure 1 shows the computation time per step when *N*-body simulations of terrestrial planet formation using 1 million particles is executed with PENTACLE. The horizontal axis shows the number of cores used for the calculations, which scales to about 1000 cores. As the number of cores increases, the load of data communication limits the computation speed. We will optimize this part and aim to utilize a larger number of cores in the future. Figure 2 shows the time evolution of the energy error when changing the parameters that determine the calculation speed and accuracy. It turns out that *N*-body simulations using PENTACLE can sufficiently suppress energy errors by adopting appropriate parameters.

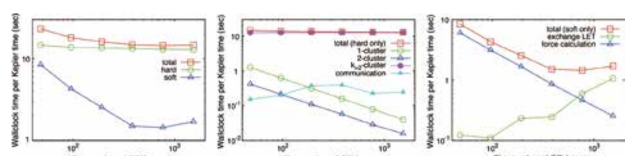

Figure 1: The calculation time per Kepler time against the number of CPU cores.

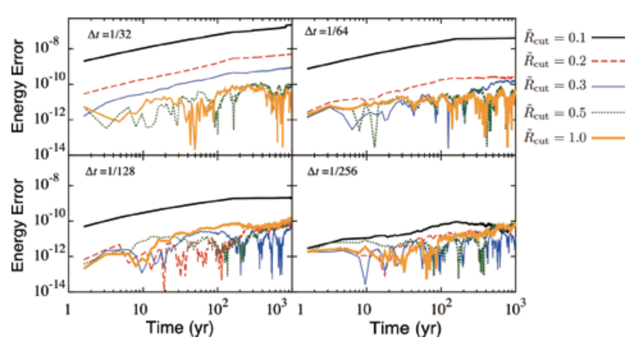

Figure 2: Relative energy error as a function of time.

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Production of Left-handed Amino Acids in Space in the Supernova Neutrino Amino Acid Processing (SNAAP) Model

BOYD, Richard
(Ohio State University)
FAMIANO, Michael
(NAOJ/Western Michigan University)
ONAKA, Takashi
(University of Tokyo)
KAJINO, Toshitaka
(NAOJ/University of Tokyo/Beihang University)

The ability of the Supernova Neutrino Amino Acid Processing (SNAAP) model to produce enantiomeric amino acids in space has been studied in detail [1]. This model uses the magnetic field from a source object such as a neutron star, along with the Lorentz force electric field from the motion of objects in the magnetic field, to distinguish between the two chiral states of amino acids. Then the electron antineutrinos from a neutron star or a supernova selectively destroy one chirality, producing enantiomeric amino acids in nearby meteoroids.

In the present paper, several possible sites that could produce the requisite conditions for the SNAAP model were studied to determine their viability for processing meteoroids so as to produce left-handed favoring amino acids. Several sites appear to provide the requisite magnetic field intensities and electron anti-neutrino fluxes, although other factors constrain their viability.

Perhaps the most obvious site would be a core-collapse supernova; they produce both a strong magnetic field and an intense electron antineutrino flux. However, this site alone cannot serve as the SNAAP model source. The magnetic field from the nascent neutron star when the supernova occurs was found to be effective out to only about 1 percent of an A.U., while the star would expand to about 100 times that radius when it entered its red giant phase, surely cooking any preexisting amino acids, and preventing any new ones from being made.

A more likely candidate is a close binary system consisting of a neutron star and a massive star. The latter would shed its outer one or two layers to form an accretion disk around the neutron star, converting the massive star to a Wolf-Rayet star, circumventing the red giant expansion of the massive star. The dense matter in the accretion disk is thought to develop into dust grains, meteoroids, and even planets, and amino acids could be created in these objects as they formed in the outer layers of the disk. The magnetic field necessary for the SNAAP model would result from the neutron star. Electron antineutrinos might be provided over long periods of time from the neutron star, but might also occur from the burst that would be produced when the WR star became Type Ib or Ic supernova. Other possible candidates, e.g., merging neutron stars, were also studied, but have larger parameter uncertainties.

A recent paper [2] suggests, from the local ^{26}Al abundance, that the Solar System was formed from a WR star. While this isn't exactly the binary system that we concluded was necessary for the SNAAP model, the needs of the SNAAP model do not preclude the WR star that study concludes formed the Solar System. Furthermore, similarities are sufficiently striking to conclude that this second paper might serve to confirm, at some level, the SNAAP model.

These results have obvious implications for the origin of life on Earth.

References

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Selection of Amino Acid Homochirality in Stellar Environments

FAMIANO, Michael (NAOJ/Western Michigan University)
BOYD, Richard (Ohio State University)
KAJINO, Toshitaka (NAOJ/University of Tokyo/Beihang University)
ONAKA, Takashi (University of Tokyo)
MO, Yirong (Western Michigan University)

Because they are asymmetric, amino acids (an example of which is shown in Figure 1) have two chiral states - or mirror images - referred to as “left-handed” and “right-handed” forms. With very few notable exceptions, nearly all life on earth utilizes only left-handed amino acids, a phenomenon referred to as biomolecular homochirality. Additionally, analyses of inclusions in meteoritic carbonaceous chondrites have revealed numerous amino acids. The discovery that *meteorites not only contain amino acids, but can have amino acids favoring left handed amino acids* is a possible indicator that amino acid chiral selection may have extra-terrestrial origins and has led to several hotly contested theories. Some of the amino acids so synthesized have an excess of a few percent of the left-handed chirality that is observed in earthly amino acids. It is generally accepted that if some mechanism can introduce an imbalance in the populations of the left- and right-handed forms of any amino acid, successive autocatalysis can amplify this enantiomeric excess to ultimately produce a single form. What is not well understood is the mechanism by which the initial imbalance is produced and the means by which it produces the left-handed chirality observed in the amino acids. *The origin of biomolecular homochirality is one of the top questions in science today* [1].

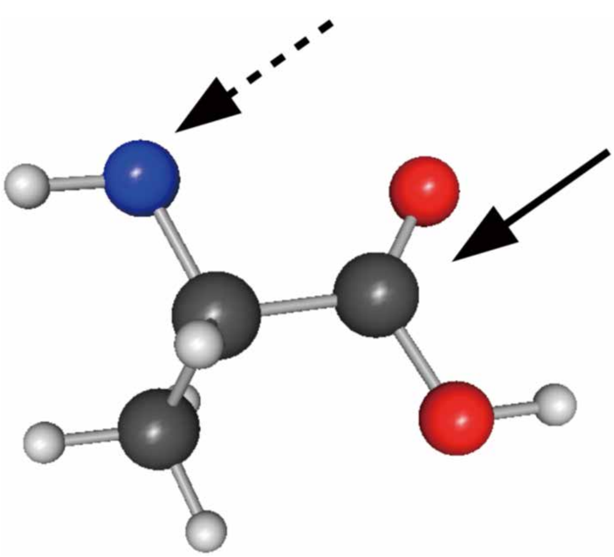

Figure 1: The left-handed enantiomer of the amino acid, alanine, L-alanine. The amine group is indicated by the dashed arrow and the carboxyl group by the solid arrow.

A model has been created which predicts the origins of amino acid homochirality in an emergent stellar phenomenon involving lepton interactions in magnetic fields [2]. Multiple sites capable of implementing this models have been proposed [3].

The results of an evaluation are shown in Figure 2 for the amino acid isovaline (in cationic form) for a scenario representing conditions of a meteoroid in the vicinity of a neutron star. The antineutrino reaction rates are given by the ratios $f = 0, 0, 10^{-9}, 5\times10^{-9}, 10^{-8}, 2\times10^{-8}$, and 5×10^{-8}, where f is defined as the ratio of the neutrino interaction rate to the nitrogen nuclear spin relaxation rate.

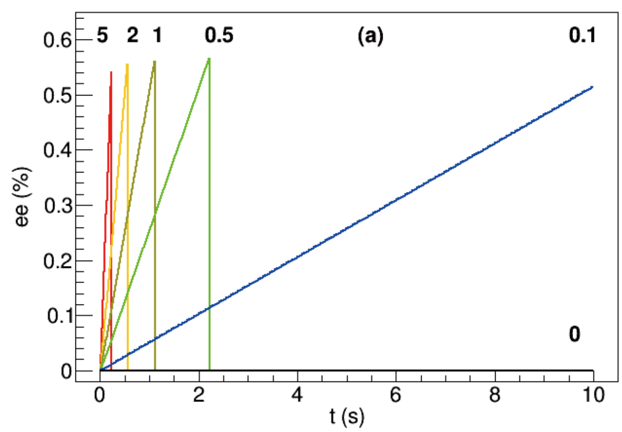

Figure 2: Enantiomeric excess of isovaline in a high-field, high flux environment for several different neutrino interaction rates.

In this figure, the relative amount by which one chiral state outnumbers another is given by the “enantiomeric excess,” *ee*, defined as $ee \equiv (N_L - N_D)/(N_L + N_D)$ where N_L and N_D represent the number of left- and right-handed amino acids, respectively, of a specific type in an ensemble. The *ee*s computed in this model are similar to those found in meteorites. It is possible that amino acid *ee*s have their origin in space, while subsequent autocatalysis via chemical or biological means can increase the *ee* to the homochiral values observed today.

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Short-baseline Electron Antineutrino Disappearance Study by Using Neutrino Sources from $^{13}C + {}^{9}Be$ Reaction

SHIN, Jae Won, CHEOUN, Myung-Ki
(Soongsil University)

KAJINO, Toshitaka
(NAOJ/University of Tokyo/Beihang University)

HAYAKAWA, Takehito
(QST / NAOJ)

Over the past few decades, a considerable number of studies has been done on the neutrino oscillation with a great success of measuring neutrino mixing angles. However, some experiments (LSND, MiniBoone, reactor experiments and gallium experiments) for the neutrino oscillation revealed more or less disagreements with the three-flavor neutrino model, which termed as neutrino anomalies. One of the approaches for explaining the anomalies is to presume the existence of the hypothetical fourth neutrino (sterile neutrino) because the sterile neutrino does not interact with other particles except for a mixing with active neutrinos.

In our work [1], to investigate the existence of sterile neutrino, we propose new experimental setup (see figure 1) and electron antineutrino source using ^{13}C beams based IsoDAR concept. The neutrino source is obtained through β^- decays of unstable isotopes which are generated from the $^{13}C + {}^{9}Be$ reaction. Main isotopes (^{8}Li, ^{9}Li, ^{12}Be, ^{12}B, and ^{13}B) for neutrino production have similar half-lives and reaction Q values of β^- decay, and thus the neutrino energy spectrum with a single broad peak is expected.

The production yields of those isotopes are calculated using three different nucleus-nucleus (AA) reaction models [1]. Even though different yields of the isotopes are obtained from the models, the neutrino spectra are almost identical. This unique feature gives a realistic chance to neutrino oscillation study through shape analysis, regardless of the theoretical AA models considered.

Ratios of the expected total event rate for the P_{3+1} model to that for the P_3 model (R_{3+1}-to-R_3) at L = 13 m and L = 21 m show distinguishable features of the event rates (see Figure 2), and thus it can also give a meaningful signal for the existence of the hypothetical ν_s. The expected deviation between the maximum and the minimum values is approximately 17 %, and thus it can give an effective answer of whether P_{3+1} models is the most appropriate model for the sterile neutrino.

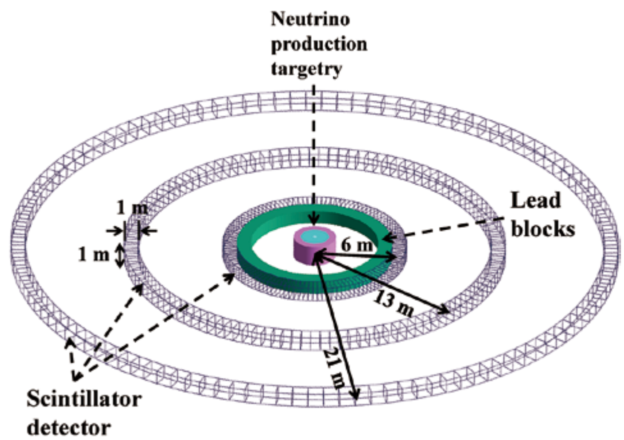

Figure 1: A schematic view showing proposed short baseline experiment setup.

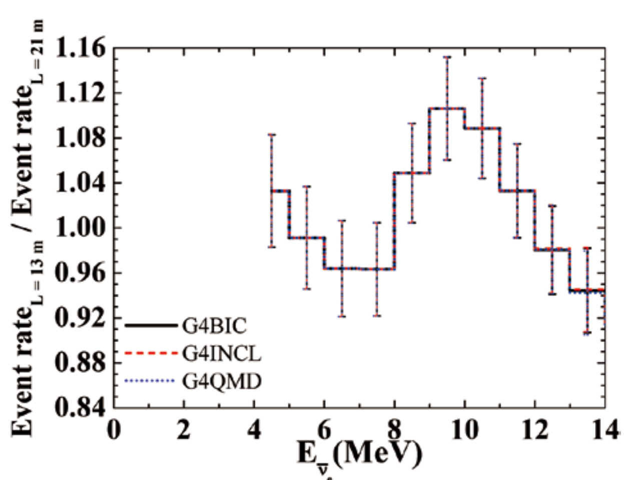

Figure 2: Ratios of R_{3+1}-to-R_3 with respect to $E_{\bar{\nu}_e}$ at different L are shown.

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II Status Reports of Research Activities

1. Subaru Telescope

1. Subaru Telescope Staff

As of the end of FY 2017, the Subaru Telescope staff consisted of 19 dedicated faculty members including seven stationed at Mitaka, four engineers, two specially appointed senior specialist, and three administrative staff members. Additional staff members include one specially appointed research staff, seven specially appointed senior specialist, one research expert, and six administration associates, all of whom are stationed at Mitaka. Moreover, 14 research/teaching staff members, 13 of whom are stationed at Mitaka and one of whom is stationed at Pasadena, and three engineers, two of whom are stationed at Mitaka and one of whom is stationed at Nobeyama are posted concurrently. The project also has 70 local staff members dispatched from the Research Corporation of the University of Hawaii (RCUH), including scientific assistants; engineers in charge of software and observational instruments; technicians for facilities, machinery, vehicles, and laboratories; telescope/instrument operators; secretaries; librarians; administrative staff; researchers employed for Grant-in-Aid for Scientific Research; and graduate students. These staff members work together in operating the telescope, observational instruments, and observational facilities; and in conducting open-use observations, R&D, public outreach, and educational activities.

2. Science Highlights

In FY 2017, Subaru Telescope produced many outstanding scientific outcomes which were published in major international journals. Below are some examples:

(1) The electromagnetic counterpart of a gravitational wave event was detected for the first time. Based on the time variation of the optical and infrared emission brightness, the first observational indication of the "r-process" (one of the processes to create elements heavier than iron) was obtained.

(2) The light curve of a type Ia supernova discovered with the very wide field optical camera, Hyper Suprime-Cam (HSC), soon after the explosion was investigated in detail. The widely believed hypothesis that "helium nuclear detonation near the surface of a white dwarf triggers a stellar explosion" was strongly supported.

(3) Using HSC, nearly 200 proto-clusters (ancestors of the clusters of galaxies) were detected at 12 billion light-years away. This number is ten times larger than have previously been found, enabling systematic investigations of proto-clusters in the distant Universe for the first time. Unprecedentedly wide and sharp dark matter maps were also obtained using HSC and the gravitational lensing technique.

(4) For nearby galaxies, using unprecedentedly deep and sharp optical images obtained with HSC, clear signs of mergers with small galaxies were revealed in M77 which has an actively mass-accreting supermassive black hole but looks like a normal quiet spiral galaxy. Using HSC, as many as 11 dwarf galaxies and 2 tidal streams were detected in a large spiral galaxy (Whale Galaxy) at the distance of 23 million light-years away from the Earth.

3. Open-use

In S17A, 42 programs (69 nights) were accepted out of 166 submitted proposals, requesting 418.3 nights in total. In S17B, 37 proposals (55 nights) were accepted out of 135 submitted proposals, requesting 294 nights in total. Service observations were made for 9.5 nights. In S17A and S17B, 4 and 2 accepted open-use proposals were by foreign principal investigators, excluding University of Hawai`i and East Asian Observatory observing time. The number of applicants in submitted proposals was 2278 for Japanese researchers (Japanese astronomers at any institute and non-Japanese astronomers belonging to Japanese institutes) and 887 for foreign researchers. The number of researchers in accepted proposals was 751 for Japanese astronomers and 285 for foreign astronomers. In S17A and S17B, the number of open-use visiting observers was 271, of which 61 were foreign astronomers. 113 astronomers observed remotely from Mitaka. In S17A and S17B, 85.42 % of the open-use time (including University of Hawai`i time) was used for actual astronomical observations, after excluding weather factor and scheduled maintenance downtime. About 1.41 %, 0.19 %, 12.92 %, and 0.06 % of observing time was lost due to instrument trouble, communication trouble, telescope trouble, and operation trouble, respectively. In S17A and S17B, remote observations from Hilo were conducted for 12 programs with 14.5 nights. On the other hand, remote observations from Mitaka were conducted for 76 nights with 28 programs including HSC SSP. The number of telescope time exchange nights between Subaru Telescope and Keck was 8.0 nights in S17A and 8.5 nights in S17B. For time exchange between Subaru Telescope and Gemini, Subaru Telescope users used Gemini time 10.7 nights in S17A and 4.7 nights in S17B while Gemini users used Subaru time 6.0 nights in S17A and 4.5 nights in S17B.

4. Telescope Maintenance and Performance Improvement

A windscreen incident happened during night operation on

April 10, 2017. The chain to drive the screen panels up and down and some of the panels of the windscreen fell. Observations for that night were cancelled immediately. Restoration work was done from April 10 to April 17. Observation resumed from April 17. Later, the broken panels and chains were removed. As of this writing, science operation has been carried out without a windscreen since the incident.

The mirror hatch, which had an incident in February 2016, was repaired in June and July. Finally we confirmed the hatch was fully and safely operational in August.

After the mirror hatch repair, we carried out the primary mirror recoating work which was originally scheduled for summer 2016. This was the eighth recoating of the mirror since its arrival at Maunakea, Hawai`i in 1998 and was about four years after the previous recoating. The mirror recoating work and telescope related works were performed from October 2 to December 14. After the recoating work, the reflectivity of the primary mirror was recovered up to 92 % (at 400 nm).

Other general functions and performances of the telescope are continuing to be maintained the same as the previous year. Due to the tight financial situation, the remote maintenance contract was cancelled, but mass production of the primary mirror actuator CPU cards was run as scheduled. Some studies for the Telescope System Computer (TSC) replacement and the telescope UPS (Uninterruptible Power supply System) replacement were also run.

To reduce costs, we are developing in-house manufacturing. A study for a Programmable Logic Controller (PLC), preparation for full remote control of the telescope, preventive maintenance based on log data, study for dome-rail flatness measurement, and modification of a coolant water bottleneck are examples.

However, aging of both the telescope and the dome structure has been increasing the risk of critical failure. The telescope is in a wear-out failure phase. We should look straight at this severe reality.

5. Instrumentation

The eight open-use facility instruments of Subaru Telescope were operated stably in FY 2016. 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), and the 188-elements Adaptive Optics and Laser Guide Star system (AO188/LGS).

In these years, there have been discussions on how we maintain or stop the operation of the facility instruments. Last year (2016), we decommissioned FMOS. In this year, Suprime-Cam was decommissioned in May, 2017 and we shifted completely to HSC for prime-focus wide-field imaging observations. Thanks to the users' efforts, we have twelve narrow-band filters available for open-use observations.

The operation of HSC has been stable similarly to the last fiscal year, though minor troubles in the filer exchange unit (FEU) still happened. Tests for replacing filter sets during HSC observing runs while HSC is on the telescope were completed and this capability is planned to be in operation from the latter half of 2018. Preparation of the new monochromatic dome-flat system, which enables scanning the wavelength of the light source for precise photometric accuracy, has also been conducted in this fiscal year.

The ongoing upgrade projects for the other facility instruments are the fiber MOS unit for HDS, the polarimetric function in thermal infrared for IRCS and in mid-infrared for COMICS, the integral field unit (IFU) for FOCAS and MOIRCS, the Transponder-Based Aircraft Detector (TBAD) for the LGS system, and an upgrade of the real-time control system and laser guide star system for AO188. Upgrades of the aging control computers and devices of the first generation instruments are ongoing. In addition, a design study for a NsIR beam switcher, which will enable switching NsIR instruments without physically moving the instruments, has started as a collaboration with Australian institutes.

In FY 2016, three carry-in (PI-type) instruments HiCIAO (high-contrast coronagraph imager), SCExAO (Subaru Coronagraphic Extreme Adaptive Optics) and CHARIS (high-contrast integral-field spectrograph) have been offered to the Subaru open-use program. Operation of HiCIAO at the Subaru Telescope ended in S17B. Among the instrument modules of SCExAO, VAMPIRES (visible interferometric imager with differential polarimetry) was open for public use.

A new PI-type instrument, IRD (InfraRed Doppler instrument), has made engineering observations aiming to start open-use observation in S18B. Two other PI-type instruments proposed by the University of Tokyo team, SWIMS (Simultaneous-color Wide-field Infrared Multi-object Spectrograph) and MIMIZUKU (mid-infrared multi-field imager and spectrograph), were transferred to the Hilo Base Facility. Errors in the mechanical dimensions were found, and countermeasures were taken. They will have engineering observations starting in S18A.

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 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. There are slight delays in the schedule: the engineering first-light will be in 2019 and science operation is expected to begin in 2021. Subaru Telescope is responsible for modifying the telescope and enclosure to accept PFS. The design works and reinforcement of the spectrograph floor has been conducted. The data reduction pipeline and the database that combine HSC and PFS data is being developed with US collaborators.

We are conducting a conceptual study of "ULTIMATE-Subaru," the 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 2020's. We are studying the concept of a wide-field near-infrared imager, multi-object spectrograph, and multi-object integral field unit (IFU) spectrograph, assisted by a ground-layer adaptive optics (GLAO) system. GLAO will allow us to uniformly improve the image quality over a wide field of view by correcting the turbulence at the ground layer of the Earth's atmosphere by using an adaptive secondary mirror. In FY 2017, with an official (short-term) agreement established in FY 2016, we have been collaborating with Australia on the GLAO feasibility study. We are working together toward the Conceptual Design Review to be scheduled in FY 2018. We also had the first ULTIMATE-Subaru "collaboration meeting" in NAOJ (Mitaka) by inviting scientists in potential partner countries (Australia, Taiwan, Canada) to share the goals and roles of each partner country. We are pleased to report that our ULTIMATE-Subaru project has been officially kicked-off with an external budget (KAKENHI Kiban-S with M. Akiyama [Tohoku Univ.]).

6. Computer and Network

Subaru Telescope focused on stable operation of the fourth-generation system of computers and network called STN4 as well as the design, installation, and operation of the fifth-generation system called STN5. Stable operation was achieved without serious trouble or attacks/intrusions such as illegal access.

The observation data archive has been ongoing from the previous year. The archive is operational without serious problem. The data archive system in Mitaka also showed stable performance.

Subaru Telescope has officially offered remote observations from Mitaka using the Remote Observation Monitor System since 2015. Remote observation is now available for more instruments than before. An increasing number of observers use the Remote Observation Monitor System in Mitaka. About 40 observation programs utilized the remote observation monitor system for 139 nights during May 2017 to March 2018.

Computers for HSC data analysis (HSC On-site Data Analysis System) were procured in Fiscal Years 2010 and 2011. We have been replacing and adding hardware as needed. We replaced a part of the computers in Fiscal Years 2017.

Subaru Telescope has been developing and operating web applications that support open-use observations. The Proposal Management System (ProMS) has been updated as the contents of the calls for proposals change, and has been working well. Subaru Telescope is planning to develop a web application to help the referees who score the proposals. Two online visitor forms are in operation, one for those who visit Subaru Telescope in Hilo for observations and the other for those who visit NAOJ Mitaka Campus for remote observation monitoring.

Since the rental contract for our computer and network infrastructure ended in February 2018, we procured the computer and network system that started operation in March 2018. Subaru Telescope developed the specifications and held a briefing for bidding in June 2017 and a bidding and technical review of proposals in July 2017. We opened the bids in August 2017 and signed the contract in September 2017. Detailed design, installation, and data migration were done with computer/network staff at Subaru Telescope and the contractor. The new system started as scheduled from March 2018.

7. Education (Under-graduate and Graduate Courses)

The number of Subaru Telescope staff members in Hilo who were concurrently appointed by SOKENDAI (graduate school) was eleven. The number of SOKENDAI students who had primary supervisors affiliated with Subaru Telescope (including those concurrently belonging to Subaru Telescope) was ten, which constituted about one-third of the total 31 Sokendai students hosted in NAOJ. Of those, five had supervisors who belonged primarily to Subaru Telescope.

In FY 2017, Subaru Telescope hosted 3 graduate students for long stays in Hilo, 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 in all of Japan who obtained master's degrees and PhD's based on Subaru Telescope data were 17 and eight, respectively, of which two and three belonged to the Division of Optical and IR Astronomy.

We also regularly hosted a series of educational programs at Subaru Telescope. In September 2017, we hosted a Subaru Autumn School in Mitaka. There were 14 participants. They learned the reduction and analysis of Subaru Telescope data and heard a series of lectures. Moreover, we hosted two Subaru Telescope observation training courses. One was for eight undergraduate students from all over Japan held in January 2018, and the other for five new SOKENDAI students at NAOJ held in September 2017. In the Hilo office, we had regular Subaru Telescope seminars in English 2-3 times per month, where open-use observers, visitors, and Subaru Telescope staff members presented their own new research. Also in the Subaru Telescope Mitaka office, we had many official and informal seminars, many of which were jointly organized with other divisions in NAOJ and/or neighboring universities.

8. Public Information and Outreach (PIO)

The goal of the Public Information and Outreach Office (PIO) is to document, share, and promote the activities and scientific achievements of Subaru Telescope (Subaru) throughout the general population. Raising positive awareness of Subaru Telescope -- within the local community, in particular -- is critical for the success of the Subaru project as well as the next generation telescope project on Maunakea. The PIO has three major tasks to achieve its goal.

Task 1: Provide information about activities and scientific results from Subaru Telescope by effectively using website and social media platforms. Subaru Telescope provides press releases to the Japanese, local, and international media and holds press conferences. During Fiscal Year 2017, there were 12 web-postings (6 in Japanese and 6 in English) about discoveries from Subaru Telescope. Articles about instrument development, the work and activities at the Subaru Telescope and other announcement totaled 43 (24 in Japanese, 19 in English). For major scientific discoveries, PIO actively distributes press release articles to local and Japanese media as well as an international network via the American Astronomical Society's mailing exploder. As a result, scientific results from Subaru Telescope often appear in Japanese and local newspapers and web news.

Social media tools such as Twitter, Facebook, and YouTube are highly effective nowadays in rapidly disseminating information. Subaru's PIO has effectively used these new platforms by producing and sharing photographs and videos. Media inquiries and filming requests totaled 22 from Japanese media and 10 from English media. In addition to media interaction, PIO also responds to the numerous inquiries and questions from educational institutions and museums.

Task 2: Provide escorted tours of the summit and base facilities for the public and special groups. Subaru Telescope started the public tour program in 2004, providing opportunities for guests from Hawaiʻi, Japan, and around the world to see the telescope up-close. Those requesting tours receive prompt responses from a dedicated full-time tour staff. People can sign up for summit tours via an online form on the Subaru Telescope website. During Fiscal Year 2017, 307 people visited the summit facility through the public tour program. This number does not include tours that were suspended due to poor weather conditions. An additional 67 groups visited the summit facility via special tour programs. In total, 677 people visited the summit facility in Fiscal Year 2017. This includes 8 special tours dedicated for the residents of Hawaiʻi. All tours are escorted by assigned staff and conducted in either Japanese or English.

Tours of the Hilo base facility are often accompanied by a special lecture by staff or a hands-on astronomy workshop. Some school groups give student presentations and Subaru staff provide comments and advice. A total of 23 groups (252 people) visited the base facility this year.

Task 3: Provide on-site and remote lectures for the local community as well as Japanese schools and museums. During Fiscal Year 2017, PIO provided/coordinated a total of 84 lectures at the Subaru Hilo Base Facility or at nearby locations, such as ʻImiloa Astronomy Center and local schools. This number includes 45 classroom presentations during the annual Journey through the Universe program which takes place over the course of a week. Subaru staff also conducted 31 lectures outside Hawaiʻi and 10 remote lectures for Japanese schools.

In addition to providing lectures, Subaru Telescope actively participates in various outreach events and career fairs on Hawaiʻi Island. One of the major outreach events is AstroDay, a family-friendly event held at the local shopping mall. Each year, more than 2,000 people come to this event. AstroDay is coordinated by Maunakea observatories, and many astronomy and scientific institutions such as ʻImiloa Astronomy Center, Maunakea Visitor Information Station, and the University of Hawaiʻi at Hilo participate. This year, AstroDay was also held in Kona, on the west side of the island, attracting over 3,000 people.

Another major outreach event on Hawaiʻi Island is the annual Onizuka Science Day at the University of Hawaiʻi at Hilo. Six hundred students between grade 4 and 12 (upper elementary school to high school) with families and teachers from all over the island come to this event. Subaru PIO provided two hands-on astronomy workshops and held an exhibit booth. Events like these where Subaru Telescope staff meet and directly interact with students and members of the local community are effective for improving the recognition of the Subaru Telescope. The Subaru PIO has been sharing information about outreach activities via the website and social media.

It is also important for the staff to have a strong understanding of the host community. Subaru Telescope started a new seminar series for the staff to learn Hawaiian culture, history, and perspectives with lectures from experts in the field.

2. Okayama Astrophysical Observatory

Okayama Astrophysical Observatory, (hereafter the Observatory) served as the observing and research base of the optical and infrared astronomy in Japan, and it promoted open use, primarily of the 188-cm telescope, to universities throughout the country. It also pursued joint R&D projects with universities, contributing toward forming stronger foundations for astronomy research at the universities. Concurrently, the Observatory pursued its own research activities, taking advantage of its location and observational environment. In addition, the Observatory developed activities to realize the nation-wide openuse of the telescope time on Kyoto University's Okayama 3.8-m New Technology Optical and Infrared Telescope in FY 2017.

About 230 nights at the 188-cm telescope were exploited for observations by researchers from across the country through the open use. The Observatory maintained and operated the observing instruments and provided the observers with support for observations, travel expenses, accommodations, everyday needs, etc. It also supported carry-in instruments from other institutions.

Several joint projects with universities were conducted, including Kyoto University's Okayama 3.8-m New Technology Optical and Infrared Telescope Project, the Tokyo Institute of Technology's Gamma-Ray Burst Optical Afterglow Follow-up Project, and "The Optical & Near-Infrared Astronomy Inter-University Cooperation Program" supported by MEXT.

The Observatory's unique research activities included a comprehensive survey of infrared-variable objects in the Galactic plane using the 91-cm telescope which has been converted into an ultra-wide-field near-infrared camera (OAO-WFC). The project to automate the 188-cm telescope and to improve the stability and sensitivity of the high dispersion spectrograph through a Grant-in-Aid for Scientific Research (Basic Research (A), FY 2016–2020) was continued. This project aimed at establishing a large sample of exoplanets. Collaborations with foreign researchers also continued actively.

The personnel breakdown as of March 2018 was five full-time staff members without term limits, including two associate professors, one assistant professor, one engineer, and one Chief of the Administration Office; ten contract employees, including one specially appointed associate professor, one research expert, one specially appointed research staff member, one specially appointed senior specialist, one research supporter, three administrative supporters, and two administrative maintenance staff members; and one temporary staff member.

NAOJ secured the transfer of the nation-wide open use from Okayama Astrophysical Observatory to Kyoto University's 3.8-m telescope starting from FY 2018 and dissolved the C Project "Okayama Astrophysical Observatory" on March 31, 2018.

0. Dissolution of the C Project "Okayama Astrophysical Observatory"

The National Astronomical Observatory of Japan has positioned Kyoto University's 3.8-meter telescope as the successor to the 188-cm telescope, and has placed the promotion of nation-wide open use with the 3.8-meter telescope, instead of with the 188-cm telescope, at the center of the future plan of the Okayama observatory. NAOJ announced its intention to dissolve the Okayama observatory, and to apply a considerable part of its operating expenses and 3 faculty and staff members to the operation of the 3.8-m telescope, and to provide about half of the observing time of the 3.8-m telescope for the nation-wide openuse, as soon as the 3.8-m telescope is ready for scientific observations. The memorandum of understanding exchanged between NAOJ and the Graduate School of Science of Kyoto University on October 12, 2017 guaranteed that NAOJ can provide about half of the observing time at the 3.8-m telescope for the nation-wide open use starting from FY 2018, and fixed the end of the open use of the 188-cm telescope at the end of Calendar Year (CY) 2017, in line with the discussions between NAOJ, the optical and infrared astronomy community, and Kyoto University. The Observatory submitted a proposal to dissolve the C-Project Okayama Astrophysical Observatory at the end of FY 2017 to the Planning Committee. Having passed the Executive Committee and the Advisory Committee for Research and Management, the dissolution was finally approved at the Board of Directors and Executive Committee of the National Institutes of Natural Sciences in November, 2017. On the other hand, NAOJ decided to establish the Okayama Branch Office of Subaru Telescope as a promotion organization for the nation-wide open use at the 3.8-m telescope.

From the fall of CY 2017, preparations for the dissolution of OAO and the establishment of the Okayama Branch Office were carried out at the Observatory. The Observatory abolished the library, moved about 1,000 books to the Mitaka Library, and discarded the remaining thousands of books. Two temporary buildings were abolished and removed. About 15,000 photographic plates of images and spectra of celestial bodies, stored in one of the two temporary buildings, were moved to the Mitaka Library. Other valuable materials were also moved to the Mitaka Library. The Observatory renovated the library room into two smaller rooms and transferred the computer server room and optical laboratory in the solar telescope building to the renovated rooms. The office kitchenette, women's changing room, and ladies room were modernly renovated. The laying route of the optical network cable was reorganized. A power meter was installed on each telescope dome. The gateway was retired and a new gate was installed. Preparation work was done for transiting to a new security system. The vacuum chamber for aluminizing the primary of the 1.5 m infrared simulator was discarded. Through these, the functions that were dispersed in the telescope domes and temporary buildings were concentrated in the main building. And as of March 31, the C Project Okayama Astrophysical Observatory was dissolved.

1. Open Use

(1) Overview

The numbers of nights allotted to open use in 2017 were 120 for the first semester (2017A, January to June) and 111 for the second semester (2017B, July to December). Observing proposals submitted in response to the calls for proposals were reviewed by the Okayama observatory program subcommittee and 1 project observation program, 0 academic degree support programs, 13 general observation proposals, 1 miscellaneous observation proposal, and 1 ToO observation proposal were accepted for 2017A, and 1, 0, 13, 0, and 0 were accepted for 2017B. Two proposals, one from each of Chinese Taipei and Poland, were accepted in 2017A, and two proposals, one from each of Chinese Taipei and Poland, were accepted in 2017B. The Observatory supported their observations with human resources. There were no major troubles with the telescope or the dome in either semester. Observing instruments were operated smoothly in the former semester, but a serious trouble occurred in one of the three instruments in the latter. Efforts were made in vain to restore the instrument, and its operation was terminated before the end of the overall open use scheduled at the end of CY 2017. Remaining observing time allotted to this instrument was redistributed to research subjects using other instruments as much as possible and the open use continued.

(2) Observation/Research Results

The majority of objects observed through the open use in 2017 were stellar sources, exoplanets, and galaxies. The following primary observation themes were noted: exploration of the physical properties and activities of single and binary stars via high-dispersion spectroscopy; exoplanet search and binary-mass determination via precise radial velocity measurements; exploration of exoplanet atmospheres by transits observations; and studies of physical processes in galaxies with near-infrared low-dispersion spectroscopy. As in previous years, a number of observational studies were conducted by individual groups of researchers within the open-use framework, and their respective research results were reported in meetings and conferences or were published in peer-reviewed journals.

(3) Facility and Instrument Maintenance/Management

The 188-cm telescope and its dome had evolved into a stable and high-functioning observing system by FY 2014 after the major refurbishment in FY 2012. Efforts were made to improve the completeness of the automated high dispersion spectroscopic observations with the fiber-feeding system developed in FY 2016. The remote observing environment provided to the open use with no conditions since 2016A was maintained and its use greatly increased to over 50 % of the open-use observations. During the maintenance period in June, the annual re-aluminization of the primary mirror of the 188-cm telescope and lubrication of the telescope and dome were completed. The 1.5-m primary of the KANATA Telescope at Hiroshima University was also accepted for re-aluminization in the maintenance period. Participants in the aluminization work from that organization were given NAOJ-mandated safety and hygiene training as necessary. Utmost efforts were made to maintain high observing efficiency by conducting monthly cleaning of the primary mirror of the 188-cm telescope from October to December. The dome was checked regularly. Repair of the worn-down guiding rails for the slit doors and replacement of the dome rotation drivers were done, in order to achieve smooth open-use operation. Safe storage of the acquired observing data and appropriate maintenance of the computer and network environment were carried out. Work safety was given priority in accomplishing the aforementioned maintenance work and observing instrument exchanges. In the total comprehensive replacement of the computer system of NAOJ at the end of FY 2017, the Observatory successfully completed the updating with the cooperation of the Astronomical Data Center. As a result, the Observatory continued to share the Okayama data archive function of the large-scale data-archive/public-subsystem of the National Astronomical Observatory Data-Analysis/Archive/Open System; and the remote backup function of Mizusawa RISE, Solar, and SMOKA data.

(4) Conferences

In FY 2017, the Observatory cooperated with Kyoto University and the Okayama Observatory Program Subcommittee to prepare for transferring the nation-wide open use from the 188-cm telescope to the 3.8-meter telescope. The program subcommittee met 13 times during FY 2017.

In early July of 2017, a joint call for proposals was issued on the first generation open-use observing instruments of the 3.8-m telescope by the program subcommittee, Kyoto University, and the Observatory. It was closed in early August and one application was received. At the program subcommittee in late September, 2017, it was decided to accept the fiber-type optical integral field spectrograph “KOOLS-IFU” (PI: Koji Ohta at Kyoto University).

The Observatory held the Okayama Users Meeting (The 28th Optical and Infrared Users Meeting, UM) at the Large Seminar Room of NAOJ Mitaka Campus on September 4 and 5. The present status of the Observatory, including the 188-cm telescope and dome; current condition of the open-use observing instruments and remote observation system; execution summary of the open-use observation programming of semester 2017A and B; future operation of the 188-cm telescope; development status of the fully automated observing system for HIDES Fiber-Feed observation; research results based on openuse of the 188-cm telescope; progress situation of the 3.8-m telescope project and study/preparation of observing instruments; proposals for scientific research using the 3.8-m telescope; status of study and preparation of the promotion system for nation-wide open use at the 3.8-m telescope; current situation of the optical infrared observation facilities such as the Hiroshima University Space Science Center and their research results; etc. were reported. Regarding the nation-wide open use at the 3.8-m telescope, the content of the discussion through the previous year was reconfirmed and shared among the participants, and the changes due to the change of the newly generated situation was explained by the Observatory, and the specific policies were discussed comprehensively by the participants. As a particularly significant change, it was explained that NAOJ concluded that it would be difficult for three faculty and staff members to be dispatched to Kyoto University and planned to establish the Okayama Branch Office to promote the nation-wide open use at the 3.8-m telescope and post three faculty and staff members.

The program subcommittee made the draft of the second report on the nation-wide open use at the 3.8-m telescope titled "The policy for open use in Kyoto University's Okayama 3.8-m New Technology Optical and Infrared Telescope Project." The report was expected to be handed to the Director General of NAOJ from the Advisory Committee for Optical and Infrared Astronomy around the end of FY 2017, and the subcommittee submitted it to the parent Advisory Committee on March 30, 2017 (The first report was titled "Plans for the transfer to and operation of the open use of the Kyoto University 3.8-m telescope."). In the report, the importance of time domain astronomy and that of student education are emphasized, and a queue observing mode was defined as the main observing mode at the 3.8-m telescope. It was recommended that in the future Kyoto University and NAOJ should aim to implement integrated operation of observations for research subjects with Kyoto University time and open-use time. It was also suggested to categorize the observing subjects into "general research", "ToO", "degree support", and "other", place higher importance on ToO observations, and implement a system that carries out ToO observation smoothly.

On October 6, 2017, at the initiative of Okayama Prefecture, the 18th liaison meeting on the cooperation for preserving the observational environment for the Okayama Astrophysical Observatory of the National Astronomical Observatory was held in Okayama City. Greetings from the Deputy Director of the Environment and Culture Department of Okayama Prefectural government office, greetings by the Director General of NAOJ, a special lecture by Dr. Takao Doi, a Program-Specific Professor at Kyoto University and an astronaut at JAXA, and approval of the regulations were conducted. Then, there were introductions about recent trends in observational research, the current status of the 3.8-m telescope of Kyoto University, and measures to prevent light pollution in Okayama Prefecture. Calls for conservation efforts for the observation environment were made to various related areas in the prefecture.

2. Developing and Maintaining Open-Use Observing Instruments

(1) HIDES (High-Dispersion Echelle Spectrograph)

The instrument HIDES is a cross-dispersed high-dispersion echelle spectrograph with two fiber-link systems (HIDES-F). The high-efficiency (HE) fiber link with approximately 50-K wavelength resolution offers an improvement in throughput of nearly one magnitude over the previous value with the Coudé light path and radial velocity measurement precision of approximately 2 m/s, which is comparable to the case of the Coudé light path. The high-resolution (HR) link with 100-K wavelength resolution provides a 4 times better sensitivity at maximum than the case of the Coudé light path. All functions of HIDES-F were kept available to the open use in FY 2017. The HE mode dominated the open use. This year the total numbers of accepted proposals to HIDES were 6 and 7 in 2017A and 2017B, including 1 and 1 project observations, respectively.

Regarding the optical comb developed by researchers at the National Institute of Advanced Industrial Science and Technology (AIST) and others and installed in the 188-cm telescope dome last year as a next generation high precision wavelength standard, the collection of experimental data for astronomical applications was terminated in December. The optical comb was collected by AIST.

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

ISLE was a near-infrared imager and low- or mid-dispersion spectrograph. It was characterized as having the world's best low-noise readout capability (less than 10 electrons). Relative photometry at the one milli-magnitude level was regularly achievable with its imaging mode for bright sources. A carry-in YJH-band filter from a user and the HK-band filter as standard equipment enabled it to obtain a well-connected spectrum from Y-band to K-band. In FY 2017 as well, the open use of all functions was continued. A failure occurred and the detector did not operate properly at the end of July, 2017. Among 13 open-use observing nights using ISLE in July and August, 3 nights were transferred to other equipment and the open-use observations were carried out. The Observatory cancelled the remaining 10 night open-use observing program and transferred the 10 nights to observatory time. The Observatory tried restoration work but concluded that it was not recoverable at the end of September and decided to terminate the operation of ISLE. The Observatory redistributed 17 nights of open-use observations scheduled to use ISLE from October to December to open-use research subjects with other observing instruments. The numbers of accepted open-use programs using ISLE in semester 2017A was five, three of which were spectroscopy and the other two of which were imaging photometry. In 2017B, five were accepted, four of which were spectroscopy and one of which was imaging photometry, but they were not executed due to the malfunction of the instrument.

(3) MuSCAT

MuSCAT is a Multicolor Simultaneous Camera for studying Atmospheres of Transiting exoplanets in three visible colors (g, r, z band). A relative photometric accuracy of 0.05% (0.5 mmag) is achieved in the case of repeating one-minute exposures for a star of 10-th mag in V-band. The Observatory continued to operate MuSCAT as a PI type open-use instrument in FY 2017. In the first semester of 2017, five open-use programs (including one miscellaneous program) were conducted, and three open-use observing programs were conducted in the second semester of 2017.

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 Astro-Aerospace, Inc., regarding the 3.8-m telescope project as part of the future plan of the Observatory. Discussions were held on technological issues regarding the telescope and observing instruments through weekly TV conferences and in-person meetings held every three months in FY 2017 also. The 3.8-m telescope in the temporary housing was disassembled, moved to the main dome, reassembled, and continued on to adjustment work in July. In July, a joint call for proposals was issued on the first generation open-use observing instruments by the program subcommittee, Kyoto University, and the Observatory. At the program subcommittee in September, 2017, it was decided to accept the fiber-type optical integral field spectrograph "KOOLS-IFU" (PI: Koji Ohta at Kyoto University). The Observatory cooperated with researchers at Kyoto University to further develop and strengthen KOOLS-IFU. The Observatory also collaborated with the researchers at Kyoto University to design the instrument rotator to be installed on the Nasmyth focus platform. Development of a near-infrared fiber-fed spectrometer was continued through a JSPS grant for scientific research (Basic Research A (General), FY 2016-2019) applied for and acquired by the Kyoto University side, in which an observatory staff member participated as a co-investigator. Workshops on high dispersion spectroscopy were held to reinforce the research groups and enhance the application activities for external funds.

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

The Program entered its second term from FY 2017 as a continuation of the previous program.

The Observatory decided not to receive budget allocation from the program in FY 2017 and contributed to the program by keeping the 50-cm telescope system operable and available for the program.

