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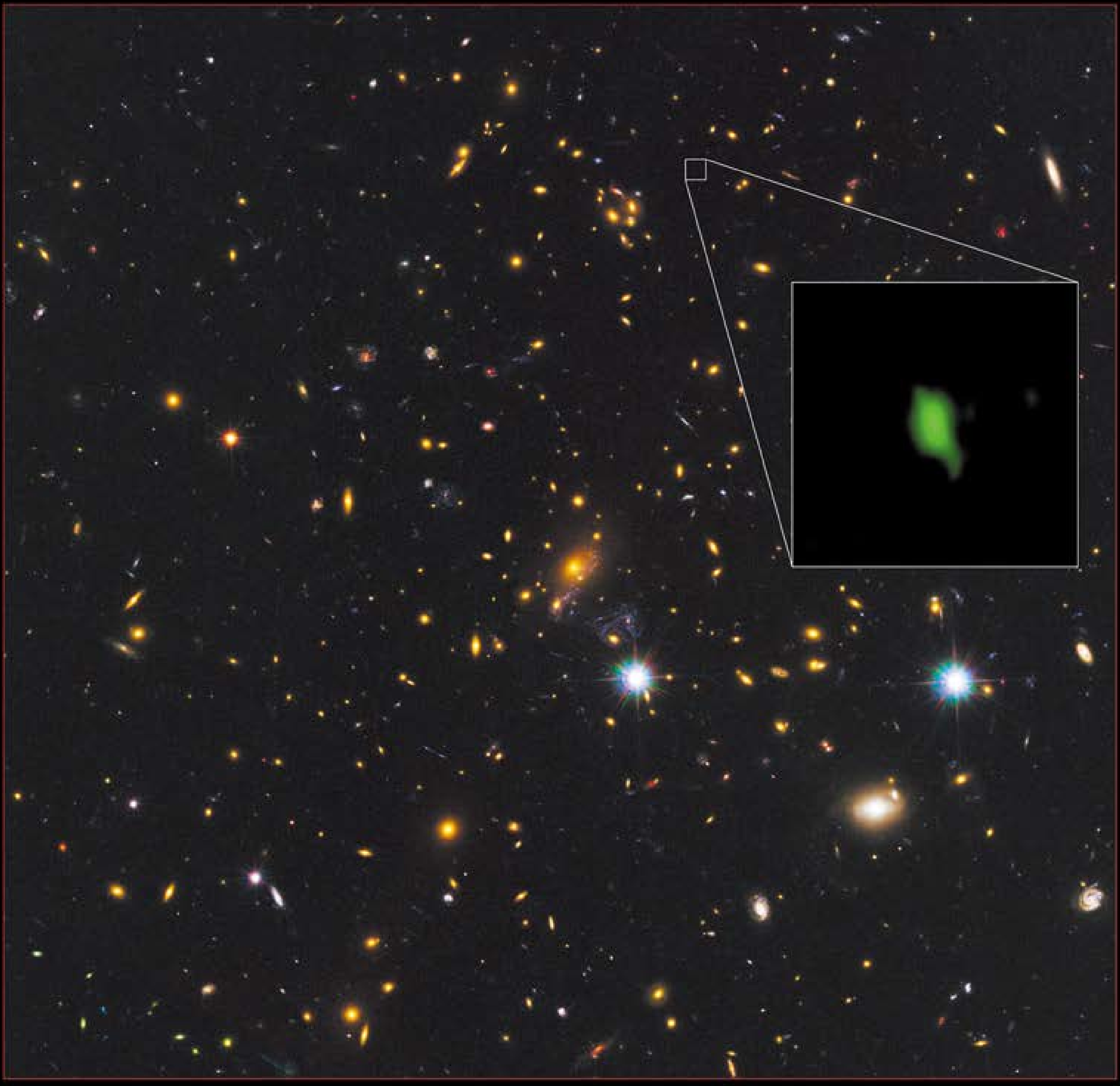

Cover Caption

This image shows the galaxy cluster MACS J1149.5+2223 taken with the NASA/ESA Hubble Space Telescope and the inset image is the galaxy MACS1149-JD1 located 13.28 billion light-years away observed with ALMA. Here, the oxygen distribution detected with ALMA is depicted in green.
Credit: ALMA (ESO/NAOJ/NRAO), NASA/ESA Hubble Space Telescope, W. Zheng (JHU), M. Postman (STScI <http://www.stsci.edu/>), the CLASH Team, Hashimoto et al.

Postscript

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Annual Report of the National Astronomical Observatory of Japan

Volume 21, Fiscal 2018

PREFACE

Saku TSUNETA
Director General of NAOJ

In 2018, NAOJ celebrated its 30th anniversary. Over these three decades Japanese astronomy and world astronomy have seen great development. Now the new trends are observational research crossing the traditional boundaries between wavelengths, unified research between observations and theory, and multi-messenger astronomy including gravitational wave and neutrino observations. In this dynamically changing field of study, NAOJ decided to combine the former Division of Optical and Infrared Astronomy, Division of Radio Astronomy, Division of Solar and Plasma Physics, and Division of Theoretical Astronomy to form the new Division of Science. In addition, aiming to open a new era of astronomy, we reconsidered the definition of "projects" at NAOJ to promote the inauguration of new projects based on novel ideas. We received many responses to our call for new project proposals. We have high hopes that from among these there will emerge projects that will carry NAOJ into the future. We established the DG's Fund to support still germinating research and development research as well. We announced the first NAOJ Young Researchers Award and revised the criteria for the Director General's Prize. Together these changes create a system to reward young researchers and employees who support the activities of NAOJ. Currently as of April 1, 2019 women comprise 14 % of the NAOJ research faculty, but efforts are continuing to encourage female researchers. Finally the Science Strategy Committee was established as a place to discuss NAOJ's future plans, while committees which have become obsolete have been disbanded. In these ways, NAOJ has continued to evolve as an active organization.

KAGRA

Commissioning continued at KAGRA, the Large-scale Cryogenic Gravitational Wave Telescope being constructed through collaboration led by the Institute for Cosmic Ray Research of the University of Tokyo and including NAOJ and the High Energy Accelerator Research Organization KEK, with the goal of starting observations in FY 2019. Experience gained from TAMA300 built in Mitaka Campus in the 1990's and the technology of the Advanced Technology Center contributed to the important components developed at NAOJ, including low frequency vibration isolators, large-scale optical baffles, and a transmitted light monitoring system.

The American LIGO and European VIRGO improved performance following the O2 observing run, and the two LIGO detectors achieved a maximum detection distance for binary neutron star mergers of better than 100 megaparsecs. (A megaparsec is 3.26 million light-years.) They are expected to detect many binary black hole mergers and binary neutron star mergers during the O3 observing run which starts from April of 2019. We are looking forward to great progress in multi-messenger astronomy through the addition of KAGRA with its unique subterranean site and cryogenic mirrors and follow-up observation support from the wide field-of-view Subaru Telescope.

ALMA

In ALMA, the 7th open-use observations (Cycle 6) started in October 2018. The number of observation proposals submitted from around the world increased from Cycle 5 to 1836 in total. Cycle 6, like Cycle 5, achieved stable operation and reached a total of 4000 hours of observation time using the 12 meter diameter antennas. In addition, the observation capabilities have been continuously enhanced through improvements such as circular polarization observation capability for bands 3~7 and the newly offered band 8 stand-alone Atacama Compact Array observations. We have seen a growth in publications comparable to the Hubble Space Telescope; in the approximately seven-and-a-half years up through FY 2018 the total number of papers published using ALMA data reached 1,379. In terms of total number of papers, Japan placed second, losing only to the United States.

In FY 2018, we saw new development in the research of the earliest galaxies in the Universe. The greatly redshifted 88 micrometer wavelength emission line of ionized oxygen was detected in a galaxy 13.28 billion light-years away ($z = 9.11$), breaking simultaneously the records for the most distant detection of oxygen and the most distant galaxy observed by high-precision spectroscopy. Combining these results with other observations such as infrared showed that in this galaxy star formation had already started approximately 250 million years after the birth of the Universe. This result brings us closer to the era of the formation of the first stars in the Universe.