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

Optical follow-up observations of GRBs using the 50-cm telescope were conducted in cooperation with the Tokyo Institute of Technology's Kawai Laboratory. During FY 2017, the automatic observation scheduler performed observations on nearly every possible night; 47 GRBs were observed, with upper limits for optical afterglows published as 7 GRB Coordinates Network (GCN) circulars. In addition, follow-up observations of candidate gravitational wave sources and monitoring of objects that include X-ray binaries, active galactic nuclei, and supernovae were concurrently performed, which resulted in publication of six peer-reviewed papers. In FY 2017, the Observatory contributed to the operation through the maintenance of the telescope, dome, and the electric power supply.

(4) Use of the existing telescopes including the 188-cm reflector starting from FY 2018

Regarding the use of the existing 188-cm telescope and smaller ones starting from FY 2018, discussions have been held repeatedly between NAOJ, researchers at universities, and the local municipality since FY 2016. For the 188-cm telescope, the Center for Observation and Research on Exoplanets of the School of Science of Tokyo Institute of Technology was established in April, 2017, with an intention to operate the telescope. Asakuchi City, the local municipality, also expressed the positive intention to use the 188-cm telescope. The Observatory cooperated with the executive board and administrative departments of NAOJ in response to these developments. The Observatory assisted the preparation for conclusion of the agreement by the three parties of NAOJ, Tokyo Institute of Technology, and Asakuchi City on the use of the 188-cm telescope.

(5) Other

The Observatory welcomed four third-year undergraduate students and their supervisor from the University of Tokyo between August 23 and 25 and provided them with an opportunity to conduct high-dispersion spectroscopic observations using the 188-cm telescope during the early half-night on August 23.

In collaboration with researchers at Tohoku University, IR-TMT, a bright star observing system equipped with Tohoku University's 30 mm diameter wide field of view near infrared camera mounted on the equatorial mounting for 30 cm class telescopes owned by the Observatory was operated, and data acquisition continued to create a highly accurate near-infrared photometric catalog of stars in the solar neighborhood. The observations were conducted exclusively by remote control from Tohoku University.

4. Unique Research Projects

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

With the 91-cm reflector having been converted into an infrared camera with an ultra-wide field of view, observations in the Ks band were conducted to identify infrared counterparts for objects such as GRBs and gravitational wave sources. Along with them, a comprehensive survey of infrared variable stars in the Galactic plane was carried out. In FY 2017, frequent observations were made extending out in the direction of the galactic longitude from the two zones (centered on 30 and 80 degrees in the galactic longitude) that were monitored last year, and low frequency (~ every few tens of days) observations of the two zones were added so that long period variables could be detected there. Based on preliminary analysis of acquired data, 90 cepheid candidates were detected, and it was confirmed that most of them were not detected in visible light due to heavy interstellar extinction. In addition, automatic monitoring of other objects, such as the Orion star forming region and bright blazars were continued.

(2) Development of a far larger scale exoplanet search

Through a Grant-in-Aid for Scientific Research (Basic Research (A), “Large-scale exoplanet search with a robotic telescope for high dispersion spectroscopy,” representative: Hideyuki Izumiura, FY 2016–2020), a project was initiated to establish an original large-scale sample of exoplanets in the previous FY. For that purpose, activities were continued to develop robotic operation of spectroscopic observations with the 188-cm telescope and to improve the sensitivity and stability of the spectrograph. Concerning the robotic operation of the observing system, once a target list following a certain format is given to the system by the observer, the system automatically executes the evaluation of the sunset and weather; opening/closing of the dome slit and mirror covers; telescope focusing; acquisition and tracking of the target; exposure control of the spectrograph; choice of the next target; and the termination process for the night. The progress of the observations can be checked with a web browser. Time-based observing efficiency comparable to those realized by highly experienced observers has been achieved by tuning through the test observing runs. On the other hand, the sensitivity of the observing system was enhanced by applying a new coating to the secondary mirror of the 188-cm telescope and by introducing a new collimator mirror and a new cross-disperser grating. The spectrograph was stabilized by replacing its thermostat equipment.

(3) East Asian Planet Search Network

The Observatory also conducted studies focusing on the search for exoplanetary systems, involving researchers from South Korea, China, Turkey, and Russia. Efforts were continued in FY 2017 to secure telescope time on the Korean 1.8-m telescope, Chinese 2.16-m telescope, Turkish 1.5-m telescope, and the Observatory’s own 188-cm telescope for continued searches for exoplanetary systems around G-type giant stars. A meeting on exoplanet searches using precise radial velocity measurements and astero-seismology was held in Nara City, welcoming related researchers from Japan, China, South Korea, and Germany in October 2017. With the above collaborations two peer-reviewed papers were published and the network was able to lead the world wide search for exoplanets around G-type giant stars.

5. PR/Awareness Promotion Activities

In this FY about 30 astronomy-related questions from the public were posed irregularly to the Observatory and were answered appropriately. The 4D2U screenings, co-hosted with the Okayama Astronomical Museum, attracted about 2,300 visitors. Fifteen Observatory tours were conducted, including those for pupils from local elementary schools in Asakuchi City and Yakage Town. The Observatory also responded to two lecture requests made by local boards of education and community centers. The Observatory posted one research result web release and no press releases. A special website “Complete History of Okayama Astrophysical Observatory” (https://www.nao.ac.jp/study/oao/) was opened upon dissolution of the C Project Okayama Astrophysical Observatory.

6. Contract Staff Transfers

The following transfers of contract staff members took place in FY 2017: Hiroyuki Maehara resigned as a research expert on December 31 and moved out to a Program-Specific Associate Professor position (The Optical & Near-Infrared Astronomy Inter-University Cooperation Program) at Kyoto University on January 1. Nobuharu Ukita retired at mandatory age from NAOJ as an associate professor on March 31. On March 31, specially appointed associate professor Eiji Kambe, research expert Daisuke Kuroda, specially appointed research staff member Kazuya Matsubayashi, research supporter Hiroyuki Toda, administrative supporter Kumiko Katayama, and administrative maintenance staff member Shoji Koyama all resigned. A worker dispatch contract for a temporary staff member was terminated on March 31.

3. Nobeyama Radio Observatory

1. Nobeyama 45-m Radio Telescope

(1) Open Use Observations

The 36th open use observations period started on December 8, 2017. The statistics of the successful proposals are as follows, “General Programs”: 26 programs were accepted out of 55 submitted proposals including eleven programs from abroad (out of 20 submitted), “Large Program”: one program was accepted out of one submitted, “Short Programs”: nine were accepted out of twelve, “Backup Programs,” which are to be carried out when weather is not good enough for the main observations: one program was accepted (out of one submitted), “GTO (Guaranteed Time Observation) programs”: one program was accepted and another was treated as a filler program out of two submitted proposals. “DDT Programs”: no proposals were submitted. VLBI open use observations including the 45-m telescope: 3 proposals were accepted out of three.

In addition, carry-over programs from the master collimator driving system failure in the last observing season were conducted.

Remote observations were conducted from Kagoshima University, Kyoto University, Nagoya University, University of Tsukuba, and ASIAA (Taiwan). A remote operation test was conducted from KASI (Korea).

(2) Improvements and Developments

Taking into account the reduction of the human and budgetary resources of Nobeyama Radio Observatory, we introduced a call for Nobeyama Development Proposals from this fiscal year. The main purpose is to concentrate on the enhancement of the capabilities of the open use with the 45-m telescope rather than general opportunities. The review panel members were Tomoharu Oka (chair), Kotaro Kohno, Shigehisa Takakuwa, and Tomoya Hirota. The Director of NRO and Tetsuhiro Minamidani (as technical assessor) also attended the review as observers from the observatory side. A total of eight proposals were received, and three of them (3-band simultaneous observing system HINOTORI, frequency-modulation local oscillation FMLO, Band 1 receiver by Taiwan) were accepted.

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

- The repair of the master collimator driving system was completed during the summer maintenance term. The observatory investigated the pointing accuracy and confirmed that the typical pointing accuracy is the same as before.
- A malfunction in the sub-reflector driving system was found, and tentative measures were done.
- Preventive and corrective paint to the antenna main-reflector structure was done.
- The replacement of a mirror exchange system (new one) was completed. The design works for the replacements of the other mirror exchange system (old one) and the beam switching system were started.
- The “On-On” observation mode with the FOREST receiver was implemented, and was offered to open-use observations. The TZ receiver was decommissioned.
- Replacing boards of the SAM45 spectrometer reduced the frequency of trouble occurrences. A test of a GPU spectrometer was started for the next generation spectrometer.
- New observing-script generator, “nobs,” was developed, and used for open-use observations.
- Nobeyama 45-m Science Data Archive has been opened.
- Development of the data reduction procedure with the CASA pipeline is continued. These will lead to an automated observing system in the future.
- Simultaneous observations of 22 and 43 GHz bands were realized by installing a frequency selective filter developed by the HINOTORI program.

(3) Scientific Results

1) 45-m telescope Legacy Projects

(a) Star Formation Legacy Project

In the Star Formation Legacy Project, we conducted large-scale mapping observations toward three nearby star-forming regions, Orion A, Aquila Rift, and M17 in ^{12}CO (1–0), ^{13}CO (1–0), C^{18}O (1–0), and N_2H^+ (1–0). Many cores and clumps have been identified from structure analysis of these data. In particular thanks to the high sensitivity, a protostellar molecular outflow was found that was not in the data taken with BEARS.

(b) Galactic Plane Survey Project (FUGIN: FOREST Unbiased Galactic plane Imaging survey with the Nobeyama 45-m telescope)

We conducted a simultaneous survey of the ^{12}CO (1–0), ^{13}CO (1–0), and C^{18}O (1–0) emission lines in the Galactic Plane at the highest spatial resolution using FOREST aboard the 45-m telescope. The detailed structure of the molecular gas in our Galaxy was made clear, from large scales to internal structures (filaments, clumps, and cores) inside giant molecular clouds. Hints of evidence of the cloud-cloud collision were obtained toward the massive star forming region W33 (Kohno et al.), the giant molecular cloud M17 (Nishimura et al.), and others.

(c) Nearby Galaxy Project (COMING: CO Multiline Imaging of Nearby Galaxies)

The COMING (CO Multiline Imaging of Nearby Galaxies) project mapped about 140 nearby galaxies in ^{12}CO (1–0), ^{13}CO (1–0), and C^{18}O (1–0) emission lines using FOREST, and analyzed the data automatically. It was found that in the dwarf spiral galaxy NGC 2976 the fraction of the molecular gas depends on the surface density of the total gas (atomic and molecular) and star formation rate (Hatakeyama et al.)

2) Results from Open Use Programs with the 45-m telescope

- Using also ALMA data, it is found that in the Barred Spiral Galaxy M83 the CO Integrated Intensity Probability Distribution Function (PDF) on the bright side in the bar has a tail, while that in the arm does not (Egusa et al.). Also, it is found that a large velocity dispersion is responsible for this tail and suppression of star formation.
- By comparing the molecular gas fraction and star formation efficiency in nearby galaxies, it is found that star formation activity in individual galaxies depends on molecular gas content rather than the global environment (Koyama et al.).
- By observing two strong barred galaxies, NGC 1300 and NGC 5383, observational results were obtained supporting the scenario that high-speed collisions in the bar suppress massive star formation (Maeda et al.)
- The most distant molecular cloud in our Galaxy from us was discovered (Matsuo et al.).
- In an active star-forming filament G82.65-2.00, it was found that the filament is in the process of dispersing, and a region possibly suggesting accretion onto the main filament through the striation was discovered (Saajasto et al.).
- By observing four massive star forming regions, it was found that there is HC_5N in the warm molecular gas (Taniguchi et al.)
- By observing three ^{13}C isotope molecules of HC_3N, it was found that the formation path differs depending on the region (Taniguchi et al.).
- $H(C_5)(^{15}N)$ was discovered in the interstellar medium (Taniguchi et al.)
- By observing the Cygnus X region, it was shown that the CN/$C^{18}O$ ratio is enhanced due to photodissociation (Yamagishi et al.).
- Observing 62 LIRG/ULIRG galaxies revealed that the molecular gas mass within several kpc is almost constant (Yamashita et al.).

2. Radio Polarimeters

- Operations and maintenance were performed.
- On a monthly basis, the data are examined by solar research groups in Kyoto University, Ibaraki University, NICT, and NAOJ Solar Observatory, and are archived as public data in the NAOJ Astronomy Data Center so that researchers all over the world can access them.
- 2 GHz: Data unavailability has continued due to the strong interference since late June and the malfunction of an origin sensor since December.
- 9.4 GHz: Data unavailability has continued due to the malfunction of an amplifier since late June and an origin sensor since January.

3. Research Support

(1) SPART (10-m telescope) (Osaka prefecture University)

To better understand the influence of the activities of host stars on the atmospheric environment of habitable planets, we continued monitoring observations of the planets in the Solar System at 100 and 200 GHz bands with a 10-m telescope, the Solar Planetary Atmosphere Research Telescope (SPART). For investigations of short-, medium-, and long-term changes of CO abundance in the Venusian middle atmosphere revealed by SPART, we carried out synergetic observations with the Atacama Large Millimeter/Submillimeter Array, and Japanese Venus Climate Orbiter AKATSUKI (JAXA/ISAS) in May 2017, and the 1.6-m Pirka Telescope (Nayoro Observatory, Faculty of Science, Hokkaido University) employing a Near Infrared Echelle Spectrograph (The University of Tokyo) in July 2017. These studies of the Venusian atmosphere allow us to address the links between photochemistry and dynamical circulation of materials in the Venusian atmosphere and space weather environment. In addition, in the NINS Nobeyama Exhibition Room, we started to show the state of the remote operation and the SPART observations in the computer display.

(2) Radio Heliograph (Nagoya University)

In FY 2015, an international consortium (ICCON) assumed operation of the Nobeyama Radioheliograph (NoRH, see https://hinode.isee.nagoya-u.ac.jp/ICCON/). The remote operating system via internet has functioned very well. About 30 researchers from seven countries (China, Germany, Japan, the Republic of Korea, Russia, the UK, and the USA) participated in operation, including the system health check and data verification. Observational data are automatically transferred to NAOJ and Nagoya University and are stored/maintained there. Since the middle of February in 2018, we stopped the operation of NoRH because we found problems in some cables. They will be exchanged and the operation of NoRH will be resumed in early April in 2018. Using data of NoRH, one PhD thesis and seventeen refereed papers were published in Fiscal Year 2017.

4. Public Outreach

(1) PR activities at Nobeyama Campus

The Nobeyama Campus received a cumulative total of 44,853 visitors throughout the year, including participants in the Special Open House event. Staff members conducted 49 guided tours, including ones for Super Science High School (SSH) students and the Campus Tour Week, while 4 requests for lectures and 36 requests for on-site filming and interviews were granted. These requests, especially those by some local broadcast stations in Nagano Prefecture, drastically increased due to efforts to strengthen cooperation with local communities, especially the “Nagano Prefecture is the Astro-Prefecture” promotion. The Campus Tour Week for educational institutions was scheduled during the summer. Six groups took advantage of this opportunity, and many students in the groups enjoyed the visit. For the workplace visits, 9 students from 4 schools, primarily local junior-high schools, visited the observatory. For the SSH initiative, three schools visited NRO and participated in lectures.

In the area for permanent public access, a controllable radio-telescope antenna miniature and introduction movies are available along with posters and panel displays. In this year, we officially inaugurated the Nobeyama Exhibition Room of NINS, and open it every day.

Moreover, we received and answered about 170 phone calls a year from the public regarding the regular opening of the observatory, observatory events, and general astronomy.

(2) Cooperation with Local Communities

The annual Nobeyama Special Open House was held with contributions by Nagano Prefecture as well as Minamimaki Village, the Minamimaki Chamber of Commerce, and its youth division. Moreover, Jimoto Kansha Day (Thanks Day for the Locals) was held as the Special Open House for locals (Minamimaki and Kawakami Village) at NINS Nobeyama exhibition room by NRO as the main host. Special sponsorship was made to the sora-girl event “Tebura de Hoshizora Kansho-kai (Drop-by Star Gazing Event),” hosted by the Minamimaki Tourism Association. The 29th national convention of “Hoshizora-no-machi, Aozora-no-machi (Streets of starry sky and blue sky)” was held in Minamimaki Village by the Ministry of the Environment with Minamimaki Village as the host, which cooperated with Nobeyama Radio Observatory. The commemorative lecture and guided tour of NRO facilities were offered.

Moreover, a “Nagano Prefecture is Astro-Prefecture” summer stamp-rally event was carried out as the first event by the “Nagano Prefecture is Astro-Prefecture” liaison council, which was founded through cooperation with Kiso Observatory and other organizations last year. The second meeting was held at the National Institute of Technology, Nagano College on February 4 with about 80 participants. A lecture, some activity reports, and discussion on the future activities were presented.

(3) NINS Nobeyama exhibition room

After the improvement work on the building of the Nobeyama Millimeter Array, NINS Nobeyama exhibition room was officially opened and started year-round operation. NINS Nobeyama exhibition room was open to the public at the same time as the open time of Nobeyama Campus. The opening ceremony of NINS Nobeyama exhibition room and the press conference with the President of NINS were held on April 29. The 4D2U theater was operated during the summer season from April to September. The exhibition room played a role in improving awareness of the other institutes of NINS as well as NAOJ.

5. Education

NRO accepted one third-grade Ph.D. student in SOKENDAI studying chemical reaction of carbon chain molecules.

SOKENDAI held the workshop on Radio Astronomical Observation using the Nobeyama 45-m Radio Telescope from June 5 to 9, with 12 undergraduate students in attendance. While guiding the students, from observations to presentation of the results, requires significant efforts, the event offers an invaluable opportunity for undergraduates to experience observations using a radio telescope and think of their future careers.

6. Misc. Activities

(1) Nobeyama 45-m Radio Telescope was certified as milestones of IEEE and IEICE

Nobeyama 45-m Radio Telescope was certified as milestones of IEEE and IEICE. It was nationally and globally recognized to have significant technical achievements and to have greatly benefited industrial progress and regional society for a long time. The commemorative ceremony including presentation of the IEEE milestone plaque was held at Josui-Kaikan in Tokyo on June 14. Moreover, the unveiling ceremony of the IEEE milestone plaque and pedestal was held in NRO on June 16. In these ceremonies, the telescope was greatly honored by the local people including the village mayor as well as members concerned with development and operation. It also seems to have made great social and cultural contributions to the local area.

(2) Hiring, Transfer (incoming)

Ken’ichi Tatematsu: Professor from NAOJ Chile Observatory
Masaru Takahashi: Senior Staff from Shinshu University
Hidemi Ide: Technical Expert, hired
Kim Gwanjeong: Specially Appointed Research Staff, hired

(3) Retirement, Transfer (outgoing)

Kunio Iijima: Senior Staff, moved to Shinshu University
Yusuke Miyamoto: Specially Appointed Research Staff, moved to NAOJ Chile Observatory
Hiroko Ide: Administrative Maintenance Staff, retired
Ikuko Koike: Administrative Maintenance Staff, retired
Jyunko Tsuchiya: Administrative Maintenance Staff, retired
Jyunko Kadoshima: Administrative Maintenance Staff, retired
Michiko Kikuchi: Administrative Maintenance Staff, retired
Eiko Htakeyama: Administrative Supporter, retired
Chisato Tokui: Administrative Supporter, retired
Kotomi Taniguchi: SOKENDAI, obtained PhD

(4) NRO Conference Workshops and Users Meeting

- August 1–2, 2017, Nobeyama Radio Observatory
  NRO45-m/ASTE Single Dish Science Workshop 2017 (Organizing Committee: Tomofumi Umemoto, Ken’ichi Tatematsu (NRO), Daisuke Iono (Chile Observatory)
- December 26–27, 2017, NAOJ Mitaka, Large Seminar Room
  ALMA/45-m/ASTE Users Meeting 2017 (Organizing Committee: Fumi Egusa (NAOJ Chile Observatory) Ken’ichi Tatematsu, Tomofumi Umemoto (NRO), Daisuke Iono (NAOJ Chile Observatory))

4. Mizusawa VLBI Observatory

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

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

1. VERA

(1) Observations and Common-Use Observations

The four stations of VERA were operated by remote control from AOC (Array Operation Center) at NAOJ Mizusawa Campus. In FY 2017, the total of 523 (4,160 hours) VLBI observations were conducted with VERA, such as common use observations, VERA project observations, fringe detection observations for maser and reference sources, geodesy observations, JVN (Japanese VLBI Network) observations, KaVA (KVN and VERA Array) observations, and others. These VLBI data, except for KaVA, were processed at the Mizusawa Correlation Center in NAOJ Mizusawa Campus. The correlated data were sent to each researcher for the case of common-use and JVN observations and to persons in charge of data analyses in the case of project data and geodesy data.

VERA common-use call-for-proposals with the 43 GHz, 22 GHz, and 6.7 GHz bands for semesters 2017B and 2018A were released in April and September, respectively. A total of five proposals, which requested a total time of 112 hours, were submitted, including one proposal for 30 hours from overseas. Based on the evaluations by referees elected from scientists in related fields, VLBI program committee decided to accept a total of five proposals (97 hours) in 2017B and 2018A.

(2) Science Research

In FY 2017, Mizusawa VLBI Observatory published a total of 37 refereed journal papers for scientific achievements. Among them, seven papers were published by the Observatory staff or students as PI. For those directly related to VERA, four papers were scientific results from VERA astrometry observations, three were the results from Korea-Japan international collaboration, KaVA, and eight were from other domestic and international VLBI arrays based on previous studies with VERA. Representative observational results from VERA are proper motion measurements of jets and shocked gas associated with water masers in high-mass star-forming regions, and verification of high accuracy astrometry with multiple phase calibration sources toward the Galactic Center region. In addition, as KaVA has started large programs since 2016, verification results for amplitude calibration accuracy and initial results for monitoring observations of a high velocity radio jet ejected from an active galactic nucleus (AGN) M87 were reported. In recent years, high resolution VLBI observational studies are combined with new instruments, and discussion on future projects such as ALMA, EHT (Event Horizon Telescope), and SKA (Square Kilometer Array) has been carried out. For these new projects, four, three, and one refereed journal papers, respectively, were published. With ALMA, a rotating outflow was detected in a high-mass protostar Orion Source I, which has been studied with VERA for a long time. It provides important information on angular momentum transfer in star-formation processes. In terms of future plans, a review paper on cosmic magnetism was published, which will become one of the key sciences with the future SKA.

2. The Japanese VLBI Network (JVN)

The University VLBI Collaboration Observation project is carried out as a joint research project between NAOJ and six universities. We organize the radio telescopes of VERA, universities, and research institutes (JAXA/ISAS, NICT) to make the Japanese VLBI Network (JVN), which is operated at three bands of 6.7 GHz, 8 GHz, and 22 GHz. VLBI observations were carried out for about 100 hours in total in FY 2017. The main research subjects are active galactic nuclei and maser/star formation. In addition, single-dish observations of up to 2000 hours were carried out as research related to JVN by Ibaraki University.

The University Collaborative Workshop was held at Ibaraki in July 2016, and a white paper entitled "High-Spatial-Resolution/Time-Domain Astronomy in the centimeter band" was approved as the baseline of the university collaboration. Along with this white paper, maser/star formation study is led mainly by Ibaraki University, while active-galactic-nuclei/black-hole science is led by Yamaguchi University. In particular, observations with the Ibaraki-Yamaguchi interferometer are the key for these studies. Survey observations of 1) Compact radio sources in the galactic center, 2) High-z AGN's, 3) Fermi gamma-ray sources, have been carried out.

Some papers were published in FY 2017 by using JVN, such as Takefuji et al. (2017) for phase-up technique, Cho et al. (2017) for EAVN calibration, Morokuma et al. (2017) for peculiar AGN with Optical/Infrared and VLBI collaboration, and Yoshida et al. (2017) for follow-up observation for the gravitational wave event. Two short reports were issued as ATel (Sugiyama et al. and Takefuji et al.) for transient events. For development study, some students of Ibaraki and Yamaguchi Universities were supervised by Professor Ogawa in Osaka Prefecture University.

3. Japan-Korea VLBI

(1) Observations and Common Use Observations

In FY 2017, a total of 131 (1138 hours) VLBI observations, common use observations, large program observations, and test observations, were conducted by KaVA (KVN and VERA Array) at 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 semester 2017 B and 2018 A were made in April and September of FY 2017, respectively. In total, 23 proposals requesting a total time of 888 hours were submitted. Through the evaluations by referees elected from scientists in related fields and subsequent decisions made by the VERA and KVN combined Time Allocation Committee, in total 17 proposals (482 hours) were accepted in 2017 B and 2018 A.

(2) Results of Research

The number of science results based on KaVA data is steadily increasing since the opening of the KaVA common use in FY 2014. In FY 2017, two research papers that made use of KaVA common-use data were published in peer-reviewed journals, one proceedings of an international conference was published, and one paper was submitted to a peer-reviewed journal. These include a detailed monitoring of the M87 jet (Hada et al. 2017), detailed observations of SgrA* (Cho et al. 2017, Zhao et al. 2017), and the discovery of jet-cloud interaction in 3C84. These sources are all key sources for studying AGN activities, and these publications demonstrated that KaVA is a powerful tool to investigate AGN physics.

The three KaVA Large Programs (LP), which were launched in late FY 2015, are continuing smoothly, and the analyses of these data are actively ongoing by each KaVA Science Working Group (AGN, star-formation regions, late-type stars). An interim review of the LP's was made at Daejeon in November. Although there was a comment that the number of publication for each LP was still relatively small, the review result was overall positive because a number of interesting preliminary results have already been obtained. Therefore, the continuation of the LP's was approved expecting that more publications will be out soon. The LP data are also used for master/PhD theses of new students.

4. EAVN

To expand the capability of the international VLBI throughout East Asia, the commissioning of the East Asia VLBI Network (EAVN) is actively ongoing through collaboration between Japan, the Republic of Korea, and China. In FY 2017, EAVN commissioning observations were performed for a total of 13 epochs (and a total of 13 stations joined), which is the largest EAVN campaign ever made. In particular, the Shanghai-Tianma 65-m station joined all of these sessions, and we succeeded in quasi-regular EAVN operation. Moreover, these data allowed detailed performance evaluation of the Tianma station. As a result, it was officially approved that the common-use of KaVA+Tianma (plus partially Nobeyama) will open from the second semester of FY 2018 (up to 100 hours per semester).

The activities of EAVN were presented at the annual conference of the Chinese Astronomical Society held in Urumqi. We also made intensive discussions to accelerate EAVN commissioning including Urumqi/Nanshan, which contributes to the longest EAVN baselines. We aim to start the EAVN common-use including Urumqi from FY 2019.

Along with the commissioning, continuous efforts have been made to produce early EAVN science results by collaborating with the Event Horizon Telescope which observes nearby supermassive black holes.

5. Future Plans for SKA

The observatory has been investigating The Square Kilometre Array (SKA) Project as one of the possible future projects of the observatory. In FY 2017, the observatory released a report on SKA science cases which have been studied by the observatory task force for two years. The report concludes that, with SKA, we can extend our current research quantitatively and can evolve our future research qualitatively.

Next, based on a request from the Japan SKA Consortium, the observatory examined the way to establish the NAOJ SKA Promotion Office (NSPO). The observatory provided opportunities for discussion about SKA at the VERA users meeting and VLBI Consortium symposium. A consensus for establishing NSPO has been growing in the VLBI community. The observatory consulted about NSPO with VLBI and Radio advisory committees in NAOJ and obtained positive statements about the NSPO proposal. Through these processes, the observatory applied to establish NSPO as a new sub-project in NAOJ.

For the first two years of the project, NSPO will define the project. NSPO will start preliminary negotiation about Japanese participation and investigate possible options for scientific and engineering strategies. For the next three years, NSPO will execute the project, i.e. formal negotiation, funding, and design reviews, and will achieve Japanese participation in SKA1 as a minor partner.

Finally, the observatory applied to the SKA organization for a SKA pathfinder designation for VERA. This would be beneficial for enhancing the international presence of VERA, and for promoting SKA science and technology with VERA. The application was approved recently.

6. Geodesy and Geophysics

The regular geodetic sessions of VERA are allocated two or three times per month to maintain the orientation and figure of the array. VERA internal geodetic observations are performed once or twice per month using K-band, and Mizusawa station participates in IVS sessions using S and X-bands on a once-per-month basis. The experimental observations which aimed at the improvement in accuracy of the solution by wideband recording were also continued, and a satisfactory result was obtained.

In FY 2017, we participated in eight IVS sessions and performed 18 VERA internal geodetic sessions including a joint VERA and KVN geodetic session. The final estimation of geodetic parameters was reconstructed in the ITRF2014 system and derived by using the software developed by the VERA team.

After "The 2011 Earthquake off the Tohoku Pacific coast" (Mw = 9.0), displacement of Mizusawa station continued by post-seismic creeping, and the position of Mizusawa station changed by 6.4 cm during FY 2017. And, in Ogasawara and Ishigakijima, fluctuations of the displacement by slow slip events were detected.

Continuous GPS observations at VERA stations are carried out in order to detect short term coordinate variations and to estimate atmospheric propagation delays. The result of GPS positioning at Mizusawa shows a post-seismic motion to the East-Southeast direction even though seven years have passed since the occurrence of the 2011 earthquake. The gravity tide observation data at VERA stations were analyzed and the tidal displacements were estimated. The observed displacements were consistent with the Earth Model which is used in VERA data reduction. We confirmed that the tidal displacements never affect the accuracy of VERA astrometry observations. The gravity change observation at Ishigakijima continued through joint work with other institutes and universities. The strain and tilt observation data obtained at the Esashi Earth Tides Station are distributed in real time to several institutes based on the research agreement between the Earthquake Research Institute, the University of Tokyo, and Mizusawa VLBI Observatory.

7. System Development

In FY 2017, we have developed two down-converters and IF-switches for dual polarization receiving of the Q-band. We have installed these instruments at Mizusawa and Iriki and performed a VLBI experiment. As a result, we obtained good fringes and started scientific test observations with KaVA. We have installed new RF direct A/D samplers "OCTAD" and high-speed recorders "OCTADISK2" developed by NAOJ at all the VERA stations and performed VLBI experiments at a recording rate of 8 Gbps. We successfully obtained fringes between all the stations. We continued discussion on the SKA project and high frequency VLBI as future plans of Mizusawa VLBI Observatory. With regard to SKA1, we considered development of the Band 5C broad-band receiver, AIV (Assembly, Integration, and Verification), and VLBI back-end system development as potential items to be contributed from Japan. With regard to SKA2, we performed various basic design and development, including a low power consumption optical transmitter/correlator. With regard to high frequency VLBI, we performed various development and AIV for a balloon-borne VLBI station. The system was completed and was ready to be launched in the 2017 summer season. However due to bad weather, its launch was postponed to next year.

8. Timekeeping Office Operations

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

9. Ishigakijima Astronomical Observatory

FY 2017 was the 12th year of Ishigakijima Astronomical Observatory (IAO). Four refereed papers using the observational data of IAO were published, and the total number has reached 23. The number of visitors was 14,000 people and has exceeded 10,000 people for the past five years in a row. The establishment purposes of observational study, public outreach, and regional promotion have been accomplished satisfactorily.

The commemoration ceremony for reaching 120,000 visitors was held in January. The number of foreign tourists has increased in recent years, from 450 in the previous year to 795 people this year.

In terms of the research, observations of transient objects were conducted in collaboration with Japanese universities, and the follow-up observations of Near-Earth Objects were also carried out in accordance with an invitation from JAXA. IAO participated in two international projects: JOVIAL for detection of Jupiter's oscillation with Japan, France, and the United States and GROWTH with Titech, Caltech, and others; several joint observations were performed. As for the research results, refereed papers including the study of a binary black hole V404 Cyg and comet C/2013 US10 were published.

In regards to the education, more than 1,000 people visited IAO as part of group visits from elementary and junior high schools, and inspections from government offices. The lifelong study for Okinawa prefectural inhabitants was opened in July. The Chura-boshi Research Team Workshop for high school students and the observational experiment for undergraduate students of the University of the Ryukyus were held in

August. The lecture for the 179th committee of JSPS photonics information system was carried out in December.

As for the public outreach, three special events were held. At the Golden Week event, 610 people attended in five days. In the "Southern Island Star Festival" event, 1,043 people visited to IAO in nine days. And 78 people joined in the spring vacation event "Urizun Starry Sky Class" in three days. In the 16th year of "the Southern Island Star Festival," which is hosted by Ishigaki City and IAO from August 12 to August 20, 11,337 people participated. At "the Star Festival" held in Kohamajima, which is hosted by IAO and Yaeyama greater metropolitan area affairs association, 300 people attended. Approximately 200 people joined in the weather class for parents and children hosted by Ishigakijima local meteorological observatory and IAO.

On the other hand, IAO cooperated with the international conference of "the East Asian Young Astronomers Meeting 2017" (73 participants) held in November, and many foreign participants joined in the star party. After the conference, the public lecture "Frontiers of astronomy –two astronomical discovery stories-" was held, and more than 30 people took part and contributed to the regional development through the two events.

10. Public Relations (PR) and Awareness Promotion Activities

(1) Open House Events

At each telescope site operated by Mizusawa VLBI Observatory, we held the following open house events.

On April 16, 2017: the Eighth Open Observatory Event held at the Ibaraki University Center for Astronomy, and NAOJ Mizusawa VLBI Observatory, Ibaraki Station, with a cumulative total of 1,141 visitors in attendance.

On July 16: 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.

From August 12 to August 20: "The Southern Island Star Festival 2017" held together with the special open house event at the VERA Ishigakijima Station and Ishigakijima Astronomical Observatory with 11,337 visitors to the whole "Star Festival." Events included the astronomical observation party at Ishigakijima Astronomical Observatory, attended by 1,043 visitors; and the special public opening of the VERA Station attended by 273 visitors.

On August 12: Special open house of VERA Iriki station held jointly with "The Yaeyama Highland Star Festival 2017," with approximately 3,800 visitors in attendance.

On August 19: "Iwate Galaxy Festival 2017," open house of NAOJ Mizusawa Campus, held with 1,165 visitors in attendance.

On January 20, 2018: "Star Island 17," open house event of VERA Ogasawara Station held, with 167 visitors in attendance.

(2) Regular Public Visiting

Throughout the year, the following stations are open to the public on a regular basis. The four VERA stations are open to the public every day, 9 a.m. to 5 p.m., except during the New Year's season. Ishigakijima Astronomical Observatory is open 10 a.m. to 5 p.m., Wednesday to Sunday except during the New Year's season and other closures.

The numbers of visitors to each facility are as follows,

a) VERA Mizusawa Observatory 19,389
The campus is regularly open to the general public with the cooperation of the Oshu Yugakukan (OSAM: Oshu Space & Astronomy Museum) located in the campus.
b) VERA Iriki Station 1,602
c) VERA Ogasawara Station 8,340
d) VERA Ishigakijima Station 2,577
e) Ishigakijima Astronomical Observatory 14,192

Stargazing sessions: Evenings on Saturdays, Sundays. "The Starry Sky Study Room" (featuring the 4D2U "Four-Dimensional Digital Universe"), constructed adjacent to the observatory in FY 2013 by Ishigaki City, was very popular, welcoming 4,478 guests.

11. Education

(1) Under-graduate and Post-graduate Education

Regarding postgraduate education, Mizusawa VLBI Observatory assisted two doctor and one master students from the University of Tokyo, and two doctor and one master students from SOKENDAI for their thesis research. One of the students from the University of Tokyo completed his Ph.D. thesis. In addition, one master course student from Yamaguchi University was accepted for education. Two undergraduate students from Tokyo University of Science and Ochanomizu University were accepted as summer students of SOKENDAI. The University of the Ryukyus and NAOJ have offered a joint course on astronomy from FY 2009. Classroom lectures at the university took place August 21, 23–25 at the Nishihara main campus and were opened to the public at the satellite campuses. Observational workshops were held in Ishigakijima from August 28–31, with about 33 participants. In addition, staff members of Mizusawa VLBI Observatory give lectures at the University of Tokyo, Tohoku University, and Teikyo University of Science as visiting professors. In 2018 from January 16 to January 19, NARIT-SOKENDAI Winter School was co-organized under collaboration with NARIT in Chiang Mai, Thailand. 21 students, mainly from Thailand and South-East Asian countries, attended the school. From Japan, three students from the University of Tokyo and SOKENDAI attended, and four staff members of Mizusawa VLBI Observatory gave lectures in the school.

(2) Research experience for high school students

From August 9 to August 11, the VERA Ishigakijima station and the Ishigakijima Astronomical Observatory held "the Churaboshi Research Team Workshop" for 10 local high school students including three from the Okinawa main island. It was organized under support from JSPS. "The 11th Z Star

Research Team Event” was held from August 4 to August 6 to use the VERA Mizusawa antenna for observation. A total of 12 high school students from the Tohoku region were accepted for research experience. From this year, a similar observational event was started at VERA Ogasawara station and one local high school student was accepted for this program from July 20 to July 22. Continued from previous years, Mizusawa VLBI Observatory supported the SSH (Super Science High school) research activities for Akita Prefectural Yokote Seiryo High School to use the Mizusawa 20-m antenna.

5. Solar Science Observatory (SSO)

This project started at the beginning of FY 2017 by combining two projects, the 'Hinode Science Center' and 'Solar Observatory,' to proceed the cutting-edge science from observations with the Hinode satellite and ground-based observatories.

1. Hinode Space Observatory

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). Hinode is equipped with three telescopes: the solar optical telescope (SOT), the X-ray telescope (XRT), and the extreme ultraviolet imaging spectrometer (EIS). In addition to the detailed magnetic field and velocity field of the solar photosphere, it carries out simultaneous observations of the radiance and velocity field from the chromosphere to the corona. The telescopes equipped on the Hinode satellite were developed through international collaboration with the US NASA and the UK STFC under the cooperation of ISAS/JAXA and NAOJ, and the European Space Agency ESA and the Norwegian Space Center NSC join its scientific operations. NAOJ played a central role in the development of the science payload in Japan and has been making a significant contribution to the science operation and the data analysis since the launch. The data acquired with Hinode is released to everyone as soon as the data for analysis are ready.

The Hinode Science Working Group (SWG), composed of representatives from the international team, offers support in scientific operation and data analysis. It has a total of 17 members, including two from SSO: Y. Suematsu for SOT and T. Watanabe for EIS. The Science Schedule Coordinators (SSC) have been organized to leverage the open-use observation system. Two Japanese members from NAOJ (Sekii for SOT and Watanabe for Co-chairman/EIS) join the SSC activity. The SSC serves as a window observation proposals from world solar physics researchers to use Hinode and promotes joint observations between Hinode and the other science satellite or ground-based observatories.

FY 2017 corresponds to the first year of the third extension period (FY 2017 to FY 2020) on the Hinode science operation. During this period; the emphasis is placed on the evolution of the magnetic field at the site of solar flares, observations of the locations of magnetic reconnection; long-term observation of general magnetic fields in the photosphere during the declining activity phase; and joint observations with the ERG satellite, ALMA, and new ground-based observatories. The Hinode science payload has been steadily observing the Sun from space, except for the SOT imaging instrument which was terminated in Feb 2016. New science results have been obtained via joint observations with SDO, IRIS, ALMA as well as long-term standalone observation by Hinode. The number of Hinode related referred papers published in FY 2017 is 87, and further achievements are expected in the coming years.

The power switch of EIS suddenly turned off on January 21, 2018 and the science operation was suspended for a long time beyond the end of the fiscal year. The recovery operation is postponed until May 2018 in order to prepare for the recovery procedure with careful event analysis and to prioritize joint observations with ALMA.

2. Ground-based Observations in Mitaka Campus

Full-disk observations of the Sun have been carried out on the western area of the Mitaka Campus for recording the solar activity. The primary instrument is a telescope measuring the solar magnetic fields. The others are an Hα imaging instrument for detection of solar flares as sudden phenomena and an optical imaging instrument observing sunspots and active regions as a proxy of long-term solar magnetic activity.

The magnetic field observation that has been conducted with the Solar Flare Telescope (SFT) since 1992 has provided vector magnetic fields in the photosphere with a field of view covering sunspot regions by observing an absorption line in the visible wavelength range. It has been replaced with near-infrared Stokes polarimetric observations since 2010 for higher precision measurement of magnetic fields in the chromosphere at 1.083 microns and those in the photosphere at 1.565 microns. Factors that determine the efficiency and precision of magnetic field measurements are the imaging pixel format of the imaging camera and the read noise. Toward introduction of a large-format detector and low-read-noise performance, an imaging camera with an H2RG sensor is being developed in the Program of the Solar-Terrestrial Environment Prediction (PSTEP), Grand-in-Aid for Scientific Research on Innovative Area.

The sunspot observation that started in 1929 continues, although it was upgraded to imaging observation using a digital camera in 1998. Full-disk imaging observations in the visible continuum, the G-band (430 nm), Ca II K line (393 nm), and Hα line (653 nm) are regularly conducted with the SFT to monitor the photosphere and chromosphere which change according to the solar magnetic activity. The Hα observation is currently carried out at multiple wavelength points within the absorption line with narrow-band filters to enable the measurement of the Doppler velocity and watch eruptive prominences associated with solar flares. These regular observation data including a set of real-time images are available on the SSO website.

NAOJ has long-term solar observation data, the initial 70 years of which were acquired by the Tokyo Astronomical Observatory, the predecessor of NAOJ. FY 2017 corresponds to the 100th anniversary since the record keeping began. Full-disk images, observed in the continuum, Ca II K line, and Hα line, were recorded on film, photographic plates, and hand-drawn sketches. SSO proceeds with the digitization of these data for research on the long-term variation of the solar activity. While these digitized data are opened to the public when ready, high precision digitization has been applied to the Ca II K line data for improving the quality as a part of the PSTEP research activity.

Although the Nobeyama Solar Radio Observatory (NSRO) was closed at the end of FY 2014, the observation of intensity and circular polarization at seven frequencies, acquired over a half century, continues because of its importance in monitoring long-term solar activity. The Nobeyama Radio Observatory carries out the operation and maintenance of the automated telescope system, and SSO leads the scientific verification and calibration of the data with the solar researchers in universities and the National Institute of Information and Communications Technology.

In addition, members in SSO have observed the total solar eclipse on August 21, 2017 in Idaho, USA, and imaging and polarization observations were carried out.

3. SDAS

Solar Data Analysis System (SDAS) in the Astronomy Data Center (ADC), which developed from the open-use data analysis system of the Hinode Science Center and NSRO in addition to the data archive/public release system of the Solar Observatory, fulfilled the roles of data analysis and data distribution, and it finally completed its task at the end of FY 2017. The data analysis functionality was integrated into the ADC Multi-wavelength Data Analysis System, and the new SDAS, Solar Data Archive System, has started since the end of FY 2017 for the archiving and public release of the solar data. SSO operated SDAS with ADC.

4. Educational Activity

The Project accepted and teaches two Ph.D. course students and two Master course students, and two postdocs (Specially Appointed Research Staff) belong to SSO. Two members (T. Sekii and H. Hara) contributed to the undergraduate course lectures in astronomy at the University of Tokyo.

5. Public Outreach (PO) Activity

SSO has been conducting various public outreach activities for education and returning the results obtained through the scientific research of the Sun to the public: exhibition booth at academic conferences and symposiums, press releases, web releases, cooperation for exhibition activity at science museums, media appearances by responding to media interviews and providing materials to the media, etc. The following were created in the FY 2017 SSO PO activity: explanatory videos for the 10th Hinode anniversary, new Hinode pamphlet revised with the latest results, and solar VR contents developed for the exhibition at the FY 2017 NAOJ open house. Since the VR contents were well-received by visitors, the distribution of the software for smartphones is planned. In addition, there were many media interviews on the large solar flares that occurred in September 2017, which shows that it was a subject of social concern.

6. Science and Community Meetings

The Hinode Science Meeting has been regularly held to advance the solar physics research with the Hinode satellite. We co-organized the 11th meeting held May 30 to June 2, 2017 in Seattle, USA. The number of participants and papers were 130 and 129, respectively.

In cooperation with the DKIST Project, the 4 m diameter solar telescope scheduled to start its operation in 2019, SSO co-organized the DKIST workshop for the initial observation plan at Nagoya University on February 26–29, 2018. The initial science plan on the research subject of the photosphere and chromosphere has been discussed, and as a result, many observation proposals were created during the workshop.

SSO co-organized two solar physics community meetings: ‘Research of the Sun from Space in the 2020s’ (July 13, 2017 at NAOJ, Mitaka) and ‘JSPC (Japan Solar Physics Community) Symposium’ (February 20–22, 2018 at Kyoto University).

7. Awards

The following staff in SSO have been awarded for their research activity:

Y. Katsukawa: 6th NINS Young Researcher Award

R. Kano: 4th ISAS Award

8. Others

The Project Review Committee reviewed the SSO research activity in FY 2015–2017.

Prof. V. Pipin of the Russsian Academy of Sciences and Prof. S. Brun of CEA Pris-Saclay stayed as visiting professors over an extended period (more than a month).

Prof. T. Watanabe and K. Yaji left NAOJ at the end of FY 2017. The personnel transfer of M. Fujiyoshi to another project is scheduled.

6. NAOJ Chile Observatory

The ALMA Project is a global partnership of East Asia (led by Japan), Europe, and North America (led by the United States) in cooperation with the Republic of Chile to operate a gigantic millimeter/submillimeter radio telescope deploying 66 high-precision parabolic antennas in the 5000-m altitude Atacama highlands in northern Chile. ALMA aims to achieve a spatial resolution of nearly ten times higher than that of the Subaru Telescope and 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 and has been operated to make headway into submillimeter observations toward the ALMA Era. This report also describes the progress of the ASTE telescope.

1. Progress of ALMA Project

ALMA scientific observations and commissioning observations are currently underway. Commissioning observations include polarization tests, solar observation tests, and observation tests using the newly installed Band 5 receiver, which are all making good progress. In these activities, East Asian researchers have been taking initiatives in international teams, as demonstrated by Koichiro Nakanishi and Hiroshi Nagai for polarization, and Masumi Shimojo for solar observation tests. Also, the sub-components developed by Japan such as the antennas, correlators, and receivers (Bands 4, 8, and 10) are working properly.

2. ALMA Open-Use and Scientific Observations

The sixth round of ALMA open-use observations commenced in October 2017 as Cycle 5. The main capabilities of Cycle 5 include: interferometric observations using forty-three 12-m antennas; Atacama Compact Array (ACA) observations (interferometric observation with ten 7-m antennas and single-dish observations with three 12-m antennas); eight frequency bands (Bands 3, 4, 5, 6, 7, 8, 9, and 10); and maximum baselines extended to 16.2 km (for Bands 3, 4, and 6), 8.5 km (for Band 7), 3.6 km (for Bands 8, 9, and 10) and 1.4 km (for Band 5). In addition to these, Cycle 5 continuously provides open-use opportunities for large programs that require long observations over 50 hours, millimeter-wavelength VLBI, ACA stand-alone mode, solar observations, polarization for spectral line observations, and new Band 5 observations. In response to the Cycle 5 call for proposals, 1,661 proposals were submitted from all over the world.

The call for the seventh round of open-use observations was issued as Cycle 6. The Cycle 6 capabilities will include: interferometric observations using forty-three 12-m antennas; ACA observations (interferometric observation with ten 7-m antennas and single-dish observations with three 12-m antennas); eight frequency bands (Bands 3, 4, 5, 6, 7, 8, 9, and 10), maximum baselines of 16 km (for Bands 3 to 6), 8.5 km (for Band 7), and 3.6 km (for Bands 8 to 10). Also, Cycle 6 will provide new circular polarization in Bands 3 to 7, and Band 8 ACA standalone mode. Another remarkable progression is that the Band 6 IF bandwidth has been extended to cover 4.5 to 10 GHz. The call for proposals for Cycle 6 is set to be closed at 00:00 JST on April 20, 2018. Cycle 6 is scheduled to start in October 2018.

Open use of ALMA has already produced a number of scientific results. This section describes some of the achievements focusing mainly on East Asian projects.

A research team led by Tomoya Hirota observed a massive baby star called Orion KL Source I with ALMA and imaged clearly the rotation of outflow ejected from the baby star. The result shows the outflow carries angular momentum away from the system, which gives us a clue to understanding how interstellar material dissipates angular momentum in accretion onto a baby star.

Ryo Ando, a graduate student of the University of Tokyo, and his colleagues observed the center of the starburst galaxy NGC 253, an active star forming region, with ALMA high-resolution and identified eight clouds of star-forming gas. From the results, it was found that the eight clouds have evident diversity in their chemical composition and signal strength, as the data of one cloud shows an extremely rich chemical composition filled with the signals of various molecules forming a “molecular forest.” This is the first molecular forest ever found outside the Milky Way Galaxy, which indicates that there must be an enormous diversity among star-forming molecular clouds in the starburst galaxies.

Masatoshi Imanishi at NAOJ and his colleagues observed an active galactic nucleus (AGN) at the center of the spiral galaxy M77 with ALMA high-resolution and imaged a rotating gas torus around an active supermassive black hole. Such structure was theoretically suggested as ‘the unified model of AGN’ and they successfully proved the theory true through observation for the first time. This is an important step in understanding the co-evolution of supermassive black holes and their host galaxies.

3. Educational Activities and Internships

During summer vacation of universities, the NAOJ Chile Observatory accepted six undergraduate students, four of which were involved in research activities in Mitaka and the other two in Chile. Also, the NAOJ Chile Observatory accepted one post-doctoral fellow as a visiting researcher for a month each from the University of Utah (US.), Leibniz Institute for Astrophysics Potsdam (Germany), and Thai Nguyen University (Vietnam).

On March 9, 2018, the NAOJ Chile Office and the Joint ALMA Observatory Santiago Office hosted the students from

Yamagata University as part of the university's short-term study program in Chile. The visit includes the introduction of the ALMA project and a talk session between students and staff members working at an international institute overseas, which served as a valuable opportunity for them to reflect on their career paths.

4. Public Outreach Activities

Achievements of ALMA scientific observations and test observations were covered by nearly 110 newspaper/journal articles and 8 television/radio programs, reporting ALMA observation results in various fields of astronomy. In particular, the detection of the rotation of outflow ejected from Orion KL Source I with ALMA was featured on a news program called "News Shibu Go Ji" on NHK G channel and another news program called "Your Time" on Fuji Television in June 2017. The observation results of Orion KL Source I were covered by more than 180 news websites worldwide, while the detection of the rotating dusty gaseous donut around a black hole at the center of the spiral galaxy M77 was posted on more than 200 news websites. As demonstrated by these figures, the scientific results by Japanese researchers have been increasingly broadcast worldwide.

In November 2017, twelve Japanese journalists including newspaper/magazine writers and freelance writers participated in the ALMA Site Media Tour that includes the visits to the ALMA Santiago Central Office (SCO), NAOJ Chile Office, ALMA Operations Support Facility (OSF), and Array Operations Site (AOS); photo/movie sessions; and interviews with researchers and engineers. The reports of the tour were covered by many newspapers and magazines, providing information on the ALMA site, latest results, and the future development plan of ALMA widely to the public.

The NAOJ ALMA website was renewed in May 2017. The new site has an increased number of articles including review articles that summarize the ALMA research themes and interviews with ALMA staff members, together with 49 news articles and eight press releases posted this year. Furthermore, the contents of the new website (e.g. images) became more openly available in accordance with the terms of use under the Creative Commons License, which allows easier use of contents. 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 38,500 followers as of the end of FY 2017.

In May 2017, the NAOJ Chile Observatory hosted a week-long ALMA booth at the Japanese Geoscience Union Meeting held in Makuhari Messe. Public lectures and Science Cafe events were organized on 15 occasions in FY 2017 to make the current status and achievements of ALMA widely known through dialogue with visitors. In particular, the NAOJ Public Talk / the 23rd ALMA Public Lecture titled "ALMA Telescope Exploring the Cold Universe – To Solve the Mysteries of Planetary Formation with State-of-the-Art Technology", held at the Tokyo International Exchange Center (TIEC) on February 4, 2018, attracted a big audience of over 200, which was a great opportunity to introduce the latest scientific results of ALMA to the public.

From mid-March 2015, ALMA started to accept public visitors to the ALMA Operations Support Facility (OSF) at an altitude of 2900 meters. Every Saturday and Sunday, ALMA is open to the public up to 40 people/day (advance registration is required). Visitors to the OSF can have a guided OSF tour including the control room tour and videos on ALMA. The registration often reaches the full capacity soon after the start of registration every weekend. Public visits to ALMA are now becoming a good opportunity to provide many people with live experience at the workplace of ALMA researchers. The number of public visitors in FY 2017 amounted to 3,904 people.

On August 25 and 26, a traditional TANABATA event was held in San Pedro de Atacama, a town at the foot of the ALMA site. Inviting local residents and tourists to write wishes on tanzaku (small pieces of colored paper), the TANABATA star festival was celebrated with tanzaku decorations on bamboo stalks and star gazing. The event served as a public outreach activity for the ALMA project and NAOJ as well as an opportunity to promote international friendship.

5. International Collaboration (committees, etc.)

In the international ALMA project, meetings are held frequently by various committees. In FY 2017, the ALMA Board met face-to-face twice, and the ALMA Scientific Advisory Committee (ASAC) twice. In addition to these, teleconferences have been held on a near-monthly basis among the members of the ALMA Board and ASAC. The ALMA East Asian Science Advisory Committee (EASAC) had meetings face-to-face or via teleconferences on a quarterly basis. Each working group holds meetings and teleconferences more frequently to maintain close communication in implementing their respective tasks in the international project.

6. Workshops and Town Meetings

- Aug 1 to 2, 2017 NRO45/ASTE/Single Dish Science Workshop 2017 at NAOJ Nobeyama Radio Observatory (NRO)
- October 3 to 5, 2017 ALMA Long Baseline Workshop at Mielparque Kyoto
- December 27 to 28, 2017 ALMA Users Meeting at NAOJ Mitaka
- March 26, 2018 ALMA Town Meeting at Kagoshima University

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

- Hitoshi Kiuchi: Funded externally by the Ministry of Internal Affairs and Communications (Strategic Information and Communications R&D Promotion Programme: SCOPE) R&D for Promotion of Effective Radio Use (Advanced Effective

Radio Use-Phase II)

8. Research Staff Changes

(1) Hired
- Daniel Walker: Specially Appointed Research Staff
- Andres Guzman: Specially Appointed Research Staff
- Yu-Ting Wu: Specially Appointed Research Staff
- Andrea Silva: Specially Appointed Research Staff
- Yuri Nishimura: Specially Appointed Research Staff (secondment to the University of Tokyo)
- Tao Wang: Specially Appointed Research Staff (secondment to the University of Tokyo)
- Salinas Nicolas: Specially Appointed Research Staff (secondment to Kagoshima University)
- Kei Tanaka: Specially Appointed Research Staff (secondment to Osaka University)

(2) Departed or transferred
- Toshiki Saito: Specially Appointed Research Staff
- Naslim Neelamkodan: Specially Appointed Research Staff

9. Main Visitors

- June 25, 2017
  Prof. Kajita Takaaki, Director of the Institute for Cosmic Ray Research (ICRR) at the University of Tokyo visited the ALMA site.
- July 29, 2017
  Mr. Yoshinobu Hiraishi, Ambassador of Japan to Chile, visited the ALMA site.
- September 28, 2017
  Japan's Prince Akishino and Princess Kiko visited Chile. NAOJ Chile Observatory Director Seiichi Sakamoto explained the NAOJ projects.
- January 12 to 13, 2018
  The Japanese State Minister of Education, Culture, Sports, Science, and Technology, Toshiei Mizuochi visited ALMA.

10. Progress of ASTE Telescope

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

Except for ALMA, there are only two large-scale submillimeter telescopes with a 10-m-class antenna that can observe the southern sky in the world: one is ASTE and the other is APEX operated by Europe. Therefore, having ASTE operated by Japan will be a big advantage in strengthening ALMA proposals and in implementing our strategies for further extended capabilities with new observing instruments. For the future, ASTE will continue to be important for nurturing young researchers who will play key roles in the equipment development for the next generation. In the near future, ASTE will be incorporated into the open-use program for promoting organic collaboration with the Nobeyama 45-m Telescope.

The open-use program in FY 2017 provided spectroscopic observations in 345 GHz and 460 GHz bands for a period of four months. 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 to exclusively make proposals for the GTO slots. A total of 25 proposals for open-use observations were submitted. These proposals were reviewed by the Millimeter/submillimeter Program Subcommittee and 20 proposals were adopted. Open-use observations were carried out from the ASTE Mitaka operation room or from other universities and research institutes from early June to late September, 2017. Also, the ASTE telescope has been tentatively equipped with DESHIMA (Deep Spectroscopic High-redshift Mapper), a superconducting on-chip filterbank spectrometer under joint research and development by Delft University of Technology (Netherlands), SRON (Netherlands), the University of Tokyo, Nagoya University, and the National Astronomical Observatory of Japan since October 2017, and successfully detected astronomical spectra for the first time with this new technology.

On November 21, 2017, the ASTE telescope had a failure in the Azimuth drive that went out of control during a remote observation. The result of investigation shows that the cause of the failure was age deterioration of the AZ reduction gear and the device must be replaced.

7. Center for Computational Astrophysics (CfCA)

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 computer for gravitational many-body problems, carrying out research and development of computational astrophysics, and performing astronomical research with simulations. The main supercomputer of the present system, ATERUI (Cray XC30), has the theoretical peak performance of 1 Pflops, which is the world's fastest supercomputer for astronomy. The center also continued operation of other computers such as GRAPE-DR and GRAPE-9 that are dedicated for gravitational many-body problems, in addition to general-purpose servers. The center continued to prepare for the supercomputer replacement in 2018. Efforts in visualizing astronomical data also continue.

2. Open Use

(1) Computer Systems

This year marked the fifth year of the upgraded astronomical simulation system, which includes the open-use supercomputer Cray XC30. It is installed and under operation at Mizusawa VLBI Observatory. The users have been making academically significant progress as before.

While XC30 is leased for five years from Cray Japan Inc., the center has built the following equipment to aid the open-use computer operations: a series of dedicated computers for gravitational N-body problems, known as GRAPE's; 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 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 hardware and software for the system this year.

Computational resources are allocated to the XC30, GRAPE's, and smaller PC clusters in accordance with a formal review process. The statistics of applications and approvals for this year are listed below. Our center conducted a survey this year on the number of peer-reviewed papers published in English in this fiscal year on studies that involved the project's open-use computers. It turned out that 128 refereed papers (written in English) were published in this fiscal year.

The center uses Drupal, a content management system introduced for data exchange with users of open-use computers. The acceptance of various applications and the management of the users' personal information are all handled through Drupal. The regular CfCA News is an additional channel of information dissemination. The center leverages this newsletter to inform people of all useful and necessary information regarding the computer system. A subsidy system for publishing and advertising is continuing this year for research papers whose major results were obtained by using the center's computers.

(Statistics on the Cray XC30)
- Operating hours
  Annual operating hours: 8535.7
  Annual core operating ratio: 94.46 %
- Number of Users
  Category S: 0 adopted in the first term, 0 in the second term; total 0
  Category A: 11 adopted at the beginning of the year, 0 in the second term; total 11
  Category B+: 10 adopted at the beginning of the year, 1 in the second term; total 11
  Category B: 100 adopted at the beginning of the year, 19 in the second term; total 119
  Category MD: 11 adopted at the beginning of the year, 3 in the second term; total 14
  Category Trial: 54 (at the end of the fiscal year)

(Statistics on the GRAPE system)
- Number of Users
  10 (at the end of the fiscal year)

(Statistics on PC cluster)
- Operation stats
  Total number of submitted PBS jobs: 225,374
  Annual core operation ratio by users' PBS jobs: 72%
- Number of Users
  51 (at the end of the fiscal year)

(2) Tutorials and Users Meeting

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

- Cray XC30 workshop for intermediate users
  August 10, 2017, 6 attendees
- Hydrodynamics simulation school
  February 13-16, 2018, 22 attendees
- N-body simulation Winter School
  January 24-26, 2018, 11 attendees
- CfCA Users Meeting
  November 28-29, 2017, 66 attendees

3. PR Activity

In FY 2017, the following press releases were issued from the center:

• "First Global Simulation Yields New Insights into Ring System"
April 28, 2017, Shugo Michikoshi and Eiichiro Kokubo
• "Electron surfing and drift accelerations in a Weibel-dominated high-Mach-number shock"
September 25, 2017, Yosuke Matsumoto, Tsunehiko Kato, et al.
• "Supersonic gas streams left over from the Big Bang drive massive black hole formation"
September 29, 2017, Shingo Hirano, et al.
• "Surface Helium Detonation Spells End for White Dwarf"
October 5, 2017, Ji-an Jiang, Masaomi Tanaka, et al.
• "Astronomers Follow Gravitational Waves to Treasure"
October 16, 2017, Masaomi Tanaka, et al.
• "Rare First Moment of Stellar Explosion Captured by Amateur Astronomer"
February 22, 2018, Masaomi Tanaka, et al.

The center took part in the special open house of Mizusawa Campus, Iwate Galaxy Festival 2017, held on August 19, 2017. About 150 visitors attended the ATERUI guided tours and experienced a close-up observation of the facility. At the Mitaka open house held on October 14, 2017, CfCA made the computer room accessible to the public and introduced simulation astronomy with GRAPE and the PC cluster. In addition to the open house, CfCA accepted a group of high school students to tour the computer room in Mitaka Campus. Moreover, at OPIE'17, CfCA displayed the GRAPE boards, an ATERUI blade, and posters to introduce research activities and results of simulation astronomy performed by the CfCA system. A Twitter account @CfCA_NAOJ and YouTube channel have been operated to provide the information on CfCA.

4. 4D2U Project

In FY 2017, the 4D2U project continued to develop and provide movie contents and software. A simulation movie titled "A Journey Through the Milky Way" was released on the 4D2U website in June 2017. This movie was also published on the 4D2U YouTube channel with a format for VR on smartphones. In addition, this movie won the Grand Prix for the VR Category of the Lumiere Japan Awards 2017 promoted by the Advanced Imaging Society of Japan, and the Best VR Science Experience at the Lumiere Awards promoted by the US Headquarters of the Advanced Imaging Society.

The updated version of the four-dimensional digital universe viewer, "Mitaka," was released in July 2017 (ver.1.4.0). This version of Mitaka included new functions, e.g. displaying the final mission of Cassini; and adding the 3D model of Gaia and the Milky Way texture generated by Gaia's data. Moreover, through calculating the reflection and scattering of light on Saturn's rings and the surface of the Moon based on physical models, we are able to draw Saturn and the Moon more realistically. In March, 2018, the new version, ver.1.4.3 with a new function for displaying constellation outlines was released.

In FY 2017, demonstrations of Mitaka VR were given during OPIE'17, the Science Centre World Summit 2017, and the open campus days of Mizusawa and Mitaka. Many people were able to enjoy Mitaka outside of the 4D2U Dome Theater.

4D2U contents were provided both domestically and internationally for TV programs, planetarium programs, lecture presentations, books, and so on.

A Twitter account @4d2u and YouTube Channel have been operated to provide information on 4D2U.

5. External Activities

(1) Joint Institute for Computational Fundamental Science

The Joint Institute for Computational Fundamental Science (JICFuS) is an inter-organizational institute established in February 2009 as a collaboration base between three organizations including 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 (it has now expanded to include eight institutes). 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 each community to provide considerate and rigorous support to present and future researchers. Another important mission of the institute is to provide researchers around Japan with advice regarding efficient supercomputer use and the development of novel algorithms for high-performance computing to meet research goals from the perspective of computer specialists. In addition, JICFuS was chosen as the organization responsible for "Research and Development, Application Development of scientific/social issues that require particular attention by the use of the Post K-computer" in FY 2014.

In order to implement research plans, Hiroyuki Takahashi was engaged as a project assistant professor. Since the central objects of some ultra-luminous X-ray sources (ULXs) have been revealed to be neutron stars (NSs), Takahashi investigated the gas dynamics around NSs using general relativistic radiation magnetohydrodynamics simulations. It was found that, if the NSs are strongly magnetized, the gas accretes onto the vicinity of the magnetic poles, since inflow around the equatorial plane is prevented by the strong magnetic fields. In addition, Takahashi performed high-resolution simulations of the outflows launched from the black-hole accretion disks. As a result, it was revealed that the outflow fragments into many clumps via the hydrodynamical instability in the radiation pressure-dominated region. Since such clumps are thought to pass across the observation line of sight, they can account for the observed time variation of the luminosity. The origin of the luminosity variations of ULXs is thus revealed by the simulations.

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

(2) HPCI Consortium

As a participant in the government-led High-Performance Computing Infrastructure (HPCI) project since its planning stage in FY 2010, the center has engaged in the promotion of the HPC research field in Japan, centering on the use of the national "K" supercomputer and the “Post-K” plan. Note that although the center is involved with the JICFuS-led HPCI Strategic Program Field 5 as well as Priority Issue 9 to be tackled using the Post-K Computer as mentioned in (1), the activity in the HPCI consortium is basically independent from them. The HPCI consortium is an incorporated association established in April 2012, and the center is currently an associate member that is able to express views, obtain information, and observe overall trends in the planning, although we are devoid of voting rights as well as the obligation to pay membership fees. Continuing from last year, a number of conferences and WG’s have been held where participants discuss a next-generation national supercomputing framework to follow the “K”. The Post-K project has already started with some budget from the Ministry of Education, Culture, Sports, Science, and Technology (MEXT). The primary institutes and groups responsible for its development have been established. Now the detailed discussions as to how we can fully exploit the resources of the post-K system have begun in relevant communities and organizations. This fiscal year the shutdown schedule of the current K computer was finally announced. Now the major subject of the community's discussions has moved into how we should secure computing resources necessary for the HPCI program until the flagship Post-K machine becomes available.

6. Staff Transfers

• Staff members hired in this FY
(Research expert) n/a
(Postdoctoral fellow) n/a
(Research associate) Shoko Oshigami, Shogo Ishikawa

• Staff members who departed in this FY
(Assistant professor) Ken Ohsuga
(Research expert) Shigeru Wakita
(Postdoctoral fellow) Yuta Asahina
(Research associate) Shogo Ishikawa, Tetsuo Taki, Yuki Tanaka
(Admin. associate) Yuko Kimura

8. Gravitational Wave Project Office

In August 2017, gravitational waves from the merger of binary neutron stars were detected by LIGO and Virgo. With an extensive campaign of follow up observations, a source object was identified. The theoretically expected electromagnetic radiation burst, called a Kilonova, was also observed. This marks the beginning of multi-messenger astronomy, where multiple observation channels are analyzed together to better understand gravitational wave events. The Gravitational Wave Project Office (GWPO) is putting most of its resources into the construction of KAGRA, a large-scale Japanese gravitational wave detector, so that Japan can make important contributions to the emerging field of gravitational wave astronomy.

1. Development of KAGRA

KAGRA is a laser interferometric gravitational wave detector being constructed in an underground site at Kamioka in Gifu prefecture Japan. Cryogenic mirrors for the reduction of thermal noise as well as the use of a quiet and stable underground environment are two unique features of KAGRA compared with other gravitational wave detectors in the world. KAGRA's construction is divided into several phases which gradually upgrade the interferometer to its final configuration. In March 2016, KAGRA successfully operated a km-scale interferometer in an underground site for the first time in the world, although the configuration was a simple Michelson interferometer. In the Fiscal Year 2017, our effort was focused on the realization of a cryogenic Michelson interferometer. NAOJ assembled and installed all the necessary components for which we are responsible.

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

(1) Vibration Isolation Systems

In KAGRA, vibration isolation systems are necessary to isolate all the interferometer mirrors and some other optical components from the ground vibrations. We have developed four different types of vibration isolation systems, having different complexities, to meet varied isolation requirements of different components. In this fiscal year, we assembled and installed the isolation systems necessary for the test operation of the cryogenic Michelson interferometer. We have installed two of the world's largest isolation systems, each with a total length of 13.5 m for the cryogenic mirrors, and four large isolation systems for room temperature mirrors. The damping control of those isolation systems was implemented. They performed mostly as expected during the test operation of the cryogenic Michelson interferometer. In order to finish the installation of the remaining five isolation systems, about 10 members from our office are continuing the hard work in Kamioka.

(2) Auxiliary Optics

The Auxiliary Optics (AOS) subsystem is responsible for providing optical components for stray light control, optical angular sensors, beam reducing telescopes (BRT's), beam monitoring cameras and optical windows. Highlights of the activities in FY 2017 involve the BRT's and the large optical baffles for stray light control. A prototype of the baffles for blocking wide angle scattering from cryogenic mirrors was installed in an actual cryostat, and the cooling test was started as scheduled. At the same time, the BRT was assembled and installed at the Y end of KAGRA. A vibration isolation stage for the BRT was assembled and the test has been started as well. For these achievements, ATC provided us great support in mechanical/thermal design, assembly work, and modifications.

(3) Mirror Characterization

We completed a system to measure the optical absorption of mirrors, which is a critical characteristic for the cryogenic operation of KAGRA. The system was originally capable of measuring samples of up to 2-inch diameter. Now we are able to make absorption maps of KAGRA-sized (22-cm diameter) mirrors. We tested the system with a KAGRA sapphire substrate. We made calibration checks on sapphire bulk absorption using different measurement methods in collaboration with LMA (Laboratoire des Matériaux Avancés) in Lyon.

2. R&D

(1) R&D for upgrades of KAGRA

Alongside the construction of KAGRA, the GWPO is actively pursuing the research and development of new upgrades for KAGRA. One of the targeted upgrades is the realization of frequency dependent squeezed states. Thanks to the TAMA infrastructure (which is a unique facility in the world), we had the possibility to realize a 300-meter-long high-finesse filter cavity which in the last year has been extensively characterized, showing results that exceed the expectations. The frequency-independent squeezed light source is currently being finalized. Thanks to this experiment, we established long-term collaborations and got many visitors from abroad. The absorption measurement bench developed to characterize the KAGRA mirror is also used to study the performance of crystalline coatings, a possible solution to reduce coating thermal noise. The optical performance of crystalline coatings has been measured in collaboration with LMA. We also directly measured the thermal noise of such coatings, using a setup developed at MIT, and obtained promising results. Thermal noise investigation is also the objective of another experiment being conducted at ATC to directly measure coating thermal noise at cryogenic temperatures.

(2) DECIGO

Following on from the conceptual design of the B-DECIGO, which was compiled in the last fiscal year, the discussion on how to advance the project is ongoing. Some discussions with new members for expanding the project collaborators were done in the annual DECIGO workshop.

3. Education

During FY 2017 the GWPO included among its members two graduate students from the University of Tokyo and two from SOKENDAI. An additional student joined SOKENDAI from China from October. During the same period the office hosted one master student from Institut d'Optique (France), one master student from Beijing Normal University (China) and one master student from UEC (Japan). All of them worked at NAOJ for six months. The office also hosted two undergraduate students as SOKENDAI summer students. The members of the office gave lectures at the University of Tokyo on gravitational waves and at Hosei University on fluid mechanics.

4. Outreach

Gravitational wave research continued to attract public interest, partly stimulated by the gravitational-wave-related Nobel Prize. For outreach purposes, we produced an English version of the leaflet for our office and helped with the production of a virtual reality video of TAMA300 and a PR video for NAOJ. Our office members appeared twice in press conferences, gave 6 public lectures and wrote articles for a newspaper and a popular scientific magazine. We accepted visits/interviews by NHK, Nikkei Shinbun, ASCII, and the Toyota Engineering Society. Our office members took care of more than 200 visitors to the KAGRA site. In TAMA300, we had about 700 visitors on the open day and accepted more than 240 visitors on other occasions.

5. International Collaboration and Visitors

The office continued its collaboration with CNRS/APC in Paris and with BNU in Beijing on the development of a frequency-dependent squeezed vacuum source at TAMA. In this context a PhD student from University Paris Diderot visited NAOJ for two months to complete her PhD work on this topic (she is now a project research fellow at NAOJ). Two more scientists and one research engineer from CNRS/APC visited NAOJ for a total duration of one and a half month. We started the EU-funded NEWS project and, in this context, we received a visit from Dr. Helios Vocca. One of our PhD students visited CNRS/LAPP (France) for 3 months and another spent two weeks at MIT (USA) to perform measurements on crystalline mirrors. On this topic, we published a paper with our collaborators at CNRS/LMA (France) and CMS (USA). As usual we received several visitors at TAMA, among which were the Director General of SKA, the Dean for Research of Princeton University, and the PI of the LISA project.

6. Publications, Presentations, and Workshop Organization

The members of the office have authored 36 peer-reviewed publications including the paper reporting the first detection of gravitational waves from a merger of binary neutron stars. Moreover, 11 presentations were given by members of the office at international conferences. In November 2017, members of our office organized a commissioning workshop at the KAGRA site, where active researchers from LIGO and Virgo came to join KAGRA researchers in commissioning work, to share practical techniques and knowledge.

7. Acquisition of External Funds

Our office did not receive external funds apart from 4 Kakenhi grants allocated by JSPS.

8. Staff

During FY 2017 the GWPO hired one assistant professor and one project research fellow from abroad. As of March 31, 2018 the GWPO included 1 professor, 1 associate professor, 4 assistant professors, 1 specially appointed assistant professor, 1 researcher, and 3 project research fellows. The team also included 3 engineers, 2 specialists, 4 administrative staff, and 6 graduate students. Considering 3 affiliated researchers, the total number of members reached a count of 29 members. A position to hire a new professor was opened.

9. TMT-J Project Office

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

The telescope is scheduled to be constructed on Maunakea, Hawai‘i, with the Conservation District Use Permit issued by the State of Hawai‘i for the TMT construction in September 2017. Scheduled to commence onsite construction in FY 2018, all the partner countries have engaged in their respective assigned work; Japan has proceeded with the mass production of the telescope primary mirror segments, the preparation for the fabrication of the telescope structure, and the design and development of the science instruments throughout FY 2017.

As of the end of FY 2017, the TMT-J Project Office was comprised of three Professors, five Associate Professors, a Chief Research Engineer, a Specially Appointed Associate Professor, an Assistant Professor, five Specially Appointed Senior Specialists, a URA employee, a Special Senior Specialist, a Research Expert, a Research Supporter, three Specially Appointed Research Staff members, four Administrative Supporters, and a RCUH employee for full-time positions, of whom the Chief Research Engineer, a Specially Appointed Senior Specialist, the Research Supporter, and an Administrative Supporter resigned at the end of the fiscal year upon reaching the retirement age or due to expiration of their respective terms of office. In addition, a Professor, four Associate Professors, two Assistant Professors, and a Research Engineer primarily assigned to the Advanced Technology Center, the Subaru Telescope, the NAOJ Chile Observatory, and the RISE Project have concurrent positions in the TMT-J Project Office and take part in activities that include the development of TMT science instruments at the Advanced Technology Center.

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

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

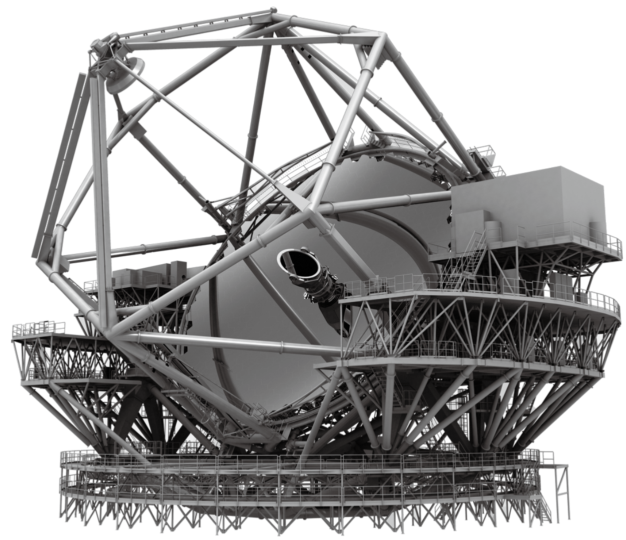

Figure 1: Conceptual image of the completed TMT.

In December 2015, as the protest movement on Maunakea continued to gain momentum, the Supreme Court of the State of Hawai‘i ruled the permit approval process for the use of the land in the Maunakea Conservation District, the site of planned construction, to be flawed and consequently invalidated the permit, although full-fledged construction at the summit of Maunakea was expected to have commenced by April 2015. In response to this ruling, the Hawai‘i Board of Land and Natural Resources started a review process in February 2016 that included a contested case hearing, and a new Conservation District Use Permit was subsequently approved in September 2017. During this process, the TMT-J Project Office put in its own effort as well to garner more understanding by holding dialogues with local stakeholders.

Although the permit for the construction was issued, a group of opponents initiated a lawsuit against this approval which is pending before the Hawai‘i Supreme Court as of March 2018. Additionally, another litigation is in progress at the Supreme Court against the sublease from the University of Hawai‘i, which manages the summit of Maunakea, for the TMT construction site approved by the Board of Land and Natural Resources in 2014. Under the TMT International Observatory’s plan to resume the onsite construction in FY 2018 while monitoring the progress of these lawsuits, all the partner countries have engaged in their respective assigned work.

In parallel with this process, the TMT International Observatory conducted procedures and investigation for construction at a backup construction site at La Palma in the Canary Islands, Spain, in case construction at Maunakea becomes impossible.

2. Japan's progress on Its Work Share – Fabrication of the Telescope Structure and the Primary Mirror and Promotion of Development of the Science Instruments

For the construction of TMT, Japan is responsible for the design and fabrication of the main telescope structure and its control system and the manufacturing of the primary mirror and portions of the science instruments as according to the executed agreements. Progress made in FY 2017 is provided below.

(1) Fabrication of the primary mirror segments

The TMT primary mirror, comprised of 492 segment mirrors, requires the fabrication of 574 segment mirrors in all with the replacements included. The fabrication processes of mirror segments are: fabrication of the mirror blanks, spherical grinding of the front and back surfaces, aspherical grinding and polishing of the front surface, hexagonal cutting, and mounting of the mirror segments onto support assemblies. These processes are followed by final surface finish completed in the U.S. and coating with reflective metal performed onsite before the mirror segments are finally installed on the telescope.

Of these processes, the plan calls for Japan to fabricate the mirror blanks and to perform spherical grinding on all 574 segment mirrors. In FY 2017, fifty-two mirror blanks were fabricated, and spherical grinding was performed on sixty blanks. The running total rose to 214 blanks that have been spherically ground by the end of FY 2017.

With the share of work for the processes beginning from aspherical grinding and polishing and ending with mounting of the mirror segment on a support assembly distributed among four countries, the plan calls for Japan to be leading this work for 175 of the mirror segments. Aspherical polishing was performed on eleven blanks in FY 2017. In addition, with the U.S. scheduled to begin their share of the work to make the mirror segments aspherical, shipment of spherical mirror blanks to the U.S. was commenced.

Figure 2: Mirror segment blanks shipped overseas.

(2) Design and preparation for the fabrication of the main telescope structure and its control system

Japan is leading the design and production of the telescope structure, as well as its control system, which functions as a mount for the optics systems such as the primary mirror and the science instruments, and points them in the direction of a target astronomical object. With the baseline and detailed design developed by FY 2016, work on the telescope structure in FY 2017 mainly constituted the reduction of technical risks involving parts with a high degree of difficulty, the establishment of a concrete process of performance verification, and the determination of the interface in detail, with an aim to commence the production. As for the reduction of technical risks, a seismic isolation mechanism for the structure and an elevation cable wrap were partly prototyped. The vibration test, which was performed on the prototype of a reduced-size seismic isolator model with the use of a vibration test system, confirmed that a nonlinear analysis result of the detailed design was mostly reproducible. The elevation-axis motion test was also carried out on the prototype of a reduced-size cable wrap to quantitatively assess small-scale vibrations that were produced externally, and confirmed the current design satisfied the technical specifications. A series of these efforts allowed the production process for the seismic isolation mechanism and the elevation cable wrap to be established. Additionally, FY 2017 saw development in determining the detailed requirements of the interface between the structure and subsystems, such as the science instruments, in accordance with the progress of each subsystem design. This included the reinforcement of the safety plan by addressing unconfirmed safety issues in the interface, adjustments of other details, and the implementation of the accompanying processes.

(3) Science instruments

As part of the international collaboration, Japan is leading the design and fabrication for a portion of two out of the three first-light science instruments to be commissioned once the telescope is complete.

One of them is IRIS (Infrared Imaging Spectrograph). Being in charge of its imager, Japan currently engages in the development that includes designing and prototyping in cooperation with the Advanced Technology Center. Following the review regarding the opto-mechanical system in the previous year, an international review was conducted on the electronics design, software, and other parts in September 2017, and gave the green light to enter the final design phase.

With the planned primary role in the camera system of WFOS (Wide-Field Optical Spectrograph), Japan examined and developed the optical parts in FY 2017. At the same time, studies of possible architectures for WFOS are currently underway for a significant change; Japan explores one of the potential architectures, a multi-object spectrometer using an image slicer.

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

The TMT Science Forum, which has been held annually since 2013, was convened in Mysore, India, in November 2017 to discuss science instruments and the background science goals, including preparation of white papers (see below) for proposal and selection of second-generation instrumentation.

The TMT Project plans to implement new instruments every two to three years subsequent to the first-light instruments which will be commissioned once the telescope is complete and operational. The Science Advisory Committee, which will conduct a review for the selection of second-generation instrumentation, called for white papers proposing scientific goals and design concepts for new instruments as the first step of the selection procedure. White papers on multiple instruments were submitted by the deadline of March 2018, and Japanese scientists played a leading role in some of those white papers. The review of the second-generation instrumentation is scheduled to be held in FY 2018, looking into the proposals.

In Japan, continued effort has been made to reflect on the project opinions of the science community communicated through venues such as the TMT-J Science Advisory Committee. The committee has engaged in activities such as the design change of WFOS and the support for the call for second generation instrumentation. Also, with the continuation of the strategic fundamental research fund for the purpose of basic technology research for the development and design of second generation science instruments, support funding for development was made available and provided to six universities and institutions that applied to the public offering for the funding support.

Information on the TMT Project is provided in the TMT-J Project Office website and includes updates particularly regarding the situation at the Maunakea construction site and the work share progress made by Japan. Additionally, TMT Newsletters No. 51 through 56 were delivered. Efforts for public outreach have been made through lectures and exhibitions in various regions of Japan. A total of sixty-five lectures and classes on demand were held for the public.

Contributions were also made through the dispatch of an on-demand lecturer for the science/technology education and PR event “Journey Through the Universe” (March 2018) held in Hawai‘i where TMT is to be constructed.

TMT also assembles an international team that includes Japan to study topics such as education and personnel training, and as part of this activity, an international workshop was held at the University of California, Santa Cruz in August 2017 catering to the young researchers and engineers that will lead the next generation. About forty graduate students and young researchers that included seven participants from Japan learned about a wide range of topics that encompassed not only scientific research and development, but also international cooperation with people of different cultural backgrounds and the management and operation of large scale projects. At the Communicating Astronomy with the Public Conference 2018, CAP2018, organized in Fukuoka City in March 2018, the TMT-J Project Office reported on its public relations and outreach and, as part of the TMT international team, held a workshop to discuss activities for an international project.

Donations to the TMT Project have been raised continually; two corporations and 196 individuals provided donations in 2017 (from January to December).


Courtesy of Institute for Scientist and Engineer Educators

Figure 3: International workshop “Preparing TMT Future Science and Technology Leaders” held at the University of California, Santa Cruz in August 2017 for the young researchers and engineers.

10. JASMINE Project Office

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

(1) Overview

The JASMINE mission seeks to survey virtually the entire 20° × 10° Galactic Bulge around the center of the Galaxy and to perform infrared (Kw-band: 1.5–2.5 μm) measurements of the annual parallaxes, proper motions, and celestial coordinates of the stars at a high precision 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 a 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 the vicinity of the Solar System. 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 motions and annual parallaxes. 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 2024. This satellite will engage in observations of a limited area around the nuclear bulge and certain specific astronomical objects. This small-sized version has the goal of obtaining advanced scientific results at an early stage. The mid-sized JASMINE satellite, with a main aperture of approximately 80 cm, is designed for surveying the entire bulge and is targeted for launch in the 2030’s. Internationally, Japan shares responsibilities with ESA. With the Gaia Project, ESA performs visible-light observation of the entire sky at a precision of 10 μas, while Japan engages in infrared observation of the bulge, which is a method suitable for observations in the direction of the Galactic Center.

(2) Major Progress in FY 2017

1) Organization of the office

The JASMINE Project Office is composed of four full-time staff members, six staff members with concurrent posts, two research associates, one technical associate, and three graduate students. Significant contributions were made by members of the following organizations: Kyoto University’s Graduate School of Science; ISAS at JAXA; the University of Tokyo’s School of Engineering; Tokyo University of Marine Science and Technology; the University of Tsukuba; and the Institute of Statistical Mathematics.

2) Progress of the Nano-JASMINE Project

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

The satellite was scheduled to be launched from a Brazilian launch site operated by Alcantara Cyclone Space using a Cyclone-4 rocket built by Yuzhnoye, a Ukrainian rocket developer. The launch has been impossible due to the adverse influence of international situations. We now have the possibility that a foreign company for launch services using small vehicles can launch the Nano-JASMINE satellite. We are now negotiating for the launch. Assembly of the flight model that will actually be launched into space was completed in FY 2010. The extra time yielded by the launch delay has been used for additional testing to further ensure project success. Maintenance of the satellite has also been performed. Steady progress was also made in the development of the algorithms and software required to determine astrometric information from raw observational data at the required level of precision. International cooperation with the data analysis team for the Gaia Project has been conducted smoothly.

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

The objective of the small-sized JASMINE project is to use a three-mirror optical system telescope with a primary mirror aperture of 30 cm to perform infrared astrometric observations (Hw band: 1.1–1.7 μm). A goal is to measure annual parallaxes at a precision of less than or equal to 20 µas and proper motions, or transverse angular velocities across the celestial sphere, at a precision of less than or equal to 20 μas/year in the direction of an area of a few degrees within the Galactic nuclear 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 histories of the Galactic nuclear bulge and the superrmassive black hole at the Galactic Center; the gravitational field in the Galactic Nuclear Bulge, the activity around the Galactic Center and formations of star clusters; the orbital elements of X-ray binary stars and the identification of the compact object in an X-ray binary; the physics of fixed stars; star formation; planetary systems; and gravitational lensing. Such data will allow for the compilation of a more meaningful catalog when combined with data from terrestrial observations of the line-of-sight velocities and chemical compositions of stars in the bulge. Conceptual planning and design of the Small-JASMINE satellite system and detailed planning of the subsystems began in November 2008 with cooperation from nearly 10 engineers from JAXA's SE Office (the Systems Engineering Office), ARD (Aerospace R&D Directorate), 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 bus system to ascertain the target precision in astrometric measurement as a general objective. The SWG, led by Masayuki Umemura of the University of Tsukuba and including volunteers from diverse fields in Japan, continued to make scientific considerations. Other activities such as conceptual planning, design, technical testing, and international project collaboration have been continued.

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

As planning has progressed so far, the full mission proposal was prepared and submitted in January 2016 to the ISAS call for small-sized scientific satellite mission proposals and the Small-JASMINE mission is going through the ISAS selection process. Small-JASMINE has successfully passed the review held by the space science committee at ISAS in May 2017 and had an international review at ISAS in December 2017. The international review committee has given us action items for the next development phase and much useful advice. We have been making preparations for the next review at ISAS to upgrade the development phase.

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

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

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

The project office evolved in to a new institute, the "Astrobiology Center" of NINS in December, 2017. There are 37 refereed papers in English and 89 presentations in this year.

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

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

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

(2) IRD (Infrared Doppler Instrument)

IRD is a high precision (~1 m/s) radial velocity spectrometer working at near-infrared wavelengths, whose aim is to detect habitable Earth-like planets around M dwarfs and brown dwarfs (Fig. 1). Science discussions on habitable planets around M dwarfs are also proceeding.

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

EXPO has been involved in the development of these next-generation high-contrast instrumentations being carried out at Hawai`i and Princeton, respectively (Fig. 2).

2. Exoplanet Instrument Development for Future Space and Ground-based Telescopes and International Collaborations

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

These missions aim to directly image and characterize the Earth-like planets and super-Earths for signatures of life. As a member of the WACO working group (currently WFIRST WG), a coronagraph performance test at the JPL testbed is being conducted with collaborators.

(2) SEIT (Second Earth Imager for TMT)

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

3. Science Research, Education, and Outreach

The SEEDS project successfully finished in January 2015 without any major troubles. SEEDS has published about 60 papers so far. Post-SEEDS activitiers using the next generation direct imaging are also promoted.

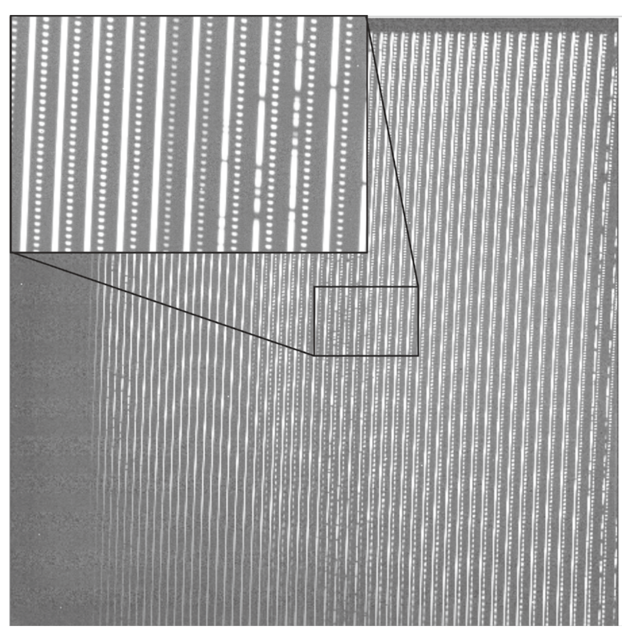

Figure 1: First light image of IRD obtained on the Subaru Telescope. Both stellar spectra and laser frequency comb spectra are imaged on the detector through optical fbers.

About 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.