ALMA's highest frequency band (band 10) receivers, developed at NAOJ with cooperation from the National Institute of Information and Communications Technology (NICT), produced their first observational results. Observations of a gas cloud surrounding massive protostars detected 695 spectral lines emitted from various molecules. This is 10 times more spectral lines than detected by the European Space Agency (ESA) Herschel Space Observatory which observed the same region at the same frequency range, demonstrating the vast improvement in observation capability enabled by the band 10 receivers. The molecules detected this time include the simplest sugar related molecule, glycolaldehyde, providing important clues to elucidate the chemical composition in massive-star forming regions.

In research related to organic molecules, we must mention the discovery of various organic molecules, including methanol and acetaldehyde, around a young star which has experienced a sudden increase in brightness. These molecules, released by the sublimation of ice caused by the sudden increase in brightness, would be very difficult to observe under normal conditions. This is an important result for elucidating the composition of ices in protoplanetary disks which are the birthplaces of planets.

High resolution imaging observations of many protoplanetary disks also continued. Not only concentric ring structures but also spiral structures and uneven dust distributions were depicted, showing clearly the diversity of protoplanetary disks. This is an area to keep an eye on in the future as research seeking the origins of the diversity seen in exoplanet systems.

Preparations continue hoping to realize the ALMA2 plan. The ALMA2 plan is a project to drastically improve ALMA's observational capabilities in the coming 10 years. Against this backdrop, the Advanced Technology Center, in cooperation with NAOJ Chile Observatory (reorganized as the NAOJ ALMA Project in January 2019), was the first in the world to successfully develop a wideband receiver using a high critical current density SIS (superconductor-insulator-superconductor) junction. Especially thanks to the demonstration of wider bandwidth in the intermediate frequency (IF) band, "upgrading the receivers to deliver larger IF bandwidths" was listed as one of the important development goals in "The ALMA Development Roadmap" approved by the ALMA Board and published in 2018 and a proposal for ALMA2 was submitted to "The 24th Term Japanese Master Plan of Large Research Projects (Master Plan 2020)" of the Science Council of Japan in March 2019.

Subaru Telescope

The Subaru Telescope made great contributions to the field of cosmology in FY 2018. In FY 2017, Hyper Suprime-Cam (HSC) enabled the creation of a three-dimensional map of dark matter distribution across a wide area estimated by the weak gravitational lensing technique. A more detailed analysis of that data succeeded in placing strong constraints on the cosmological parameters of the rate of cosmic structure formation and the fraction of matter comprising the Universe. These cosmic parameters which govern the evolution of the Universe provide important clues for understanding the characteristics of dark energy and dark matter. There is also the tantalizing possibility that the results from the Subaru Telescope may be in disagreement with the values obtained from cosmic background radiation observations.

From high resolution observations of distant galaxies we learned that the progenitors of modern giant elliptical galaxies were only one-tenth of their current size 12 billion years ago. This result showing that giant elliptical galaxies evolved through minor mergers is making waves in the study of elliptical galaxy evolution. HSC also discovered a quasar at $z > 7$ (only the 3rd example in history) and through the luminosity distribution measured from a large sample of quasars at $z \sim 6$–7 showed that quasars made virtually no contribution to cosmic reionization.

HSC also discovered a new Solar System object 120 astronomical units from the Sun, the most distant ever recorded. The nature of the outer periphery of the Solar System is almost completely unknown. This is an important step towards elucidating the structure of the Solar System, including the possibility of a true 9th planet (not the demoted dwarf planet Pluto).

FY 2018 was marked by various natural disasters including earthquakes and hurricanes, resulting in the loss of valuable observing time. Through the efforts of the observatory staff, we pulled through these difficult times and have been able to continue open-use observations. Even though HSC Subaru Strategic Program observations were suspended for about half a year as a result, HSC has continued to demonstrate its ability to produce numerous results across a wide range of research fields.

Another prime focus instrument, in addition to HSC, the Prime Focus Spectrograph (PFS) is being developed by a collaboration of seven countries and regions 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 FY 2022. The eruption of the Kilauea volcano in FY 2018 forced large adjustments to the schedule. Metrology Camera which will be needed to detect the positions of the optical fibers was transported from Taiwan to Hawai'i and tests at the summit are proceeding well. Production of the fiber optics actuators and spectrograph is also proceeding at overseas institutes. Also, in order to analyze the voluminous data to be produced by PFS, we have started developing a data reduction pipeline and science database to work organically with the science data from other instruments like HSC. 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.

We conducted an international conceptual design review for Ground Layer Adaptive Optics (GLAO), the next generation adaptive optics system for the Subaru Telescope, and having received a high evaluation, we will proceed to the preliminary design phase. Having obtained the prospect of producing important results throughout the 2020's through large-scale survey observations conducted with HSC, PFS, and the wide-field, high-resolution infrared observational instrument ULTIMATE using GLAO, we submitted a proposal for the Subaru Telescope 2 plan to the Master Plan 2020 of the Science Council of Japan.

Furthermore, we continued instrument development for exoplanet research and conducted observations with those instruments. The InfraRed Doppler instrument (IRD) completed commissioning at the summit and was made available for open use. To make best use of the precision speed measurements at infrared wavelengths using the laser frequency comb developed through cooperation with the Tokyo University of Agriculture and Technology we are also developing a new Subaru Strategic Plan to search for habitable terrestrial planets around red dwarf stars, which are lighter than the Sun. The Subaru Coronagraphic Extreme Adaptive Optics (SCExAO) and Coronagraphic High Angular Resolution Imaging Spectrograph (CHARIS) instruments for direct observation of exoplanets were offered for open use without any major problems, and succeeded in direct observation of the spectrum of the exoplanet Kappa And b

(Kappa Andromeda b) which had been first discovered by the Subaru Telescope. The development and operation of this instrument has been carried out through collaboration between Subaru Telescope and the NINS Astrobiology Center. We are also investigating the possibility of using the Subaru Telescope to support development of a second generation instrument for the Thirty Meter Telescope (TMT).

TMT

The Thirty Meter Telescope (TMT) is an extremely large telescope being planned as a joint project between Japan, the United States, Canada, China, and India. It will be able to investigate terrestrial exoplanets, and shed light on dark energy, the early history of the Universe, and other questions. NAOJ is in charge of designing and fabricating the telescope structure, primary mirror segments, etc. The construction site is located on Maunakea in Hawai‘i, however construction has been suspended for four years, causing concern for all involved. In FY 2018, planning and development have progressed steadily in Japan, as well as the other countries, in preparation for the resumption of construction.

Having completed the design, review, and preparations for production the previous fiscal year, in FY 2018 we proceeded to make the blueprints for the telescope structure, which constitutes part of Japan’s workshare. Making best use of the delay caused by the suspension of onsite construction, cable-wrap equipment test pieces were manufactured to quantitatively evaluate the telescope vibration suppression. Tests like these will ultimately improve the quality of the telescope and reduce risk. Manufacturing, grinding, and polishing continued for the mirror blanks which will comprise the segmented primary mirror; aspherical grinding and polishing are being conducted by Japan and overseas partners. A critical international review on the telescope system and observational instrument development occurring in the Advanced Technology Center, confirmed that the specifications required for TMT have been achieved, ensuring that Japan will continue to play a central role in the international collaboration for development.

Summary

The number of papers published by members of NAOJ, from FY 2014 through FY 2018 was 3,087. In terms of citations, of these reports 14 % were in the top 10 % of papers and 2.4 % were in the top 1 %. The international collaboration rate was 73 % (according to InCites as of December 2019). As of the end of FY 2018, Japanese members of the International Astronomical Union accounted for 5.8 % of the total membership (approximately one-fourth the number of United States members), but Japan accounts for an 8.6 % share of the papers published worldwide in the field of astronomy (according to Web of Science). This world share is Japan’s highest across the 22 major categories of science, exceeding physics. Amongst fears that scientific progress has stalled in Japan, the number of papers from the Japanese astronomy community may be smaller than in other fields in terms of absolute number, reflecting the smaller number of researchers, but is outstanding in terms of world share. This exceptionally high science productivity is thanks to large-scale facilities including the Subaru Telescope, ALMA, Hinode Solar Observatory, and the supercomputers of the Center for Computational Astronomy.

In order to aspire to actualizing the highest-priority projects with limited resources (budget, personnel) we must always look for ways to cut costs and use resources effectively. It would not be an exaggeration to say that the entire history of NAOJ has been a story of scrap-and-build. While promoting new large-scale projects including the Subaru Telescope, ALMA, and TMT, it has also closed domestic facilities which had for many years supported the development of Japanese astronomy. This is because as astronomy progresses, the ability of these facilities to compete in the world becomes comparatively weaker, and their roles change by necessity. Following the closures of Nobeyama Solar Radio Observatory (March 2015) and Okayama Astrophysical Observatory (March 2018), we are also trying to improve the efficiency of open-use at Nobeyama Radio Observatory and Mizusawa VLBI Observatory while continuing a dialog to explain the situation to the astronomy community. Telescopes which remained after the observatory closures have obtained working capital from other domestic and overseas organizations, primarily universities, with a strong desire to continue using them; allowing the instruments to be maintained even now. There are also facilities like the interferometer gravitational wave antenna TAMA300 which have finished observations and have been converted to testbeds for new developments and platforms for educational purposes.

In order to promote the nation-wide open-use of the Kyoto University Seimei Telescope, the Subaru Telescope Okayama Branch Office was established in place of Okayama Astrophysical Observatory. Integration work is proceeding well on Japan’s first segmented primary mirror, and the first open-use observations were realized in March 2019. Now they will endeavor to expand and improve the open-use observations. Furthermore, the 188-cm telescope was refurbished into a dedicated exoplanet observation system by a group of university researchers led by the Tokyo Institute of Technology and an automated Doppler Effect exoplanet survey started from January 2019. The facility has also started to be used as a resource to advance education and outreach activities.

At Nobeyama Radio Observatory which has passed its 36th anniversary since opening, data taken as part of Legacy Projects, most notably a survey of the Galactic Plane, has been opened to the public. We expect the data to be utilized by many scientists, serving as a basis for next generation research. Also, in March 2019, Nobeyama Radio Observatory and Minamimaki Village entered an agreement for cooperation and mutual support.

Since its establishment in 1988, NAOJ has consistently run at the leading edge of astronomy. I believe that NAOJ will continue leading Japanese and world astronomy as a center for international collaboration equipped with world leading facilities including the Subaru Telescope which began operation in 2000; ALMA, which started science observations in 2011 as an international project including East Asia, Europe, and North America; and the world's most powerful dedicated astronomy supercomputer “ATERUI II.”

Saku Tsuneta

I Scientific Highlights

(April 2018 – March 2019)

Physical Properties of Near-Earth Asteroids for the Hayabusa2 Mission

HASEGAWA, Sunao[1], KURODA, Daisuke[2], HANAYAMA, Hidekazu[3], KITAZATO, Kohei[4]
KASUGA, Toshihiro[3/5], SEKIGUCHI, Tomohiko[6], TAKATO, Naruhisa[3], AOKI, Kentaro[3], ARAI, Akira[5]
CHOI, Young-Jun[7], FUSE, Tetsuharu[8], HATTORI, Takashi[3], HSIAO, Hsiang-Yao[9], KASHIKAWA, Nobunari[10]
KAWAI, Nobuyuki[11], KAWAKAMI, Kyoko[1/10], KINOSHITA, Daisuke[9], LARSON, Steve[12], LIN, Chi-Sheng[9]
MIYASAKA, Seidai[13], MIURA, Naoya[10], NAGAYAMA, Shogo[3], NAGUMO, Yu[6], NISHIHARA, Setsuko[1/10]
OHBA, Yohei[1/10], OHTA, Kouji[2], OHYAMA, Youichi[14], OKUMURA, Shin-ichiro[15], SARUGAKU, Yuki[5]
SHIMIZU, Yasuhiro[3], TAKAGI, Yuhei[3], TAKAHASHI, Jun[16], TODA, Hiroyuki[2], URAKAWA, Seitaro[15]
USUI, Fumihiko[17], WATANABE, Makoto[18], WEISSMAN, Paul[19], YANAGISAWA, Kenshi[3], YANG, Hongu[7]
YOSHIDA, Michitoshi[3], YOSHIKAWA, Makoto[1], ISHIGURO, Masateru[20], ABE, Masanao[1]

1: Japan Aerospace Exploration Agency, 2: Kyoto University, 3: National Astronomical Observatory of Japan, 4: University of Aizu, 5: Kyoto Sangyo University, 6: Hokkaido University of Education, 7: Korea Astronomy and Space Science Institute, 8: National Institute of Information and Communications Technology, 9: National Central University, 10: University of Tokyo, 11: Tokyo Institute of Technology, 12: Lunar and Planetary Laboratory, 13: Tokyo Metropolitan Government, 14: Academia Sinica, Institute of Astronomy and Astrophysics, 15: Japan Spaceguard Association, 16: University of Hyogo, 17: Kobe University, 18: Okayama University of Science, 19: Planetary Science Institute, 20: Seoul National University

Sample return from on the near-Earth S-type asteroid 25143 Itokawa was carried out by the Hayabusa spacecraft and a lot of scientific results draw from returned samples. Following Hayabusa mission, Hayabusa2 which aimed at sample returns from a primitive asteroid scuh as C-type was planned. The primary target body of Hayabusa2 is the C-type asteroid 162173 Ryugu, but, it was necessary to gather physical information for selecting backup targets. In oder to select candidates of buckup target bodies for Hayabusa2 mission, it is essential to know their physical characteristics such as spectral type and rotational period in advance. So we carried out five asteroids in spectroscopically, forty-three ones in spectrophotometrically, forty-one ones for periodic analysis [1]. Physical properties of sixty-seven near-Earth anf seven main-belt asteroids were gained, and it helped to searching for backups for Hayabusa2 and understanding of the physical properties of individual asteroids and their origins. Among observed asteroids in this study, the C-type asteroids that Hayabusa2 can reach is 153591 2001 SN_{263} (Fig. 1) and 341843 2008 EV_5 (Fig. 2).

Reference

[1] Haseagwa, S., et al.: 2018, *PASJ*, **70**, 114.

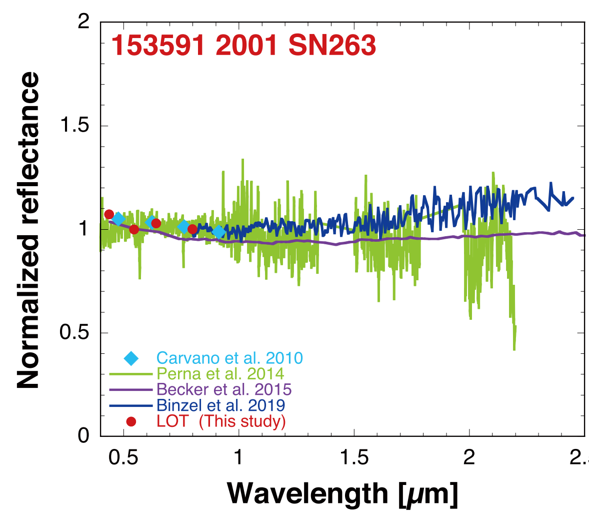

Figure 1: Spectra of the asteroid 153591 2001 SN263.