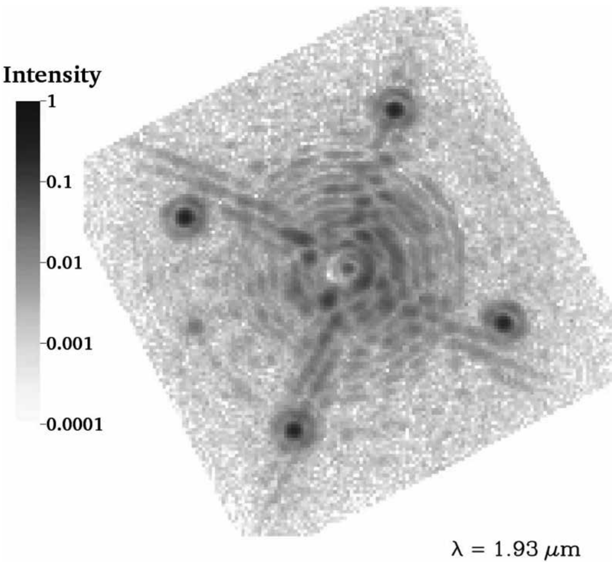

Figure 2: Point source image at 1.93 micron from an extreme adaptive optics system SCExAO and infrared integral field spectrometer. The four point-like structures are artificial point sources made by a deformable mirror for accurate astrometry. From Brandt et al. 2017.

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

1. Project Overview

In FY 2017, operation preparation of the Laser Altimeter (LIDAR) of Hayabusa2 for arrival at the target asteroid was carried out. At the same time, a test of the thermal strap of the Ganymede Laser Altimeter (GALA) for the Jupiter Icy Moon Explorer (JUICE) mission was conducted. Also, the RISE Project Office proposed a new plan for a future asteroid mission as a planetary science project within the National Astronomical Observatory of Japan.

The RISE Project Office (1) arranged and determined the contents of the initial check-out test and nominal observation, (2) confirmed the analytical procedures of the landing site selection, (3) prepared for data publishing by revising the types of open data and drawing up ancillary documents, (4) conducted crossover simulations for precise determination of the Hayabusa2 spacecraft's position, and studied the spatial distribution and temporal variation of the expected laser footprints and crossover points, and (5) investigated the performance of LIDAR albedo mapping by using a LIDAR engineering model, and examined the reflectivity of the meteorite by changing phase angle as a cross-calibration between LIDAR and three other optical instruments on board.

For GALA, a thermal strap of the detector was tested under various thermal conditions and its elastic properties were measured. Furthermore, the detector sensor was tested in one-bar atmosphere with different temperatures aiming to advance the thermal design. A RISE Project Office member presented at an international science meeting in June 2017 about a radiation test and its influence on the receiver detector. This work has been already accepted by a peer-review journal.

For the Martian Moons explorer (MMX), in order to constrain the moment of inertia and internal density variations of Phobos, the Office members carefully examined and confirmed mission requirements and prerequisites of in-situ observations, such as how low an orbit of the spacecraft could be for density measurements, and how significant images taken near the asteroid are for determining shape models and rotational state.

For a future plan of the RISE Project Office, a RISE review was carried out at Mizusawa Campus from April 24 to 25. The review panels carefully examined input packages in advance, then returned a list of possible problems. Following replies from the RISE Project Office, the Planetary Science Advisory Committee and the RISE Project Office discussed intensively to put together a new proposal for asteroid exploration.

2. Educational Activities/Internship

Seven RISE members delivered lectures in turns at the undergraduate school of the University of Aizu for half a year. Also, one RISE member served as a part-time lecturer at the University of Tokyo for half a semester for an undergraduate class and half a semester for a graduate class. The Office accepted one undergraduate student from University alliance of Tohoku. Furthermore, one student of SOKENDAI was accepted for each of the “laboratory rotation class” and “Experimental radio astronomy class.”

3. Outreach/PR

In FY 2017, the Office members volunteered for Kirari Oshu Astronomy School of Oshu City for four times as well as 3 times for Fureai Astronomy classes. RISE members attended both Mizusawa and Ishigakijima Campus open house days. They not only interacted with the guests, but also provided special lectures.

4. Joint Research/International Collaborations

From Russia, Ms. Ekaterina Kronrod visited the Office for one month for joint research on thermo-mineralogical modeling of the lunar mantle. In July, the summer school was held for Chinese, Korean, and Japanese students who are studying planetary sciences. An Office member attended this summer school together with 3 graduate students from Japan to promote science interaction among the three countries.

5. Career Development

A new research expert joined the Office in August. And one research expert left the RISE Project Office in March because he was hired as an assistant professor of Institut de Physique du Globe de Paris.

13. Solar-C Project Office

The SOLAR-C Project Office has engaged in planning the next solar observation satellite project SOLAR-C, promoting the sounding rocket experiments FOXSI-3 (Focusing Optics X-ray Imaging Spectrometer) and CLASP (the Chromospheric LAyer Spectro Polarimeter), and also preparing for participation in the large balloon-borne experiment Sunrise-3.

1. SOLAR-C Project

SOLAR-C is a planned project and may become Japan's fourth solar observation satellite, after Hinotori, Yohkoh, and Hinode. The plan is to realize the launch in the 2020's. The project is intended to investigate the solar magnetic plasma activities that influence space weather and space climate around the Earth. The investigations involve the high-resolution imaging / spectroscopic observations of the outer solar atmosphere with a seamless temperature coverage that has not been achieved to date. The themes include major problems in solar research: the heating mechanism of the chromosphere/corona, the origin of solar explosive events, and the mechanism of the solar magnetic activity cycle. 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 and satellite; and the science instruments will be developed through the international collaborations with the U.S. and European space agencies and institutions.

2. Small-sized Projects

(1) 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 in the ultraviolet wavelengths. Planning and basic development started in FY 2009. The project involves an international research team with participation from Japan, the U.S., and other countries. The spectropolarimeter was prepared in Japan with components provided by the U.S. and France, and an American sounding rocket is used for the flight. The CLASP project entered the development stage fully in the latter half of FY 2012 and carried out the first flight experiment in September 2015. The second flight experiment is scheduled for 2019 and will change the observed spectral line from H I Lyα to the chromospheric Mg II line at 280 nm.

(2) Sunrise-3 Project

The Sunrise-3 project is the third balloon-borne experiment in the German Sunrise program. The preparation of the plan started in FY 2015 for the flight experiment scheduled in 2021. Under the international collaboration, the Japanese team will jointly develop a high-resolution spectropolarimeter that is equivalent to the science instrument for a future space mission. The project will tackle the development demonstration of a state-of-the–art remote-sensing instrument and the challenges to front-line science studies ahead of the satellite observations.

(3) FOXSI-3 Project

The FOXSI-3 project is the approved third observational sounding rocket experiment in the US FOXSI program with focusing hard X-ray telescopes and is planned to be conducted in 2018. One of the hard X-ray detectors is to be replaced by the high-speed CMOS camera that was developed by the Japanese team for soft X-ray coronal imaging spectroscopy. The soft X-ray energy spectrum is to be obtained at each CMOS imaging pixel by photon counting.

3. Major Activity in FY 2017

The SOLAR-C proposal, which was submitted to JAXA in February 2015, was not selected in the mission definition review as the candidate for the 1st JAXA Strategic Large-class Satellite Mission. The SOLAR-C WG has been working to refine the mission concept and rebuild the international collaboration framework aiming at re-submitting the proposal to the next opportunity for a JAXA Strategic Large-class Satellite Mission. At the same time, the SOLAR-C WG has been studying the possibility of realizing a part of the SOLAR-C science in earlier stages by using the opportunity provided by the JAXA Competitively-chosen Middle-class Satellite Mission. In terms of international collaboration, the science objectives team for the next generation solar physics mission (NGSPM-SOT), which was formed at the request of the space agencies JAXA, NASA, and ESA in 2016, has completed its task, i.e., to prioritize the potential JAXA-led solar physics missions for launch in the mid-2020's, and delivered the final report to the three agencies in July 2017. By taking the provisional schedule of JAXA's space missions in the forthcoming 10 years into account, and after extensive discussions in the solar physics community in Japan, the SOLAR-C WG decided to position the UV-EUV Spectroscopic Telescope (EUVST), which was regarded as the most important instrument in the 2020's by the NGSPM-SOT, as the top priority project, and submitted the mission proposal for SOLAR-C_EUVST to JAXA's Competitively-chosen Middle-class Satellite Mission in January 2018.

Since publishing the first science results from the flight experiment in September 2015, the CLASP project has been preparing for the second flight experiment, which is scheduled for 2019. The Japanese CLASP team fabricated new flight components, which are needed to observe a different spectral window from the first flight, and started the assembly of the telescope and the spectrograph. The proposal for the gondola for Sunrise-3 has also been approved by NASA in this fiscal year, and Sunrise-3 is scheduled to be flown in FY 2021. We made the optical, mechanical, and thermal designs of the Sunrise Chromospheric Infrared spectroPolarimeter (SCIP), and developed mechanisms for the polarization modulator and image scanner. The interfaces with various European components were clarified. About half of total budget for CLASP-2 and Sunrise-3 was funded by JAXA through the Small-size Solar Observing Program. The development of a high-speed CMOS camera for FOXSI-3 was completed successfully and the combination test with the X-ray mirror provided by the US team was performed. The FOXSI-3 project is now in the final prepartations for flight in summer of 2018.

4. Others

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

14. Astronomy Data Center

1. Introduction

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

2. DB/DA Project

The DB/DA-project conducts research and development on astronomical Data Bases 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 opens 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 150-cm KANATA Telescope (Hiroshima University). The total amount of opened data is about 20 million frames (154 TB) as of May 2018. SMOKA contributes to many astronomical products. The total number of refereed papers using SMOKA data is 220 as of May 2018.

3. Network Project

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

(1) NAOJ and the WIDE project are jointly operating the Transpac, the US-JAPAN Academic research and education network. The Transpac has had 100 Gbps bandwidth of circuits between Tokyo and Seattle since 2016. In 2017, SINET, JGN, and the University of Hawai`i submitted applications to use this circuit. Also, a new high-bandwidth optical circuit has been developed between the University of Hawai`i at Hilo and Subaru Telescope.

(2) A computer security incident was caused by inappropriate information management and unsuitable service configuration. NAOJ CSIRT (Computer Security Incident Response Team) was responsible for responding to and reviewing this incident and reported that the probability of information leakage was extremely low. We will consider effective measures to prevent a recurrence of the problem; the computer system and operation standards will be updated.

4. JVO Project

ALMA WebQL v3 (renamed to FITS WebQL), which became a Web based quick-look service for generic FITS data, was released. This service will also be used to display the Nobeyama data. A desktop version of FITS WebQL was also released. This can be used to display a user's own FITS files in a web browser. New VO service search interfaces, JVOIndex and JVOExplorer, were released. JVOIndex is a GUI to enable a user to search a VO service based on the index extracted from the VO resource metadata. JVOExplorer is a GUI to find a VO service by tracing the hierarchical structure of the resource identifier. Preparation for releasing the Nobeyama Legacy data sets of FUGIN, COMING, and the Star Formation project was carried out. Those data will be released in June 2018. Collaboration between JVO and C-SODA of JAXA/ISAS is going on. Total access count for the JVO services was 5.85 million and the download size was 1.24 TB in the 2017 fiscal year.

5. HSC Data Analysis/Archiving Software Development

This project started in January 2009, to primarily develop the data analysis pipeline and data archiving software for Hyper Suprime-Cam (HSC). Our main efforts focus on the implementation of the software for effective data analysis/archiving by parallel and distributed processing, for the sake of precise photometric and astrometric calibrations, by correcting various effects originated from the camera system. HSC operation has been stable, generating a large volume (300–400 GB/night) of data.

In the Subaru Strategic Program (SSP) with HSC, started in March 2014, we performed data analysis of the SSP data and produced databases storing the processed results. We made the 6th internal data release to the SSP team collaborators in September 2017, which covers over 225 sq. degree areas in all bands, full depth. The total size of image products reached 280 TB, and the catalog database stores about 350 million objects. We have continued developing various user interface software for getting images or catalog products using the database through web browsers. The first HSC public data release (PDR) service launched in February 2017 hosts more than 600 registered users from institutes across 35 countries. Based on the data releases, 40 scientific and technical papers have been published in the PASJ HSC special issue (2018.1), and more outcomes from the HSC data will be anticipated. The hardware and software for the data releases are in a stable operation, even after renewal of the computer platform in March 2018. We have been working on improvements to the pipeline functions to achieve the planned accuracies for calibrations/measurements of objects. The on-site data analysis system being developed since 2011 has played an important role for supporting SSP and general observations including queue-mode observations. The next-generation multi-object spectrograph PFS at Subaru Telescope will start its commissioning with early-delivered hardware components this year. We have been involved in discussions of data formats, and development of science data archives which are tied to the HSC products.

6. Open-use Computer System and Service

The rental open-use computer system, "National Astronomical Observatory of Japan: Data analysis, archive, and service system", was replaced and the new system has been in operation since March 2018. 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 archive; ALMA data archive; VERA data archive; NRO data archive and shared servers; Okayama data archive; and Solar archive)", "JVO subsystem", "Data analysis subsystem in Mizusawa Campus", "Development subsystem", and "Open-use terminals and printers in Mitaka Campus."

The total storage, memory, and number of CPU cores in the new system are about 17 PB, 22 TB, and 2,200 cores, respectively. The total storage volume is about 3 times that of the previous system (The total memory and the number of CPU cores are about 1.7 times and 1.1 times those of the previous system, respectively).

In the course of the Inter-University Research we held and supported some workshops on using software and systems, too. The dates and numbers of participants in JFY 2017 were as follows.

1. 1st Python + Jupyter notebook data analysis school, Jul 13–14, 2017, 12 users
2. HSC imaging analysis school, Jul 20–21, 2017, 12 users
3. SOKENDAI summer student program (Support), Aug 1–31, 2017, 10 users
4. 2nd Python + Jupyter notebook data analysis school, Aug 24–25, 2017, 12 users
5. Subaru Autumn school 2017 (Co-host), Sep 19–22, 2017, 14 users
6. IDL School for FITS data analysis, Oct 26–27, 2017, 5 users
7. IRAF/PyRAF installation school, Dec 19, 2017, 3 users
8. N-body simulation school, Jan 24–26, 2018, 13 users
9. Solar data analysis workshop, Mar 26–28, 2018, 9 users.

The total number of participants in the schools in JFY 2017 was 90 users.

7. Others

As part of outreach and promotions activities, 129 issues of "ADC News" were published from No. 580 to No. 708 in JFY 2017. The news was distributed by E-mail to users and appeared on the ADC web pages. The number of "ADC News" in JFY 2017 is about 1.5 times the last year because of the replacement of the computer system.

15. Advanced Technology Center (ATC)

1. Organization and Summary of Activities in ATC

At the Advanced Technology Center (ATC), we are working on the development of astronomical observation equipment that is requested by and to be used in the projects driven forward by the National Astronomical Observatory of Japan as "priority area development" and development research contributing to the future astronomical projects as “advanced technology development.”

Furthermore, in FY 2017 we have finished setting up a new R&D framework called “Basic Technology Development,” which does not belong to either category of “priority area development” or “Advanced Technology Development.” Those research and development themes shall be realized or dissolved within two years starting from 2016. At the same time, the Advisory Committee for ATC discusses the approach to research and development issues to be tackled at ATC, in particular, in order to make clear the direction of selecting the themes for “advanced technology development,” as well as how to approach them, and to review the activities being done in ATC.

As one of the “high priority areas for development,” development of ALMA receivers (Bands 4, 8, 10) has been done with the highest priority. The shipping of all cartridge receivers was completed in FY 2013 (by March 2014). Since then, while keeping the central importance of the maintenance of the ALMA receivers, we have been carrying out ALMA future development and studies for upgrades to the receivers of the Nobeyama 45-m Radio Telescope and ASTE telescope.

As another “high priority area for development,” development of the observational instruments Infrared Imaging Spectrograph (IRIS) and Wide-Field Optical Spectrometer (WFOS) for the Thirty Meter Telescope (TMT) were promoted. In addition, as key parts of the gravitational wave telescope KAGRA under construction in Kamioka Gifu, the anti-vibration system and auxiliary optical system were successfully developed mainly in ATC.

For “advanced technology development,” the main themes of research and development are comprised of the development of space-borne solar observation telescopes: CLASP-2 and SUNRISE-3; the development of radio astronomical receivers and the support of such development outside NAOJ; and the upgrade and maintenance of the ultra-broad field of view primary focus camera, Hyper-Suprime-Cam, operating at the Subaru Telescope.

In the “basic technology development,” we will focus on "development of radio cameras" and "infrared detector development" as the themes of technology development aiming for the development of basic technologies, both for future detectors and observation instruments.

2. Workshops and Development Support Facilities

(1) Mechanical Engineering Shop (ME shop)

The Mechanical Engineering (ME) shop engages in a comprehensive manufacturing process to fabricate experimental and observational instruments, from design to fabrication and verification. Three teams including design, fabrication, and measurement teams cooperate to advance projects by leveraging their expertise.

The design team has mainly been working on mechanical designs for TMT/IRIS and KAGRA. In addition, the team has started to work for TMT/WFOS, CLASP-2, and SUNRISE-3. Major contributions to the projects are as follows.

[TMT/IRIS project]
- Design work
  - Cryostat for mirror surface measurement
  - Opt-Mech design of pupil viewing optics
- Testing
  - Glass to metal bonding tests
- Meetings and Reviews
  - Preliminary design review

[TMT/WFOS project]
- Design work
  - Conceptual design of mask exchange mechanism (mechanisms, facilities, cost, etc.)
- Meetings and Reviews
  - WFOS Trade Study Down-Select Review.

[KAGRA project]
- Design work
  - Suspension system for Narrow Angle Baffle
- Assembly and verification
  - Vibration isolation table for Beam Reducing Telescope
  - Optics mounts for Beam Reducing Telescope
  - Suspension system for Wide Angle Baffle
  - Bottom filters for mirror suspensions.

[CLASP-2 project]
- Design work
  - Design verification of magnifier and mirror holders
  - Slit holder and pinhole array holder
- Assembly and verification
  - Process control of fabrication and black plating of structural parts
  - Bonding of flight mirrors and holders

[SUNRISE-3 project]
- Design work
  - Detailed design of opt-mechanical parts for spectropolarimeter
  - Thermal structural analysis and shock response analysis
  - Integrated opt-mechanical analysis
  - Design verification of overall structure

The fabrication team has been working on the auxiliary optical system of KAGRA, and has fabricated five-axis lens positioners for the Beam Reducing Telescopes. In addition, blade springs that are made from beryllium copper and Maraging steel for the vibration isolation system and various parts of the auxiliary optical system were delivered.

For TMT/IRIS, mechanical parts for test equipment were machined in order to be able to supply them upon request from the design team.

For airborne instrumentation, we completed fabrication of the flight models of mirror holders for the M4 and M5 mirrors equipped on CLASP-2. Flight parts and a test jig for the SUNRISE-3 and FOXSI-3 projects were delivered.

In collaborative development programs, we have been fabricating the base plate and height adjusting plate final models for the Tomo-e Gozen project under development by the University of Tokyo, Institute of Astronomy. In addition, we responded to requests to fabricate the improved receiver holder, parts for cooling tests of anti-reflection coatings, and other components for a radio wave camera (MKID)

The ultra-precision section of the fabrication team has responded to fabrication requests as follows.

- -Trial of the profiled horn for ALMA Band 10 including micro-fabrication of grooves on the narrow area.
- -Development of a new type anti-reflection coating using glass beads for the Si lens array of the radio wave camera MKID.
- -Fabrication of the slicing mirror jig for an image slicer.
- -Trial of a high resolution grating.

Furthermore, it was found that a malfunction (out-of-step) in the ultra-precision processing machine occurs when repeating high load processes. As a result of verification processing, it was revealed that depending on the combination of material, tool, and processing condition, there is a region causing malfunction without machine error due to overload by repetition for multiple iteration processing.

The measurement team has responded to not just measurement requests but also supported fabrication in order to assure the high specifications.

Table 1 shows the number of fabrication and measurement requests in FY 2017.

Table 1: The requests in FY 2017.

From FY 2016	5
ATC	6
TMT/IRIS	3
KAGRA	20
ASTE	1
SOLAR-C,CLASP-2,SUNRISE-3,FOXSI-3	13
Astrobiology Center	3
Division of Optical and Infrared Astronomy	1
Division of Radio Astronomy	1
Public Relations Center	2
Solar Science Observatory	2
Subaru Observatory	5
External Organizations	
IoA, Univ. of Tokyo	4
Univ. of Tsukuba	9
JAXA/ISAS	1
Total	75
To FY 2018	4

(2) Thin Film Processing Unit

Fundamental experiments were continued to design and to develop the concrete coating processes, taking into account the applications and expected performance.

Multilayer design software using the multilayer/WKBJ approximation for inhomogeneous layers is being built. An interface program for the fabrication system is under development.

(3) Space Chamber Shop and Space Optics

Acquisition and accumulation of fundamental technologies for space observations using platforms such as balloons, sounding rockets, and satellites are progressing with involvement in the research and development of ongoing project activities. In FY 2017, in collaboration with the SOLAR-C Project Office and the ME shop, we have assisted the development activities of solar observation projects (CLASP-2, SUNRISE-3) that are situated as Advanced Technology Developments in ATC. Concerning the CLASP-2 sounding-rocket experiment in which observations of the solar chromospheric magnetic fields are planned at ultraviolet wavelengths, we have supported the development of flight components for the second flight. Among these activities, the facilities of the Space Chamber Shop were frequently used for the vacuum bakeout of the flight parts and outgassing measurements before assembly. The development of the light source for polarization calibration was completed, including the confirmation of the brightness of the ultraviolet lamp and the spectral profile of emission lines to be used. In the SUNRISE-3 project aiming at observing high-resolution chromospheric magnetic fields from a balloon altitude, a facility of the Space Chamber Shop was used for the outgassing measurement of test blackened metals after the surface finish that is to be applied to holders and mounts of optical elements.

(4) Optical Shop

Activity of optical shop in 2017

1) Management

We are providing some optical measurement systems and technical consulting about the measurement system for open-use users as usual and doing daily inspections in order to keep the measurement systems in good condition.

2) Repairing and upgrading measurement systems

- Replacement of the light source for the FT/IR spectrometer (FT/IR 410)
- Replacement of the light source for the autocollimator (Nikon model 6D)
- Cleaning of the optical system of the UV-VIS-NIR Spectrophotometer (Solid Spec3700).
- Installation of the small diameter fiberscopes (OLYMPUS IF2D5-6-E)

3) Open use

• The number of annual user: 268
  NAOJ: 208 (including 87 from ATC)
  External organizations: 60 (including 12 from Institute of Astronomy, University of Tokyo)
• Use of LEGEX910 (large-scale 3-D measurement machine): 9
  Number of operating days: 16
• Technical consulting for users: 48

(5) Optical and Infrared Detector Group

We have conducted twice the joint purchasing program of MESSIA6, a general purpose focal plane array controller for astronomical instruments, as part of shared use of the Advanced Technology Center so far. As continuing user support for MESSIA6, we assisted the development of a CCD camera for Nishi-Harima Astronomical Observatory and the University of Hyogo. In this year, we advised on the design of a cryogenic dewar to install e2v CCD's.

(6) Facility Management Unit

The Facility Management Unit conducts the management of ATC facilities including the buildings, and electric facilities; daily maintenance of the Cold Evaporator (CE); maintenance of building equipment; oversight of construction; and management of hazardous material and laboratory equipment.

Regarding the four draft chambers used for cleaning work etc. in the clean room, we have re-renovated one unit that did not meet the regulation values. As the circulation cooling water facility and the water pipeline become polluted due to aging, inspection and cleaning work including the outdoor cooling tower was carried out to prevent deterioration of water quality. As a countermeasure against the decrease in positive air pressure inside the cleanrooms and resulting degradation in the cleanness, the filter units in the outdoor air-compressor have been replaced. Also, we investigated the possibility of storing and keeping combustible gas cylinders in an outdoor chamber in accordance with the High Pressure Gas Safety Law.

With regard to the newly built No. 3 building (TMT building), construction of circulating cooling water facilities has been finished, which enables the use of refrigerators in each laboratory. Cold evaporator (CE) piping connections have been done to distribute nitrogen gas to each laboratory.

There are many projects that use laboratory equipment, including ATC members, KAGRA, TMT, the Division of Radio Astronomy/Chile Observatory, HSC, JASMINE, the Division of Optical and Infrared Astronomy, Extrasolar Planet Detection Project Office (now the Astrobiology Center), Subaru Telescope, Hinode Science team, and SOLAR-C/CLASP-2. Projects that require high cleanliness in equipment development use cleanrooms. In the 110 cleanroom of the No.1 building and the 101 large cleanroom of the No.2 building, equipment related to KAGRA was developed. In addition, the main body of the CLASP telescope successfully launched in the United States in 2015 will return and new equipment will be developed at the 101 large cleanroom of the No.2 building as a new CLASP-2.

3. Prioritized Area Developments

(1) ALMA receiver maintenance of Band 4, 8, 10

For the ALMA project, the mass-production and shipment to Chile of the Band 4, 8, and 10 receiver cartridges, which were assigned to Japan, were completed in FY 2013. In Chile, most of the receivers have been installed and operated in the ALMA antennas, and many scientific results have been published. At the Advanced Technology Center (ATC), the ALMA receiver maintenance team has the responsibility of reparing the defective receiver cartridges. In FY 2017, one Band 4 and two Band 10 receiver cartridges were repaired and delivered to Chile.

Table 2 shows the total number of defective receiver cartridges broken down into "initial failure" and "aging failure." And also shown are the number of receiver cartridges repaired in FY 2017, and the number of receiver cartridges remaining to be repaired. The remaining repaired Band 4 receiver cartridge is planned to be stored as a spare receiver cartridge to be install on an antenna. Its shipping was delayed because of the approaching end of the fiscal year. The remaining defective Band 10 receiver cartridges, which are possibly due to degradation of electrical devices, are still inside of the antennas and have not returned to Japan yet. The unloading of defective receiver cartridges must follow the system operation cycle at the ALMA site because the receiver cartridges are loaded into cryostats installed on the antennas. A defective receiver cartridge is unloaded when the cryostat is uninstalled from an antenna for maintenance of the cryostat. And then, the defective receiver cartridge will return to Japan after unloading, to be investigated in detail to determine the cause of the failure and then repaired. We have continued good collaboration with local engineers in Chile for monitor the status of receiver cartridges, such as periodic health checks, and carry out maintenance operations by taking measures.

The repairing of defective receiver cartridges caused by initial failure is almost finished. Although defects caused by aging failure are infrequent at present because of good quality control during mass-production, this is not enough to predict and judge the defect frequency caused by aging failure at the current

Table 2: Total number of defective receivers.

Receiver	Total	Breakdown		Repaired in FY 2017	Remained
		Initial failure	Aging failure		
Band 4	8	4	4	1	1
Band 8	17	14	3	0	0
Band 10	21	6	15	2	3

moment. It is very important to keep the long-term maintenance system in ATC to continue to be able to respond promptly.

(2) TMT

We, the IRIS-Japan team at ATC, have been continuing development of the first generation Thirty Meter Telescope (TMT) instrument IRIS since 2011.

The Preliminary Design Phase is continuing in FY 2017. We defined and released the design requirement document of the IRIS imager, for which NAOJ/ATC has been taking responsibility, and interface control documents between the IRIS imager and other IRIS subsystem. Also we finished the preliminary software and electronics design of the IRIS imager. The cost of the IRIS imager in the final design phase and fabrication phase has been estimated and documented. All these designs and documents were reviewed and accepted at the review (Preliminary Design Review 2) in September, 2017. After the PDR-2, we started the final design phase from October 2017.

In parallel, we have conducted the prototype experiment on bonding strength between optical substrates and metal pads. Also we measured the high-precision aspheric mirror.

We have been working on a conceptual study of a WFOS camera system, which is another first generation instrument of TMT. There are three competitive concepts for the WFOS camera system, one of which is being developed in NAOJ, i.e. a high resolution multi-object spectrometer based on an 'image slicer' where object images are sliced into three to achive a narrower effective slit width. We have been also working on the conceptual study of the camera system of the spectrograph. This continues in FY 2017. In particular, we proposed the conceptual solution of the system for changing the mask plates, which is the main part of the system. We also carried out the optical design as well as the tolerance analysis of the image slicer module in ATC.

(3) KAGRA

We have developed KAGRA's auxiliary optics subsystem (AOS) and vibration isolation subsystem (VIS) with the Gravitational-wave project office (GWPO).

About AOS, we have continued the design of the wide-angle baffle (WAB)'s suspension and started the cooling test. We have also done the design of the narrow-angle baffle (NAB)'s suspension, the assembly and the installation of one of the transmission monitors (TMS), and the assembly of two TMS's vibration isolation stages.

The WAB will be located close to KAGRA's main mirror to absorb stray light from the mirror in wide angle, and thus needs to be cooled down along with the mirror. The cooling test of the WAB has started in March 2018 as scheduled, after finishing the installation into the actual KAGRA cryostat. A TMS will be located at the end of each 3-km arm optical cavity of KAGRA to monitor the tilt and shift of the beam line, and make feedback signals to the control system. We assembled, tested, and shipped one of the TMS's, and it has been installed at KAGRA in March 2018 as scheduled. In addition, two TMS vibration isolation stages have been assembled at the large clean room in ATC.

KAGRA-VIS is a subsystem to suspend mirrors required for the KAGRA interferometer to isolate them from seismic disturbance. The system consists of multi-stage isolation mechanical filters. Most of the parts of the isolation system have been brushed up, assembled, and tested by the ME shop. So the ME shop is essential for KAGRA. In this fiscal year, we mostly completed the major VIS works assigned to ATC; we assembled, tested, and shipped the remaining two mechanical filters, "bottom filters," cooperating with GWPO. After some discussion about the schedule, the remaining six "standard filters" were brought to Kamioka, and then GWPO took care of them. In addition, the remaining one traverser was assembled, tested, and shipped as well.

As shared uses of the ATC facilities, the three-dimensional measurement system (FARO) was used several times to evaluate the installation accuracy in the KAGRA tunnel, and the location accuracy of the ears for the main mirrors at University of Toyama.

4. Advanced Technology Developments

(1) CLASP-2/SUNRISE/SOLAR-C

ATC has assisted the design and assembly of the instruments in the development activities of the solar observation projects (CLASP-2, SUNRISE-3) of the SOLAR-C Project Office. In CLASP-2 aiming at the measurement of chromospheric magnetic fields in the ultraviolet wavelengths, the design of the new optical system and the design confirmation of newly introduced structures have been carried out for the flight instrument. In the SUNRISE-3 project aiming at observing high-resolution chromospheric magnetic fields from a balloon altitude, ATC has carried out the detailed optical design of the spectropolarimeter operating in near-infrared wavelength ranges and the design of holder and mount structures supporting the major optical elements in the instrument. The structural strength under environmental conditions has been confirmed through a modeling activity of a finite element model of the entire instrument. The degree of thermal deformation of the structure under the operating temperature range and the degree of deterioration of optical performance due to the thermal deformation have also been evaluated in the in-house activity.

(2) Telescope Receiver Developments

1) Telescope Receiver Developments

Based on the technical skills acquired through the ALMA receiver developments, the “telescope receiver development” team has provided support and development for telescope receiver of other projects and institutes. We have responsibility for the trouble-shooting of the ASTE new receiver that we developed in 2016. Also, technical support for the DESHIMA receiver (TU Delft) elements such as the support structure and chopper was done. We maintain good collaboration with other radio telescopes being developed by universities (Nagoya University, Osaka Prefecture University, Kwansei Gakuin

University). Fabrication of two ALMA Band 8 mixers was done for the APEX telescope through a manufacturing cooperation contract with the Max-Planck-Institut für Radioastronomie.

ATC can increase the technology standards of the community by giving feedback using the technologies and knowledge accumulated through development of specific projects, and promote the technology development of other projects, universities, and research institutions. It is also important to make the best use of the achievements of the projects.

2) Development of advanced future receivers

In the field of future developments in heterodyne receivers, we focus on two main activities. Firstly, we are involved in international collaboration for the development of the ALMA receivers in frequency bands not implemented in the array yet: Band 1 and Band 2. Secondly, we have started receiver development to support future upgrade plans for ALMA in three main directions: ultra wideband, terahertz, and multibeam receivers.

1.ALMA Band 1, 2+ and 2+3 receivers

ATC supported, in close collaboration with Chile Observatory, the ALMA Band 1 receiver project led by ASIAA in Taiwan through several technical studies. We also supported the different initiatives led by North America (Band 2+, 67-95 GHz) and Europe (Band 2+3, 67-116 GHz) to develop a Band 2 receiver for ALMA, with waveguide components and receiver optics designs and measurements. Both studies successfully passed their Preliminary Design Review meetings in FY 2017. With respect to component design, we successfully designed dielectric lenses, corrugated horns, and OMT’s with wideband performance and low loss.

2. Ultra-Wideband receiver

In terms of RF bandwidth, we are developing SIS mixers with the goal of covering the full ALMA Band 7+8 (275-500 GHz). Based on the development of DSB mixers in last fiscal year, we have demonstrated a 2SB mixer which satisfies ALMA requirements in the full 275-500 GHz band. We have worked on the experiment of a sideband separating receiver based on digital technologies in collaboration with University of Chile.

With respect to IF bandwidth, we have analyzed a SIS-mixer-preamplifier module in detail, which extends IF bandwidth to 3-18 GHz, and designed a 2nd prototype to allow wider bandwidth.

3. Terahertz receiver

In FY 2017, we designed, fabricated, and measured the performance of 1.25-1.57 THz receiver optics based on corrugated horns. Measurement results are compliant with the stringent requirements of ALMA, and represent the best performance ever measured at these high frequencies.

With respect to superconducting mixers, we demonstrated lower noise and wider bandwidth ALMA Band-10 (787-950 GHz) SIS mixers by employing high current density SIS junctions.

4. Multibeam receiver

We have established the concept for planar integration of multibeam SIS receivers, which allows us to realize a very compact multibeam frontend with dual polarization and a sideband separation scheme. We have demonstrated the feasibility with a concept-proof model at 2 mm wavelength, showing a cross-polarization level lower than -20 dB together with the noise temperature. We are proceeding toward a four-beam demonstrating model.

(3) SIS junction development

During the past year our junction technology based on Nb/AlNx/Nb tri-layers has been further refined and high quality junctions with current densities jc = 10 – 60 kA/cm2 are now fabricated on a regular basis. The excellent degree of reliability in the fabrication process is made possible by having access to high-level equipment in the ATC clean room, maintained by our group, for thin film deposition, lithography, and dry etching, among others.

SIS mixers based on our high-jc junction technology are being used in various types of low noise receivers, either as part of an upgrade or demonstrating advanced receiver capabilities: several ALMA Band 8 type cartridges have been delivered to the APEX telescope (operated by partners from Max-Planck-Institute Bonn, Germany), we demonstrated ultra wide IF and RF bandwidths and state-of-the-art sensitivity performance in the 790-950 GHz band.

In parallel with the development of high-Jc junctions, we have made encouraging progresses in fabricating SIS mixers on free-standing membranes. This technique is essential to implement the new concept of planar integration of multibeam receivers. We have established a dedicated fabrication process base on SOI (silicon on insulator) wafers. From this process, prototype planar integrated circuit chips have been successfully fabricated, which were used for RF performance demonstration. Compared with the SIS mixer chips that we have fabricated, this planar circuit is considerably larger in circuit format and more complicated in fabrication. This brought about new challenges to our cleanroom and new motivation of future development.

We also setup a new piece of equipment, a plasma-enhanced chemical vapor deposition (PE-CVD) system (PD-200STLT, Samco Co.) to improve the junction quality by enhancing the step-coverage of the insulating layer. The insulator fabricated with PE-CVD is also considered to be less lossy at RF, which is essential for superconducting detectors.

(4) HSC

During the fiscal year of 2017, HSC has been intensively used for 130 nights. Half of the observing times were allocated to the Subaru Strategic Program (HSC-SSP) and the other half were for general observer programs including UH time, and Gemini/Keck exchange time. Over the year, we had two mechanical problems in the Filter Exchange Units (FEU’s) and each time we had to ask Uraguchi-san, who designed the FEU’s, to do the trouble shooting. Minimum impacts on the actual observations were recorded. However, because HSC has been operated for more than four years since its first light, we started to encounter troubles occasionally which had not been expected originally. Therefore, new maintenance schemes should be worked out in collaboration with the Subaru Telescope staff. In the meantime, as for the concerned CCD trouble, we observed no new problems and we keep following the progress. At the detector lab, we successfully worked out a new clock pattern to reduce the readout time of a CCD and cut 5 seconds by accepting a gain loss of 2/3. We applied the clock pattern on the actual HSC camera and will make a test observing run to see if we have other side effects.

5. Basic Technology Development

(1) MKID camera /CMB Instruments

We are developing a wide field of view, broadband, and high sensitivity millimeter / submillimeter wave instrument.

In collaboration with the University of Tsukuba and Saitama University, we have developed a superconducting MKID camera for a future Antarctica terahertz telescope. As a pathfinder, the MKID camera was installed on the Nobeyama 45-m Radio Telescope.

In collaboration with KEK, ISAS, Kavli IPMU, and Riken, we are developing LiteBIRD and GroundBIRD which observe B-mode polarizations of the cosmic microwave background radiation (CMB). The LiteBIRD has been selected as one of the higher priority projects of the master plan 2017 of the Science Council of Japan.

In this year, the following research results were obtained.

1) Design of the sub-wavelength structure for the broad-band antireflection coating of the Si lens of the LiteBIRD Low-Frequency Telescope.
2) Larger focal plane detector of lens-coupled MKID (37 pixels → 109 pixels)
3) Antireflection coating with glass beads on Si lens array
4) Optical measurements of the MKID camera for the Nobeyama 45-m Radio Telescope (109 pixels)
5) Optimization of the readout system of the MKID camera

(2) Near-IR Imaging Sensor Developments

There were two requirements to fabricate near-infrared image sensors by a domestic manufacturer, which were low noise, and small pixel large format. So far, we have almost achieved them separately. From this year, we will employ a newer CMOS manufacturing process to achieve both low noise and small pixel large format in the same chip, expecting a potential to output near-infrared data complementary to optical CCD sensors. We have designed a small format trial chip with the newer CMOS process in this year.

(3) Multicolor Millimeter/Submillimeter Continuum Camera

To efficiently estimate the redshift of submillimeter galaxies, study the internal structure of hot plasma in clusters of galaxies using the Sunyaev-Zel'dovich effect, and constrain physical properties of the dust in star-forming regions and the spectral index of the initial submillimeter afterglow of gamma ray bursts (GRB's), 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. We presented two papers on a novel method, tested during the FY 2016 commissioning run, to calibrate the input power and detector nonlinearity. For the coming upgrade, to make the most effective use of the focal plane, we made a design of the multichroic detector utilizing the on-chip frequency selective filters, based on the electromagnetic simulation, which will enable the simultaneous triple band observations.

Furthermore, we are developing an add-on polarimeter, Apol, and a moderate resolution spectrometer, DESHIMA, in collaboration with the Chinese University of Hong Kong and TUDelft, respectively. By taking full advantage of our lessons learned with our multicolor camera, we performed the end to end test of DESHIMA on the ASTE telescope. As a result, we succeeded not only in detecting the first light from an astronomical object as scheduled but also in achieving a bonus goal of detecting molecular line emission from an external galaxy.

(4) Development of Terahertz Intensity Interferometry

Terahertz Intensity Interferometry is being developed. Achievements of this year include realization of an extremely low leakage SIS junction with 1 pA in collaboration with the National Institute of Advanced Industrial Science and Technology (AIST), which can be used for fast terahertz photon counting. Twin-slot antenna coupled SIS photon detectors were designed for 500 GHz and fabricated. Simulation studies on aperture synthesis imaging with intensity interferometry were formalized and quantitative comparison was made against standard amplitude interferometry. This development is supported by the JAXA grant for basic R&D for future space science missions and the grant-in-aid for challenging exploratory research programs from JSPS.

6. Open Use Programs, Joint Research and Development

We accepted open use programs of ATC facilities twice a year including 15 collaboration programs and 30 facility use programs. Applicant names and program titles are listed in the section "Open Use Programs etc." Results of the programs can be found on the ATC homepage.

16. 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. In FY 2017, the Center has been comprised of 6 offices and 1 unit: the Public Relations Office, the Outreach and Education Office, the Ephemeris Computation Office, the Library Unit, the Publications Office, the IAU Office for Astronomy Outreach (OAO), and the General Affairs Office.

2. Personnel

In FY 2017, the Public Relations Center was composed of Director Toshio Fukushima and the following staff members: 2 professors, 2 associate professors, 1 assistant professor (one holds concurrent posts), 1 research engineer, 1 chief senior engineer, 1 chief engineer, 1 chief, 6 specially appointed senior specialists, 2 research experts, 19 public outreach officials, 1 research supporter, and 2 administrative supporters.

On April 1, 2017, public outreach official Takashi Horiuchi arrived in the Outreach and Education Office and transferred to Ishigakijima Astronomical Observatory, Mizusawa VLBI Observatory on December 1, 2017.

On March 1, 2018, public outreach official Hironori Ito arrived in the Public Relations Office and public outreach official Ayako Fujimura arrived in the Publications Office.

3. Public Relations Office

Through press conferences and web releases, the Public Relations Office actively developed public outreach activities focused around the results of each research project, first and foremost ALMA and Subaru Telescope, including open-use and collaborative results with other universities and research institutes. In addition, our office hosted lectures to publicize cutting-edge astronomy. In cooperation with the Outreach and Education Office, the Public Relations Office also conducted observation campaigns to promote astronomical phenomena of interest to the public, like the meteor showers. To improve the skills of outreach personnel, the officials attended workshops such as copyright seminars.

(1) Online-Based Information Sharing

The Public Relations Office runs the NAOJ website (http://www.nao.ac.jp/en/), disseminating information via the internet. Table 1 shows the access counts for the website.

Along with the completion of open-use at Okayama Astrophysical Observatory, a special website "Okayama Astrophysical Observatory: An Overview of the Past, Present, and Future (Japanese version)" was opened in collaboration with Okayama Astrophysical Observatory to preserve its results for future generations.

The office opened Twitter accounts and Facebook accounts in Japanese and English sequentially from 2010. We have been actively disseminating information on social networking services. Our office disseminates information on the status of various NAOJ projects such as public visits, regular stargazing parties at Mitaka Campus, and position openings, both in English and Japanese. As of the end of March 2018, the number of Japanese version twitter followers exceeds 160,000. Information dissemination via the English version of Twitter, the interactive NAOJ quizzes on Twitter, as well as the release of visual images on Instagram have been conducted continuously this year.

NAOJ e-mail newsletters No.172–188 were issued, introducing research results and NAOJ hosted events.

We continued to produce videos explaining research results, videos explaining astronomical phenomena, and videos introducing outreach activities. Including English versions, 22 original videos were produced. The videos are uploaded mainly on YouTube. As of the end of March 2018, these videos have accumulated a total of 1,383,083 minutes of play time and 385,982 views. Continued from last year, our office performed live stream broadcasting five times of heavenly bodies with the 50-cm Telescope for Public Outreach. There were about 7,590 viewers in total. We were also invited to do an official live broadcast for niconico and there were more than 30,000 viewers. In addition, we conducted live internet broadcasts of lectures on the Special Open House Day for Nobeyama Radio Observatory and Mitaka Open House Day.

Month	Access counts	Month	Access counts	Month	Access counts
April 2017	360,945	August 2017	806,200	December 2017	1,094,577
May 2017	429,503	September 2017	490,786	January 2018	1,674,509
June 2017	390,178	October 2017	630,664	February 2018	653,580
July 2017	417,534	November 2017	418,373	March 2018	413,780
Total: 7,780,629					

Table 1: Monthly website access statistics for the Public Relations Office website, NAOJ Public Relations Center (April 2017–March 2018).

Project PR movie “Public Relations Center”	English Version
Project PR movie “Okayama Astrophysical Observatory”	English Version
Project PR movie “Subaru Telescope”	English Version
Project PR movie “NAOJ Chile Observatory”	English Version
Mitaka Campus Public Visits Reach 200,000 Guests!*	Japanese Version
Project PR movie “Solar Science Observatory”	Japanese/English Versions
Eclipse - Crossroads in the Sky	Japanese/English Versions
National Astronomical Observatory of Japan: Striving to Solve the Mysteries of the Universe	Japanese caption Version
Time-lapse photography of Phoenicid meteor shower (marked)	
Project PR movie “Gravitational Wave Project Office”	Japanese/English Versions
Project PR movie “Subaru Telescope” 2nd version	Japanese/English Versions
Total Lunar Eclipse on January 31	Japanese Version
Exploring the Universe with “Subaru”*	Japanese/English Versions
Operation Guide for the HSC Viewer*	Japanese/English Versions
Message from New Director General of NAOJ, Dr. Saku Tsuneta	Japanese/English Versions
“Mitaka” Now Delivers More Realistic Universe in More Languages*	Japanese/English Versions

Table 2: Summary of Produced Videos.