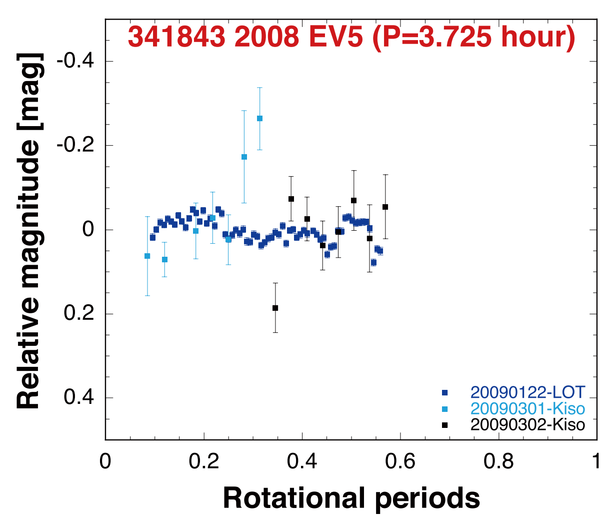

Figure 2: Lightcurve of the asteroid 341843 2008 EV5.

Colors of Centaurs Observed by the Subaru/Hyper Suprime-Cam

OHTSUKI, Keiji, SAKUGAWA, Haruka (Kobe University)
TERAI, Tsuyoshi (NAOJ)
YOSHIDA, Fumi (Chiba Inst. Tech.)
TAKATO, Naruhisa (NAOJ)
LYKAWKA, Patryk Sofia (Kindai University)
WANG, Shiang-Yu (Academia Sinica)

Centaurs are small solar system bodies located between the orbits of Jupiter and Neptune, and more than 400 bodies with confirmed orbits are listed in the JPL database. They are likely delivered from the trans-Neptunian disk by planetary perturbations, but their origin is not well understood. Owing to perturbations by the giant planets, Centaurs' dynamical lifetime is rather short ($\sim 10^6$ years). Some Centaurs may evolve to become Jupiter-family comets; but eventually, these objects will be ejected from the solar system or collide with one of the planets. Therefore, studies on the origin of Centaurs allow us to better understand the process of delivery of small icy bodies from the trans-Neptunian region as well as the origin of Jupiter-family comets.

In the present work, we obtained the color distribution of nine Centaurs observed by the Hyper Suprime-Cam (HSC) installed on the Subaru Telescope [1]. The data we used in the present work are those obtained through the HSC Subaru Strategic Program (HSC-SSP; [2]) by the end of June 2017 as well as those available in the public HSC data archive, which were obtained by the end of March 2016. We use data taken with the g and i band filters. The procedures for data reduction and analysis adopted in the present work are similar to those in [3].

The color distribution of the nine Centaurs obtained in the present work is shown in Figure 1. We find that the colors of the nine Centaurs are distributed over the range from neutral to slightly red colors. In order to understand how our data for the nine Centaurs fit in previous studies with larger samples, we calculated spectral slopes from the $g-i$ color for the nine objects in our sample and from the $B-R$ color for the 61 Centaurs obtained by Tegler et al. [4,5], and compared them in Figure 2. Although a bimodal color distribution was not clearly shown for our nine objects alone, in this figure seven objects of our sample seem to be in the gray group and the other two seem to belong to the red group in the bimodal distribution found by Tegler et al. Further observations of Centaurs, TNOs, and other small solar system bodies are essential to better understand the origin and evolution of Centaurs and their parent population.

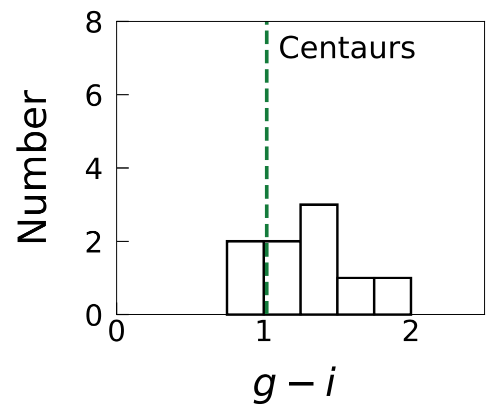

Figure 1: Distribution of $g-i$ color of the nine Centaurs examined in the present work. The vertical dashed line represents the solar color ($g-i = 1.02$; [3]).

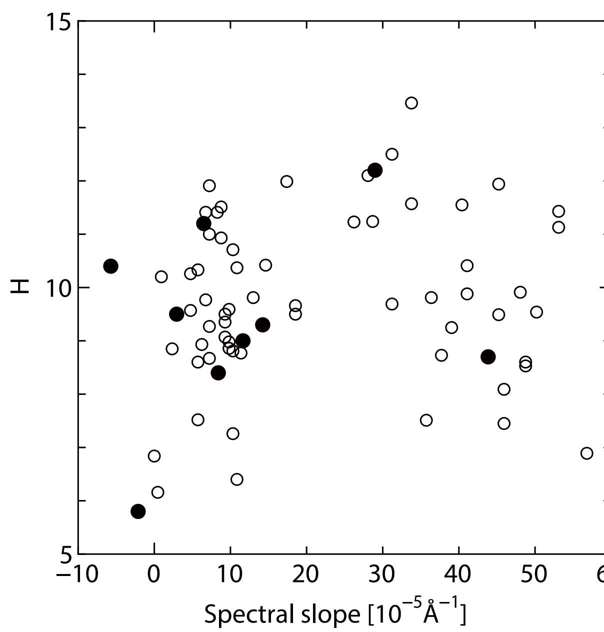

Figure 2: Relationship between absolute magnitude and spectral slope for Centaurs. Filled circles are calculated from the $g-i$ colors of our nine objects, while open circles represent the $B-R$ colors for the 61 objects examined by Tegler et al.

References

[1] Sakugawa, H., et al.: 2018, *PASJ*, **70**, 116.
[2] Aihara, H., et al.: 2018, *PASJ*, **70**, S4.
[3] Terai, T., et al.: 2018, *PASJ*, **70**, S40.
[4] Tegler, S. C., et al.: 2008, in The Solar System Beyond Neptune, ed. Barucci, M. A. et al. (Tucson: University of Arizona Press), 105.
[5] Tegler, S. C., et al.: 2016, *AJ*, **152**, 210.

ALMA Reveals Luminous Buried AGNs in Gas-rich Galaxy Mergers

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Collision and merging of gas-rich galaxies with supermassive black holes (SMBHs) at their centers are common in our universe. Not only rapid starbursts but also AGN activity (= active mass accretion onto a SMBH) should happen at obscured regions by gas and dust during such galaxy mergers, making them highly infrared luminous. Distinguishing the energetic roles of starbursts and AGNs in merging ultraluminous infrared galaxies (ULIRGs) is indispensable to understand how stars and SMBHs grow in their masses during gas-rich galaxy mergers, but is not easy because compact AGNs can be easily buried deep inside a large amount of gas and dust. We need to observe at wavelengths of low dust extinction. Since a starburst (= nuclear fusion inside stars) and an AGN (= mass-accreting SMBH) have different radiative energy generation mechanisms, chemical and physical effects to the surrounding molecular gas should also be different. Thus, it is expected that molecular rotational J-transition line flux ratios in the almost-dust-extinction-free (sub) millimeter wavelength range are different, depending on primary energy sources. HCN, HCO^+, and HNC lines are particularly effective to investigate the physical properties of mass-dominating dense molecular gas at ULIRG's nuclei.

Using ALMA, we had found a trend that AGN-important galaxies show higher HCN-to-HCO^+ J=3–2 flux ratios than starburst-dominated galaxies at millimeter (~1.2 mm or ~250 GHz) [1]. Its reason can be either (1) high HCN abundance caused by AGN radiation and/or (2) higher nuclear gas density and temperature which can excite HCN to a larger extent (regardless of whether ULIRG's nuclear energy sources are AGNs or starbursts). We were unable to distinguish between the two scenarios based on one J-transition line alone. We thus conducted ALMA HCN J=4–3 and HCO^+ J=4–3 line observations of ULIRGs at sub-millimeter (~0.85 mm or ~350 GHz) (Figure 1). We found elevated HCN-to-HCO^+ flux ratios in AGN-important galaxies both at J=4–3 and J=3–2 in a similar manner (Figure 2), suggesting that high HCN abundance is largely responsible, which was confirmed from optically-thin isotopologue line observations (Figure 3). We also found a few candidates of extremely deeply buried luminous AGNs which were not identified with previous optical, infrared, and hard X-ray spectroscopy, but first detected at (sub)millimeter [2]. Our (sub)millimeter molecular line energy diagnostics can be a very powerful tool to scrutinize luminous buried AGNs in ULIRGs most comprehensively.

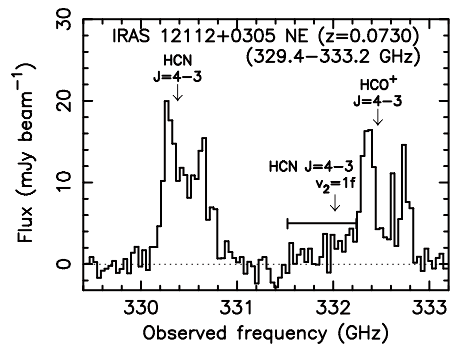

Figure 1: Example spectrum of a ULIRG at HCN J=4–3 and HCO^+ J=4–3 lines.

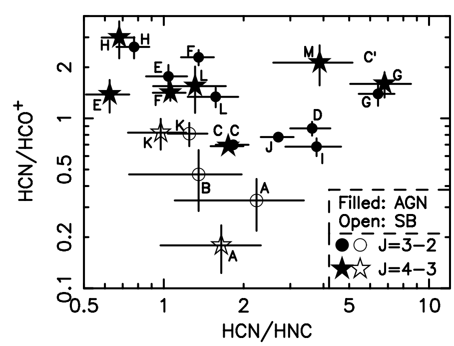

Figure 2: Dense molecular line flux ratios of galaxies. AGN-important ULIRGs (filled symbols) tend to show higher HCN-to-HCO^+ flux ratios than starburst-dominated galaxies (open symbols) both at J=3–2 (circles) and J=4–3 (stars) in the ordinate. The variation of HCN-to-HNC flux ratios among AGN-important galaxies in the abscissa can be explained by different column density of surrounding obscuring material and the effects of infrared radiative pumping by AGN-heated hot dust emission.

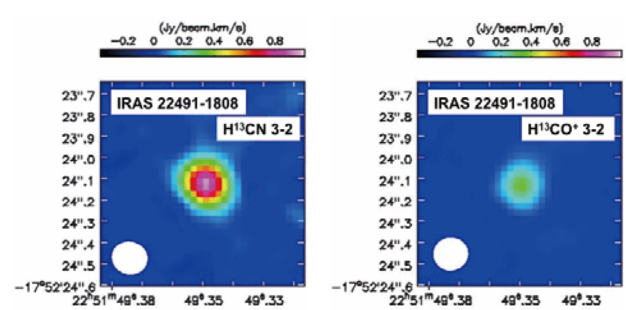

Figure 3: Isotopologue emission from a ULIRG. (Left): $H^{13}CN$ J=3–2, (Right): $H^{13}CO^+$ J=3–2. $H^{13}CN$ J=3–2 emission is much brighter, meaning that HCN abundance is higher than HCO^+.

References

[1] Imanishi, M., et al.: 2016, *AJ*, **152**, 218.
[2] Imanishi, M., et al.: 2018, *ApJ*, **856**, 143.

Search for the Most Distant Quasars

MATSUOKA, Yoshiki
(Ehime University)
KASHIKAWA, Nobunari
(The University of Tokyo)
ONOUE, Masafusa
(Max Planck Institute for Astronomy)
IMANISHI, Masatoshi
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The first billion years of the universe is considered to be one of the last frontiers of astronomy and astrophysics. The universe became once neutral at the time of "Recombination", and then re-ionized, likely due to strong ionizing radiation emitted by the first populations of light sources born after the cosmic dark age. However, it is still unclear when and how these populations formed and evolved, how the reionization proceeded, and exactly what provided the high-energy photons required to re-ionize the intergalactic medium. A wide variety of theoretical and observational researches are being carried out to tackle these problems.

Since 2000, astronomers have found in this epoch (redshift $z \geq 6$) supermassive black holes (quasars) with masses exceeding a billion solar masses. If we assume that they formed by the death of the first stars, then it would be difficult to grow to such massive objects in a billion years, under normal circumstances. This represents a major challenge to theories of supermassive black hole formation, which have not been solved yet. In addition, high-energy photons released through black hole growth are considered to be a likely candidate of the origin of cosmic reionization, but it is not clear exactly what amount of such photons were created by the quasars. In order to answer these questions, it is vital to search for quasars in the early universe, and derive their luminosity function.

We are carrying out a survey for the most distant quasars since 2014, based on the Hyper Suprime-Cam Subaru Strategic Program survey. Our project has continued to proceed successfully this year, and the total number of quasar discovery has grown to 83 (see Figure 1). These objects have typically an order of magnitude lower luminosities than do the quasars known prior to our survey, which demonstrates the power of Subaru and Hyper Suprime-Cam. We have also achieved two milestones this year. First, we have derived the quasar luminosity function at $z = 6$ [1]. The luminosity function flattens at the ultraviolet absolute magnitude $M_{1450} \sim -25$ mag toward the faint side, which implies relatively small number of black holes with low mass and/or radiation efficiency. The overall shape of the luminosity function doesn't change significantly from $z = 4$, while the number density declines rapidly toward higher redshift. We also found, by integrating the luminosity function, that quasars cannot provide more than 10 % of the ionizing photons that are required to keep the intergalactic medium fully ionized. Second, we discovered a quasar at $z = 7.07$ [2]. This is not only the third most distant quasar ever known, but also the first low-luminosity quasar at $z > 7$, with the estimated black hole mass being a tenth of those known previously at the similar redshifts. We also found evidence of a large amount of gas around the black hole, which may indicate that this black hole is in the early phase of evolution.

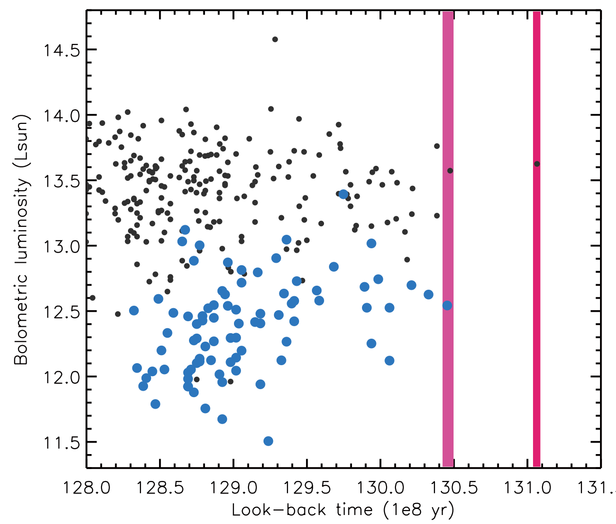

Figure 1: Distant quasars known to date, as a function of look-back time and bolometric luminosity. The small black dots represent quasars discovered by other surveys, while the blue dots represent our discovery. The red vertical lines represent the redshift records of the quasar discovery.