April 12, 2017	Collisions generate gas in debris disks
April 28, 2017	First Global Simulation Yields New Insights into Ring System
May 18, 2017	First Direct Exploration of Magnetic Fields in the Upper Solar Atmosphere - Ultraviolet spectropolarimetry opens a new window for solar physics research -
June 13, 2017	ALMA Hears Birth Cry of a Massive Baby Star
June 14, 2017	Nobeyama 45-m Radio Telescope Developed by the National Astronomical Observatory of Japan and Mitsubishi Electric Recognized as “IEEE Milestone”
August 2, 2017	Running Out of Gas: Gas Loss Puts Brakes on Stellar Baby Boom
August 25, 2017	Phoenicid Meteor Shower from Dead Comet Arises again after 58 Years*
September 28, 2017 (EN) September 5, 2017 (JP)	First Detection of an Intermediate-Mass Black Hole Candidate in the Milky Way
September 11, 2017 (EN) August 8, 2017 (JP)	Photosynthesis under the light conditions different from the Earth: New prediction of a detection wavelength for searching phototrophs on exoplanets
September 29, 2017	Supersonic gas streams left over from the Big Bang drive massive black hole formation
October 5, 2017	Surface Helium Detonation Spells End for White Dwarf
October 31, 2017	Minor Merger Kicks Supermassive Black Hole into High Gear
November 6, 2017	Forest of Molecular Signals in Star Forming Galaxy
November 10, 2017	Winds blowing off a dying star
November 17, 2017	Solar Minimum Surprisingly Constant - More than Half a Century of Observation yields New Discovery
November 21, 2017 (EN) August 3, 2017 (JP)	Uncovering the Origins of Galaxies' Halos
January 12, 2018	Black Hole Spin Cranks-up Radio Volume
January 25, 2018	FUGIN Project: Large-scale Exploration of the Invisible Milky Way - Making the Most Detailed Radio Map of the Milky Way
February 6, 2018	HINODE Captures Record Breaking Solar Magnetic Field
February 14, 2018	Rotating Dusty Gaseous Donut around an Active Supermassive Black Hole
February 20, 2018	No relation between a supermassive black hole and its host galaxy!? - The co-evolution mystery deepened by a new ALMA observation
February 22, 2018	Rare first moment of stellar explosion captured by amateur astronomer
March 13, 2018 (EN) March 5, 2018 (JP)	Double or Nothing: Astronomers Rethink Quasar Environment

Table 3: Web Releases.

October 17, 2017	Astronomers Follow Gravitational Waves to Treasure
February 27, 2018	Early science results from the Hyper Suprime-Cam Survey

Table 4: Press Conferences.

(2) Research Result PR

There were 25 research result announcements (compared to 20 in FY 2016 and 27 in FY 2015). For press releases aimed towards overseas audiences, the Office has continued to use the delivery services of the American Astronomical Society, AlphaGalileo, and EurekAlert! from AAAS. We released all the research releases in both English and Japanese. We made videos introducing the content indicated with a * mark.

In the perennially popular Astronomy Lectures for Science Journalists program, the 24th lecture entitled "Approaching the Mysteries of the Solar Corona from Magnetic Field Observation - Present and Prospects for Solar Research - " was held on July 25, 2017. Nineteen people (8 companies) participated in the lecture.

(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 organized lectures with research projects. On February 4, 2018, the NAOJ lecture meeting/23rd ALMA public lecture "ALMA Explores the Cold Universe - Revealing the Mysteries of Planets' Birth - " was held with 265 guests in attendance.

We ordered an outside filmmaker to make a 2nd episode of "NAOJ Topics," a video introducing NAOJ's research activities for the public (Japanese and English versions).

For the purpose of promoting the use of the contents on the website and improving the work efficiency, we updated the "Terms of Use of the Website of NAOJ."

We opened the special site "NAOJ VR." Visitors can experience a virtual tour of Mitaka Campus.

To publicize NAOJ abroad, we hosted/co-hosted booths at overseas meetings where the press and museum personnel gather (World Conference of Science Journalists in San Francisco October 2017, Science Centre World Summit 2017 in Tokyo November 2017, and AAAS meeting in Austin February 2018).

Upon request from the Graduate University for Advanced Studies (SOKENDAI), we translated the website of the Department of Astronomical Science, School of Physical Sciences, SOKENDAI, into English.

(4) New Astronomical Objects

Four staff members, including one full-time and three part-time, handled reports of new astronomical objects and other communications submitted to NAOJ. In this fiscal year, there was a total of 18 reports including confirmation requests for new celestial object candidates and other reports. The contents were: 4 novae/supernovae, 5 variable stars/transient objects, 4 comets, 4 luminous objects, 1 other. Among the many examples of reporting a known asteroid or ghosts as a new object, the report of an object in March 2018, was communicated via NAOJ to the IAU Central Bureau for Astronomical Telegrams and was recognized as an independent discovery of Nova Canis Majoris 2018.

(5) Citizen Astronomy

From FY 2016, the Public Relations Office has promoted "Citizen Astronomy," in which the public plays a part in astronomical research activities using observational data released by NAOJ. Citizen astronomy is one example of "Citizen Science" projects in which researchers / research institutes and the public collaborate on scientific activities. In FY 2017, we considered a concrete citizen astronomy program using the first dataset published in February 2017 from the Hyper Suprime-Cam Subaru Strategic Plan (HSC-SSP) done by the Subaru Telescope and Hyper Suprime-Cam. We developed the user-friendly website to display the HSC images and opened it to the public. We developed a program to determine the shapes of colliding galaxies by using the website. In order to verify the functions and browsing capabilities of this program, a workshop was held on January 8, 2018 for educational officials and astronomy enthusiasts with 26 participants. Under the initiative of the Public Relations Center, this program is being promoted through cooperation with the Subaru Telescope and Astronomy Data Center.

4. Outreach and Education Office

(1) Public Visits

A total of 21,310 people participated in Mitaka Campus Public Visits (former name was Visitors' Area) in FY 2017. In addition, the group tours in 2017 consisted of 111 general tours (4,171 guests), and 30 workplace visits by schools (361 guests), and 5 others such as inspections (108 guests), for a total of 153 tours accommodating 4,640 guests. Therefore, 25,950 guests visited Mitaka Campus in total. Note that for the integrated studies, lectures by researchers, question-and-answer sessions, and visits to research facilities also took place. The office developed an audio guide for most of the Visitors' Area, including making the scripts for the audio guide and recording them in Japanese and English.

Regular stargazing parties were held twice a month (the day before the 2nd Saturday and the 4th Saturday) with the 50-cm Telescope for Public Outreach. These were held regardless of cloudy or rainy weather. Advance booking (300 people for each session; a lottery system from April to September and advanced reservations until filled system from October to March) was introduced in FY 2012 for these events. A total of 23 sessions were held with 4,772 participants this year. In addition to this, the telescope was used by 15 groups (794 people) for group tours, inspections, etc.; so a total of 5,566 people observed with the 50-cm Telescope for Public Outreach.

The Outreach and Education Office held the regular public screenings at the 4D2U Dome Theater four times per month (1st, 2nd, 3rd Saturday, the day before the 2nd Saturday). Advanced reservations were required for these. A total of 45 screenings were held this year, with 5,097 guests participating. For five of the regular public screenings, the office held "Astronomers' Talks" where researchers talked about the latest research and these were popular. Group screenings were performed on Wednesdays and Fridays for 69 groups (2,007 people). In addition, 93 group tours (1,384 people) were organized and a total of 8,488 guests watched the 4D2U stereoscopic movies.

Guided tours corresponding to cultural property events (November 3 and March 21, advanced reservations needed) and the NAOJ Solar Tower Telescope Special Open Days (November 4, November 5, March 24, and March 25, no reservations needed) were held with 1,058 attendees.

(2) Telephone Inquiries

The office received inquiries from the media, government offices, and the general public. The Outreach and Education Office responded to 5,320 telephone inquiries (Table 5) and 111 letters, 48 of which were official documents.

(3) Educational and Outreach Activities

The "FUREAI (Friendly) Astronomy" project, now in its 8th year, provided lectures to 85 schools which is the highest number of schools ever. In this fiscal year, a total of 57 lecturers provided events for 7,801 students. In eight years, 47,149 students in total have attended the lectures in 481 schools from Hokkaido in the north to Okinawa in the south.

"Summer Nights: Let's Count Shooting Stars 2017 (August 2017)", "Let's Gaze at the Geminid Meteor Shower 2017 (December 2017)", and "Let's Observe the Total Lunar Eclipse 2018 (January 2018)" were held and we received 1,411 reports, 2,569 reports, and 2,042 reports, respectively.

For three days from July 31 (Mon) to August 2 (Wed), "Astronomy Classes for Kids in Summer" events were held for elementary and junior high school students around the Mitaka area. Each day had different themes (assembly of telescopes, three-dimensional star handcrafts, and radio telescope observation) with 138 participants in total. Participants experienced things unique to the observatory, such as being taught by astronomers and using the teaching material produced in collaboration with projects.

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 13 (Friday) and October 14 (Saturday) with the theme "The Universe, Hot and Cold." It was co-hosted by the Astrobiology Center, National Institutes of Natural Sciences; the Institute of Astronomy, the School of Science, the University of Tokyo; and the Department of Astronomical Science at the School of Physical Sciences of the Graduate University of Advanced Studies. The event flourished: 303 guests attended on pre-open day, and 2,966 guests attended on open day, so 3,269 guests attended in total. Activities included the viewing of facilities not normally open to the public, interactive panel displays, mini lectures, quizzes and games that are popular among children, and a virtual reality experience. Each Project offered a selection of activities based on their own expertise which were suitable for a wide range of age groups.

(4) Community Activities

The "Mitaka Picture Book House in the Astronomical Observatory Forest" welcomed 38,457 visitors in FY 2017. The Outreach and Education Office supervised the exhibition "Elements of Things - How We are Made - (July 2017 - June 2018)." We also cooperated with an opening ceremony, modern and traditional Tanabata events, moon viewing event, and other events. In addition, through the "Mitaka Picture Book House in the Astronomical Observatory Forest, Picture Book Original Drawings Hallway Exhibit Contest" which started from FY 2013, the Outreach and Education Office cooperated in the selection of 6 winning books.

The Outreach and Education Office conducted the 9th "Mitaka Solar System Walk" from September 22 (Fri) to Sunday, October 22 (Sun) in cooperation with Mitaka City and the non-profit organization (NPO) Mitaka Network University. Stamps were placed at 246 shops and facilities around Mitaka City. Adding 18 limited event stamps, 264 stamps were placed and this is a record number. Approximately 20,000 guide-maps/stamp sheets were distributed, of which 3,256 people turned theirs in for a prize. The number of participants who collected all the stamps was 380. It was a good chance to tour the Solar System while promoting commerce, industry, sightseeing and providing people a way to enjoy Mitaka and rediscover the city's charm.

The Office also provided the venue for "Astronomy Course for Apprentice Starry Sky Guides, Star Sommelier Mitaka - Let's Become Apprentice Starry Sky Guides! - " hosted by Mitaka Network University and also assisted by providing teachers and workshops.

The "Information Space of Astronomy and Science" for which Mitaka City, Mitaka Network University, and Mitaka City Planning Board co-operate celebrated the third year since its opening and 7 exhibitions were held in FY 2017. The Public Relations Center had proposed 2 of these exhibitions and helped with 3 lectures. Also, the office offered outreach and monthly astronomical information images through large-scale information displays and "Cosmic Reading Bookstore Corner," a display of sample books available to read which changes themes (once every 2 months), and cooperated on the

	Solar Ephemeris	Lunar Ephemeris	Ephemeris	Time	Solar System	Universe	Astronomy	Other	Total
April–June	134	101	35	7	158	120	97	577	1229
July–September	127	90	49	5	176	108	103	677	1335
October–December	163	137	44	8	198	103	89	581	1323
January–March	157	258	38	5	126	110	97	642	1433

Table 5: Telephone inquiries made to the Outreach and Education Office of the NAOJ Public Relations Center (April 2017–March 2018).

"M Marche Project" conducted on the 4th Sunday of every month. We welcomed 11,062 guests in the 2017 fiscal year and celebrated 40,000 visitors since the opening. It has been acknowledged as a location in town where science can be easily accessed.

(5) Merchandizing Business

Continued from the last fiscal year, the Office cooperated with merchants who organized the NAOJ original goods and aided in making them. Especially this year, there was a new effort that made use of NAOJ's intellectual property such as packaged products of teaching materials developed for Astronomy Classes for Kids in Summer. In addition to vending machines dispensing capsule toys which are already in place, the office invited the merchants to place a "Jumbo Carddass Machine," so that they can sell photo cards. The office contributed to placing the sales location at the Mitaka Open House Day and Special Open House Day for Nobeyama Radio Observatory. A total of 1,424 items of these goods were sold in the fiscal year. In order to share information on merchandizing know-how, we invited the public relations specialists of each project to a meeting and exchanged opinions about NAOJ original goods, which are spreading to all projects.

(6) International Activities

NAOJ and Leiden University (the Netherlands) co-organized "Astronomy Museums, Visitor Centres & Public Observatories Workshop" at Leiden University from September 27 to September 29, 2017. This workshop is about the activities of astronomical museums, visitor centers, etc., and was conducted at NAOJ Mitaka Campus for the first time in September 2015. We plan to hold it every two years and this is the second time that it had been held. About 30 people participated and there were 25 lectures, workshops, etc.

In cooperation with IAU/OAD (South Africa), Leiden University and others, we are proposing and discussing about making the international guidelines on astronomy education with the IAU executive department and commission C1.

From March 24 to March 28, 2018, NAOJ and Fukuoka City co-hosted CAP2018 (Communicating Astronomy with the Public 2018) at the Fukuoka City Science Museum with 446 participants from 53 countries. The CAP2018 main theme was "Communicating Astronomy in Today's World: Purpose & Methods." This edition was the largest CAP Conference ever. The conference hosted 5 plenary sessions with 24 plenary talks, 141 parallel sessions, including a planetarium session; 24 workshop sessions with 20 unique workshops, 111 posters, and a special session dedicated to the 100 Year Anniversary of the IAU.

5. Ephemeris Computation Office

The Ephemeris Computation Office (ECO) estimates calendrical phenomena such as the apparent positions of the Sun, Moon, and planets on the basis of international standards and publishes the "Calendar and Ephemeris" as part of the compilation of almanacs, which is one of NAOJ's raisons d'être.

(1) ECO published the 2018 edition of the Calendar and Ephemeris, the 2018 version of the calendrical section of the Rika Nenpyo (Chronological Scientific Tables), and the 2019 edition of the Reki Yoko (posted in the official gazette on February 1, 2018). The Calendar and Ephemeris webpage was 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), ECO continuously updated the contents of the Ephemeris Wiki and worked on checking the accessibility sequentially. ECO cooperated with the astronomical phenomena awareness campaigns again this year. The radiant points of the Perseid and Geminid meteor showers were published in the Astronomical Information section of the website. There were about 25 million page views for this fiscal year.

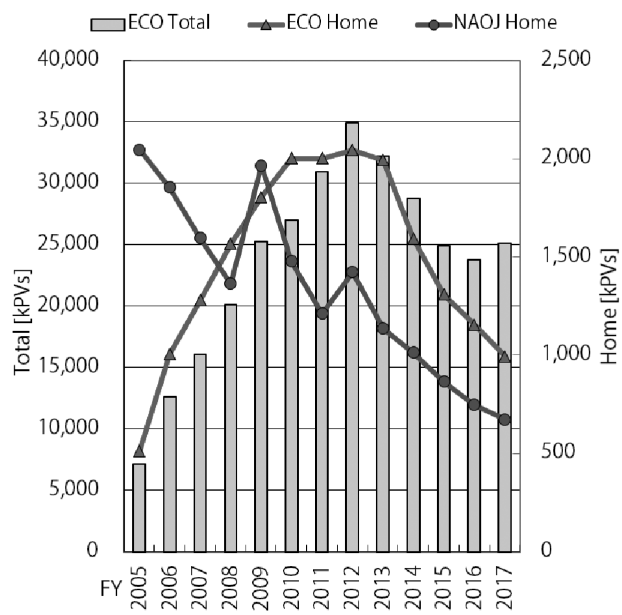

Figure 1: Pageview Statistics of ECO Website.

(3) The Japan Association for Calendars and Culture Promotion hosted Calendar Culture Mini Forum, its 7th General Meeting, and the Calendar Presentation Ceremony.

(4) ECO hosted regular exhibitions in collaboration with the Library, selecting from NAOJ's invaluable collection of historical archives for Japanese and Chinese books. The theme of the 56th permanent exhibition was "Achievements of Sekisui Nagakubo." This exhibit 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).

6. Library Unit

The Library Unit collects and sorts scientific journals and books in order to make them available for the research and study of NAOJ researchers and students. In recent years, with the continuing digitalization of scientific materials, the portion of the materials in electronic format has increased.

For non-NAOJ personnel who wish to use the Mitaka Library materials, the Library is open to the public on weekdays. In FY 2017, 232 non-NAOJ personnel came to use the Library. Also for researchers and students belonging to other organizations, we loan books or provide photocopies via the institute's library. In FY 2017, photocopies or loans were provided in a total of 93 cases.

Important documents, especially those originating from the Edo Era Tenmonkata (Shogunate Astronomer), are preserved while taking into account the environment of a specialized library. Images of some of the important documents are available to the public on the Library Unit homepage.

On June 1, 2017, the Unit updated the library information system. This improved the convenience of the Online Public Access Catalog (OPAC).

During the Mitaka Open House Day festivities in October, we opened part of the Mitaka Library to the public as in the past. We extended the subject themes again as we did in Fiscal Year 2016. In addition to materials for general and young readers, we actually allowed visitors to take a look at many specialized books related to astronomy.

The number of books and journals owned by Mitaka Library and each observatory and the condition of continuing NAOJ publications are published in Section XI Library, Publications.

7. 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:

- Annual Report of the National Astronomical Observatory of JAPAN Volume 29 Fiscal 2016 (Japanese)
- Annual Report of the National Astronomical Observatory of JAPAN Volume 19 Fiscal 2016 (English)
- Report of the National Astronomical Observatory of JAPAN Volume 19 (Japanese)
- Publication of the National Astronomical Observatory of JAPAN Volume 14
- NAOJ Pamphlet (Japanese)
- NAOJ Pamphlet (English)
- NAOJ News, No. 285 – No. 293 (April 2017 – March 2018)
- NAOJ Calendar (The 13th in the series)
- Radio Astronomy Public Relations Comic "ALMAr's Adventure" (#7)
- NAOJ Publicity Poster Series (#7 and #8)

Continuing from the previous year, the Publications Office strove to strengthen its international publication ability and digital publication ability. Regarding the production of an international edition of the Rika Nenpyo (Chronological Scientific Tables), we finished proofreading and we are in the final editing process. In digitalization efforts, we expanded the Publications Office's digital publication website for e-books and prepared for publication of contents by categorizing them into "public relations," "science writing," "academic," and "general." In normal business, the Office produced and distributed the Annual Report of the NAOJ, Publication of NAOJ, and the NAOJ pamphlets. In particular, the Office promoted multilingualization of the pamphlet, produced a Spanish version in addition to Japanese and English, prepared data for Chinese and Korean versions, and prepared to publish five language versions in total.

In the systematic production of special editions with the goal of developing project outreach support in NAOJ News, extra copies of each of the special editions ("People Advancing the TMT Project Vol. 02 Special Edition" April; "People Advancing the TMT Project Vol. 03 Special Edition" November; "CfCA Special Edition" October; and "Okayama Astrophysical Observatory Special Edition" March 2018) were printed and these aided the outreach efforts of each project. From now on, to develop and share NAOJ News articles as a resource to be used as outreach content for each project, we plan to promote the production of overall, basic articles through close cooperation with researchers and promote international magazine compiling. Other than periodicals, the 2018 calendar "Okayama Astrophysical Observatory" (the 13th since 2005) was created. The Office provided native check services to the Public Relations Office; CfCA; the Graduate University for Advanced Studies; the NAOJ Directorate, and CAP2018 for English language publications, contributing to the expansion and enhancement of NAOJ's international information dissemination. In addition, like in other years editing support was also given to the publication of the "Rika Nenpyo 2018 (Chronological Scientific Tables, Astronomy section)."

8. International Astronomical Union Office for Astronomy Outreach (IAU/OAO)

International Astronomical Union (IAU) Office for Astronomy Outreach (OAO) is tasked to communicate with and manage National Outreach Contacts (NOC's, windows for outreach in each country) as a priority issue. The Office also started to discuss new selection methods and guidelines for NOC's in order to smoothly and continuously develop the NOC activities in each country.

In FY 2017, the editing and publishing of the CAP journal returned from the European Southern Observatory (ESO) to NAOJ for the first time in four years. Journal #23 was issued in February 2017 and 2,700 copies of the printed edition were distributed, mainly overseas. The online edition can be freely browsed at the IAU web page.

For international information provision, the office posted a total of 460 postings from OAO on IAU social media during FY 2017. The Facebook community grew by 23 % and the Twitter community by 22 %. Meanwhile, the IAU Astronomy Outreach Newsletter (e-mail news) was delivered 24 times and 300 items of information were provided to 4,600 subscribers all over the world. The newsletter has been translated and redistributed into four different languages by collaborators in the respective countries. The Office is also responsible for making the website contents (Themes) of the IAU website for the Public.

We are promoting the Astronomy Translation Network (translation work by volunteer network) as an NAOJ proposal project for OAO activities. There are 144 registered volunteers and five working groups (Indonesian, Portuguese, Chinese, Spanish, and French) have started work for each language.

For the international conference CAP2018 in Fukuoka, the OAO Coordinator participated in the operation as one of the Co-Chairs of the Science Organizing Committee, and the OAO Sub-Coordinator was in charge of public relations and making the proceedings as the Vice-Chair of the Local Organizing Committee. For the details of the conference, please refer to the section of the Outreach and Education Office, which hosted the conference.

In addition, OAO participated in the "Strategic Plan 2020–2030," IAU's plan for the next ten years, during FY 2017. In cooperation with the IAU 100 Secretariat established at the IAU secretariat and Leiden University, OAO is preparing the IAU 100 project as one of the implementing organizations of the IAU 100 anniversary project in 2019.

In cooperation with the Outreach and Education Office, NARIT (Thailand), and IAU/OAD, we held the "You are Galileo!" workshop at the University of Mandalay (Myanmar) on November 29–30, 2017.

17. Division of Optical and Infrared Astronomy

1. Overview

The primary objectives of divisions in NAOJ are facilitating and invigorating projects and individual research through personnel exchanges to place researchers in environments more suitable for their individual projects. While pursuing challenging exploratory research on observation and development, the Division furthers these goals by launching new projects as necessary. The Division also actively engages in graduate education efforts to foster next-generation talent. These activities are based on the concept that the Division of Optical and Infrared Astronomy is a center for personnel exchange between Subaru Telescope, which engages in open use, and universities and research institutes in Japan, which focus on developmental research into new instruments and observational research. This fundamental principle has been developed since the Subaru Telescope was constructed.

The Division of Optical and Infrared Astronomy oversees OAO (Okayama Astrophysical Observatory) and Subaru Telescope (C Projects); the TMT-Japan (TMT-J) Project Office and the Gravitational Wave Project Office (B Projects); and the JASMINE Project Office and the Extrasolar Planet Detection Project Office (A Projects). The Extrasolar Planet Detection Project Office migrated to the Astrobiology Center of the National Institutes of Natural Sciences on December 31, 2017. This transition extends its vision to explore "life in the Universe" and uncover its mysteries. Most of its members concurrently held positions of the Division. The Division and the Projects carry equal weight in organizational terms. Almost all NAOJ members in optical- and infrared-related fields have positions in the Division with either the Division or one of the A, B, or C Projects as the primary appointment. At times, they may also have concurrent positions in other projects. The primary staff of the Division of Optical and Infrared Astronomy in FY 2017 consisted of one professor, five assistant professors, four research affiliates, and three JSPS postdoctoral fellows.

The Division coordinates educational, research, and administrative activities for Subaru Telescope Mitaka Office and the Extrasolar Planet Detection Project Office. Since personnel transfer often occurs within the Division of Optical and Infrared Astronomy, the Division plays an increasingly important role in coordinating between Subaru Telescope and the TMT-J Project Office. The Division as a whole maintains and operates facilities which are auxiliary to research, such as mailing lists and web servers for Division of Optical and Infrared Astronomy-related projects such as Subaru Telescope, TMT-J, the Extrasolar Planet Detection Project Office, Gravitational Wave Project Office, and JASMINE Project Office. The remainder of this report will focus on the research projects conducted by the primary staff of the Division of Optical and Infrared Astronomy and the activities of projects that support open use.

2. Observational Research

(1) Observational Research Using Various Types of Telescopes

Observational research utilizing the Subaru Telescope focuses on a wide variety of fields such as cosmology; galaxy formation and evolution; the formation of stars and planets; the structure and evolution of the Milky Way; stellar spectroscopy; Solar System bodies; and the search for exo-planets.

Optical and Infrared Synergetic Telescopes for Education and Research (OISTER) is a NAOJ-lead initiative to form a network of small aperture size, 0.5 meter to 2.0 meter, telescopes owned by universities around Japan and overseas to promote Time Domain Astronomy research and graduate level astronomy education. FY 2017 marked the achievement of one of the most important objectives, successful observations of a gravitational wave source (GW170817). A result of Time Domain Astronomy research by OISTER was presented in a “You are Galileo!” workshop.

With great help from both Subaru Infrared Camera and Spectrograph (IRCS) and the second-generation adaptive optics (AO188) high angular resolution observations for star-forming galaxies at z~2.5 were realized in order to investigate their internal structures. By combining adaptive optics (AO188) and narrow-band filters, spatially resolved maps of star-forming regions within galaxies were obtained. Observation of extended ionized gas in a cluster of galaxies with the Subaru Telescope was also conducted.

Utilizing the Sloan Digital Sky Survey (SDSS) catalogue, four scientific reports were published. Two of them focused on low-ionization broad absorption line quasars. The third shows evidence for higher black hole spin in radio-loud quasars. This result was made into an NAOJ press release with the help of NAOJ’s Public Relations Office. The fourth report focused on the quenching of super massive black hole (SMBH) growth. This shows the first observational evidence that the number fraction of radio-loud quasars increases with the mass of the SMBH’s above a critical BH mass of $2 \times 10^9 M_\odot$.

The dust torus cooling timescale once the active galactic nucleus (AGN) is quenched was estimated. The dust torus emission completely disappears within 100 years for most of the AGN luminosity range.

Combining data from the Gemini optical and NuSTAR X-ray observatories, a study on the relevance of the nuclear geometrical structure of the AGN to the extension of ionized gas on host galaxy scales was conducted. Based on ALMA submillimeter/millimeter and Chandra X-ray data, observational study on an active galactic nucleus (AGN) was conducted, particularly focusing on the effects of its X-ray radiation on the surrounding interstellar media.

A study on protoplanetary disks by using both Subaru and ALMA observations is on-going. An observational proposal to ALMA was approved. Now the obtained ALMA data are being analyzed.

(2) International Cooperative Observational Research

The Division also engages in international collaborative studies with overseas researchers.

Site survey for a future large infrared telescope in the western Tibet area was continued in cooperation with the National Astronomical Observatories and Chinese Academy of Sciences (NAOC). Based on past meteorological data in China, clear-sky probabilities in the area were evaluated. This result was presented in the NAOJ Symposium on Engineering in Astronomy 2017.

A study on extended ultraviolet regions around galaxies continues with researchers in the USA.

(3) Research Using Archives

The image data of all Kiso Ultraviolet-Excess Galaxies were released on the website of Kiso Observatory, University of Tokyo. A paper on this work was published. Digitization of Kiso Schmidt plates continued. As of the end of FY 2017, we have scanned 2393 plates out of about 7000 plates, together with some special project plates. These data are archived in the Astronomical Data Archive Center (ADAC), NAOJ, and will be opened for public access.

Research on the verification of astronomical phenomena described in the New Testament is being done jointly with the National Institutes for the Humanities. Studies of astronomical phenomena based on other old ephemerides and documents are continuing.

A study on the relics of past interaction in the outskirts of nearby galaxies was conducted.

3. Observational Instrument Development

Studies of coronagraph masks for the Subaru Telescope and WFIRST were conducted.

The Infrared Doppler Instrument (IRD) at Subaru Telescope was developed and engineering runs were conducted with a laser frequency comb system as a spectrograph drift calibrator.

One of the topics of interest is the search for the undiscovered “axion,” a dark matter candidate. An axion will interact with a magnetic field and create a photon. To investigate this phenomenon both laser interferometric techniques and long superconducting magnets are powerful tools. A joint NAOJ and KEK group has started to discuss this experiment.

The analysis of ghosts in Hyper Suprime-Cam continued.

For the Hosei Twin Astronomical Telescopes (HOTATE), we supported observations, improvement, and the construction of the data archive.

4. Operational Support for Subaru Telescope

The Division of Optical and Infrared Astronomy offers support for the open use of the Subaru Telescope. This includes organizing open calls for open-use programs, program selection, administration, management of open-use-related travel expenses, and promoting PR activities for Subaru Telescope. The Division also provides support for various research conferences held at Mitaka Campus.

5. Research Environment Maintenance

A web server has been maintained for research activity PR. In this year both the web server and the mailing-list server were replaced with new hardware. And also the web contents were restructured to improve robustness.

The Division manages the printers and rented multi-function photocopiers; sub-networks; and data backup servers for Subaru Telescope Mitaka Office as part of its efforts to maintain the research environment, and also gives assistance for setting-up computers for new administrative supporters.

6. PR, Outreach, and Discoveries of New Astronomical Objects

The Division cooperates with the Public Relations Center in supporting matters related to discoveries of new astronomical objects and PR/outreach activities such as web releases and press conferences related to Subaru Telescope research results.

The Division actively participates in a special public event held at Mitaka Campus (Mitaka Open House Day).

To introduce the activities of the Division of Optical and Infrared Astronomy, we contributed to the Symposium of the Inter-University Research Institute Corporations in 2017.

7. Contributions to International Committees and Events

As a cooperative program between EACOA (East Asian Core Observatory Association) and SEAAN (South-East Asian Astronomy Network), the “You are Galileo!” workshop was held at Mandalay University, Myanmar on November 29 & 30, 2017.

NAOJ, with Hyogo University, conducts a joint program with the National Astronomical Observatory of Vietnam, Nha Trang to strengthen our research and education capabilities.

8. Hosting Scientific Conferences and Meetings

Department members contributed as SOC and LOC co-chairs to the East Asian Young Astronomers Meeting (EAYAM) 2017 in Ishigaki Island.

The 8th OISTER workshop was held at NAOJ Mitaka Campus on December 14 & 15, 2018.

9. Visitors

The OISTER program conducted short-term visiting observation training courses for 14 graduate students. In March 2018, researchers from Hyogo University and NAOJ visited Nha

Trang and one researcher from Vietnam came to Japan for the observation programs. Prof. Xue-bing Wu in the Kavli Institute for Astronomy and Astrophysics at Peking University visited NAOJ. Prof. Jin Koda of Stony Brook University also visited.

10. Educational Activities

The Division of Optical and Infrared Astronomy provides postgraduate education to 20 graduate students from the Graduate University of Advanced Studies, the University of Tokyo, Tokyo University of Agriculture, and Japan Women's University.

Division staff members made active contributions to seminars and self-directed studies. Since April 2015 we have held a 30-minute seminar in the afternoon every day throughout the year. In December, we held the annual workshop of the Division of Optical and Infrared Astronomy so that staff members and graduate students can understand the current studies and interests of each other.

18. Division of Radio Astronomy

The Division of Radio Astronomy oversees Nobeyama Radio Observatory, Mizusawa VLBI Observatory, the RISE Lunar Exploration Project, and NAOJ Chile Observatory operating the Atacama Large Millimeter/submillimeter Array (ALMA) and Atacama Submillimeter Telescope Experiment (ASTE). The scientists and engineers of these projects are attached to the Division of Radio Astronomy to conduct radio astronomy research under mutual cooperation among these radio astronomy projects. The research themes of the Division of Radio Astronomy are represented by keywords such as Big Bang, early Universe, galaxy formation, black holes, galactic dynamics, star formation, planetary system formation, planets and satellites, the Moon, the evolution of interstellar matter, and the origin of life in the context of the evolution of the Universe. Radio astronomy unravels mysteries and phenomena in the Universe through radio waves, which are invisible to human eyes. The detailed research results are reported in each project's section and in the research highlights. The Radio Astronomy Frequency Subcommittee has been established within the division, engaging in discussions on protection against artificial interference generated by electrical equipment, which causes major obstacles in radio astronomical observations.

1. Radio Astronomy Frequency Subcommittee

The mission of the Radio Astronomy Frequency Subcommittee is to protect the environment for radio astronomy observations. In 1932, Karl Jansky of the U.S.A. first discovered radio waves emitted by astronomical objects, albeit accidentally. Since then, dramatic advances have been made in radio observation methods, showing us new perspectives of the Universe invisible at the optical spectrum. Four Novel Prizes have been awarded to achievements made in the field of radio astronomy so far.

Just as light pollution from artificial light sources is an obstacle in optical observation, artificial radio interference generated by the electronic devices surrounding us is a major obstacle in radio observations. As breathtaking advancement has been achieved in wireless communication technologies in recent years, wireless commercial products such as mobile phones, wireless LAN's, and automotive radars are widely used. The areas of radio applications will continue to expand in the future owing to their ubiquitous nature. But because of its unique capabilities, compatibility among various radio services, including both active and passive ones, will become a serious issue. Frequency is a finite resource and its sharing is an unavoidable issue. Therefore, further efforts will be necessary for maintaining the sky free from artificial interference for better radio astronomy observations.

(1) Role and Organization

The purpose of the Radio Astronomy Frequency Subcommittee is to ensure that radio astronomical observations are free from artificial interference and to raise public awareness of the importance of 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 in Japan and internationally by the International Telecommunication Union (ITU) Radiocommunication Sector (ITU-R) of the United Nations. As part of the activities for FY 2017 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:
After the Great East Japan Earthquake in 2011, risk of radio interference has been increased by new wireless communication services prepared for natural disasters.

• Development of new radio applications:
There has been a rapid increase in demand for higher frequencies. 76 GHz automobile radars become common. Wide band radars up to 81 GHz may become more popular as they may reduce car accidents resulting in injury or death. It is anticipated that industrial structures will dramatically change with the advent of the fifth generation mobile phone technology allowing high-speed, multiple concurrent connections, and ultra-low latency, which will be installed into various mobile phones. Some satellite operators launched new plans for improving broad-band communication to ships and planes globally.

• Reassigning of vacant frequency bands resulting from enhanced efficiency in radio use:
The digitization of television broadcasting has created vacant frequency bands, which have been reassigned for mobile phones and other applications.

The effect of interference arising from such radio applications (e.g. wireless business) varies widely depending on the frequency band used. Radio astronomy observations have been given priority in a number of frequency bands within the range between 13.36 MHz and 275 GHz under the ITU Radio Regulations (RR). However, negotiations will be necessary between some radio services and radio astronomy if the same priority level is to be shared within a certain band or under adjacent/proximity conditions. Even faint signals of negligible significance to general radio services, 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; 1.6 GHz mobile satellite phones for emergencies, where the observation of pulsars and the like are affected; the fifth generation mobile phones, where silicon monoxide (SiO) maser observations are affected by the 43.5 GHz band (one of the candidate frequency bands); and Ka-band broad-band communication from airliners to satellites, where water maser observations are affected. 79 GHz automotive radars around Nobeyama Radio Observatory have considerable impact on the observing conditions. Although radio astronomy observations in the 60 GHz band are not common because of the high rate of absorption in the atmosphere, the 60 GHz system must be watched closely because its second harmonic can have adverse effects on CO observations in the 115 GHz band.

(3) International Activities

The ITU Radio Regulations (RR), which allocate radio frequencies to wireless applications, are revised once every three to four years in the World Radiocommunication Conference (WRC). The RR includes frequency bands in which radio astronomy observation is prioritized. Among these meetings, the Radio Astronomy Frequency Subcommittee is regularly involved in the WP7D (radio astronomy) and WP1A (frequency management) meetings. The Subcommittee also takes part in various international conferences, representing the Japanese community of radio astronomy researchers.

In FY 2017, the Subcommittee participated in the ITU-R WP7D meetings held in April and October in Geneva. In these meetings, the following items were discussed as major agenda items related to radio astronomy: modernization of Global Maritime Distress Safety Systems (GMDSS) utilizing 1.6 GHz satellite communication; upgrades of the maritime radio communication system utilizing the 160 MHz maritime mobile-satellites, establishment of a correspondence group for compatibility studies to ensure compatibility between vehicle radars and radio astronomy, identification of frequency band candidates for the new International Mobile Telecommunications (IMT2020), and so on. The WRC-19, which is scheduled for 2019, aims to identify frequency bands for IMT2020 from 11 candidate frequency bands ranging from 24 GHz to 86 GHz and to allocate active services to frequencies above 275 GHz.

(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 with wireless operators regulated by the MIC, and informative activities 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 to formulate Japan's strategies on various wireless issues for international conferences. Other MIC-related meetings provide opportunities for discussing the radio application technologies related to MIC's wireless policy, and for negotiating on interference issues with wireless operators authorized by MIC. Negotiations directly affecting the protection of radio astronomy observations have been conducted concurrently to dealing with the interference problems related to societal and technological trends.

Several examples of the interference problems discussed in section (2) above are given below.

In November 2015, WRC-15 resolved to allocate 77.5–78 GHz to the radiolocation service, allowing automotive vehicles to utilize the whole 76–81 GHz band for their radar, which may invite large scale commercial use of high-resolution automobile radars in the 76 GHz and 79 GHz bands. Of particular concern are the possible effects of interference from these radars on the 45-m radio telescope at Nobeyama Radio Observatory, which engages in observations of spectral-lines of deuterated compounds and other molecules in interstellar matter. The observations with the Nobeyama 45-m Radio Telescope located in Japan will continue to carry significance in relation to the international project ALMA, which deploys 66 high-performance radio telescopes at an altitude of 5,000 m in Chile. Since automotive radars are highly relevant to human life safety, negotiations have been conducted with careful analysis in order to reach a mutually acceptable agreement.

A new radio wave application is being planned for 21 GHz next-generation satellite broadcasting with a picture resolution 16-fold higher than that of the current HDTV. This band is near the 22 GHz radio astronomy band, which is important for water maser observation. The radio signals from the satellite come from outer space. Their detrimental effects need to be alleviated with a filter at the output stage of the satellite. The NHK Science & Technology Research Laboratories developed a bandpass filter to suppress spurious signals to an acceptable level. The measurement results of radio emissions from the satellite launched in December 2017 verified that the filter has a proper protective effect against radio interference.

Radio observations in the 60 GHz band are not common because of the high atmospheric absorption rate in that frequency range. Albeit in fact, the 60 GHz system must be watched closely in terms of its proliferation in the market, since interference from it may affect CO observations in the 115 GHz band, which is within the band of the second harmonics of the 60 GHz radio system.

In response to the update plan of the satellite systems announced by Iridium LLC (U.S.A.), the committee started discussions aiming to reduce radio interference risks caused by unwanted emissions from the 1.6 GHz signal to the astronomy band (OH maser observations). Discussions are being held on what interference risks are involved and what measures should be taken to alleviate radio interference.

The World Radiocommunication Conference (WRC) will determine the frequency band for the next-generation mobile phones in 2019. The MIC organized a joint working group with some radio services and organizations including the Radio Astronomy Frequency Subcommittee. The Subcommittee played an active role in preparing a joint study report regarding the 11 candidate frequency bands given in the WRC-19 Agenda Items.

Additionally, radio astronomy observations could be adversely affected by some of the new wireless technologies: wireless power transmission (WPT) for electric vehicle energy charging (non-beam), next generation railway radio communication systems between bullet trains and trackside, and so on. The Subcommittee continues to monitor their progress and shares the information with related radio astronomers.

Moreover, the Subcommittee has been engaged in making applications to the MIC to request frequency protection for the NAOJ telescopes as well as other telescopes owned by the Japanese community of radio astronomers on their behalf.

Collecting actual interference cases at various observatories 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 materials for the general public. As optical astronomers are actively working to protect 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.

19. Division of Solar and Plasma Astrophysics

The Division of Solar and Plasma Astrophysics is mainly made of staff members from the Solar Science Observatory and the Solar-C Project Office. It conducts research on the Sun in close coordination with these projects. An NAOJ fellow and graduate students supervised by the staff of the above-mentioned projects also belong to the Division.

The Division conducts both theoretical and observational research into the inner structure of the Sun and outer solar atmosphere including the photosphere, chromosphere, corona, and solar wind; and various phenomena in the magnetized plasma such as flares, sunspots, solar faculae, and prominences. The Division's theoretical research includes helioseismology studies of the internal structure of the Sun, and applications of plasma physics and magnetohydrodynamics to various phenomena on the Sun as well as on Sun-like stars. The solar group at NAOJ started observations from space in the very early stages of Japan's space program. The Division has participated in the development of the Hinode satellite, which is currently in orbit, and is playing a major role in its scientific operation. Research is also being carried out using the Solar Flare Telescope and other telescopes in Mitaka Campus. In ground based observations, the Division conducted research to introduce and utilize new technologies in the Solar Flare Telescope and has been conducting long-term monitoring observations of solar activity, and the obtained data are open to the community.

1. Research in Solar Physics

NAOJ fellow S. Toriumi published one paper in a refereed journal as lead author. This work is about the numerical MHD modeling of flare-productive active regions, and he revealed the evolution processes by which subsurface magnetic fields create magnetically energetic active regions above the surface. He also published three refereed papers as a co-author, including for example, theoretical investigations of the relationship between flare durations and magnetic structures, and research related to 18th Century Japanese sunspot sketches. Toriumi has been promoting collaborative research with international partners; he invited Dr. V. Pipin of the Institute of Solar-Terrestrial Physics, Russian Academy of Sciences, and conducted collaborative research on solar-stellar dynamos and starspots.

The Division has a seminar (on Friday afternoon, roughly twice a month) whose speakers are from both inside and outside of the Division. The organizer for this year was S. Toriumi.

2. Educational Activities

The teaching staff of the Division supervised three graduate students from SOKENDAI (the Graduate University for Advanced Studies) and one from the University of Tokyo. Among them, Y. Hatta passed the examination for the Master's thesis. The Division, in cooperation with Kyoto University and Nagoya University, supported the annual "Leading-edge Solar Research-Experience Tour" in March for undergraduate students; nine students visited solar-related research organizations and experienced the latest research in the field.

3. International Cooperation

Y. Katsukawa has been a member of the Science Working Group of the Daniel K. Inouye Solar Telescope, a 4-m telescope under construction at Haleakala, Hawai`i. In Europe, another 4-m solar telescope is now in the planning stage. NAOJ sent a Letter of Intent and is watching the progress. Several plans are also under consideration for future ground-based telescopes that would involve collaborations with East Asian countries and Peru.

20. Division of Theoretical Astronomy

1. Overview

The Division of Theoretical Astronomy (DTA) aimed at achieving internationally outstanding research results both in quality and quantity toward the accomplishment of the following four goals that were set by the NAOJ Board, and is engaged in research activities for FY 2017 accordingly:

- Advance the world class cutting-edge theoretical research.
- Pursue theoretical astronomy research, particularly in areas that utilize the NAOJ supercomputer or large-scale observational instruments to give further insight into their new development.
- Encourage collaborations among researchers in Japan and strengthen the 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 physical state of matter, covering a span from the early Universe to galaxies, stars, planetary formation, activities of compact objects, and plasma phenomena in astronomy and astrophysics; joint research with observational astronomy using observational facilities of various frequency bands such as the Subaru, ALMA, and Nobeyama radio telescopes; and interdisciplinary research with physics of elementary particles and atomic nuclei.

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. 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, and it leads research activities in various related fields of astronomical science. 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, and the Graduate School of Japan Women's University.

2. Current Members and Transfers

In FY 2017, the dedicated faculties of the Division of Theoretical Astronomy included two professors, two associate professors, and four assistant professors in addition to one adjunct professor and one adjunct assistant professor who concurrently held primary positions at the Center for Computation Astrophysics. In addition to these research and educational members, the division was served by four project assistant professors, including one research associate, two JSPS fellow, one EACOA fellow, and in addition one administration associate who gave full support to all activities of the division. Among them Akimasa Kataoka, an assistant professor, joined our division from December in 2017, Ken Ohsuga, an assistant professor, moved to Tsukuba University as a professor, and Masaomi Tanaka, an assistant professor, moved to Tohoku University as an associate professor at the end of March in 2018.

3. Research Results

The research papers and presentations in the international conferences carried out by the division member(s) as author(s) or presenter(s) are listed below. Categories with fewer than 5 publications have been omitted.

- Peer-reviewed journal papers in English: 117
- Journal papers in English (proceedings of the meetings): 10
- Reports in English (talks at international conferences): 50 (invited talks: 21)
- Reports in Japanese (talks at national meetings, etc.): 34

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:

- General Relativistic Radiation MHD Simulations of Supercritical Accretion onto a Magnetized Neutron Star: Modeling of Ultraluminous X-Ray Pulsars (Takahashi, H. & Ohsuga, K.)
- Superluminous transients at AGN centers from interaction between black hole disk winds and broad-line region clouds (Moriya, T., Tanaka, M., Ohsuga, K. et al.)
- Big Bang Nucleosynthesis and Modern Cosmology (Kajino, T. et al.)
- Big-Bang Lithium Problem, and Effects of Long-Lived Negatively Charged Massive Particles on Primordial Nucleosynthesis (Kajino, T. et al.)
- The new hybrid BBN model with the photon cooling, X particle, and the primordial magnetic field (Kajino, T. et al.)
- Production of Left-handed Amino Acids in Space in the Supernova Neutrino Amino Acid Processing (SNAAP) Model

(Kajino, T. et al.)
- Selection of Amino Acid Homochirality in Stellar Environments (Kajino, T. et al.)
- Short-baseline electron antineutrino disappearance study by using neutrino sources from $^{13}C + {}^{9}Be$ reaction (Kajino, T. et al.)