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Phase-polarization Curve of Asteroid (3200) Phaethon

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Phaethon is an Apollo-type near-Earth asteroid, which has a large orbital inclination (22°.2) and small perihelion distance (0.14 au). Phaethon is likely the parent body of the Geminid meteor shower because of their orbital association. Because current mass-loss events of Phaethon are not sufficient to explain the activity of the Geminids, Phaethon probably released a large amount of dust particles in the past. Various observational, experimental, and theoretical studies suggest that its surface is covered by rocks with coarser grain size and contains hydrated minerals. Because the linear polarization degree referred to the scattering plane, P_r, as a function of the solar phase angle, α, of solar system objects is a good diagnostic for understanding the scattering properties of their surface materials. We carried out the polarimetric survey of Phaethon from 2017 December 9 to 21, corresponding to α is from 19°.1 to 114°.3 [1]. Figure 1 shows the derived phase-polarization curve of Phaethon, which shows that the maximum of P_r, P_{max}, is > 42.4 % at α > 114°.3, a value significantly larger than those of the moderate albedo asteroids (P_{max} ~ 9 %; [2,3]). The phase-polarization curve classifies Phaethon as *B*-type as well as *M*- and *K*-type asteroids, in the polarimetric taxonomy, being compatible with the spectral property. We compute the geometric albedo, p_V, of 0.14 ± 0.04 independently by using an empirical slope-albedo relation, and the derived p_V is consistent with previous results determined from mid-infrared spectra and thermophysical modeling [4]. We find no periodic variation of P_r in our polarimetric data in the range from 0 up to 7.208 hr (e.g., less than twice the rotational period). We also find significant differences between our P_r during the 2017 approach toward Earth and that in 2016 [5,6], implying that Phaethon has a region with different properties for light scattering near its rotational pole.

We are grateful to the staff of the Public Relation Center of the National Astronomical Observatory of Japan for their support during our observations. This research was supported by Grant-in-Aid for Japan Society for the Promotion of Science (JSPS) Fellows grant No. 15J10864 (YS), JSPS KAKENHI grant No. 17H06459 (NN), and National Science Foundation Planetary Astronomy Program (USA) grant No. 0908529 (DCB).

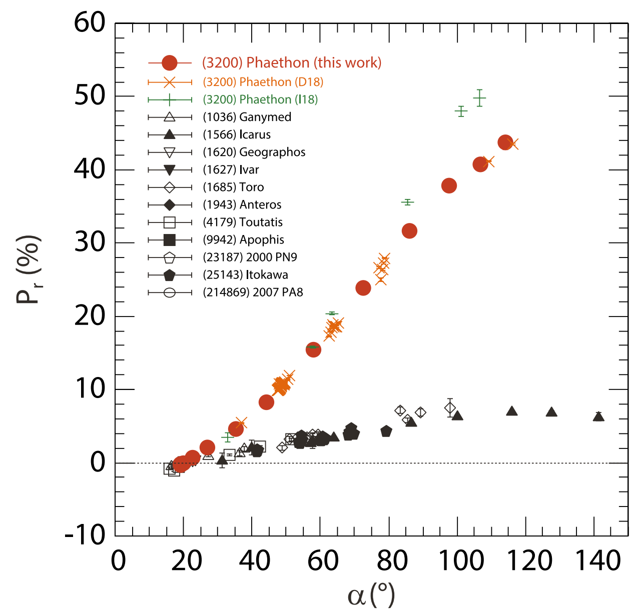

Figure 1: Phase-polarization curve of Phaethon in the R_C-band. Vertical and horizontal axes are the degree of linear polarization, P_r, and the solar phase angle, α, respectively. Red circles are the observed P_r of Phaethon at α on each date. Orange crosses (D18) and green plus symbols (I18) are the P_r of Phaethon taken on 2017 December [5] and during 2016 September–November [6], respectively. Black symbols are the P_r of the moderate albedo asteroids [2,3]. The horizontal black dotted line shows P_r = 0 %.

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Mineral Abundance of Comet 17P/Holmes Immediately after Its Great Outburst in 2007 October

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Comet 17P/Holmes is a short-period comet with an orbital period of ~7 years. The comet underwent a great outburst starting on October 23, 2007 (when the comet was 2.5 au from the Sun), five months after perihelion at 2.05 au on May 5, 2007. The total magnitude of this outburst reached a maximum brightness of ~2–3 mag in V-band within two days after the outburst, increasing from an initial brightness of ~17 mag. This huge outburst, with a 15 mag brightness increase, was unlike any other. Other than the outburst in 2007, Comet 17P/Holmes had exhibited outbursts in November 1892, when the comet was discovered by E. Holmes, and January 1893.

We focuses on the dust components released from Comet 17P/Holmes. A cometary nucleus includes minerals called silicates. Cometary silicates consist of both amorphous and crystalline forms. Silicates in amorphous form exist in interstellar space and might have been incorporated into the cometary nucleus in the solar nebula in the early solar system. Meanwhile, it has been thought that crystalline silicates formed by the annealing of amorphous silicate grains or direct condensation of gaseous materials in hot regions of the solar nebula near the Sun and were incorporated into cometary nuclei in the cold comet-forming region (~5–30 au from the Sun) after radial transportation of the silicate grains in the solar nebula. Because the mass fraction of crystalline silicates with respect to the total (amorphous and crystalline) silicates is expected to be smaller for further distances from the Sun in the solar nebula, it is thought that a smaller mass fraction of crystalline silicates in a comet indicates that the comet formed at a further distance from the Sun in the solar nebula.

On the basis of analysis of the archived mid-infrared data of comet 17P/Holmes taken by the Subaru Telescope on 2007 October 25 to 28, we found that dust grains of Comet 17P/Holmes contain a large amount of amorphous silicates (less crystalline silicates) compared with grains of other comets [1]. This result is evidence that Comet 17P/Holmes formed in a farther, colder region in the solar nebula than other comets. At such a region, it is expected that much CO ice which has a low sublimation temperature of ~30 K and amorphous water ices which through crystallization in the low temperature conditions become an energy source for explosive sublimation would have existed.

This study was financially supported by JSPS grants (15J10864, 17K05381).

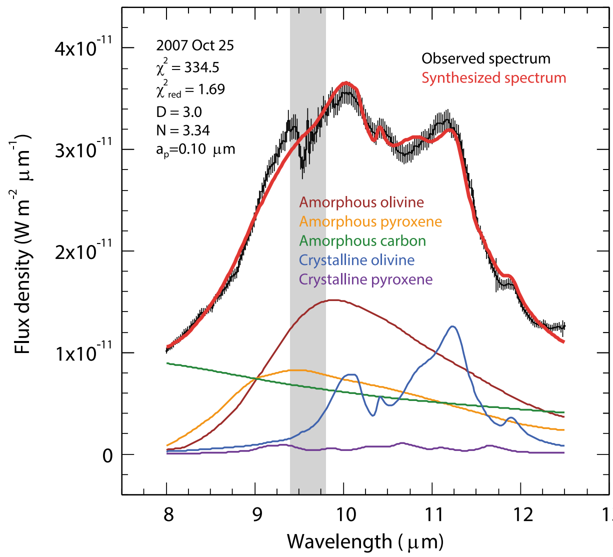

Figure 1: Comparison between synthetic and observed spectra of comet 17P/Holmes on UT 2007 October 25 [1]. Black bars are observed spectra with error. Thick red line indicates best-fitted synthetic spectrum reproduced by the thermal emission model [2]. Thin color lines indicate best-fitted mineral spectra. Gray area between 9.4 and 9.8 μm is strong absorption band of telluric ozone. In left upper side of each panel, fitting results (χ^2 and reduced-χ^2) and best-fit dust properties (fractal dimension of dust grains, D, size distribution of dust grains, N, and peak radius, a_p) are listed.

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The 7-year MAXI/GSC X-Ray Source Catalog in the High Galactic Latitude Sky

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YOSHIDA, Atsumasa[8], IWAKIRI, Wataru[3], KAWAKUBO, Yuta[8], SUGAWARA, Yasuharu[5]
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The Monitor of All-sky X-ray Image (MAXI; [1]) is an instrument on board the International Space Station (ISS), and has been successfully monitoring the X-ray sky since 2009 August. The Gas Slit Camera (GSC) carried by the MAXI covers the 2–30 keV band, and surveys the sky with two instantaneous fields of view of $160° \times 1.°5$ (FWHM) separated by 84° [2]. While rotating its fields of view with a period of 92 minutes according to the orbital motion of the ISS, the GSC eventually covers a large fraction of the sky (95 %) within one day [3].

High-latitude X-ray source catalogs have been used as a basis to study extragalactic objects, mainly active galactic nuclei (AGNs). This time, we created the third MAXI/GSC X-ray source catalog in the high-latitude sky ($|b|>10°$) utilizing the first 7-year (2009 August 13 to 2016 July 31) data in the 4–10 keV band [4]. The catalog contains 682 X-ray sources with significances (the ratio of the flux to its 1σ error) above 6.5 (Fig. 1). The sensitivity reaches 5.9×10^{-12} erg cm^{-2} s^{-1} over half of the survey area. This is the highest ever achieved as an all-sky X-ray survey in a similar energy band. The source number has increased by a factor of ~1.4 compared with the previous 37-month catalog [5]. By cross-matching the cataloged sources with those in other X-ray catalogs, we found the counterparts of 422 sources.

We also created one-year-bin 4–10 keV light curves for all the detected sources (e.g., Fig. 2). Their variabilities were quantified by following a past study [6], and we found that the compact objects, such as X-ray binaries and AGNs, show strong variability, demonstrating that the variability is a key to uncovering the nature of unidentified X-ray sources.

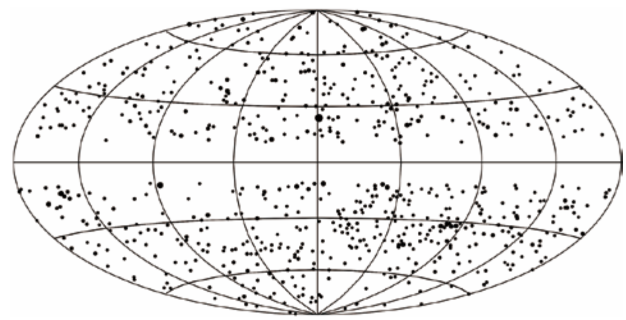

Figure 1: High latitude X-ray sources detected by the MAXI/GSC. The galactic coordinates are adopted. The size of each source is scaled with its flux in logarithmic scale.

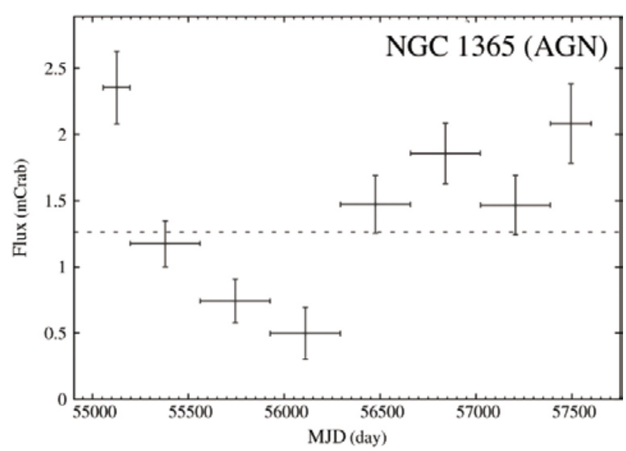

Figure 2: Lightcurve of NGC 1365 (AGN) in the 4–10 keV band, a representative one among variable X-ray sources.

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Optical Design Approach "Co-axis Double TMA" for Vignetting-free Off-axis Reflective Relay Optics

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As a result of my design study for a next-generation astronomical instrument, I have developed a new optical design approach called "Co-axis Double TMA". The design approach consists of two optical design foundations: (1) use of the symmetrical property of the combination of two optical systems; and (2) reversal combination of the components of a well-known on-axis reflecting telescope. This approach enables the elimination of rotationally asymmetric aberrations that becomes a problem for vignetting-free off-axis reflective optics by utilizing two components of an on-axis telescopes and placing the central axis of the two components in parallel.

The validity of the proposed approach has been confirmed by a next-generation astronomical instrument (TMT/IRIS, the first-light instrument of TMT). The basic layout of the optics is shown in Fig. 1. The design has a collimator comprising three off-axis conic mirrors that share a central axis. Similarly, the camera comprises three off-axis conic mirrors that also share a central axis. In addition, the central axis of the collimator and of the camera are virtually placed in parallel. Due to the difference in the F-numbers of the collimator and camera (i.e. F/15 and F/17.19, respectively), their focal lengths also differ (collimator: 1425 mm, camera: 1633 mm). In addition, for the collimated light portion, a cold stop, ADC, filter wheel, and several fold mirrors for the pupil-viewing optics are inserted. Therefore, an optical path of at least 600 mm is required for the collimated beam. With the proposed arrangement, we can eliminate the rotationally asymmetric aberration that occurs at the collimator and camera even though they are not identical due to their magnifications and boundary condition specifications.

Fig. 2 shows a wavefront aberration map for a wavelength of 1 μm. The figure clearly shows that the distribution of the wavefront aberration is both horizontally and vertically symmetrical. This is caused by the optics having a rotationally symmetrical wavefront aberration about the center of the optical axis (center of the four detectors) in the case of a single image plane, making it both horizontally and vertically symmetrical due to the field curvature compensation realized with the tilts of the four detectors. The WFE is less than 6 nm RMS over the FoV of the instrument, which satisfies the image quality requirement of instruments with vignetting-free optics.

TMT/IRIS using this optical design passed the Preliminary Design Review in November 2017. This design and concept won "The 21st Outstanding Optical Design Award" from the Optics Design Group of the Optical Society of Japan in October 2018. The details of this design and concept are given in [1,2].

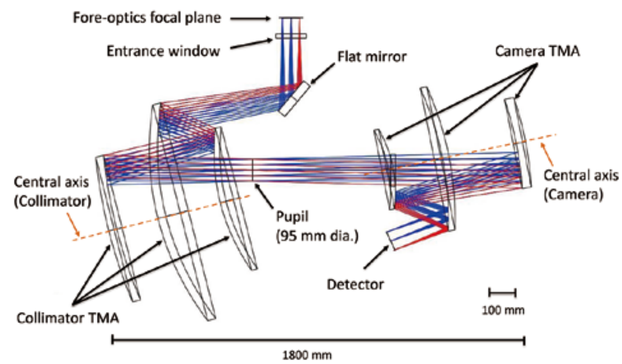

Figure 1: Optical layout of the latest IRIS imager design. In addition to the portions that are being used, the overall system of off-axis mirrors is also described in the figure.

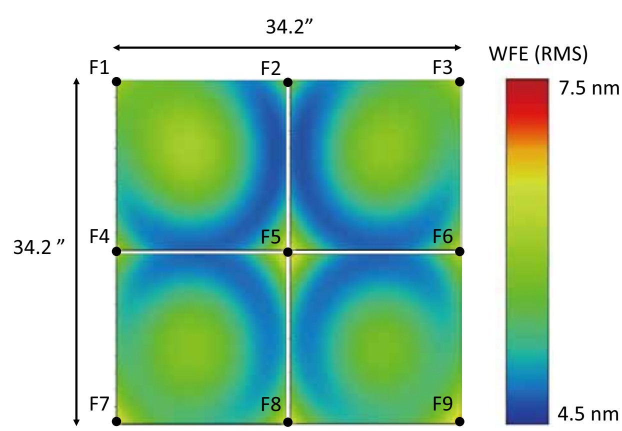

Figure 2: WFE map of IRIS Imager for the overall FoV (1 μm single-wavelength). The quadrants indicate four detectors.

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Chemical Diversity and Chemical Evolution in High-Mass Star-Forming Regions

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Massive stars ($>8\,M_\odot$) play essential roles in evolution of galaxies, because they emit elements which are synthesized in them and energies. Recent studies show that our Sun was born in a cluster regions which resemble high-mass star-forming regions [1]. Hence, it is important for revealing the formation process of the solar system to understand evolution of high-mass star-forming regions.