The following research results are released on the division's website (http://th.nao.ac.jp/) as research highlights:

- Rare first moment of stellar explosion captured by amateur astronomer (Tanaka, M., Moriya, T. et al.)
- Discovery of a supernova beyond the standard explosion paradigm (Moriya, T. et al.)
- Astronomers Follow Gravitational Waves to Treasure (Tanaka, M. et al.)
- Surface Helium Detonation Spells End for White Dwarf (Tanaka, M. et al.)
- The effect of collective neutrino oscillations on νp process nucleosynthesis (Sasaki, H., Kajino, T. et al.)
- Efficiency of Metal Mixing in Dwarf Galaxies (Hirai, Y., Kajino, T. et al.)
- ALMA polarization observation of the protoplanetary disk around HL Tau (Kataoka, A. et al.)
- First Global Simulation Yields New Insights into Ring System (Kokubo, E. et al.)

4. Domestic Collaborations

The Division of Theoretical Astronomy played leading roles in organizing the following domestic conferences:

- Symposium on "Stellar formation and the role of magnetic field in Galactic structure formation," Kagoshima University, December 20–22 in 2017. (Participants; 45)
- 7th TDA Symposium on "Neutron Stars: Theory and Observation," NAOJ Mitaka, November 22–24 in 2017. (Participants; 67)
-30th RIRONKON Symposium on "Beyond the Horizon of Stellar Astrophysics," University of Tokyo Hongo, December 25–27 in 2017. (Participants; 182)

Toshitaka Kajino performed duties as a chairman of Japan Forum of Nuclear Astrophysics for planning and managing international and domestic conferences related to cosmo-nuclear physics and promoting research collaboration in related fields such as astronomy, astrophysics and nuclear physics in Japan.

5. International Collaborations

Eiichiro Kokubo served on the organizing committee of Commission A4 (Celestial Mechanics and Dynamical Astronomy) of IAU.

Toshitaka Kajino performed duties of the following posts: international referee for the Science, Technology and Innovation Council of Canada; international referee for Partnership for Advanced Computing in Europe (PRACE); international associate for the European Centre for Theoretical Studies in Nuclear Physics and Related Areas (ECT*); and international referee for the Swiss National Science Foundation (SNSF).

The Division of Theoretical Astronomy played leading roles in organizing the following international conferences:

- 14th International Symposium on "Origin of Matter and Evolution of Galaxies," Institute of Basic Science in Daejeon, Korea, June 26–29 in 2017. (Participants; 110)
- International Symposium on "Cosmic Dust X," NAOJ Mitaka, August 14–18 in 2017. (Participants; 55)
- International Symposium on "Stellar Evolution, Supernova and Nucleosynthesis Across Cosmic Time," University of Tokyo, Kavli Institute, September 19–29 in 2017. (Participants; 56)
- East-Asian AGN Workshop 2017, University of Tokyo, Kagoshima University, December 4–6 in 2017. (Participants; 107)
- International Workshop on "Impact of Exotic Nuclear Structure on Explosive Nucleosynthesis," Beihang University, China, November 22–24 in 2017. (Participants; 59)
- International Workshop on "WFIRST-Subaru Synergistic Observations," NAOJ Mitaka, December 18–20 in 2017. (Participants; 88)
- International Symposium "GWASNe2018," NAOJ Mitaka, January 29–31 in 2018. (Participants; 44)
- The 8th DTA Symposium on "Challenge to super-Earths and their atmospheres," NAOJ Mitaka, March 6–8 in 2018. (Participants; 41)

6. Educational Activities

The lecture subjects are listed below to supplement Section III on activities of research and educational adjunct lecturership at the high schools, universities, and graduate schools:

- Eiichiro Kokubo: Earth and Planetary Science I at the University of Tokyo; SSH lecture on The Earth in the Universe at Hibiya high school.
- Haruo Yoshida: UEC passport program seminar entitled Integrable and non-integrable problems in classical mechanics for the first year students of the University of Electro-Communications.
- Tomoya Takiwaki: Special lectures III on Numerical Physics, at the Graduate Course of Chiba University.
- Toshitaka Kajino: Lectures on fundamentals of theoretical astronomy at the Graduate University for Advanced Studies; science of time, space, and matter, and fundamentals of physics at Gakushuin University; astrophysics and modern physics at Japan Women's University; astrophysics at Jissen Women's University; nuclear physics at Meiji University; astronomy investigation I & II, reading papers in turn I & II, and special astronomy investigation II at the Graduate School of the University of Tokyo.

7. Outreach Activities

The Division of Theoretical Astronomy actively engaged in public promotions and outreach activities by offering lectures to the general public. The following lectures were delivered this year:

- Eiichiro Kokubo: “Saturn from Cassini: A Beautiful Ring World” at Aasahi Culture Center at Yokohama and Nakanoshima, “New Solar System 2017” at Ikebukuro Community College, “From Stardust to the Earth” at Space Expo.
- Takiwaki Tomoya: “Supernova Explosion simulated by Supercomputer, A Telescope for Theory” (Mitaka Network University), “Supercomputer reveals the Explosion Mechanism of Supernovae” (Asahi Culture Center Shonan).
- Takashi Moriya: “Origin of the elements” (Asahi Culture Center Yokohama).
- Toshitaka Kajino: “Nobel Prize on Modern Cosmology: Beginning of the Universe and the Discovery of Cosmic Microwave Background Radiation” (Asahi Culture Center Yokohama).

8. Awards

Masaomo Tanaka received the NCU-DELTA Young Astronomer Lectureship Award (October 18 in 2017) in Taiwan. Toshitaka Kajino received the honors of One Thousand Talents Plan Foreign Expert (April 15 in 2017) and State Special Recruited Expert (1 January 2018) in the People’s Republic of China.

9. Main Visitors from Overseas

The Division of Theoretical Astronomy strives to fulfill its roles as a center of excellence in Japan for theoretical studies in astronomy and astrophysics and also as an international research institution by providing an excellent research environment. It engages in various joint research projects with visiting researchers from overseas, with the help of Grants-in-Aid for Scientific Research, government subsidies for operating expenses, the NAOJ budget for guest visitors, and others. The main international visitors of FY 2017 to the division are listed below:

BALANTEKIN, Akif B. (University of Wisconsin–Madison, USA)
BAUER, Franz (Pontificia Universidad Catolica de Chile, Chili)
CAI, Maxwell (Leiden University, Netherland)
CASELLI, Paola (Max-Planck-Institute, Germany)
CHAU, Ching Chong (Academia Scinica, Taiwan)
CHEOUN, Myung-Ki (Soongsil University, South Korea)
DELIDUMAN, Cemsinan (Mimar Sinan University of Fine Art, Turkey)
FAMIANO, Michael A. (Western Michigan University, USA)
GAO, Weijia (Beijing Normal University, P. R. China)
HASAGAWA Yasuhiro (NASA Jet Propulsion Laboratory)
LAMBRECHTS, Michiel (Lund University, Sweden)
LIM, Wanggi (University of Florida, USA)
MATTHEW, Kenworthy (Leiden University, Netherland)
MATHEWS, Grant J. (University of Notre Dame, USA)
MAZZALI, Paolo (Liberpool John Moores University)
NORMAN, Colin Arthur (Johns Hopkins University)
PEHLIVAN, Yamac (Mimar Sinan University of Fine Art, Turkey)
PENZLIN, Anna (Heidelberg University, Germany)
PIAN, Elena (Italian National Institute of Astrophysics/ Institute of Space Astrophysics and Cosmic Physics, Italy)
RICHMOND, Michael (Rochester Institute of Technology)
TAN, Jonathan (University of Florida)
VOROBIEV, Eduard (Technical University of Vienna)

21. Office of International Relations

The Office of International Relations strives to promote and facilitate further internationalization at NAOJ by maintaining an environment where multi-cultural researchers and students can engage cooperatively in research and educational activities. Specifically, the Office's main activities include supporting international collaborative projects; managing Security Export Control; offering support for hosting international conferences, workshops, and seminars; hosting booths at international events, and providing support for visiting international researchers and students. In FY 2017 the Office continued to work closely with the Executive Advisor to the Director General in charge of international research coordination.

1. International Collaborative Project Support

The Office of International Relations handled administrative coordination in approval processes to sign agreements and memoranda for international collaborations, conducting preliminary reviews for legal documentation, and managing export security control for export of goods or transfer of technology. In FY 2017, nineteen international agreements, new and renewed, were signed including ones under the name of NINS. In the area of security export control, activities included review and processing of 150 cases (293 items). Out of them, an individual export license as well as a re-export license under EAR was required in one case, which we processed accordingly and obtained the licenses. A security export control briefing was held three times at Mitaka (June: 39 attendants, July: 48 attendants, and March: 6 attendants (in English)) and once in Hawai`i (July: 6 attendants) for improving the knowledge and awareness of NAOJ staff. In addition to these briefings, an explanation hosted by NINS was held in January 2018. The total number of attendants reached 150.

2. Liaison Work for Overseas Astronomical Research Organizations

The Office of International Relations joined the EAO (East Asian Observatory) financial committee meeting held in parallel with the JCMT mid-term review on July 24–29, 2017 in Hawai`i. The office participated in the exchange of opinions for financially healthy management of EAO/JCMT. Also, the office supported the East Asian Young Astronomers Meeting (EAYAM) held at Ishigaki Island on November 13–17, 2017.

The Office also assisted the Executive Advisor to the Director General in charge of international research coordination upon coordinating with the other 3 institutions forming the East Asian Core Observatories Association (EACOA) including NAOC (China), KASI (Republic of Korea), and ASIAA (Taiwan) for selection of the 2018 EACOA/EAO postdoctoral fellowship program recipients.

We hosted an NAOJ booth at the ASIA-Pacific Regional IAU Meeting held at Taipei during July 3–7, 2017 and AAS (The American Astronomical Society) meeting at Washington D.C. during January 7–14, 2018 to promote research results and to explain the current status of each project. Though it was our first time attending AAS, the reaction from the participants was much greater than we expected. We would like to keep attending AAS for the time being.

Furthermore, the Office supported the activities of the Office for Astronomical Outreach of the IAU (IAU OAO) and the IAU Office for Astronomy Development (OAD, located in South Africa). We supported CAP2018 held at Fukuoka during March 23–29, 2018 as an LOC member.

Same as last year, the Public Relations Office was responsible for overseas activities in relation to the general public, while the Office of International Relations was in charge of activities related to overseas researchers.

3. Support for Hosting International Researchers and Students

The Office enhanced its framework for offering organizational support for research, education, and living arrangements for foreign researchers and exchange students. The Support Desk offers support services to ease difficulties for foreigners living in Japan. It supports, on-site if required, covering various matters such as administrative procedures at municipal and other governmental offices, finding and moving into an apartment, and other various procedures and applications for starting up a new life, consultation on shopping, children's education, health and others, and gathering/providing useful information relating to everyday life. The Support Desk has been highly appreciated by users. To provide better services, Support Desk has been changed to be 2 staff × 3 days each shift. Thus, on Thursday when both of the SD staff members are at the office, we hold regular meetings between the SD staff and the other office members. As a result, the smooth transfer of on-going issues, as well as information sharing, became possible.

The Office continued the Japanese language lessons, helping foreign members of NAOJ acquire beginner level capability, and for FY 2017, a combination of E-learning features and classroom lessons were provided, as was in the previous year.

The Office continued its activities to support non-Japanese speaking staff, by translating various forms for applications and notices, including e-mail text and explanations of procedures (112 documents).

4. Assistance in International Partnerships Involving Japanese Research Organizations

The Office oversaw the Optical and Infrared Synergetic Telescopes for Education and Research (OISTER) project conducted by Okayama Astrophysical Observatory, Ishigakijima Astronomical Observatory, and nine Japanese universities.

Although the budget for the OISTER project was transferred to the Research Promotion Division from FY 2017 onward, the Office continued to provide administrative support.

Also the Office provided support for the Asian Core Observatories Initiative led by the Executive Advisor to the Director General in charge of international research coordination under NINS's research enhancement program with the Research University Network of Japan.

III Organization

1. Organization

- Director General
  - Advisory Committee for Research and Management
  - Vice-Director General (on General Affairs)
  - Vice-Director General (on Finance)
  - Director of Engineering
  - Director of Research Coordination
  - Executive Advisors to the Director General
  - Projects
    - (C Projects)
      - Subaru Telescope
      - Okayama Astrophysical Observatory
      - Nobeyama Radio Observatory
      - Mizusawa VLBI Observatory
      - Solar Science Observatory
      - NAOJ Chile Observatory
      - Center for Computational Astrophysics
    - (B Projects)
      - Gravitational Wave Project Office
      - TMT-J Project Office
    - (A Projects)
      - JASMINE Project Office
      - Extrasolar Planet Detection Project Office (~2017.12)
      - 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

	(2018/3/31)
Director General	1
Research and Academic Staff	151
Professor	25
Executive Engineer	0
Associate Professor	40
Chief Research Engineer	11
Assistant Professor	60
Research Associate	0
Research Engineer	15
Engineering Staff	37
Administrative Staff	59
Research Administrator Staff	11
Employees on Annual Salary System	149
Full-time Contract Employees	44
Part-time Contract Employees	124
Part-time Contract Employees Transferring to the Mandatory Retirement System	3

3. Executives

Director General	Hayashi, Masahiko
Vice-Director General	
on General Affairs	Watanabe, Jun-ichi
on Finance	Kobayashi, Hideyuki
Director of Engineering	Takami, Hideki
Director of Research Coordination	Gouda, Naoteru
Executive Advisor to the Director General	Ogasawara, Ryusuke
Executive Advisor to the Director General	Sekiguchi, Kazuhiro

4. Research Departments

Projects

C Projects

Subaru Telescope

Director	Yoshida, Michitoshi
Professor	Ohashi, Nagayoshi
Professor	Yoshida, Michitoshi
Associate Professor	Iwata, Ikuru
Associate Professor	Noumaru, Junichi
Associate Professor	Takato, Naruhisa
Associate Professor	Takeda, Yoichi
Associate Professor	Tanaka, Masayuki
Chief Research Engineer	Iwashita, Hiroyuki
Assistant Professor	Imanishi, Masatoshi
Assistant Professor	Komiyama, Yutaka
Assistant Professor	Koyama, Yusei
Assistant Professor	Minowa, Yosuke
Assistant Professor	Okita, Hirofumi
Assistant Professor	Ono, Yoshito
Assistant Professor	Onodera, Masato
Assistant Professor	Pyo, Tae-Soo
Specially Appointed Assistant Professor	Hayashi, Masao
Specially Appointed Assistant Professor	Izumi, Takuma
Research Engineer	Bando, Takamasa
Senior Engineer	Namikawa, Kazuhito
Senior Engineer	Omata, Koji
Chief Engineer	Tamura, Tomonori
Engineer	Sato, Tatsuhiro
Specially Appointed Research Staff	Niino, Yuu
Specially Appointed Senior Specialist	Ikeda, Hiroyuki
Specially Appointed Senior Specialist	Koike, Michitaro
Specially Appointed Senior Specialist	Mineo, Sogo
Specially Appointed Senior Specialist	Nakajima, Masayo
Specially Appointed Senior Specialist	Oishi, Yukie
Specially Appointed Senior Specialist	Okura, Yuki
Specially Appointed Senior Specialist	Taniguchi, Akimitsu
Specially Appointed Senior Specialist	Yamada, Yoshihiko
Specially Appointed Senior Specialist	Yamanoi, Hitomi
Research Expert	Kawanomoto, Satoshi
Administrative Supporter	Kuwata, Hitomi
Administrative Supporter	Noguchi, Masumi
Administrative Supporter	Shibata, Junko
Administrative Supporter	Suehiro, Yoko
Administrative Supporter	Takamoto, Masami
Administrative Supporter	Yoshida, Chie

Administration Department

Manager	Seto, Yoji
General Affairs Section	
Chief	Chiba, Satoko
Accounting Section	
Chief	Sugawara, Satoshi

RCUH

RCUH	Alpiche, Dex
RCUH	Aoki, Kentaro
RCUH	Balbarino, Michael
RCUH	Boggess, Christopher
RCUH	Castro, Timothy
RCUH	Clergeon, Christophe
RCUH	Conol, Jonah
RCUH	Doi, Yoshiyuki
RCUH	Elms, Brian
RCUH	Endo, Mari
RCUH	Ferreira, James
RCUH	Formanek, Keiko
RCUH	Fujiwara, Hideaki
RCUH	Fujiyoshi, Takuya
RCUH	Gaskin, Roberta
RCUH	Gorman, William
RCUH	Guyon, Olivier
RCUH	Hasegawa, Kumiko
RCUH	Hattori, Takashi
RCUH	Inagaki, Takeshi
RCUH	Jeschke, Eric
RCUH	Kackley, Russell
RCUH	Kakazu, Yuko
RCUH	Kerns, Michael
RCUH	Kim, Ji Hoon
RCUH	Koshida, Shintaro
RCUH	Kudo, Tomoyuki
RCUH	Kyono, Eiji
RCUH	Lee, Chien-Hsiu
RCUH	Lemmen, Michael
RCUH	Letawsky, Michael
RCUH	Lozi, Julien
RCUH	Medeiros, Carolyn
RCUH	Mieda, Etsuko
RCUH	Morris, Marita
RCUH	Murai, Rieko
RCUH	Nabeshima, Yoshitake
RCUH	Nakata, Fumiaki
RCUH	Niimi, Yuka
RCUH	Nishimura, Tetsuo
RCUH	Otsuki, Noriko

RCUH	Ramos, Lucio
RCUH	Roth, Noriko
RCUH	Rousselle, Julien
RCUH	Rusu, Cristian
RCUH	Sahoo, Ananya
RCUH	Schubert, Kiaina
RCUH	Spencer, Robin
RCUH	Suh, Hyewon
RCUH	Sur, Ryoko
RCUH	Suzuki, Yuko
RCUH	Tait, Philip
RCUH	Tajitsu, Akito
RCUH	Takagi, Yuhei
RCUH	Takiura, Koki
RCUH	Tamae, Richard
RCUH	Tanaka, Makoto
RCUH	Tanaka, Yoko
RCUH	Terai, Tsuyoshi
RCUH	Tomono, Daigo
RCUH	Toyofuku, Ralph
RCUH	Tsang, Emiko
RCUH	Wahl, Matthew
RCUH	Weber, Mark
RCUH	Williams, Joshua
RCUH	Winegar, Tom
RCUH	Wung, Matthew
RCUH	Yoshida, Hiroshige
RCUH	Yoshiyama, Naomi

Okayama Astrophysical Observatory

Director	Izumiura, Hideyuki
Associate Professor	Izumiura, Hideyuki
Associate Professor	Ukita, Nobuharu
Specially Appointed Associate Professor	Kambe, Eiji
Assistant Professor	Yanagisawa, Kenshi
Engineer	Tsutsui, Hironori
Specially Appointed Research Staff	Matsubayashi, Kazuya
Specially Appointed Senior Specialist	Fukui, Akihiko
Research Expert	Kuroda, Daisuke
Research Supporter	Toda, Hiroyuki

Administration Office

Administration Section

Chief	Tanabe, Keizo
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	Tatematsu, Kenichi
Professor	Tatematsu, Kenichi
Chief Research Engineer	Kanzawa, Tomio
Assistant Professor	Ishizuki, Sumio
Assistant Professor	Minamidani, Tetsuhiro
Assistant Professor	Umemoto, Tomofumi
Specially Appointed Assistant Professor	Torii, Kazufumi
Research Engineer	Mikoshiba, Hiroshi
Senior Engineer	Handa, Kazuyuki
Senior Engineer	Kurakami, Tomio
Senior Engineer	Miyazawa, Chieko
Senior Engineer	Miyazawa, Kazuhiko
Senior Engineer	Shinohara, Noriyuki
Engineer	Nishitani, Hiroyuki
Engineer	Wada, Takuya
Specially Appointed Research Staff	Kaneko, Hiroyuki
Specially Appointed Research Staff	Kim, Gwanjeong
Specially Appointed Research Staff	Miyamoto, Yusuke
Specially Appointed Senior Specialist	Hamada, Kaname
Specially Appointed Senior Specialist	Kinugasa, Kenzo
Specially Appointed Senior Specialist	Oya, Masaaki
Research Expert	Maekawa, Jun
Research Expert	Takahashi, Shigeru
Technical Expert	Hayashi, Mitsuru
Technical Expert	Ide, Hidemi
Technical Expert	Inoue, Norio
Research Supporter	Matsuo, Mitsuhiro
Administrative Supporter	Hatakeyama, Eiko

Administration Office

Deputy Manager	Otsuka, Tomoyoshi

General Affairs Section

Chief	Otsuka, Tomoyoshi
Administrative Supporter	Kikuchi, Kikue
Administrative Supporter	Shinkai, Hisako
Administrative Supporter	Yoda, Chizuko
Administrative Maintenance Staff	Fuji, Shigeru
Administrative Maintenance Staff	Hinata, Shigeto
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	Tsuchiya, Junko
Administrative Maintenance Staff	Yokomori, Yasuyuki
Accounting Section	
Chief	Miyabara, Yasuhide
Senior Staff	Takahashi, Masaru
Administrative Supporter	Kodaira, Toshiko
Administrative Supporter	Takasawa, Mitsue
Administrative Supporter	Takemura, Miwako
Administrative Supporter	Tokui, Chisato

Mizusawa VLBI Observatory

Director	Honma, Mareki
Professor	Honma, Mareki
Professor	Kobayashi, Hideyuki
Associate Professor	Shibata, Katsunori
Chief Research Engineer	Sato, Katsuhisa
Assistant Professor	Hada, Kazuhiro
Assistant Professor	Hirota, Tomoya
Assistant Professor	Jike, Takaaki
Assistant Professor	Kameya, Osamu
Assistant Professor	Kono, Yusuke
Assistant Professor	Sunada, Kazuyoshi
Assistant Professor	Tamura, Yoshiaki
Research Engineer	Ishikawa, Toshiaki
Research Engineer	Suzuki, Syunsaku
Chief Engineer	Ueno, Yuji
Engineer	Hirano, Ken
Specially Appointed Research Staff	Akahori, Takuya
Specially Appointed Research Staff	Hanayama, Hidekazu
Specially Appointed Research Staff	Horiuchi, Takashi
Specially Appointed Research Staff	Sakai, Nobuyuki
Specially Appointed Research Staff	Sugiyama, Koichiro
Specially Appointed Research Staff	Tazaki, Fumie
Specially Appointed Senior Specialist	Adachi, Yuki
Specially Appointed Senior Specialist	Kim, Mi Kyoung
Specially Appointed Senior Specialist	Miura, Mitsuo
Specially Appointed Senior Specialist	Nagayama, Takumi
Specially Appointed Senior Specialist	Oyama, Tomoaki
Specially Appointed Senior Specialist	Ozawa, Tomohiko
Technical Expert	Asakura, Yu
Technical Expert	Hachisuka, Kazuya
Technical Expert	Matsukawa, Yuki
Technical Expert	Sato, Gen
Technical Expert	Sato, Kaori
Technical Expert	Shimada, Kanae
Technical Expert	Takahashi, Ken
Technical Expert	Yamashita, Kazuyoshi
Technical Expert	Yoshida, Toshihiro
Administrative Expert	Endo, Kana
Research Supporter	Kudo, Yohei
Research Supporter	Matsueda, Chika
Technical Supporter	Konishi, Satoru
Administrative Supporter	Komori, Akiyo
Administrative Supporter	Uekiyo, Hatsue
Administration Office	
Deputy Manager	Hommyo, Susumu
General Affairs Section	
Chief	Hommyo, Susumu
Staff	Iida, Naoto
Administrative Supporter	Murakami, Mie
Administrative Supporter	Oizumi, Yuka
Administrative Supporter	Sasaki, Mie
Accounting Section	
Chief	Ito, Hiromasa
Administrative Supporter	Kikuchi, Sachiko
Administrative Supporter	Takahashi, Yumi
Ishigakijima Astronomical Observatory	
Director	Honma, Mareki
Time Keeping Office	
Director	Sato, Katsuhisa

Solar Science Observatory

Director	Watanabe, Tetsuya
Professor	Watanabe, Tetsuya
Associate Professor	Hanaoka, Yoichiro
Associate Professor	Katsukawa, Yukio
Associate Professor	Suematsu, Yoshinori
Associate Professor	Sekii, Takashi
Senior Engineer	Shinoda, Kazuya
Specially Appointed Research Staff	Joshi, Anand Diwakar
Specially Appointed Research Staff	Lee, Kyoung Sun
Specially Appointed Senior Specialist	Morita, Satoshi
Research Expert	Hagino, Masaoki
Research Expert	Yaji, Kentaro
Technical Expert	Inoue, Naoko
Research Supporter	Ishii, Shuichi
Administrative Supporter	Kano, Kaori
Administrative Supporter	Sugimoto, Junko

NAOJ Chile Observatory

Director	Sakamoto, Seiichi
Professor	Iguchi, Satoru
Professor	Kameno, Seiji
Professor	Mizuno, Norikazu
Professor	Ogasawara, Ryusuke

Professor	Sakamoto, Seiichi
Specially Appointed Professor	Hasegawa, Tetsuo
Associate Professor	Asaki, Yoshiharu
Associate Professor	Asayama, Shinichiro
Associate Professor	Gonzalez Garcia, Alvaro
Associate Professor	Iono, Daisuke
Associate Professor	Kiuchi, Hitoshi
Associate Professor	Kosugi, George
Associate Professor	Okuda, Takeshi
Specially Appointed Associate Professor	Espada Fernandez, Daniel
Specially Appointed Associate Professor	Kawamura, Akiko
Specially Appointed Associate Professor	Nagai, Hiroshi
Specially Appointed Associate Professor	Nakanishi, Koichiro
Specially Appointed Associate Professor	Tafoya Martinez, Daniel
Chief Research Engineer	Kikuchi, Kenichi
Chief Research Engineer	Nakamura, Kouji
Chief Research Engineer	Watanabe, Manabu
Assistant Professor	Ezawa, Hajime
Assistant Professor	Hiramatsu, Masaaki
Assistant Professor	Hirota, Akihiko
Assistant Professor	Ishii, Shun
Assistant Professor	Kamazaki, Takeshi
Assistant Professor	Matsuda, Yuichi
Assistant Professor	Sawada, Tsuyoshi
Assistant Professor	Shimojo, Masumi
Assistant Professor	Takahashi, Satoko
Specially Appointed Assistant Professor	Akiyama, Eiji
Specially Appointed Assistant Professor	Egusa, Fumi
Specially Appointed Assistant Professor	Hull, Charles Lindsay Hopkins
Specially Appointed Assistant Professor	Miura, Rie
Specially Appointed Assistant Professor	Okamoto, Joten
Specially Appointed Assistant Professor	Saigou, Kazuya
Specially Appointed Assistant Professor	Ueda, Junko
Research Engineer	Ashitagawa, Kyoko
Research Engineer	Nakazato, Takeshi
Research Engineer	Yamada, Masumi
Senior Engineer	Kato, Yoshihiro
Senior Engineer	Kobiki, Toshihiko
Senior Engineer	Nakamura, Kyoko
Chief Engineer	Ito, Tetsuya
Engineer	Shizugami, Makoto
Specially Appointed Research Staff	Ao, Yiping
Specially Appointed Research Staff	Guzman Fernandez, Andres Ernesto
Specially Appointed Research Staff	Hashimoto, Takuya
Specially Appointed Research Staff	Izumi, Natsuko
Specially Appointed Research Staff	Kroug, Matthias Nils
Specially Appointed Research Staff	Lu, Xing
Specially Appointed Research Staff	Nishimura, Yuri
Specially Appointed Research Staff	Salinas Poblete, Vachail Nicolas
Specially Appointed Research Staff	Sanhueza Nunez, Patricio Andres
Specially Appointed Research Staff	Silva Bustamante, Andrea Ludovina
Specially Appointed Research Staff	Takahashi, Sanemichi
Specially Appointed Research Staff	Tanaka, Kei
Specially Appointed Research Staff	Tokuda, Kazuki
Specially Appointed Research Staff	Walker, Daniel Lewis
Specially Appointed Research Staff	Wang, Tao
Specially Appointed Research Staff	Wu, Yu-Ting
Specially Appointed Research Staff	Zahorecz, Sarolta
Specially Appointed Senior Specialist	Fujimoto, Yasuhiro
Specially Appointed Senior Specialist	Fukui, Hideharu
Specially Appointed Senior Specialist	Furutani, Akio
Specially Appointed Senior Specialist	Horie, Yosaku
Specially Appointed Senior Specialist	Ikeda, Emi
Specially Appointed Senior Specialist	Kawakami, Kazuyuki
Specially Appointed Senior Specialist	Kawasaki, Wataru
Specially Appointed Senior Specialist	Kobayashi, Tsuyoshi
Specially Appointed Senior Specialist	Konuma, Mika
Specially Appointed Senior Specialist	Matsui, Takayuki
Specially Appointed Senior Specialist	Miel, Renaud Jean Christophe

Specially Appointed Senior Specialist	Miyachi, Akihira
Specially Appointed Senior Specialist	Morita, Eisuke
Specially Appointed Senior Specialist	Nakamoto, Takashi
Specially Appointed Senior Specialist	Nakanishi, Takashi
Specially Appointed Senior Specialist	Niizeki, Yasuaki
Specially Appointed Senior Specialist	Nishikawa, Tomoko
Specially Appointed Senior Specialist	Nukatani, Sorahiko
Specially Appointed Senior Specialist	Okumura, Yuji
Specially Appointed Senior Specialist	Otawara, Kazushige
Specially Appointed Senior Specialist	Shimoda, Takanobu
Specially Appointed Senior Specialist	So, Ryoken
Specially Appointed Senior Specialist	Uemizu, Kazunori
Specially Appointed Senior Specialist	Yoshino, Akira
Research Expert	Sakuma, Naoko
Technical Expert	Tanaka, Rie
Administrative Expert	Kamada, Masako
Research Supporter	Ban, Makiko
Research Supporter	Yamazaki, Toshitaka
Technical Supporter	Hayashi, Ritsuko
Administrative Supporter	Kono, Izumi
Administrative Supporter	Otawara, Hikaru
Administrative Supporter	Saito, Naoko

Chile Employee

Chile Employee	Aguilera, Javier
Chile Employee	Ichiyama, Kotoyo
Chile Employee	Jara, Ricardo
Chile Employee	Krapivka, Gabriela
Chile Employee	Toro, Lorena
Chile Employee	Zenteno, Javier

Administration Department

Manager	Okumura, Yuji
General Affairs Section	
Chief	Tsukano, Satomi
Accounting Section	
Chief	Okumura, Yuji

Center for Computational Astrophysics

Director	Kokubo, Eiichiro
Professor	Kokubo, Eiichiro
Assistant Professor	Osuga, Ken
Specially Appointed Assistant Professor	Takahashi, Hiroyuki
Specially Appointed Research Staff	Asahina, Yuta
Specially Appointed Research Staff	Ohtani, Yukari
Specially Appointed Senior Specialist	Oshino, Shoichi
Research Expert	Kato, Tsunehiko
Research Expert	Nakayama, Hirotaka
Research Expert	Wakita, Shigeru
Research Supporter	Fukushi, Hinako
Research Supporter	Hasegawa, Satoki
Research Supporter	Oshigami, Shoko
Research Supporter	Taki, Tetsuo
Administrative Supporter	Kimura, Yuko

B Projects

Gravitational Wave Project Office

Director	Flaminio, Raffaele
Specially Appointed Professor	Flaminio, Raffaele
Associate Professor	Aso, Yoichi
Affiliated Associate Professor	Ando, Masaki
Assistant Professor	Akutsu, Tomotada
Assistant Professor	Leonardi, Matteo
Assistant Professor	Ohishi, Naoko
Assistant Professor	Takahashi, Ryutaro
Specially Appointed Assistant Professor	Shoda, Ayaka
Research Engineer	Ishizaki, Hideharu
Chief Engineer	Tanaka, Nobuyuki
Specially Appointed Research Staff	Barton, Mark Andrew
Specially Appointed Research Staff	Capocasa, Eleonora
Specially Appointed Research Staff	Pena Arellano, Fabian Erasmo
Specially Appointed Research Staff	Zeidler, Simon
Specially Appointed Senior Specialist	Hirata, Naoatsu
Specially Appointed Senior Specialist	Tapia, San Martin Enzo Nicolas
Administrative Expert	Ohyama, Megumi
Research Supporter	Harada, Mikiko
Administrative Supporter	Sakamoto, Eri
Administrative Supporter	Yoshizumi, Mizuho

TMT-J Project Office

Director	Usuda, Tomonori
Professor	Saito, Masao
Professor	Usuda, Tomonori
Professor	Yamashita, Takuya
Associate Professor	Aoki, Wako
Associate Professor	Hayashi, Saeko

Associate Professor	Kashikawa, Nobunari
Associate Professor	Sugimoto, Masahiro
Associate Professor	Terada, Hiroshi
Specially Appointed Associate Professor	Oya, Shin
Chief Research Engineer	Miyashita, Takaaki
Assistant Professor	Yasui, Chikako
Specially Appointed Assistant Professor	Hattori, Masayuki
Specially Appointed Research Staff	Harakawa, Hiroki
Specially Appointed Research Staff	Kubo, Mariko
Specially Appointed Research Staff	Ozaki, Shinobu
Specially Appointed Research Staff	Schramm, Malte
Specially Appointed Senior Specialist	Chapman, Junko
Specially Appointed Senior Specialist	Endo, Tatsuki
Specially Appointed Senior Specialist	Kozu, Akihito
Specially Appointed Senior Specialist	Kusumoto, Hiroshi
Specially Appointed Senior Specialist	Shindo, Miwa
Specially Appointed Senior Specialist	Sugiyama, Motokuni
Research Expert	Ishii, Miki
Special Senior Specialist	Inatani, Junji
Research Supporter	Tajima, Toshiyuki
Administrative Supporter	Haranaka, Miyuki
Administrative Supporter	Tabata, Miwa
Administrative Supporter	Tatsugi, Tomoko
Administrative Supporter	Yamaguchi, Chiyu
RCUH	Iye, Masanori

A Projects

JASMINE Project Office

Director	Gouda, Naoteru
Professor	Gouda, Naoteru
Assistant Professor	Tsujimoto, Takuji
Assistant Professor	Ueda, Akitoshi
Assistant Professor	Yano, Taihei
Specially Appointed Research Staff	Baba, Junichi
Research Supporter	Mase, Ichiro
Research Supporter	Utsunomiya, Shin
Technical Supporter	Kashima, Shingo
Research Assistant	Kumamoto, Jun

Extrasolar Planet Detection Project Office (~2017.12)

Director	Tamura, Motohide
Assistant Professor*	Kotani, Takayuki
Assistant Professor*	Nakajima, Tadashi
Assistant Professor	Nishikawa, Jun
Assistant Professor*	Suto, Hiroshi
Specially Appointed Assistant Professor*	Hashimoto, Jun
Specially Appointed Assistant Professor*	Hori, Yasunori
Specially Appointed Research Staff*	Komatsu, Yu
Specially Appointed Research Staff	Konishi, Mihoko
Specially Appointed Research Staff*	Kuzuhara, Masayuki
Specially Appointed Research Staff	Omiya, Masashi
Specially Appointed Research Staff*	Suzuki, Taiki
Specially Appointed Senior Specialist*	Kusakabe, Nobuhiko
Research Supporter	Kurokawa, Takashi

*concurrently appointed in NINS

RISE Project

Director	Namiki, Noriyuki
Professor	Namiki, Noriyuki
Associate Professor	Hanada, Hideo
Associate Professor	Matsumoto, Koji
Chief Research Engineer	Tsuruta, Seiitsu
Assistant Professor	Araki, Hiroshi
Assistant Professor	Noda, Hirotomo
Research Engineer	Asari, Kazuyoshi
Research Engineer	Tazawa, Seiichi
Specially Appointed Research Staff	Higuchi, Arika
Specially Appointed Research Staff	Kawamura, Taichi
Specially Appointed Research Staff	Yamamoto, Keiko
Administrative Supporter	Sato, Sayaka

SOLAR-C Project Office

Director	Ichimoto, Kiyoshi
Professor	Ichimoto, Kiyoshi
Associate Professor*	Goto, Motoshi
Associate Professor	Hara, Hirohisa
Associate Professor	Kano, Ryouhei
Assistant Professor	Ishikawa, Ryoko
Assistant Professor	Kubo, Masahito
Assistant Professor	Narukage, Noriyuki
Specially Appointed Research Staff	Song, Donguk
Research Supporter	Tsuchiya, Chie
Administrative Supporter	Fujiyoshi, Marie

*concurrently appointed in NINS

Centers

Astronomy Data Center

Director	Takata, Tadafumi
Associate Professor	Ichikawa, Shinichi
Associate Professor	Ohishi, Masatoshi
Associate Professor	Takata, Tadafumi
Assistant Professor	Furusawa, Hisanori
Assistant Professor	Ito, Takashi
Assistant Professor	Oe, Masafumi
Assistant Professor	Shirasaki, Yuji
Research Engineer	Inoue, Goki
Specially Appointed Research Staff	Honma, Hidetomo
Specially Appointed Research Staff	Sorahana, Satoko
Specially Appointed Senior Specialist	Kamegai, Kazuhisa
Specially Appointed Senior Specialist	Makiuchi, Shinichiro
Specially Appointed Senior Specialist	Ozawa, Takeaki
Specially Appointed Senior Specialist	Tanaka, Nobuhiro
Specially Appointed Senior Specialist	Yamanaka, Satoshi
Specially Appointed Senior Specialist	Zapart, Christopher Andrew
Research Expert	Furusawa, Junko
Research Expert	Isogai, Mizuki
Research Supporter	Fujikawa, Makiko
Research Supporter	Noda, Sachiyo
Research Supporter	Utsumi, Motomu
Administrative Supporter	Ishii, Yuko

JVO Project

Director	Ohishi, Masatoshi

Advanced Technology Center

Director	Noguchi, Takashi
Professor	Noguchi, Takashi
Professor	Takami, Hideki
Associate Professor	Hayano, Yutaka
Associate Professor	Matsuo, Hiroshi
Associate Professor	Miyazaki, Satoshi
Associate Professor	Shan, Wenlei
Chief Research Engineer	Fujii, Yasunori
Chief Research Engineer	Okada, Norio
Assistant Professor	Kojima, Takafumi
Assistant Professor	Nakaya, Hidehiko
Assistant Professor	Oshima, Tai
Assistant Professor	Suzuki, Ryuji
Research Engineer	Fukushima, Mitsuhiro
Research Engineer	Obuchi, Yoshiyuki
Research Engineer	Sato, Naohisa
Senior Engineer	Kamata, Yukiko
Senior Engineer	Kubo, Koichi
Senior Engineer	Takahashi, Toshikazu
Senior Engineer	Uraguchi, Fumihiro
Chief Engineer	Fukuda, Takeo
Chief Engineer	Ikenoue, Bungo
Chief Engineer	Inata, Motoko
Chief Engineer	Iwashita, Hikaru
Chief Engineer	Kaneko, Keiko
Chief Engineer	Mitsui, Kenji
Chief Engineer	Waseda, Koichi
Engineer	Ezaki, Shohei
Engineer	Sakai, Ryo
Engineer	Tsuzuki, Toshihiro
Specially Appointed Research Staff	Hayashi, Kohei
Specially Appointed Research Staff	Nagai, Makoto
Specially Appointed Research Staff	Uchiyama, Mizuho
Specially Appointed Senior Specialist	Saito, Sakae
Technical Expert	Aiba, Kazukiyo
Technical Expert	Katsumoto, tatsuo
Administrative Supporter	Kuroda, Kyoko
Administrative Supporter	Murakami, Hiromi
Administrative Supporter	Yoshida, Taeko
Research Assistant	Kozuki, Yuto

Public Relations Center

Director	Fukushima, Toshio
Professor	Fukushima, Toshio
Professor	Watanabe, Jun-ichi
Associate Professor	Agata, Hidehiko
Associate Professor	Yamaoka, Hitoshi
Research Engineer	Katayama, Masato
Chief Senior Engineer	Matsuda, Ko
Chief Engineer	Nagayama, Shogo
Chief of Library Section	Todoriki, Tatsuya
Specially Appointed Senior Specialist	Cheung, Sze Leung
Specially Appointed Senior Specialist	Ishikawa, Naomi
Specially Appointed Senior Specialist	Lundock, Ramsey Guy
Specially Appointed Senior Specialist	Pires Canas, Lina Isabel
Specially Appointed Senior Specialist	Tsuzuki, Hiroko
Specially Appointed Senior Specialist	Usuda-Sato, Kumiko
Research Expert	Ono, Tomoko
Research Expert	Takata, Hiroyuki
Research Supporter	Kume, Kaori
Public Outreach Official	Endo, Isao
Public Outreach Official	Fujimura, Ayako
Public Outreach Official	Fujita, Tokiko

Public Outreach Official	Hamura, Taiga
Public Outreach Official	Hatano, Satomi
Public Outreach Official	Ishizaki, Masaharu
Public Outreach Official	Ito, Hironori
Public Outreach Official	Koike, Akio
Public Outreach Official	Kubo, Maki
Public Outreach Official	Mikami, Naotsugu
Public Outreach Official	Naito, Seiichiro
Public Outreach Official	Natsugari, Satomi
Public Outreach Official	Nemoto, Shiomi
Public Outreach Official	Ogoe, Osamu
Public Outreach Official	Oguri, Junko
Public Outreach Official	Shibata, Yukiko
Public Outreach Official	Shioya, Yasuhisa
Public Outreach Official	Takabatake, Noriko
Public Outreach Official	Takeda, Takaaki
Administrative Supporter	Aoki, Makiko
Administrative Supporter	Noguchi, Sayumi

Public Relations Office

Director	Yamaoka, Hitoshi

Outreach and Education Office

Director	Agata, Hidehiko

Ephemeris Computation Office

Director	Katayama, Masato

Library

Chief	Todoriki, Tatsuya

Publications Office

Director	Fukushima, Toshio

The Office for Astronomy Outreach of the IAU

Director	Agata, Hidehiko

Administration Office

Director	Matsuda, Ko

Divisions

Division of Optical and Infrared Astronomy

Division Chair	Kashikawa, Nobunari
Professor	Gouda, Naoteru
Professor	Ohashi, Nagayoshi
Professor	Saito, Masao
Professor	Sekiguchi, Kazuhiro
Professor	Usuda, Tomonori
Professor	Yamashita, Takuya
Professor	Yoshida, Michitoshi
Specially Appointed Professor*	Tamura, Motohide
Associate Professor	Aoki, Wako
Associate Professor	Aso, Yoichi
Associate Professor	Hayashi, Saeko
Associate Professor	Iwata, Ikuru
Associate Professor	Izumiura, Hideyuki
Associate Professor	Kashikawa, Nobunari
Associate Professor	Noumaru, Junichi
Associate Professor	Sugimoto, Masahiro
Associate Professor	Takato, Naruhisa
Associate Professor	Takeda, Yoichi
Associate Professor	Tanaka, Masayuki
Associate Professor	Terada, Hiroshi
Associate Professor	Ukita, Nobuharu
Chief Research Engineer	Iwashita, Hiroyuki
Chief Research Engineer	Miyashita, Takaaki
Assistant Professor	Akutsu, Tomotada
Assistant Professor	Imanishi, Masatoshi
Assistant Professor	Komiyama, Yutaka
Assistant Professor*	Kotani, Takayuki
Assistant Professor	Koyama, Yusei
Assistant Professor	Leonardi, Matteo
Assistant Professor	Minowa, Yosuke
Assistant Professor	Morino, Jun-ichi
Assistant Professor*	Nakajima, Tadashi
Assistant Professor	Nishikawa, Jun
Assistant Professor	Ohishi, Naoko
Assistant Professor	Okita, Hirofumi
Assistant Professor	Ono, Yoshito
Assistant Professor	Onodera, Masato
Assistant Professor	Pyo, Tae-soo
Assistant Professor	Sôma, Mitsuru
Assistant Professor*	Suto, Hiroshi
Assistant Professor	Takahashi, Ryutaro
Assistant Professor	Tatsumi, Daisuke
Assistant Professor	Tsujimoto, Takuji
Assistant Professor	Ueda, Akitoshi
Assistant Professor	Yagi, Masafumi
Assistant Professor	Yanagisawa, Kenshi
Assistant Professor	Yano, Taihei
Assistant Professor	Yasui, Chikako
Specially Appointed Assistant Professor*	Hashimoto, Jun
Specially Appointed Assistant Professor*	Hori, Yasunori
Research Engineer	Bando, Takamasa
Research Engineer	Ishizaki, Hideharu
Senior Engineer	Namikawa, Kazuhito
Senior Engineer	Omata, Koji
Chief Engineer	Tamura, Tomonori
Chief Engineer	Tanaka, Nobuyuki
Engineer	Sato, Tatsuhiro
Engineer	Tsutsui, Hironori
Specially Appointed Research Staff*	Komatsu, Yu
Specially Appointed Research Staff*	Konishi, Mihoko
Specially Appointed Research Staff*	Kuzuhara, Masayuki
Specially Appointed Research Staff*	Omiya, Masashi
Specially Appointed Research Staff*	Suzuki, Taiki
Specially Appointed Senior Specialist*	Kusakabe, Nobuhiko

Administrative Supporter	Kimura, Hiroko
Research Assistant	Onoue, Masafusa

*concurrently appointed in NINS

Division of Radio Astronomy

Division Chair	Iguchi, Satoru
Professor	Honma, Mareki
Professor	Iguchi, Satoru
Professor	Kameno, Seiji
Professor	Kawabe, Ryohei
Professor	Kobayashi, Hideyuki
Professor	Mizuno, Norikazu
Professor	Namiki, Noriyuki
Professor	Ogasawara, Ryusuke
Professor	Sakamoto, Seiichi
Professor	Tatematsu, Kenichi
Associate Professor	Asaki, Yoshiharu
Associate Professor	Asayama, Shinichiro
Associate Professor	Gonzalez Garcia, Alvaro
Associate Professor	Hanada, Hideo
Associate Professor	Iono, Daisuke
Associate Professor	Kiuchi, Hitoshi
Associate Professor	Kosugi, George
Associate Professor	Matsumoto, Koji
Associate Professor	Okuda, Takeshi
Associate Professor	Shibata, Katsunori
Chief Research Engineer	Kanzawa, Tomio
Chief Research Engineer	Kawashima, Susumu
Chief Research Engineer	Kikuchi, Kenichi
Chief Research Engineer	Nakamura, Kouji
Chief Research Engineer	Sato, Katsuhisa
Chief Research Engineer	Tsuruta, Seiitsu
Chief Research Engineer	Watanabe, Manabu
Assistant Professor	Araki, Hiroshi
Assistant Professor	Ezawa, Hajime
Assistant Professor	Hada, Kazuhiro
Assistant Professor	Hiramatsu, Masaaki
Assistant Professor	Hirota, Akihiko
Assistant Professor	Hirota, Tomoya
Assistant Professor	Ishii, Shun
Assistant Professor	Ishizuki, Sumio
Assistant Professor	Jike, Takaaki
Assistant Professor	Kamazaki, Takeshi
Assistant Professor	Kameya, Osamu
Assistant Professor	Kono, Yusuke
Assistant Professor	Matsuda, Yuichi
Assistant Professor	Minamidani, Tetsuhiro
Assistant Professor	Miyoshi, Makoto
Assistant Professor	Noda, Hirotomo
Assistant Professor	Sawada, Tsuyoshi
Assistant Professor	Shimojo, Masumi
Assistant Professor	Sunada, Kazuyoshi
Assistant Professor	Takahashi, Satoko
Assistant Professor	Tamura, Yoshiaki
Assistant Professor	Umemoto, Tomofumi
Research Engineer	Asari, Kazuyoshi
Research Engineer	Ashitagawa, Kyoko
Research Engineer	Ishikawa, Toshiaki
Research Engineer	Mikoshiba, Hiroshi
Research Engineer	Nakazato, Takeshi
Research Engineer	Suzuki, Syunsaku
Research Engineer	Tazawa, Seiichi
Research Engineer	Yamada, Masumi
Senior Engineer	Handa, Kazuyuki
Senior Engineer	Kato, Yoshihiro
Senior Engineer	Kobiki, Toshihiko
Senior Engineer	Kurakami, Tomio
Senior Engineer	Miyazawa, Chieko
Senior Engineer	Miyazawa, Kazuhiko
Senior Engineer	Nakamura, Kyoko
Senior Engineer	Shinohara, Noriyuki
Chief Engineer	Ito, Tetsuya
Chief Engineer	Ueno, Yuji
Engineer	Hirano, Ken
Engineer	Nishitani, Hiroyuki
Engineer	Shizugami, Makoto
Engineer	Wada, Takuya
Specially Appointed Senior Specialist	Takebayashi, Yasuo
Research Supporter	Tsuneyama, Junko
Research Assistant	Taniguchi, Kotomi

Division of Solar and Plasma Astrophysics

Division Chair	Hanaoka, Yoichiro
Professor	Watanabe, Tetsuya
Associate Professor	Hanaoka, Yoichiro
Associate Professor	Hara, Hirohisa
Associate Professor	Kano, Ryouhei
Associate Professor	Katsukawa, Yukio
Associate Professor	Sekii, Takashi
Associate Professor	Suematsu, Yoshinori
Assistant Professor	Ishikawa, Ryoko
Assistant Professor	Kubo, Masahito
Assistant Professor	Narukage, Noriyuki
Specially Appointed Assistant Professor	Toriumi, Shin
Senior Engineer	Shinoda, Kazuya

Division of Theoretical Astronomy

Division Chair	Tomisaka, Kohji
Professor	Kokubo, Eiichiro
Professor	Tomisaka, Kohji
Professor	Yoshida, Haruo
Associate Professor	Kajino, Toshitaka
Associate Professor	Nakamura, Fumitaka
Assistant Professor	Hamana, Takashi
Assistant Professor	Kataoka, Akimasa
Assistant Professor	Ohsuga, Ken
Assistant Professor	Takiwaki, Tomoya
Assistant Professor	Tanaka, Masaomi

Specially Appointed Assistant Professor	Moriya, Takashi
Specially Appointed Assistant Professor	Nozawa, Takaya
Specially Appointed Assistant Professor	Ogihara, Masahiro
Specially Appointed Assistant Professor	Shirasaki, Masato
Specially Appointed Assistant Professor	Sotani, Hajime
Specially Appointed Research Staff	Kawashima, Tomohisa
Specially Appointed Research Staff	Kusune, Takayoshi
Specially Appointed Research Staff	Wu, Benjamin
Administrative Supporter	Izumi, Shioko

5. Research Support Departments

Research Enhancement Strategy Office

Director	Kobayashi, Hideyuki
Specially Appointed Senior Specialist	Asaga, Akitaka
Specially Appointed Senior Specialist	Chapman, Junko
Specially Appointed Senior Specialist	Fukui, Hideharu
Specially Appointed Senior Specialist	Hasuo, Ryuichi
Specially Appointed Senior Specialist	Hori, Kuniko
Specially Appointed Senior Specialist	Lundock, Ramsey Guy
Specially Appointed Senior Specialist	Miura, Mitsuo
Specially Appointed Senior Specialist	Noda, Noboru
Specially Appointed Senior Specialist	Okamoto, Koichi
Specially Appointed Senior Specialist	Suzui, Mitsukazu
Specially Appointed Senior Specialist	Yamamiya, Osamu

Research Evaluation Support Office

Director	Watanabe, Jun-ichi
Specially Appointed Senior Specialist	Hori, Kuniko

Office of International Relations

Director	Hasuo, Ryuichi
Specially Appointed Senior Specialist	Haruki, Mutsumi
Specially Appointed Senior Specialist	Hasuo, Ryuichi
Specially Appointed Senior Specialist	Komiyama, Hiroko
Specially Appointed Senior Specialist	Matsumoto, Mizuho

Support Desk

Research Supporter	Shirato, Reiko
Research Supporter	Yamanaka, Wakana

Human Resources Planning Office

Director	Yamamiya, Osamu
Specially Appointed Senior Specialist	Noda, Noboru
Specially Appointed Senior Specialist	Yamamiya, Osamu

Safety and Health Management Office

Director	Okamoto, Koichi
Specially Appointed Senior Specialist	Okamoto, Koichi
Technical Expert	Kashiwagi, Yuji
Technical Expert	Tsuchiya, Tatsumi

Engineering Promotion Office

Director	Takami, Hideki
Chief Research Engineer	Kawashima, Susumu
Specially Appointed Senior Specialist	Suzui, Mitsukazu

Administration Department

General Manager	Sasagawa, Hikaru

General Affairs Division

Manager	Harada, Eiichiro
Deputy Manager	Furuhata, Tomoyuki
Specialist (Information Technology)	Chiba, Yoko
Specialist (Personnel Accounting)	Ishii, Katsuhiko
Specially Appointed Senior Specialist	Noguchi, Koki
Specially Appointed Senior Specialist	Takahashi, Hidehiro
Specially Appointed Senior Specialist	Yamamoto, Chieko

General Affairs Section

Chief	Chiba, Yoko
Staff	Matsukura, Koji
Staff	Mochimaru, Shiori
Staff	Morita, Akitsugu
Vehicle Driver	Amemiya, Hidemi
Administrative Expert	Murakami, Sachiko
Administrative Expert	Noguchi, Utako
Administrative Supporter	Kobayashi, Kayo
Administrative Supporter	Seki, Kumi

Personnel Section

Chief	Yamanouchi, Mika
Staff	Isozaki, Yuka
Staff	Iwasaki, Yumi
Staff	Sakamoto, Misato

Payroll Section

Chief	Ishii, Katsuhiko
Staff	Furukawa, Shinichiro
Staff	Inoue, Miyuki
Administrative Supporter	Aiba, Narukazu
Administrative Supporter	Momma, Yoko

Employee Affairs Section

Chief	Yamaura, Mari
Staff	Ouchi, Kaori
Staff	Saito, Masahiro
Administrative Expert	Noguchi, Megumi

Research Promotion Division

Manager	Ishibashi, Kazuya
Senior Specialist	Onishi, Tomoyuki
Administrative Supporter	Ito, Yoshihisa
Research Support Section	
Chief	Goto, Michiru
Staff	Nakagawa, Yukie
Administrative Expert	Tanaka, Midori
Administrative Expert	Yoshizawa, Mariko
Administrative Supporter	Komoda, Chizuru
Administrative Supporter	Suzuki, Yoshiko
Administrative Supporter	Torii, Makiko
Administrative Supporter	Urushibata, Kozue
Graduate School Section	
Chief	Fujimori, Mihiro
Administrative Expert	Inoue, Mizuho
International Academic Affairs Section	
Staff	Takada, Miyuki

MEXT Trainee

Staff	Yamafuji, Yasuto

Financial Affairs Division

Manager	Honda, Daisuke
Deputy Manager	Ikeda, Hiroshi
Specialist (Audit)	Ishikawa, Junya
Staff	Hiramatsu, Naoya
General Affairs Section	
Chief	Yamamoto, Shinichi
Administrative Supporter	Sasaki, Sayuri
Budget Section	
Chief	Akaike, Makoto
Staff	Masuda, Akio
Administrative Supporter	Ishida, Mikiko
Asset Management Section	
Chief	Kikkawa, Hiroko
Staff	Takahashi, Sachiko
Purchase Validation Center	
Chief	Kikkawa, Hiroko
Administrative Supporter	Nakagomi, Kimitoshi
Administrative Supporter	Shibui, Junko
Administrative Supporter	Tsukamoto, Satoko

Accounting Division

Manager	Tanaka, Masaru
Specialist (Contract)	Miura, Susumu
Accounting Section	
Chief	Sato, Yoko
Staff	Okubo, Kazuhiko
Administrative Supporter	Kobayashi, Rina
Administrative Supporter	Shinomiya, Miho
Administrative Supporter	Suzuki, Yukiko
Procurement Section	
Chief	Yamazaki, Go
Staff	Kayamori, Shinji
Staff	Sugimoto, Naomi
Staff	Takai, Tetsuya
Consultant	Hyuga, Tadayuki
Administrative Expert	Sato, Masako
Administrative Supporter	Ochiai, Nana

Facilities Division

Manager	Takahashi, Kazuhisa
General Affairs Section	
Chief	Kawashima, Ryota
Staff	Tamura, Makoto
Administrative Supporter	Hasegawa, Chisato
Planning Section	
Chief	Murakami, Kazuhiro
Administrative Supporter	Nagata, Yomogi
Maintenance Section	
Chief	Narisawa, Hiroyuki

6. Personnel change

Director General

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2018/3/31	Hayashi, Masahiko	Contract Expired	(Division of Optical and Infrared Astronomy, Professor)	Director General

Research and Academic Staff

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2017/4/1	Yoshida, Michitoshi	Hired	Division of Optical and Infrared Astronomy (Subaru Telescope), Professor	(Hiroshima University Hiroshima Astrophysical Science Center, Professor)
2017/10/1	Leonardi, Matteo	Hired	Division of Optical and Infrared Astronomy (Gravitational Wave Project Office), Assistant Professor	(Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Postdoctoral Researcher)
2017/11/1	Ono, Yoshito	Hired	Division of Optical and Infrared Astronomy (Subaru Telescope), Assistant Professor	(Laboratory of Astrophysics of Marseille, Post-doctoral Fellow)
2017/12/1	Kataoka, Akimasa	Hired	Division of Theoretical Astronomy, Assistant Professor	(Division of Theoretical Astronomy, Specially Appointed Assistant Professor)
2018/3/1	Tanaka, Masayuki	Hired	Division of Optical and Infrared Astronomy (Subaru Telescope), Associate Professor	(Subaru Telescope, Specially Appointed Assistant Professor)
2017/4/30	Kodama, Tadayuki	Resigned	(Tohoku University Graduate School of Science, Professor)	Division of Optical and Infrared Astronomy (Subaru Telescope), Associate Professor
2017/9/30	Sekimoto, Yutaro	Resigned	(Japan Aerospace Exploration Agency Institute of Space and Astronautical Science Department of Space Astronomy and Astrophysics, Professor)	Advanced Technology Center, Associate Professor
2018/3/31	Takami, Hideki	Resigned	(Advanced Technology Center, Specially Appointed Professor (Distinguished Professor))	Advanced Technology Center, Professor
2018/3/31	Tanaka, Masaomi	Resigned	(Tohoku University Graduate School of Science, Associate Professor)	Division of Theoretical Astronomy, Assistant Professor
2018/3/31	Ohsuga, Ken	Resigned	(University of Tsukuba Center for Computational Sciences, Professor)	Division of Theoretical Astronomy (Center for Computational Astrophysics), Assistant Professor
2018/3/31	Noguchi, Takashi	Retired		Advanced Technology Center, Professor
2018/3/31	Watanabe, Tetsuya	Retired		Division of Solar and Plasma Astrophysics (Solar Science Observatory), Professor
2018/3/31	Ukita, Nobuharu	Retired		Division of Optical and Infrared Astronomy (Okayama Astrophysical Observatory), Associate Professor
2018/3/31	Hanada, Hideo	Retired		Division of Radio Astronomy (RISE Project), Associate Professor
2018/3/31	Miyashita, Takaaki	Retired		Division of Optical and Infrared Astronomy (TMT-J Project Office), Chief Research Engineer
2018/3/31	Kawashima, Susumu	Retired		Division of Radio Astronomy (Engineering Promotion Office), Chief Research Engineer

2018/3/31	Sato, Katsuhisa	Retired		Division of Radio Astronomy (Mizusawa VLBI Observatory), Chief Research Engineer

2017/12/1	Katsukawa, Yukio	Promoted	Division of Solar and Plasma Astrophysics (Solar Science Observatory), Associate Professor	Division of Solar and Plasma Astrophysics (SOLAR-C Project Office), Assistant Professor
2017/12/1	Gonzalez Garcia, Alvaro	Promoted	Division of Radio Astronomy (NAOJ Chile Observatory), Associate Professor	Division of Radio Astronomy (NAOJ Chile Observatory), Assistant Professor

Engineering Staff

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2017/4/1	Sakai, Ryo	Hired	Advanced Technology Center, Engineer	

2018/3/1	Kurakami, Tomio	Promoted	Division of Radio Astronomy (Nobeyama Radio Observatory), Senior Engineer	Division of Radio Astronomy (Nobeyama Radio Observaory), Chief Engineer
2018/3/1	Uraguchi, Fumihiro	Promoted	Advanced Technology Center, Senior Engineer	Advanced Technology Center, Chief Engineer

Administrative Staff

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2017/4/1	Ishibashi, Kazuya	Hired	Administration Department Research Promotion Division, Manager	(University of Toyama)
2017/4/1	Honda, Daisuke	Hired	Administration Department Financial Affairs Division, Manager	(Ministry of Education, Culture, Sports, Science and Technology-Japan)
2017/4/1	Takahashi, Kazuhisa	Hired	Administration Department Facilities Division, Manager	(Tokyo University of Foreign Studies)
2017/4/1	Ishii, Katsuhiko	Hired	Administration Department General Affairs Division Payroll Section, Chief	(Tokyo Gakugei University)
2017/4/1	Fujimori, Mihiro	Hired	Administration Department Research Promotion Division Graduate Student Affairs Section, Chief	(The University of Tokyo)
2017/4/1	Miura, Susumu	Hired	Administration Department Research Promotion Division External Funding Specialist	(Tokyo Gakugei University)
2017/4/1	Iwasaki, Yumi	Hired	Administration Department General Affairs Division Personnel Section, Staff	
2017/4/1	Okubo, Kazuhiko	Hired	Administration Department Accounting Division Accounting Section, Staff	(The Graduate University for Advanced Studies)
2017/4/1	Tamura, Makoto	Hired	Administration Department Facilities Division General Affairs Section, Staff	
2017/8/1	Takahashi, Masaru	Hired	Nobeyama Radio Observatory Administration Office Accounting Section, Senior Staff	(Shinshu University)

2017/7/31	Iijima Kunio	Resigned	(Shinshu University)	Nobeyama Radio Observatory Administration Office Accounting Section, Senior Staff

2018/3/31	Amemiya, Hidemi	Retired	(Administration Department General Affairs Division, Consultant)	Administration Department General Affairs Division General Affairs Section, Vehicle Driver

2018/3/31	Hommyo, Susumu	Retired	(Mizusawa VLBI Observatory Administration Office, Consultant)	Mizusawa VLBI Observatory Administration Office, Deputy Manager and Chief of General Affairs Section

2017/8/1	Sugawara, Satoshi	Promoted	Subaru Telescope Administration Department Accounting Section, Chief	Subaru Telescope Administration Department Accounting Section, Senior Staff

Employee on Annual Salary System

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2017/4/1	Izumi, Takuma	Hired	Subaru Telescope, Specially Appointed Assistant Professor	
2017/4/1	Kataoka, Akimasa	Hired	Division of Theoretical Astronomy, Specially Appointed Assistant Professor	
2017/4/1	Sugiyama, Koichiro	Hired	Mizusawa VLBI Observatory, Specially Appointed Research Staff	
2017/4/1	Tazaki, Fumie	Hired	Mizusawa VLBI Observatory, Specially Appointed Research Staff	(Mizusawa VLBI Observatory, Specially Appointed Research Staff)
2017/4/1	Saito, Toshiki	Hired	NAOJ Chile Observatory, Specially Appointed Research Staff	
2017/4/1	Nishimura, Yuri	Hired	NAOJ Chile Observatory, Specially Appointed Research Staff	
2017/4/1	Wang, Tao	Hired	NAOJ Chile Observatory, Specially Appointed Research Staff	
2017/4/1	Baba, Jun'ichi	Hired	JASMINE Project Office, Specially Appointed Research Staff	
2017/4/1	Nagai, Makoto	Hired	Advanced Technology Center, Specially Appointed Research Staff	
2017/4/1	Kinugasa, Kenzo	Hired	Nobeyama Radio Observatory, Specially Appointed Senior Specialist	
2017/4/1	Hamada, Kaname	Hired	Nobeyama Radio Observatory, Specially Appointed Senior Specialist	
2017/4/1	Morita, Satoshi	Hired	Solar Science Observatory, Specially Appointed Senior Specialist	
2017/4/1	Yamada, Yoshihiko	Hired	Subaru Telescope, Specially Appointed Senior Specialist	
2017/4/1	Koike, Michitaro	Hired	Subaru Telescope, Specially Appointed Senior Specialist	
2017/4/1	Mineo, Sogo	Hired	Subaru Telescope, Specially Appointed Senior Specialist	
2017/4/1	Oshino, Shoichi	Hired	Center for Computational Astrophysics, Specially Appointed Senior Specialist	
2017/4/1	Miyachi, Akihira	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2017/4/1	Otawara, Kazushige	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	(NAOJ Chile Observatory, Specially Appointed Senior Specialist)
2017/4/1	Furutani, Akio	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	(NAOJ Chile Observatory, Specially Appointed Senior Specialist)
2017/4/1	Tanaka, Nobuhiro	Hired	Astronomy Data Center, Specially Appointed Senior Specialist	
2017/4/1	Yamanaka, Satoshi	Hired	Astronomy Data Center, Specially Appointed Senior Specialist	
2017/4/1	Usuda, Kumiko	Hired	Public Relations Center, Specially Appointed Senior Specialist	

2017/4/1	Saito, Sakae	Hired	Advanced Technology Center, Specially Appointed Senior Specialist	
2017/4/10	Sasada, Mahito	Hired	Mizusawa VLBI Observatory, Specially Appointed Research Staff	
2017/5/1	Adachi, Yuki	Hired	Mizusawa VLBI Observatory, Specially Appointed Senior Specialist	
2017/5/1	Nishikawa, Tomoko	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2017/6/5	Kusune, Takayoshi	Hired	Division of Theoretical Astronomy, Specially Appointed Research Staff	
2017/7/1	Hanayama, Hidekazu	Hired	Mizusawa VLBI Observatory, Specially Appointed Research Staff	
2017/8/1	Higuchi, Arika	Hired	RISE Project, Specially Appointed Research Staff	
2017/8/1	Okura, Yuki	Hired	Subaru Telescope, Specially Appointed Senior Specialist	
2017/9/1	Hull, Charles Lindsay Hopkins	Hired	NAOJ Chile Observatory, Specially Appointed Assistant Professor	
2017/9/1	Shirasaki, Masato	Hired	Division of Theoretical Astronomy, Specially Appointed Assistant Professor	
2017/9/1	Walker, Daniel Lewis	Hired	NAOJ Chile Observatory, Specially Appointed Research Staff	
2017/9/1	Nakajima, Masayo	Hired	Subaru Telescope, Specially Appointed Senior Specialist	
2017/10/1	Akahori, Takuya	Hired	Mizusawa VLBI Observatory, Specially Appointed Research Staff	
2017/10/1	Wu, Yu-Ting	Hired	NAOJ Chile Observatory, Specially Appointed Research Staff	
2017/10/1	Hayashi, Kohei	Hired	Advanced Technology Center, Specially Appointed Research Staff	
2017/10/1	Kim, Mi Kyoung	Hired	Mizusawa VLBI Observatory, Specially Appointed Senior Specialist	
2017/10/1	Yamanoi, Hitomi	Hired	Subaru Telescope, Specially Appointed Senior Specialist	
2017/10/1	Kobayashi, Tsuyoshi	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2017/10/1	Matsumoto, Mizuho	Hired	Office of International Relations, Specially Appointed Senior Specialist	
2017/11/1	Tafoya Martinez, Daniel	Hired	NAOJ Chile Observatory, Specially Appointed Associate Professor	
2017/11/1	Kim, Gwanjeong	Hired	Nobeyama Radio Observatory, Specially Appointed Research Staff	
2017/11/1	Wu, Benjamin	Hired	Division of Theoretical Astronomy, Specially Appointed Research Staff	
2017/12/1	Hattori, Masayuki	Hired	TMT-J Project Office, Specially Appointed Assistant Professor	
2017/12/1	Horiuchi Takashi	Hired	Mizusawa VLBI Observatory, Specially Appointed Research Staff	
2017/12/1	Nakanishi, Takashi	Hired	NAOJ Chile Observatory, Specially Appointed Senior Specialist	
2017/12/1	Endo, Tatsuki	Hired	TMT-J Project Office, Specially Appointed Senior Specialist	
2018/1/1	Tanaka, Kei	Hired	NAOJ Chile Observatory, Specially Appointed Research Staff	
2018/1/15	Capocasa, Eleonora	Hired	Gravitational Wave Project Office, Specially Appointed Research Staff	

2018/2/1	Ueda, Junko	Hired	NAOJ Chile Observatory, Specially Appointed Assistant Professor	
2018/2/1	Salinas Poblete, Vachail Nicolas	Hired	NAOJ Chile Observatory, Specially Appointed Research Staff	
2018/2/1	Silva Bustamante, Andrea Ludovina	Hired	NAOJ Chile Observatory, Specially Appointed Research Staff	
2018/2/13	Guzman Fernandez, Andres Ernesto	Hired	NAOJ Chile Observatory, Specially Appointed Research Staff	
2018/3/1	Ozawa, Tomohiko	Hired	Mizusawa VLBI Observatory, Specially Appointed Senior Specialist	
2018/3/1	Shindo, Miwa	Hired	TMT-J Project Office, Specially Appointed Senior Specialist	
2018/3/1	Haruki, Mutsumi	Hired	Office of International Relations, Specially Appointed Senior Specialist	
2018/3/1	Takahashi, Hidehiro	Hired	Administration Department General Affairs Division, Specially Appointed Senior Specialist	

2017/6/9	Neelamkodan, Naslim	Resigned		NAOJ Chile Observatory, Specially Appointed Research Staff
2017/6/15	Hayashi, Yusuke	Resigned		Subaru Telescope, Specially Appointed Senior Specialist
2017/6/22	Muller, Erik Michael	Resigned		NAOJ Chile Observatory, Specially Appointed Associate Professor
2017/8/31	Dominjon, Agnes Micheline	Resigned		Advanced Technology Center, Specially Appointed Research Staff
2017/9/30	Hasebe, Takashi	Resigned		Advanced Technology Center, Specially Appointed Research Staff
2017/10/31	Takagi, Yuhei	Resigned		Subaru Telescope, Specially Appointed Research Staff
2017/11/30	Kataoka, Akimasa	Resigned	(Division of Theoretical Astronomy, Assistant Professor)	Division of Theoretical Astronomy, Specially Appointed Assistant Professor
2017/12/31	Sasada, Mahito	Resigned		Mizusawa VLBI Observatory, Specially Appointed Research Staff
2018/2/28	Tanaka, Masayuki	Resigned	(Division of Optical and Infrared Astronomy (Subaru Telescope), Associate Professor)	Subaru Telescope, Specially Appointed Assistant Professor
2018/3/20	Sugimoto, Kanako	Resigned		NAOJ Chile Observatory, Specially Appointed Senior Specialist
2018/3/31	Kawamura, Taichi	Resigned		RISE Project, Specially Appointed Research Staff
2018/3/31	Hayashi, Kohei	Resigned		Advanced Technology Center, Specially Appointed Research Staff
2018/3/31	Yamanaka, Satoshi	Resigned		Astronomy Data Center, Specially Appointed Senior Specialist

2017/5/18	Wu, Yuanwei	Contract Expired		Mizusawa VLBI Observatory, Specially Appointed Research Staff
2017/9/30	Saito,Toshiki	Contract Expired		NAOJ Chile Observatory, Specially Appointed Research Staff
2017/9/30	Kuniyoshi, Masaya	Contract Expired		NAOJ Chile Observatory, Specially Appointed Senior Specialist
2018/1/31	Saito, Motoi	Contract Expired		NAOJ Chile Observatory, Specially Appointed Senior Specialist

2018/3/31	Kambe, Eiji	Contract Expired	(Subaru Telescope, Specially Appointed Associate Professor)	Okayama Astrophysical Observatory, Specially Appointed Associate Professor
2018/3/31	Kawamura, Akiko	Contract Expired		NAOJ Chile Observatory, Specially Appointed Associate Professor
2018/3/31	Akiyama, Eiji	Contract Expired		NAOJ Chile Observatory, Specially Appointed Assistant Professor
2018/3/31	Miyamoto, Yusuke	Contract Expired	(NAOJ Chile Observatory, Specially Appointed Assistant Professor)	Nobeyama Radio Observatory, Specially Appointed Research Staff
2018/3/31	Matsubayashi, Kazuya	Contract Expired		Okayama Astrophysical Observatory, Specially Appointed Research Staff
2018/3/31	Asahina, Yuta	Contract Expired		Center for Computational Astrophysics, Specially Appointed Research Staff
2018/3/31	Konuma, Mika	Contract Expired		NAOJ Chile Observatory, Specially Appointed Senior Specialist
2018/3/31	Nukatani, Sorahiko	Contract Expired		NAOJ Chile Observatory, Specially Appointed Senior Specialist
2018/3/31	Kozu, Akihito	Contract Expired		TMT-J Project Office, Specially Appointed Senior Specialist
2018/3/31	Komiyama, Hiroko	Contract Expired		Office of International Relations, Specially Appointed Senior Specialist

2017/9/1	Flaminio, Raffaele	Changed (Seconded)	Gravitational Wave Project Office, Specially Appointed Professor *Seconded based on the Agreement of Cross Appointment with Centre National de la Recherche Scientifique (CNRS)	Gravitational Wave Project Office, Specially Appointed Professor

2018/1/1	Omiya, Masashi	Reassigned	Astrobiology Center Astrobiology Equipment Development Office, Specially Appointed Research Staff	National Astronomical Observatory of Japan Extrasolar Planet Detection Project Office, Specially Appointed Research Staff
2018/1/1	Konishi, Mihoko	Reassigned	Astrobiology Center Astrobiology Equipment Development Office, Specially Appointed Research Staff	National Astronomical Observatory of Japan Extrasolar Planet Detection Project Office, Specially Appointed Research Staff

Research Administrator Staff

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2017/4/1	Okamoto, Koichi	Hired	Research Enhancement Strategy Office (Safety and Health Management Office), Specially Appointed Senior Specialist	
2017/10/1	Suzui, Mitsukazu	Hired	Research Enhancement Strategy Office (Engineering Promotion Office), Specially Appointed Senior Specialist	
2017/11/1	Asaga, Akitaka	Hired	Research Enhancement Strategy Office, Specially Appointed Senior Specialist	
2018/1/1	Noda, Noboru	Hired	Research Enhancement Strategy Office (Human Resources Planning Office), Specially Appointed Senior Specialist	

2018/3/31	Yamamiya, Osamu	Contract Expired		Research Enhancement Strategy Office (Human Resources Planning Office), Specially Appointed Senior Specialist

Foreign Visiting Researcher

Name	Period			Affiliated Institute
Richmond, Michael William	2017/4/1	~	2017/5/30	Rochester Institute of Technology (U.S.A.)
Norman, Colin Arthur	2017/4/2	~	2017/5/1	Johns Hopkins University, Physics and Astronomy & Space Telescope Science Institute (U.S.A.)
Deliduman, Cemsinan	2017/4/2	~	2017/7/30	Mimar Sinan Fine Arts University (Turkey)
Deliduman, Yamac	2017/4/2	~	2017/7/30	Mimar Sinan Fine Arts University (Turkey)
Pipin, Valerii	2017/4/4	~	2017/6/29	Institute of Solar-Terrestrial Physics, Siberian Branch Russian Academy of Sciences (Russia)
Tan, Jonathan	2017/4/15	~	2017/5/15	University of Florida (U.S.A.)
Brun, Allan Sacha Rodolphe	2017/9/14	~	2017/12/15	CEA-Saclay (France)
Overzier, Roderik Adriaan	2017/11/1	~	2017/11/30	National Observatory, Rio de Janeiro (Brazil)
Andreani, Paola Michela	2018/1/14	~	2018/2/24	European Southern Observatory (Germany)

7. Advisory Committee for Research and Management

Members

From universities and related institutes

Chiba, Seiji	Graduate School of Science and Faculty of Science, Tohoku University
Doi, Mamoru	School of Science, The University of Tokyo
Fujisawa, Kenta	The Research Institute for Time Studies at Yamaguchi University
Ichimoto, Kiyoshi	Hida Observatories, Graduate School of Science, Kyoto University
Kajita, Takaaki	Institute for Cosmic Ray Research, The University of Tokyo
Matsushita, Kyoko	Faculty of Science Division1, Tokyo University of Science
Mitsuda, Kazuhisa	Institute of Space and Astronautical Science
Murakami, Izumi	National Institute for Fusion Science
○ Momose, Munetake	College of Science, Ibaraki University
Sugita, Seiji	School of Science, The University of Tokyo

From NAOJ

Gouda, Naoteru	JASMINE Project Office
Hasegawa, Tetsuo	NAOJ Chile Observatory
Honma, Mareki	Mizusawa VLBI Observatory
Kobayashi, Hideyuki	Mizusawa VLBI Observatory
Kokubo, Eiichiro	Center for Computational Astrophysics
Sakamoto, Seiichi	NAOJ Chile Observatory
Takami, Hideki	Advanced Technology Center
Tomisaka, Kohji	Division of Theoretical Astronomy
Usuda, Tomonori	TMT-J Project Office
● Watanabe, Jun-ichi	Public Relations Center
Yoshida, Michitoshi	Subaru Telescope

● Chairperson ○ Vise-Chairperson

Period: April 1, 2016 – March 31, 2018

8. Professors Emeriti

Professors Emeriti (NAOJ)

Kakuta, Chuichi
Hiei, Eijiro
Yamashita, Yasumasa
Nishimura, Shiro
Hirayama, Tadashi
Miyamoto, Masanori
Nariai, Kyouji
Okamoto, Isao
Nakano, Takenori
Kodaira, Keiichi
Yokoyama, Koichi
Oe, Masatsugu
Kinoshita, Hiroshi
Nishimura, Tetsuo
Kaifu, Norio
Ishiguro, Masato
Inoue, Makoto
Kawano, Nobuyuki
Andou, Hiroyasu
Karoji, Hiroshi
Chikada, Yoshihiro
Noguchi, Kunio
Fujimoto, Masakatsu
Manabe, Seiji
Miyama, Shoken
Kawaguchi, Noriyuki
Iye, Masanori
Shibasaki, Kiyoto
Sakurai, Takashi
Arimoto, Nobuo
Kobayashi, Yukiyasu
Mizumoto, Yoshihiko

IV Finance

Revenue and Expenses (FY2017)

(Unit: ¥1,000)

Revenue	Budget	Final Account	Budget − Final Account
Management Expenses Grants	10,175,004	10,685,620	−510,616
Facilities Maintenance Grants	415,990	415,972	18
Subsidy Income	1,308,800	1,308,800	0
Miscellaneous Income	49,691	61,860	−12,169
Industry-Academia Research Income and Donation Income	333,362	560,448	−227,086
Reversals of Reserves for Specific Purposes	0	0	0
Total	12,282,847	13,032,700	−749,853
Expenses	Budget	Final Account	Budget − Final Account
Management Expenses	10,224,695	9,964,054	260,641
Employee Personnel Expenses	3,531,387	3,553,345	−21,958
Operating Expenses	6,693,308	6,410,709	282,599
Facilities Maintenance Expenses	415,990	415,972	18
Subsidy Expenses	1,308,800	1,308,800	0
Industry-Academia Research Expenses and Donation Expenses	333,362	367,710	−34,348
Total	12,282,847	12,056,536	226,311
Revenue-Expenses	Budget	Final Account	Budget − Final Account
	0	976,164	−976,164

V KAKENHI (Grants-in-Aid for Scientific Research)

1. Series of Single-year Grants for FY 2017

Research Categories	Number of Selected Projects	Budget (Unit: ¥1,000)		
		Direct Funding	Indirect Funding	Total
Scientific Research on Innovative Areas (Research in a proposed research area)	8	85,200	25,560	110,760
Scientific Research (S)	1	15,200	4,560	19,760
Scientific Research (A)	10	83,200	24,960	108,160
Scientific Research (B)	9	28,800	8,640	37,440
Young Scientists (A)	3	20,100	6,030	26,130
Research Activity Start-up	3	2,800	840	3,640
JSPS Research Fellows	9	9,900	2,970	12,870
JSPS International Research Fellows	1	800	0	800
Publication of Scientific Research Results	1	500	0	500
Total	45	246,500	73,560	320,060

2. Multi-year Fund for FY 2017

Research Categories	Number of Selected Projects	Budget (Unit: ¥1,000)		
		Direct Funding	Indirect Funding	Total
Scientific Research (C)	24	23,500	7,050	30,550
Challenging Exploratory Research	6	4,600	1,380	5,980
Young Scientists (B)	21	19,000	5,700	24,700
Total	51	47,100	14,130	61,230

3. Partial Multi-year Fund for FY 2017

Research Categories	Number of Selected Projects	Budget (Series of Single-year Grants) (Unit: ¥1,000)			Budget (Multi-year Fund) (Unit: ¥1,000)		
		Direct Funding	Indirect Funding	Total	Direct Funding	Indirect Funding	Total
Young Scientists (A)	1	100	30	130	0	0	0
Total	1	100	30	130	0	0	0

VI Research Collaboration

1. Open Use

Type	Project/Center	Category	Number of Accepted Proposals	Total Number of Researchers	Notes
Open Use at Project/Center	Okayama Astrophysical Observatory	188-cm Reflector Telescope (Project Program)	2	33(0)	2 Institutes
		188-cm Reflector Telescope (Normal Program)	26	202(25)	12 Institutes, 6 Countries
		188-cm Reflector Telescope (Student Program)	0		
		188-cm Reflector Telescope (Miscellaneous Program)	1	6(0)	1 Institute
		188-cm Reflector Telescope (ToO Program)	1	10(0)	2 Institutes
	Subaru Telescope		79	271(61)	53 Institutes, 8 Countries
	Solar Observatory	Ground-based Solar Observatory	*	*	*
		Solar Observing satellite "Hinode"	77	77(31)	31Institutes, 11 Countries
	Nobeyama Radio Observatory	45-m telescope (Regular Program)	26	204(88)	48 Institutes, 13 Countries
		45-m telescope (Short Program)	9	43(1)	16 Institutes, 1 Country
		45-m telescope (Large Program)	1	158(143)	70 Institutes, 16 Countries
		45-m telescope (Back-up Program)	1	12(1)	1 Institute, 1 Country
		45-m telescope (GuaranteedTimeObservations)	2	11(0)	5 Institutes
		45-m telescope (Director's Discretionary Time)	0		
	Mizusawa VLBI Observatory	VERA	23	135(70)	28 Institutes, 14 Countries
	Astronomy Data Center		369	369 (24 at foreign institutes)	20 Institutes, 13 Countries
	Center for Computational Astrophysics		270	270	59 Institutes, 10 Countries
	Advanced Technology Center	Facility Use	31	140(3)	57 Institutes, 1 Country
		Joint Research and Development	15	87(3)	34 Institutes, 1 Country
	NAOJ Chile Observatory	ALMA (Cycle 4)	475	4,857 (4,257)	397 Institutes, 42 Countries
		ASTE	20	149(23)	24 Institutes, 5 Countries
Joint Development Research			10		9 Institutes
Research Assembly			17		6 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 PI's. The country count does not include Japan.
The period of ALMA (Cycle 4) is September, 2017 from October, 2016.
* 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, 2017 – March 31, 2018

Name	Position at NAOJ	Affiliated Institute	Host Project/Center/Division
Kuno, Nario	Visiting Professor	University of Tsukuba	Nobeyama Radio Observatory
Otsubo, Toshimichi	Visiting Professor	Hitotsubashi University	RISE Project
Niinuma, Koutaro	Visiting Associate Professor	Yamaguchi University	Mizusawa VLBI Observatory
Sagawa, Hideo	Visiting Associate Professor	Kyoto Sangyo University	NAOJ Chile Observatory
Sekine, Yasuhito	Visiting Associate Professor	The University of Tokyo	RISE Project
Shima, Tatsushi	Visiting Associate Professor	Osaka University	Division of Theoretical Astronomy
Yanagisawa, Toshifumi	Visiting Associate Professor	Japan Aerospace Exploration Agency	Center for Computational Astrophisics
Nakagawa, Akiharu	Visiting Research Fellow	Kagoshima University	Mizusawa VLBI Observatory

JSPS (Japan Society for the Promotion of Science) Postdoctoral Research Fellows

Name	Research Subject	Acceptance Period	Host Researcher
Arimatsu, Kou	Exploring the outer solar system by stellar occultations observed with wide-field high-speed cameras	2015.4.1~2018.3.31	Watanabe, Jun-ichi
Shirasaki, Masato	Probing Cosmic Dark Matter and Dark Energy with Higher-Order Statistics of Weak Gravitational Lensing	2015.4.1~2017.8.31	Hamana, Takashi
Shinnaka, Yoshiharu	Physicochemistry of the early solar nebula: Thermal history of cometary dust and isotopic fractionation of cometary volatile	2015.4.1~2018.3.31	Watanabe, Jun-ichi
Yamauchi, Aya	Research in the structure of a distant region of our galaxy using a new distance measurement method with VERA	2015.4.1~2018.3.31	Honma, Mareki
Ichikawa, Kohei	Revealing the coevolution of black holes and galaxies through the newly discovered population of AGN	2016.4.1~2018.3.31	Imanishi, Masatoshi
Shibagaki, Shota	Revealing origin of r-process elements with astrophysical simulations	2017.4.1~2018.3.31	Kajino, Toshitaka
Suzuki, Tomoko	Galaxy anatomy before the peak epoch of galaxy formation: investigation of internal physical processes and their environmental dependence	2017.4.1~2018.3.31	Kashikawa, Nobunari
Tadaki, Kenichi	Revealing evolutionary pathways from disk- to elliptical galaxies with ALMA	2017.4.1~2020.3.31	Iono, Daisuke
Kawamuro, Taiki	Constraints on Supermassive Black Hole Growth Rates with Observations at Submm/mm Wavelengths, and Investigation of the Growth History	2017.4.1~2020.3.31	Imanishi, Masatoshi

JSPS (Japan Society for the Promotion of Science) Foreign Research Fellows

Name	Period	Host Researcher
Cataldi, Gianni	2016/11/21 ~ 2018/11/20	Ohashi, Nagayoshi
Wu, Benjamin	2016/9/27 ~ 2017/9/26	Nakamura, Fumitaka
Pattle, Katherine Miranda	2017/8/21 ~ 2017/10/20	Hasegawa, Tetsuo
Lopez Rodriguez, Enrique	2018/3/19 ~ 2018/4/18	Kashikawa, Nobunari

VII Graduate Course Education

1. Department of Astronomical Science, School of Physical Sciences, SOKENDAI (The Graduate University for Advanced Studies)

SOKENDAI (The Graduate University for Advanced Studies) was established in 1988 as an independent graduate university without undergraduate courses via partnerships with inter-university research institutes for the purpose of advancing graduate education.

There used to be four schools – Cultural and Social Studies, Mathematical and Physical Sciences, Life Science, and Advanced Sciences before the reorganization of the School of Mathematical and Physical Sciences into the schools of Physical Sciences, High Energy Accelerator Science, and Multidisciplinary Sciences in April 2004. Now the total of six schools are offering doctoral education and research opportunities.

NAOJ has been accepting three-year doctoral-course students since FY 1992 and five-year students since FY 2006 for the Department of Astronomical Science at the School of Physical Sciences. (The School of Mathematical and Physical Sciences was reorganized into the School of Physical Sciences in April 2004.)

(1) Objective of the Department of Astronomical Science

The Department of Astronomical Science aims to train students, through observational, theoretical, or instrument development research in astronomy or in related fields, in an environment with the most advanced observational instruments and supercomputers, as researchers who work at the forefront of world-class research; experts who carry out development of advanced technology; and specialists who endeavor in education and public outreach activities equipped with advanced and specialized knowledge.

Numbers of students to be annually:
- Two (for the five-year doctoral course)
- Three (for the three-year doctoral course)

Degree: Doctor of Philosophy

(2) Admission Policy

The Department of Astronomical Sciences seeks students with a strong interest in astronomy and the Universe; a passion for unraveling scientific questions through theoretical, observational, and instrument development research; and students who have not only basic academic skills, but also theoretical and creative aptitude required for advanced research.

(3) Department Details (Course Offerings)

Optical and Near Infrared Astronomy
[Educational and Research Guidance Field]
Ground-based astronomy / Optical and infrared telescope system / Planets / Sun, stars and interstellar matter / Galaxies and cosmology

Radio Astronomy
[Educational and Research Guidance Field]
Ground-based astronomy / Radio telescope system / Sun, stars and interstellar matter / Galaxies

General Astronomy and Astrophysics
[Educational and Research Guidance Field]
High-precision astronomical measurement / Astronomy from space / Data analysis and numerical simulation / Earth, Planets, and the Sun / Galaxies and cosmology

(4) Course-by-Course Education Program to Cultivate Researchers in Physical Sciences with Broad Perspectives

The School of Physical Sciences began its "Course-by-Course Education Program to Develop Student Research Capability and Aptitude" in FY 2009 as a part of MEXT's Program for "Enhancing Systematic Education in Graduate Schools." Currently the School is carrying out its succeeding program, "Course-by-Course Education Program to Cultivate Researchers in Physical Sciences with Broad Perspectives" since FY 2012, offering four specific courses to the students: the Basic Course, the Advanced Research Course, the Project Research Course, and the Development Research Course. In FY 2017, from the Department of Astronomical Science four students were accepted in the Basic Course and two students in the Advanced Research Course. The Department also offered the e-learning class "Introduction to Observational Astronomy II" as a school-wide common basic subject, as well as the "Exercise in Scientific English" class, in order to provide a good foundation for students at the graduate school.

The 2017 Summer Student programs were held at Mitaka, Mizusawa, Kamioka, and Chili 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 (2018/3/31)

Chair of the Department of Astronomical Science	1
Optical and Near Infrared Astronomy Course	
Professors	9
Associate Professors	14
Lecturer	1
Assistant Professors	16
Radio Astronomy Course	
Professors	8
Associate Professors	11
Assistant Professors	18
General Astronomy and Astrophysics Course	
Professors	5
Associate Professors	14
Assistant Professors	14
Total	111

(6) Graduate Students (33 students)

1st year (5 students)

Name	Principal Supervisor	Supervisor	Title of Research Project
Liang, Yongming	Kashikawa, Nobunari	Tanaka, Masayuki	Mapping the most massive large-scale structures through HI
Ito, Kei	Kashikawa, Nobunari	Matsuda, Yuichi	The study of protoclusters based on wide-imaging observations of Subaru Telescope
Tsukui, Takashi	Iguchi, Satoru	Nagai, Hiroshi	Study on the Radio galaxy formation with Supermassive Black Hole
Tsuda, Shuichiro	Honma, Mareki	Shibata, Katsunori	Measuring the Physical Properties near the Super-Massive Black Holes with the Event Horizon Telescope
Namiki, Shigeru	Kashikawa, Nobunari	Iwata, Ikuru	The evolution of galaxies in the cluster at z~1.5 and the environmental effect there

2nd year (5 students)

Name	Principal Supervisor	Supervisor	Title of Research Project
Ishikawa, Hiroyuki	Usuda, Tomonori	Hayashi, Saeko	The search and inspection of extrasolar habitable planets with a view to the discovery of the extraterrestrial life in the future
Tanioka, Satoshi	Aso, Yoichi	Flaminio, Raffaele	Direct measurement of the coating thermal noise using cryogenic optical cavities
Hatta, Yoshiki	Sekii, Takashi	Watanabe, Tetsuya Katsukawa, Yukio	Asteroseismic measurements of internal rotation of stars via solving inverse problems
Hosokawa, Kou	Kotani, Takayuki	Takami, Hideki Usuda, Tomonori	Development of a new high-resolution spectrograph with a spatial resolution and study of an exoplanet characterization
Watanabe, Noriharu	Usuda, Tomonori	Takami, Hideki Aoki, Wako	Observational Studies of Orbital Evolution of Various Exoplanets System

3rd year (9 students)

Name	Principal Supervisor	Supervisor	Title of Research Project
Cui, Yuzhu	Honma, Mareki	Nagai, Hiroshi	Observational study of jets in active galactic nuclei with the East Asian VLBI Network
Sahoo, Ananya	Minowa, Yosuke	Takato, Naruhisa	Advanced wavefront control in adaptive optics for exoplanet imaging
Zhao, Yuhang	Akutsu, Tomotada	Flaminio, Raffaele	Frequency dependent squeezing for gravitational wave detector
Fukagawa, Nao	Aoki, Wako	Iono, Daisuke	Star formation and gas flows of the distant galaxies as revealed by chemical evolution

Ando, Misaki	Iono, Daisuke	Saito, Masao Espada, Daniel	Observing Colliding Galaxies Using ALMA
Kambara, Nagaaki	Sekii, Takashi	Watanabe, Tetsuya	Local helioseismology
Kikuta, Satoshi	Imanishi, Masatoshi	Matsuda, Yuichi	AGN feedback to low-mass galaxy formation at high redshift
Matsuno, Tadafumi	Aoki, Wako	Komiyama, Yutaka	Pioneering stellar research to clarify the formation history of the Galactic halo
Yoshida, Masaki	Suematsu, Yoshinori	Hara, Hirohisa	Study of Solar Chromospheric Dynamic Phenomena by Spectro-polarimetric Observations

4th year (3 students)

Name	Principal Supervisor	Supervisor	Title of Research Project
Kim, Jungha	Honma, Mareki	Shibata, Katsunori	Understanding the circumstellar structure of high-mass young stellar objects based on KaVA observations
Michiyama, Tomonari	Iono, Daisuke	Nakanishi, Koichiro	Observing Starburst Galaxies Using ALMA
Yamamoto, Moegi	Iwata, Ikuru	Koyama, Yusei	Search for distant clusters of galaxies with Subaru HSC and evolution of galaxy populations

5th year (11 students)

Name	Principal Supervisor	Supervisor	Title of Research Project
Okutomi, Koki	Aso, Yoichi	Flaminio, Raffaele	Development of low-frequency vibration isolation system for test masses in gravitational-wave telescope KAGRA
Onoue, Masafusa	Kashikawa, Nobunari	Miyazaki, Satoshi	Exploration of Low-luminosity Quasars and the Growth of Super Massive Black Holes in the Reionization Epoch
Baba, Haruka	Aoki, Wako	Usuda, Tomonori	Development of infrared instrument and observational study for the survey of Earth-like planets
Ryu, Tsuguru	Hayashi, Saeko	Usuda, Tomonori	High-Contrast Imaging for Intermediate-Mass Giants with Long-Term Radial Velocity Trends
Yang, Yi	Hayashi, Saeko	Usuda, Tomonori	Direct Imaging of Planets and Protoplanetary Disks in Binary Systems
Sakurai, Junya	Miyazaki, Satoshi	Komiyama, Yutaka	Study of large scale structures in the universe through wide field imaging
Uchiyama, Hisakazu	Kashikawa, Nobunari	Matsuda, Yuichi	The study of the large scale structure based on wide-field imaging observation of Subaru Telescope
Taniguchi, Kotomi	Saito, Masao	Ohishi, Masatoshi	Chemical evolution and mechanisms of carbon-chain molecules in star-forming regions
Kobayashi, Hiroshi	Ohsuga, Ken	Tomisaka, Kohji	Radiation Hydrodynamics Simulations of Clumpy Outflows from Black-Hole Accretion Disks
Pathak, Prashant	Takami, Hideki	Minowa, Yosuke	Chromaticity effects on high resolution imaging
Sukom, Amnart	Tomisaka, Kohji	Hayashi, Saeko	Study of star and planetary formation process and the exoplanets based on infrared observations

2. Education and Research Collaboration with Graduate Schools

Name	Affiliated Institute	Supervisor	Title of Research Project
Guo, Kangrou	The University of Tokyo	Kokubo, Eiichiro	Formation and evolution of planetary systems
Lee, Sujin	The University of Tokyo	Kobayashi, Hideyuki	Study of highly precise astronomy by using VLBI
Ishiduka, Noriyoshi	The University of Tokyo	Hara, Hirohisa	Study of Fine Structures in Superhot Components of Solar Flare
Kashiwada, Yuuki	The University of Tokyo	Gouda, Naoteru	Analysis of the dynamical structure of the Galaxy
Kuroki, Shunshi	The University of Tokyo	Flaminio, Raffaele	Development of vibration isolation system for the KAGRA
Sato, Kazuki	The University of Tokyo	Sakamoto, Seiichi	Observational Study of Star/Planetary System Formation with Radio Telescopes
Tanimoto, Yuta	The University of Tokyo	Yamashita, Takuya	Observational studies of exoplanets
Chin, Kah Wuy	The University of Tokyo	Kawabe, Ryohei	Developments of Ultra-Wideband Spectrometers using KIDs
Terasawa, Shoko	The University of Tokyo	Ohashi, Nagayoshi	A study on star formation using radio interferometers
Luo, Yudong	The University of Tokyo	Kajino, Toshitaka	Big Bang Nucleosynthesis and Big Bang Model
Inooka, Kota	The University of Tokyo	Yamashita, Takuya	Observational studies of rapidly variable objects
Choi, Insa	The University of Tokyo	Ohashi, Nagayoshi	A study on the protostar L1489 IRS using radio interferometers
Shimizu, Takayuki	The University of Tokyo	Sekimoto, Yutaro	Design of Wide Field CMB Polarization Instruments
Tatsuuma, Misako	The University of Tokyo	Kokubo, Eiichiro	Planetary formation
Mori, Kanji	The University of Tokyo	Kajino, Toshitaka	Nucleosynthesis in X-ray bursts
Yamaguchi, Masayuki	The University of Tokyo	Kawabe, Ryohei	Super Resolution Imaging of Protoplanetary disk Using Sparse Modeling
Sasaki, Hirokazu	The University of Tokyo	Kajino, Toshitaka	Study the origin of heavy elements through the collective neutrino oscillations in core-collapse supernovae
Fujii, Yoshinori	The University of Tokyo	Flaminio, Raffaele	Development of the vibration isolation system for the KAmioka Gravitational-wave Antenna
Fujita, Ayato	The University of Tokyo	Gouda, Naoteru	Analysis of the solar motion and the Galaxy's rotation considering orbital resonance
Kuramochi, Kazuki	The University of Tokyo	Kobayashi, Hideyuki	Observational demonstration of RIAF with sub-mm VLBI using Sparse Modeling
Lee, Minju	The University of Tokyo	Kawabe, Ryohei	Environmental effect on galaxy evolution using atomic and molecular lines
Kato, Yuta	The University of Tokyo	Sakamoto, Seiichi	Star forming activity in the z=2–3 proto-clusters with Infrared Space telescope
Sakai, Daisuke	The University of Tokyo	Kobayashi, Hideyuki	Dynamical study of molecular clouds in the Galactic center with radio observations
Shibata, Takashi	The University of Tokyo	Kokubo, Eiichiro	Spin of planets
Hirai, Yutaka	The University of Tokyo	Kajino, Toshitaka	Chemo-dynamical evolution of galaxies deduced from r-process elements
Marchio, Manuel	The University of Tokyo	Flaminio, Raffaele	Development, characterization and improvement of the mirrors for the KAGRA gravitational wave detector

3. Commissioned Graduate Students

Doctoral Course	Affiliated Institute	Period	Supervisor	Title of Research Project
Kozuki, Yuto	Osaka Prefecture University	2017/4/1~ 2018/3/31	Noguchi, Takashi	Research and development of a superconducting wideband receiver at millimeter and submillimeter wavelengths
Silva, Andrea	Tufts University	2017/4/1~ 2017/12/31	Iono, Daisuke	ALMA Observations of Starburst Galaxies
Kumamoto, Jun	Tohoku University	2017/4/1~ 2018/3/31	Gouda, Naoteru	Theoretical Prediction for the Milky Way Evolution Using Galactic Dynamics

Master’s Course	Affiliated Institute	Period	Supervisor	Title of Research Project
Oyamada, Shuri	Japan Women's University	2017/4/1~ 2017/9/30	Nakamura, Fumitaka	Observational Study of Orion Molecular Cloud with a dense gas tracer
Kooriba, Motohiro	Tokyo University of Agriculture and Technology	2017/4/1~ 2018/3/31	Watanabe, Junichi	Generation of wavelength-variable broadband comb and its application to precision spectroscopy
Suzuki, Shunta	Osaka Prefecture University	2017/4/1~ 2018/3/31	Kawabe, Ryohei	Multicolor TES Bolometer Camera for the ASTE Telescope
Morozumi, Tatsuhiko	The University of Tokyo	2017/4/1~ 2017/9/30	Aso, Yoichi	Development of Beam Reducing Telescope
Sakata, Misaki	The University of Electro-Communications	2017/10/1~ 2018/3/31	Matsuo, Hiroshi	Development of THz photon counting technologies with superconducting tunnel junction detectors
Tomura, Akihiro	The University of Electro-Communications	2017/10/1~ 2018/3/31	Flaminio, Raffaele	Development of treaquency-dependent squeezing for quantum noise reduction in the gravitational wave defector
Miyachi, Yusuke	Yamaguchi University	2017/10/1~ 2018/3/31	Honma, Mareki	Comparing study between high precision astrometry results with VERA and a simulation result based on the density wave theory
Mochizuki, Chisato	Japan Women's University	2017/10/1~ 2018/3/31	Kashikawa, Nobunari	The Properties of Ultra Diffuse Galaxies explored by Subaru Telescope
Yatabe, Kazuki	The University of Electro-Communications	2017/10/1~ 2018/3/31	Hayano, Yutaka	Experiment and evaluation for TMT/IRIS prototype.

4. Degrees Achieved with NAOJ Facilities

Name	Degree	Title of Research Project
Pathak, Prashant	Doctor of Philosophy, SOKENDAI	First On-sky Closed-loop Atmospheric Dispersion Compensation: Demonstration of Sub-milliarcsecond Residual Dispersion Across H-band
Yang, Yi	Doctor of Philosophy, SOKENDAI	Near-Infrared High-Resolution Polarimetry Observations towards Protoplanetary Disks in Binary/Multiple Systems
Onoue, Masafusa	Doctor of Philosophy, SOKENDAI	Exploration of the Cosmic Dawn with High-Redshift Quasars
Kobayashi, Hiroshi	Doctor of Philosophy, SOKENDAI	Three-Dimensional Radiation-Hydrodynamic Simulation of Clumpy Outflow and Its Application to Supercritical Accretors around Black Holes
Taniguchi, Kotomi	Doctor of Philosophy, SOKENDAI	Formation Mechanisms of Cyanopolyynes and Chemical Evolution in the High-Mass Star-Forming Regions

VIII Public Access to Facilities

1. Mitaka Campus

[Open year-round]
Dates: April to March, 10:00–17:00
Every day except for New Year's season (December 28–January 4)
Visitors: 21,310
Open Facilities: Observatory History Museum (65-cm Telescope Dome), 20-cm Telescope Dome, Solar Tower Telescope, Exhibit Room, Repsold Transit Instrument Building (Transit Instrument Museum), Astronomical Instruments Museum, Gautier Meridian Circle Building, Old Library

[Regular Star Gazing Party]
Dates: Friday before second Saturday; fourth Saturday
Visitors: 4,772 (23 events)
Open Facility: 50-cm Telescope for Public Outreach

[4D2U Theater Showings]
Dates: Friday before second Saturday; first, second, and third Saturdays
Visitors: 5,097 (45 events)
Open Facility: 4D2U Dome Theater

[Special Open-House Event] Mitaka Open House Day
Dates: October 13 (Fri), 2017, 14:00–19:00
October 14 (Sat), 2017, 10:00–19:00
Topic: The Universe, Hot and Cold
Visitors: 3,269

This event is jointly sponsored by NAOJ, the University of Tokyo Graduate School of Science Institute of Astronomy, the SOKENDAI Department of Astronomical Science, and the NINS Astrobiology Center. It has been held for 2 days each year, starting from 2010.

The perennially popular lectures related to this year's theme were hosted by the Institute of Astronomy, University of Tokyo ("The WARM Universe Observed from Atacama, Chile" Takashi Miyata, Professor) and NAOJ ("ALMA Gazing at the Cold Universe" Tetsuo Hasegawa, NAOJ Specially Appointed Professor; and "Hot Solar Corona as Seen from Space" Ryohei Kano, NAOJ Associate Professor).

* Guided tours corresponding to group tours (Dantai Kengaku) and cultural property tours were also held. In addition, the "Information Space of Astronomy and Science" was opened in 2015 near the south entrance of Mitaka Station to distribute information.

2. Mizusawa Campus

[Open year-round]
Dates: April to March (except for the New Year's season), 9:00–17:00 daily
Visitors: 19,389
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.

[Special Open Day] Held as part of Iwate Galaxy Festival 2017 (Hours: 10:00-20:30)
Date: August 19 (Sat.), 2017, 10:00–20:30
Visitors: Approximately 1,165 (Until 16:30)

Same as 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 event was opened with a performance by a marching band from a local elementary school. NAOJ offered such attractions as exhibits about the research results of VERA, RISE, and CfCA; tours of the 20-m parabolic antenna; a commemorative photo booth; plastic bottle rocket launching; quiz game; tours of the supercomputer "ATERUI;" and a special guided tour of the Array Operations Center (AOC) and the VLBI correlator.

Special lectures about black holes were given by Motohide Tamura, Professor of University of Tokyo, Mareki Honma, Director of the Mizusawa VLBI Observatory, and Noriyuki Namiki, Professor of the RISE Project, and were enormously well received.

OSAM (Yugakukan) offered various experiments in the science stalls, workshops, etc., which were carried out by student interns. The Open Day was a great success to strengthen ties with the local people.

Iriki: VERA Iriki Station
[Open year-round]
Dates: April to March (except for the New Year's season)
Visitors: 1,602

[Special Open Day]
Date: August 12 (Sat.), 2017, 12:00–21:00
Visitors: 3,800

This special open event was held in conjunction with "Yaeyama Highland Star Festival 2017" hosted by the executive committee primarily formed by members of Satsuma-Sendai city hall and Kagoshima University.

At the NAOJ VERA 20-m radio telescope and the Kagoshima University 1-m optical/infrared telescope facilities, guided tours of the telescopes and observation building were held. NAOJ offered such attractions as parent-child science experiments, plastic bottle rocket launching, 4D2U (4-Dimentional Digital Universe) screening, and a stargazing party at night. This time samples of space foods were offered by JAXA, and were well received.

The special lecture of the year was given by Osamu Kameya, Assistant Professor, from Mizusawa VLBI Observatory. All visitors had fun and were satisfied with scientific programs offered in this festival.

Ogasawara: VERA Ogasawara Station

[Open year-round]

Dates: April to March (except for the New Year's season)
Visitors: 8,340

[Special Open Day]

Date: January 20 (Sat.), 2018, 10:00–16:00
Visitors: 167

A special open house event was held this year again under the name "Star Island 17." Same as last year, the free shuttle buses were appreciated by the visitors. The number of visitors was 167. (Because the number of residents in the island is about 2,000, approximately 10 % of the islanders visited this event.)

NAOJ offered such attractions as exhibits about the research results of VERA and RISE, driving experience of the 20-m parabolic antenna, quiz games, a commemorative photo booth, and short lectures.

On the night before the special open house, a Space Lecture was given by Saeko Hayashi, Associate Professor, at the Ogasawara Visitor Center, and was attended by 30 people.

A stargazing party was held by the local Ogasawara astronomy club on the day following the special open house, and NAOJ members also joined.

Ishigakijima: VERA Ishigakijima 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: 2,577

[Special Open day]

Date: August 13 (Sun.), 2017, 10:00-17:00
Visitors: 273

The Special Open Day was held as a part of the Southern Island Star Festival.

Same as previous years, attractions like antenna tours, a commemorative photo booth, merchandise, commemorative lectures, and exhibits were offered.

Ishigakijima: Ishigakijima Astronomical Observatory

[Open year-round]

Dates: April to March
Open Hours: Wednesdays through Sundays (Except for the New Year's season; when Monday is a national holiday, it is opened and closed on the following Tuesday/Wednesday), 10:00–17:00
Stargazing Sessions: Evenings on Saturdays, Sundays, Holidays, (20:00–22:00), two 30-minute sessions per evening
4D2U Screenings: from 15:00 to 15:30 every day when the Observatory is open
Visitors: 14,192 (1,043 during the Southern Island Star Festival)
Open Facilities: Murikabushi 105-cm optical/infrared telescope, Hoshizora Manabi no Heya (Starry Sky Study Room) (featuring the 4D2U "four dimensional digital universe"), interior of observation dome (including exhibits of astronomical images)

The "Hoshizora Manabi no Heya" (Starry Sky Study Room), constructed adjacent to the observatory in 2013 by the city of Ishigaki, was very popular, welcoming 4,478 guests.

[Southern Island Star Festival 2017]

Dates: August 12 (Sat.) to August 20 (Sun.), 2017
Visitors: 11,337

This year is the 16th anniversary of both the completion of VERA Ishigakijima Station and the Southern Island Star Festival. Approximately 9,000 visitors attended the dimmed-light stargazing event blessed with finer weather than ever before. The annual planetarium screening was attended by 581.

The activities at Ishigakijima Astronomical Observatory boost regional programs like school education, lifelong learning, and sightseeing. The cooperation agreement between NAOJ and the Tourism Association of the city of Ishigaki has been finalized. And it is widely recognized that the starry sky can be used as a tourism resource. Considering this situation, we will continue to strengthen our ties with other associations.

3. Nobeyama Campus

[Regular Open]

Open Time: 8:30–17:00 (every day except around New Year's Day (Dec. 29 to Jan. 3), open until 18:00 during the summer (Jul. 20 to Aug. 31))

Visitors: 42,760

Open Facilities: 45-m Radio Telescope, Nobeyama Millimeter Array, Nobeyama Radioheliograph, etc. (just viewing) and NINS Nobeyama Exhibition Room

[Open House Day]

Date: August 26 (Sat.), 2017, 9:30–16:00

Visitors: 2,093

The theme of the 2017 Open House Day was "Nagano Prefecture is the Astro-Prefecture ~Starry sky in Shinshu is a promenade to the Universe." We had two lectures on the theme, which attract large audiences every year. One was "Nagano Prefecture, which can be felt to be close to the Universe" by Prof. Ohnishi, Kouji (National Institute of Technology, Nagano Collage). The other was "The radio luminous Milky Way – the Galactic plane survey by the Nobeyama 45-m Radio Telescope" by Dr. Umemoto, Tomofumi (NAOJ).

Even though it rained in the early morning, the weather was getting better at the opening time, and we were blessed with good weather as a whole. However, we had 2,093 visitors, which was less than in a normal year because the weather forecast was not so good. We had some established hands-on events such as touch the main reflector panel of the 45-m Radio Telescope, antenna handicrafts, radio detector handicrafts, and antenna origami. At the NINS Exhibition Room, the presentation of the 4D theater and exhibitions of other institutes were carried out. In addition, the ALMA team presented the ALMA VR system and some short lectures. Moreover, we had a welcome greeting by the NRO character, Dr. Nobeyama and "Nagano Prefecture is the Astro-Prefecture" stamp-rally event. The Open House day was filled with events because we were supported by many people from the local people and Shinshu University, Faculty of Agriculture as well as NAOJ and other institutes of NINS.

[Jimoto Kansha Day (Thanks Day for the locals)]

Date: December 9 (Sat.), 2017, 13:00–18:30

Visitors: 55

The local people have difficulty participating in the Open House Day during the farming season. They have said that they do not know much about what we, not only NRO but also Tsukuba and Shinshu Universities, study in Nobeyama.

In order to respond to these comments, we established this event in cooperation with Shinshu University, Faculty of Agriculture, Education and Research Center of Alpine Field Science and Tsukuba University, Agricultural and Forestry Research Center, Yatsugatake Forest. This year, the Jimoto Kansha Day was hosted by NRO at the NINS Nobeyama Exhibition Room, which opened to the public in April 2017. We had many events such as a tour of NRO facilities, the lectures from each institute, 4D theater, and star gazing party. The lectures were "On the biological research of the Japanese dormouse" from Tsukuba University, "Will you take notice of the available nitrogen for sustainable agriculture?" from Shinshu University, and "The Milky Way observed by the Nobeyama 45-m Radio Telescope" from NRO. There was another event the same day in Minamimaki Villiage, so the number of participants was somewhat less than when NRO had hosted it before in 2014. The festival had a friendly atmosphere with the parents and children braving the cold to stay until the star gazing party.

4. Okayama Campus

Okayama Astrophysical Observatory

[Open year-round]

Dates: 9:00–16:30 daily

Visitors: 5,980 (Period: April 1–October 4)

Open Facilities: Window view of Okayama 188-cm Reflector Telescope

[Special Stargazing Party]

Date: August 11 (Fri.), 2017, 18:30–22:25

Visitors: 81

198 applications for 548 applicants were received. M13 and Saturn were viewed.

5. Subaru Telescope

[Summit Facility Tour]

Dates open for public tour: 41 (these dates are listed in the public tour program page at the Subaru Telescope's web site. Among the 41 days, 10 tour days were cancelled due to the windscreen incident. No tours scheduled during the winter months of October to March)

Public Tour Visitors: 307

Special Tour Visitors: 67 groups, 370 visitors

[Base Facility Tour]

Special Tour Visitors: 23 groups, 252 visitors

[Public information]

○ Primary means of public information is posting at the official website https://subarutelescope.org

- Science results from the Subaru Telescope – 6 Japanese and 6 English article
- Depicting special activities or making announcements on Calls for Proposals, recruitment, etc. – 24 Japanese and 19 English articles.

○ Web postings are supplemented by social media via official accounts

- Twitter accounts – SubaruTelescope (for Japanese), SubaruTel_Eng (for English)
- Facebook pages – 国立天文台 (for Japanese), National Astronomical Observatory of Japan, and Subaru Telescope Hawaii Outreach (for English)
- YouTube channels – SubaruTelescopeNAOJ (for Japanese), SubaruTelescopeNAOJe (for English)

[Outreach]

1. Lectures at the Subaru Telescope's base facility in Hilo: 18 cases, reached 579 people

2. Remote presentations, mainly to Japan: 10 cases, reached 546 people

3. Lectures, demonstrations, workshops, etc. in the vicinity: 66 cases, reached 1,578 people

4. Lectures in Japan: 31 cases, reached 1,978 people

5. Others - Exhibits etc.: 13 cases, reached approximately 6,065 people

6. Media coverage: 22 Japanese media. 10 English media.

IX Overseas Travel

Research and Academic Staff Overseas Travel

(Including employees on annual salary system)

category / country/area	Business Trip	Training	Total
South Korea	46	0	46
China	19	0	19
Thailand	10	0	10
Taiwan	33	0	33
Hong Kong	2	0	2
Singapore	2	0	2
Indonesia	0	0	0
Philippines	0	0	0
Other areas in Asia	16	0	16
Hawai`i	65	0	65
U.S.A.	116	0	116
Australia	11	0	11
Italy	15	0	15
U.K.	10	0	10
France	17	0	17
Canada	7	0	7
Guam, Saipan	1	0	1
Germany	39	0	39
Other areas in Europe and Oceania	37	0	37
Mexico	5	0	5
Brazil	0	0	0
Africa	6	0	6
Other areas in South and Central America *	39	0	39
Total	496	0	496

* Most travelers to South and Central America went to Chile.

X Award Winners

Award Recipients	Affiliated Division	Job Title	Award	Date
Kajino, Toshitaka	Division of Theoretical Astronomy	Associate Professor	One Thousand Talents Plan: Foreign Experts	2017/4/15
Honma, Mareki Kobayashi, Hideyuki Hirota, Tomoya	Mizusawa VLBI Observatory	Professor/Professor/ Assistant Professor	FY2017 The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology, Prizes for Science and Technology (Research Category)	2017/4/19
Kodaira, Keiichi	NAOJ	Professor Emeritus	The Order of the Sacred Treasure, Gold and Silver Star	2017/5/9
Katsukawa, Yukio	Solar Science Observatory	Assistant Professor	The 6th NINS Young Researcher's Prize	2017/6/11
Nobeyama 45-m Radio Telescope	-	-	IEEE Milestone	2017/6/14
ALMA	-	-	Categoría Especial, Premio ICARE 2017	2017/9/11
NAOJ (ALMA, Nobeyama 45-m Radio Telescope, VERA, and GRAPE)	-	-	IEICE Milestone	2017/9/15
Akiyama, Eiji	NAOJ Chile Observatory	Specially Appointed Assistant Professor	“Best Researcher 2016” from the Japanese Society for Planetary Sciences	2017/9/28
Gonzalez Garcia, Alvaro	NAOJ Chile Observatory	Assistant Professor	IEEE RADIO 2017 Young Scientist Award	2017/9/28
Kashikawa, Nobunari	TMT-J Project Office	Associate Professor	Award for excellent reviewers, FY2017 KAKENHI	2017/9/29
Tanaka, Masaomi	Division of Theoretical Astronomy	Assistant Professor	NCU-DELTA Young Astronomer Lectureship Award	2017/10/18
Toriumi, Shin	Division of Solar and Plasma Astrophysics	Specially Appointed Assistant Professor	2017 APSPM Young Scientist Best Presentation Award	2017/11/10
Nakayama, Hirotaka/ Baba, Junichi 4D2U Project	Center for Computational Astrophysics/JASMINE Project Office/ -	Research Expert/ Specially Appointed Research Staff/ -	the Grand Prix for the VR Category of the Lumiere Japan Awards 2017	2017/11/15
Kajino, Toshitaka	Division of Theoretical Astronomy	Associate Professor	State Specially Recruited Expert	2018/1/1
Nakayama, Hirotaka/ Baba, Junichi 4D2U Project	Center for Computational Astrophysics/JASMINE Project Office/ -	Research Expert/ Specially Appointed Research Staff/ -	“Best VR Science Experience” at the 2018 Lumiere Awards	2018/2/12
Kosugi, George Nakazato, Takeshi Sugimoto, Kanako	NAOJ Chile Observatory	Associate Professor/ Research Engineer/ Specially Appointed Senior Specialist	2017 NAOJ Director General Prize	2018/3/2
Nagai, Hiroshi Nakanishi, Koichiro Kameno, Seiji Charles L. H. Hull	NAOJ Chile Observatory	Specially Appointed Associate Professor/ Specially Appointed Associate Professor/ Professor/Specially Appointed Assistant Professor	2017 NAOJ Director General Prize	2018/3/2

Saigou, Kazuya Ohashi, Nagayoshi Akiyama, Eiji Fujiwara, Hideaki	Chile Observatory/ Subaru Telescope/ Chile Observatory/ Subaru Telescope	Specially Appointed Assistant Professor/Professor/ Specially Appointed Assistant Professor/ RCUH	2017 PASJ Excellent Paper Award	2018/3/15
Kano, Ryohei	SOLAR-C Project Office	Associate Professor	The 4th ISAS Award (FY 2017)	2018/3/22

XI Library, Publications

1. Library

Number of books in each library (2018/3/31)

	Japanese Books	Foreign Books	Total
Mitaka	17,574	45,929	63,503
Okayama	62	1,006	1,068
Nobeyama	1,225	6,294	7,519
Mizusawa	4,979	18,100	23,079
Hawai`i	1,660	4,623	6,283
Total	25,500	75,952	101,452

Number of journal titles in each library (2018/3/31)

	Japanese Journals	Foreign Journals	Total
Mitaka	360	1,677	2,037
Okayama	0	8	8
Nobeyama	16	82	98
Mizusawa	659	828	1,487
Hawai`i	15	15	30
Total	1,050	2,610	3,660

2. Publication

Here we list continuing publications produced by NAOJ in FY2017.

(Mitaka)

01) Report of the National Astronomical Observatory of Japan, Vol. 19: 1 issue
02) Annual Report of the National Astronomical Observatory of Japan (in Japanese), No. 29, Fiscal Year 2016: 1 issue
03) Annual Report of the National Astronomical Observatory of Japan (in English), Vol. 19 Fiscal Year 2016: 1 issue
04) National Astronomical Observatory Reprint, No. 2886–3026; 141 issues
05) Calendar and Ephemeris, 2018; 1 issue
06) NAOJ News, No. 285–293; 12 issues
07) Guide to the National Astronomical Observatory of Japan pamphlet (Japanese); 1 issue
08) Guide to the National Astronomical Observatory of Japan pamphlet (English); 1 issue
09) Rikanenpyo (Chronological Scientific Tables), 2018; 1 issue
10) Publication of the National Astronomical Observatory of Japan Vol. 14

XII Important Dates

April 1, 2017 – March 31, 2018

2017	
April 16	Eighth Open Observatory event held at the Ibaraki University Center for Astronomy and the NAOJ Mizusawa VLBI Observatory Ibaraki Station, with 500 visitors in attendance.
April 20	The ALMA Observatory issued the ALMA Cycle 5 call for proposals for scientific observations which start from October 2017 and received by the deadline a total of 1661 observation proposals from astronomers around the world.
April 25	As part of a continuing education program for staff, Subaru Telescope held “Subaru Makali’i Seminar” to learn Hawaiian culture, language, and history with lectures from experts in the field. Three seminars were held in 2017 on April 25, May 24, and December 6 and the Subaru staff learned Polynesian navigation and Hawaiian perspectives.
April 27~ July 2	An exhibit “ALMA Explores the Dark Universe” held at the Information Space of Astronomy and Science.
April 29	The opening ceremony of NINS Nobeyama Exhibition Room and the press conference with the President of NINS were held in Nobeyama Campus. There were about 30 participants including some journalists and writers.
May 6	Subaru Telescope staff interacted with the public during the AstroDay event in a shopping mall in Hilo.
June 5~9	Observation training of Radio Astronomy at Nobeyama Radio Observatory for Undergraduate Students was performed; there were 12 participants.
June 11	A lecture “ALMA Deepens the Mysteries of the Universe” held at the Information Space of Astronomy and Science.
June 14	The presentation ceremony of the IEEE milestone plaque for the Nobeyama 45-m Radio Telescope, the following commemorative party, and lectures were held at Josui-Kaikan in Tokyo. There were about 110 participants invited for the ceremonies.
June 16	The unveiling ceremony of the IEEE milestone plaque and pedestal for the Nobeyama 45-m Radio Telescope was held in Nobeyama Radio Observatory. We had about 20 invited participants including the mayor of Minamimaki Village.
June 25	Prof. Takaaki Kajita, Director of the Institute for Cosmic Ray Research, the University of Tokyo visited the ALMA Array Operations Site.
July 6	Seiichi Sakamoto, the director of NAOJ Chile Observatory gave a lecture as a Tanabata event at the Japanese School in Santiago.
July 7	Subaru Telescope held the annual Tanabata Star Festival together with the Japanese Chamber of Commerce and Industry of Hawai`i to deepen cultural exchanges and promote astronomy.
July 7~ September 17	An exhibit “The Universe Seen over Nobeyama” held at the Information Space of Astronomy and Science.
July 16	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.
July 24~28	Facility Guide Week for Educational Organizations was carried out at Nobeyama Radio Observatory.
July 25	“The 24th NAOJ Lecture for the Science Media” held at Hitotsubashi Hall with 19 reporters (8 companies) in attendance.
July 29	Mr. Yoshinobu Hiraishi, the Ambassador of Japan to Chile visited the ALMA Array Operations Site.
July 31~ August 1	“Astronomy Classes for Kids in Summer 2017” held in Mitaka Campus.
August 4~6	Eleventh Z-star Research Team event held for high school students in the six Tohoku prefectures, with 12 participants attending. The 12 participants were divided into two groups of A and B for observations using the VERA 20-m radio telescope and data analysis. The A squad detected 1 heavenly body (G037.419+01.513) for the first time in 23 years, and unfortunately the B squad was not able to detect meaningful water maser radio waves, but detected 1 heavenly body (RT-Her) for the first time in several years.
August 6	A lecture “Observing the Invisible Universe with Radio Waves” held at the Information Space of Astronomy and Science.
August 9~11	Chura-boshi Research Team workshop for high school students held at VERA Ishigakijima Station and Ishigakijima Astronomical Observatory, with 7 participants from Ishigakijima, and 3 participant from main island of Okinawa in attendance. The students were divided into two groups to perform observations, a radio wave observation group and an optical wavelenght group using the Murikabushi Telescope. The radio wave observation group was not able to detect a new maser object. The optical wavelength group using the Murikabushi Telescope was also unable to detect anything.

August 9~ September 8	As a part of the summer student program held by NAOJ and the Department of Astronomical Science of the Graduate University for Advanced Studies (SOKENDAI), two undergraduate students from Tokyo Institute of Technology and Kyoto University stayed at Chile Observatory and conducted research with ALMA data.
August 11	Summer 2017 Special Stargazing Party held at Okayama Astrophysical Observatory, with 81 visitors in attendance (out of 548 applicants).
August 12~20	Southern Island Star Festival 2017 held together with a special open house event at the VERA Ishigakijima Station and Ishigakijima Astronomical Observatory among other facilities with approximately 11,337 visitors to the whole Star Festival. Events included an astronomical observation party at Ishigakijima Astronomical Observatory, attended by 1,043 visitors; and a special public opening of the VERA Station attended by 273 visitors. In addition, a commemorative lecture by Vice-Director General Junichi Watanabe had approximately 100 participants.
August 12	Special open house of VERA Iriki station held jointly with the Yaeyama Highland Star Festival 2017, with approximately 3,800 visitors in attendance.
August 19	Iwate Galaxy Festival 2017, a special open house day of Mizusawa Campus, held with approximately 4,000 visitors in attendance.
August 25~26	NAOJ Chile Observatory held a traditional Tanabata event in San Pedro de Atacama.
August 26	Open House day of Nobeyama Radio Observatory. There were 2,093 visitors for this event.
August 28~31	The observation training class in Ishigakijima “Learning about Space through astronomical observation” (common education subject) based on the cooperation agreement between the University of the Ryukyus and the National Astronomical Observatory was carried out at the VERA Ishigakijima observation station, Ishigakijima Astronomical Observatory, and there were 33 participants.
August 29~ September 3	Graduate students from the Department of Astronomical Science, SOKENDAI (Graduate University for Advanced Studies) and astronomy major students from the University of Hawai`i at Hilo worked together to do an observation program at the Subaru Telescope.
September 22~ November 5	An exhibit “Mitaka Solar System Walk - Let’s walk in the Mini Mini Solar System” held at the Information Space of Astronomy and Science.
September 28	Their Imperial Highnesses Prince and Princess Akishino visited Chile. Seiichi Sakamoto, the director of the NAOJ Chile Observatory explained the activities of NAOJ in Chile.
October 10~13	Aiming to capture the first-ever photograph of “a shadow of the black hole” through VLBI observations combining worldwide millimeter and sub-millimeter telescopes, the EHT (Event Horizon Telescope) and international collaboration with 13 participating country held its first imaging workshop after nearly 10 years of work.
October 13~14	“Mitaka Open House Day” held with 3,269 visitors in attendance.
October 21~22	The 29th national convention of “Hoshizora-no-machi, Aozora-no-machi (Streets of starry sky and blue sky)” was held in Minamimaki Village by the Ministry of the Environment with the host of Minamimaki Village, and cooperation from Nobeyama Radio Observatory. Also, Takamadonomiya Princess Hisako visited Nobeyama Radio Observatory and the NINS Nobeyama Exhibition Room.
October 26~28	The Public Relations Center co-hosted a joint booth (with three Japanese universities) at the World Conference of Science Journalists (WCSJ) in San Francisco.
October 27	Four buildings formally registered as Tangible Cultural Properties with the Council for Cultural Affairs 1) Main building of the former Latitude Observatory (now the Oshu Space & Astronomy Museum) 2) the main building of the provisional Latitude Observatory (now the Kimura Hisashi Memorial Museum) 3) the visual zenith telescope housing of the provisional Latitude Observatory 4) the target stand and cover for the visual zenith telescope.
November 1	NAOJ Decadal Planning Workshop was held in NAOJ Mitaka Campus. The subtitle of this workshop was “Imagine all of you are the Director General today.” Many staff members discussed the future direction of our organizational structure and research activities.
November 3~4	“The 15th Mizusawa VLBI observatory users meeting” was held, and 11 of the 55 participants were students. The participants ranged from youths to seniors. It was a substantial meeting with lively discussion about Japanese, East Asian, and world wide VLBI.
November 15~17	The Public Relations Center hosted a booth at the Science Centre World Summit 2017 (SCWS2017) at the National Museum of Emerging Science and Innovation (Miraikan).
November 21	A ceremony for FY 2017 continuous service recognition was held. 6 NAOJ staff members were recognized: Seiichi Sakamoto, Tomonori Usuda, Kenshi Yanagisawa, Fumihiro Uraguchi, Go Yamazaki.
December 9	“Jimoto kansha Day (Thanks Day for the locals)” was held at NINS Nobeyama Exhibition Room hosted by Nobeyama Radio Observatory. It was carried out by 3 Nobeyama Institutes (Tsukuba and Shinshu Universities and Nobeyama Radio Observatory). There were 55 participants.

December 21~22	"The 37th Symposium on Astronomy Technology" held to promote astronomy related technology. It seems to be popular as a chance to meet and talk with people from other organizations, projects, and research institutes whom you normally don't have chance to speak with informally.
December 26~27	The NAOJ Chile Observatory, together with the Nobeyama Radio Observatory hosted the ALMA/45-m/ASTE Users Meeting in NAOJ Mitaka.

2018

January 6~10	A total of 12 undergraduate students from Japan and University of Hawai`i at Hilo participated in the observation experience program at the Subaru Telescope. This was the first time for students in Hilo to join Subaru's observation experience program.
January 7	Minister Masaji Matsuyama of the Cabinet Office visited the Subaru Telescope's facilities in Hilo and Maunakea.
January 12~13	Mr. Toshiei Mizuochi, State Minister for Ministry of Education, Culture, Sports, Science and Technology visited ALMA.
January 19~20	Star Island 17 open house event of VERA Ogasawara Station held, with 167 visitors in attendance.
January 27	Staff of the Subaru Telescope held a science workshop and hosted an interactive booth at the annual Onizuka Science Day at the University of Hawai`i at Hilo.
February 3	The Second "Nagano is a Astro-Prefecture" meeting was held in the campus of the National Institute of Technology, Nagano College by the executive committee consisting of Nobeyama Radio Observatory, National Institute of Technology, Nagano College, Shiojiri Star Party, and so on.There were about 80 participants.
February 4	The 23rd ALMA public lecture titled "ALMA Telescope Exploring the Cold Universe-To Solve the Mysteries of Planetary Formation with State-of-the Art Technology" was held by NAOJ at the Tokyo International Exchange Center. The event attracted 265 participants.
February 16~18	The Public Relations Center hosted a joint booth with JSPS and two Japanese universities at the American Association for the Advancement of Science (AAAS) annual meeting in Austin.
February 20	NAOJ Engineering Decadal Planning Workshop was held in NAOJ Mitaka Campus. The subtitle of this workshop was "Engineering at NAOJ: Review of the Past Decade, Strategy for the Next Decade." Many staff members discussed about the direction of future development at NAOJ.
March 2	President Mariko Hasegawa of the Graduate University for Advanced Studies (SOKENDAI) visited the Subaru Telescope's facilities in Hilo and Maunakea.
March 5~9	Staff of the Subaru Telescope visited classes in the public schools in Hilo and vicinity during the Journey through the Universe program.
March 24~28	IAU, NAOJ, and Fukuoka City co-hosted "Communicating Astronomy with the Public Conference (CAP2018)" held at Fukuoka City Science Museum with 446 participants from 53 countries in attendance.
March 31	A ceremony for FY 2017 continuous service recognition for retiring staff members was held. 8 staff members were recognized: Takashi Noguchi, Tetsuya Watanabe, Hideo Hanada, Nobuharu Ukita, Susumu Kawashima, Katsuhisa Sato, Susumu Hommyo.
Throughout the year	NAOJ staff participated in the FUREAI (Friendly) Astronomy program by visiting schools and talking about their work and the Subaru Telescope. This outreach program started eight years ago and was spearheaded by Dr. Nobuo Arimoto, the former Director of the Subaru Telescope.
Throughout the year	Together with other Maunakea Observatories, Subaru Telescope started a special tour program "Kama'āina Observatory Experience (KOE)" dedicated to Hawai`i residents. In 2017, Subaru conducted 10 KOE tours for a total of 120 visitors. KOE is separate from Subaru's public tour program that started in 2004.

XIII Publications, Presentations

1. Refereed Publications

Abbott, B. P., et al. including **Flaminio, R.**, **Vetro, F.**, **Aoki, K.**, **Aoki, W.**, **Finet, F.**, **Fujiyoshi, T.**, **Furusawa, H.**, **Kim, J. H.**, **Koshida, S.**, **Kuroda, D.**, **Lee, C.-H.**, **Matsubayashi, K.**, **Nagai, H.**, **Nakata, F.**, **Okita, H.**, **Tajitsu, A.**, **Tanaka, I.**, **Tanaka, M.**, **Terai, T.**, **Yoshida, M.**, **Kawamuro, T.**, **Castellon, J. L. N.**: 2017, Multi-messenger Observations of a Binary Neutron Star Merger, *ApJL*, **848**, L12.

Abbott, B. P., et al. including **Flaminio, R.**: 2017, Effects of waveform model systematics on the interpretation of GW150914, *Classical Quantum Gravity*, **34**, 104002.

Abbott, B. P., et al. including **Flaminio, R.**: 2017, Search for gravitational waves from Scorpius X-1 in the first Advanced LIGO observing run with a hidden Markov model, *Phys. Rev. D*, **95**, 122003.

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Abbott, B. P., et al. including **Flaminio, R.**: 2017, First low-frequency Einstein@Home all-sky search for continuous gravitational waves in Advanced LIGO data, *Phys. Rev. D*, **96**, 122004.

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Abbott, B. P., et al. including **Flaminio, R.**: 2017, GW170817: Observation of Gravitational Waves from a Binary Neutron Star Inspiral, *Phys. Rev. Lett.*, **119**, 161101.

Abbott, B. P., et al. including **Flaminio, R.**: 2017, Search for continuous gravitational waves from neutron stars in globular cluster NGC 6544, *Phys. Rev. D*, **292**, 082005.

Abbott, B. P., et al. including **Flaminio, R.**: 2017, A gravitational-wave standard siren measurement of the Hubble constant, *Nature*, **551**, 85–88.

Abbott, B. P., et al. including **Flaminio, R.**: 2017, First Search for Gravitational Waves from Known Pulsars with Advanced LIGO, *ApJ*, **839**, 12.

Abbott, B. P., et al. including **Flaminio, R.**: 2017, Search for Gravitational Waves Associated with Gamma-Ray Bursts during the First Advanced LIGO Observing Run and Implications for the Origin of GRB 150906B, *ApJ*, **841**, 89.

Abbott, B. P., et al. including **Flaminio, R.**: 2017, Upper Limits on Gravitational Waves from Scorpius X-1 from a Model-based Cross-correlation Search in Advanced LIGO Data, *ApJ*, **847**, 47.

Abbott, B. P., et al. including **Flaminio, R.**: 2017, Gravitational Waves and Gamma-Rays from a Binary Neutron Star Merger: GW170817 and GRB 170817A, *ApJL*, **848**, L13.

Abbott, B. P., et al. including **Flaminio, R.**: 2017, Estimating the Contribution of Dynamical Ejecta in the Kilonova Associated with GW170817, *ApJL*, **850**, L39.

Abbott, B. P., et al. including **Flaminio, R.**: 2017, On the Progenitor of Binary Neutron Star Merger GW170817, *ApJL*, **850**, L40.

Abbott, B. P., et al. including **Flaminio, R.**: 2017, Search for Post-merger Gravitational Waves from the Remnant of the Binary Neutron Star Merger GW170817, *ApJL*, **851**, L16.

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Abbott, B. P., et al. including **Flaminio, R.**: 2018, Effects of data quality vetoes on a search for compact binary coalescences in Advanced LIGO's first observing run, *Classical Quantum Gravity*, **35**, 65010.

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Aharonian, F., et al. including **Moriya, T. J.**: 2018, Search for thermal X-ray features from the Crab nebula with the Hitomi soft X-ray spectrometer, *PASJ*, **70**, 14.

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Cam Subaru Strategic Program, *PASJ*, **70**, S8.

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