Chemical composition is powerful tools to investigate the physical conditions and dynamical evolution of star-forming regions [2]. Chemical evolutionary indicators using carbon-chain molecules have been established in low-mass star-forming regions [3]. On the other hand, chemical evolution from starless cores to protostellar stage had not been revealed, and no chemical evolutionary indicator had been established. We carried out survey observations of molecular emission lines from HC_3N, N_2H^+, CCS, and *cyclic*-C_3H_2 in the 90 GHz band toward high-mass starless cores and high-mass protostellar objects, using the Nobeyama 45-m radio telescope [4]. Figure 1 shows that the column density ratio of N_2H^+/HC_3N is a useful chemical evolutionary indicator in high-mass star-forming regions. Furthermore, this ratio can find very young protostellar objects which cannot be found by infrared observations.

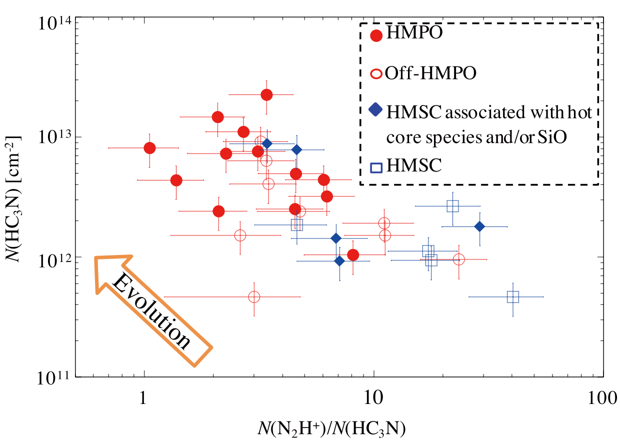

Figure 1: Chemical evolutionary indicator in high-mass star-forming regions [4].

There are two types chemistries around low-mass protostars; hot corino chemistry and warm carbon chain chemistry (WCCC) are rich in saturated complex organic molecules (COMs) and carbon-chain molecules, respectively. In high-mass star-forming regions, hot cores which are corresponding to hot corinos in low-mass star-forming regions have been well studies, but it was unclear whether the WCCC mechanism occurs around massive young stellar objects (MYSOs). We carried out observations toward three MYSOs using the Nobeyama 45-m radio telescope and ASTE, and compare chemical composition [5]. G28.28–0.36 shows a significantly high HC_5N abundance, and the WCCC mechanism may work efficiently in this source. We also carried out imaging observations of cyanopolyynes ($HC_{2n+1}N$) using the Karl G. Jansky Very Large Array [6]. The moment 0 images of cyanopolyynes coincide with the 450 μm dust continuum emission. These results suggest that cyanopolyynes are formed from CH_4 and C_2H_2 which are sublimated from dust grains.

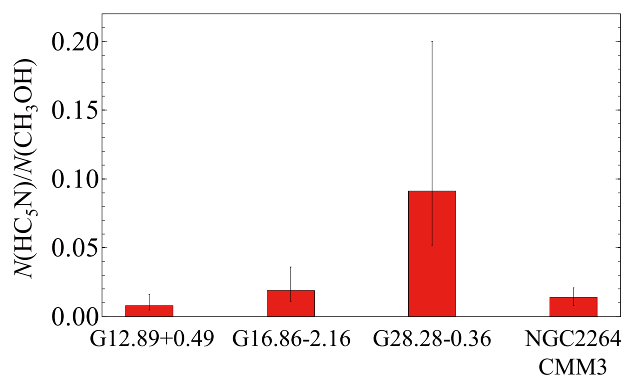

Figure 2: Chemical diversity around massive young stellar objects [5].

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Nucleosynthesis Constraints on the Explosion Mechanism for Type Ia Supernovae

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Type Ia supernovae (SNe Ia) are thought to be thermonuclear explosion of white dwarfs (WDs), but their explosion mechanism is still unclear. There are two popular scenarios called the single-degenerate (SD) and the double-degenerate (DD) scenarios. In the SD scenario, mass accretes on a WD and it explodes when its mass reaches the Chandrasekhar mass. In the DD scenario, WD binary mergers explode as SNe Ia. Detailed studies have been performed on propagation of deflagration and detonation waves and the mass of WDs which cause SN explosions based on both scenarios, but clear smoking guns of the explosion mechanism have not been proposed.

In this study, we explore methods to unveil the explosion mechanism using explosive nucleosynthesis [1]. Recent observations with the Hubble Space Telescope succeeded in drawing late-time light curves >1000 days after the explosions [2-6]. Such late-time light curves are powered by the beta-decay of ^{57}Co ($t_{1/2}$ = 272 days) and ^{55}Fe ($t_{1/2}$ = 1000 days), so it is possible to estimate the amount of those isotopes. We compare these observational abundance and theoretical models, and attempt to constrain progenitors and explosion mechanisms.

The characteristic feature of SN Ia nucleosynthesis is that the high density causes electron capture reactions so neutron-rich isotopes are produced. It is expected that the abundances of neutron-rich nuclei are dependent on the central density of the WD and hence the mass of the progenitor. We studied the correlation between the amount of the produced neutron-rich isotopes and the central density using theoretical models [7,8]. As a result, it is found that the production of ^{54}Cr is very sensitive to the density. The amount of ^{54}Cr has not been estimated observationally, but future observations of this quantity may be able to constrain the nature of progenitors and details of explosion mechanism.

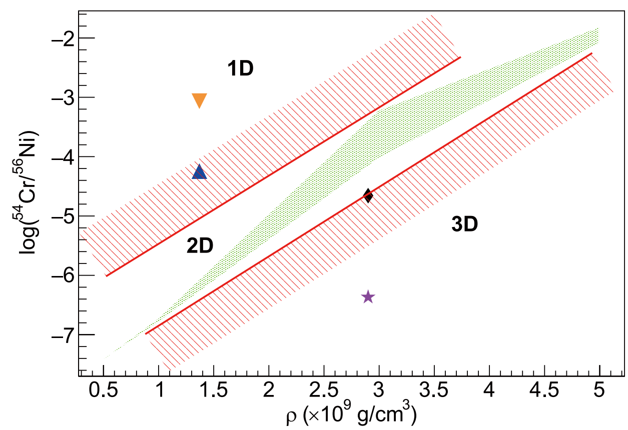

Figure 1: The abundance of ^{54}Cr in theoretical models. The horizontal axis shows the central density.

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Impacts of the New Carbon Fusion Cross Sections on Type Ia Supernovae

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Type Ia supernovae (SNe Ia) are thermonuclear explosion of CO white dwarfs, and its ignition is attributed to the $^{12}C+^{12}C$ fusion reaction. The cross sections of this reaction have been measured for long years, but it was in the year 2018 that the astrophysical low-energy cross sections were finally acquired [1]. This latest result implies that there are many low-energy resonances, which enhance the nuclear reaction rates. In this study, therefore, we investigate the impact of the enhanced reaction rates on SNe Ia [2].

One of popular scenarios on progenitors of SNe Ia is white dwarf (WD) binary mergers. In a WD merger, the secondary star is disrupted by the tidal force and forms an accretion disk. If this accretion does not increase the temperature on the surface of the primary star enough, the carbon fusion is not ignited on the surface and the system will explode as a SN Ia. On the other hand, if the carbon fusion is ignited on the surface, the CO WD is burned into an ONeMg WD, and it will collapse into a neutron star (NS). The latter evolutionary path is called the accretion induced collapse.

If the carbon fusion reaction rates are enhanced, the ignition temperature decreases. Therefore it is expected that WD mergers tend to collapse into NSs. We calculated the ignition temperature with the latest experimental cross sections and compared them with a hydrodynamical simulation [3]. As a result, we find a quantitative relation between the carbon fusion reaction rates and the event rate of SNe Ia. In addition, we study the evolution of each system on the parameter space of the mass ratio and the total mass and its dependence on the reaction rates (Fig. 1).

Previous studies [4-6] have investigated the effect of resonances on other astrophysical objects. Before 2018, they assumed the existence of resonances because the experimental result was not available. However, it has not been confirmed that the assumed resonances are possible in terms of nuclear structure. Hence we compare the assumed resonances with the Wigner limit which confines the resonance strength. It is found that some of the assumed resonances are not likely to exist because they violate the limit.

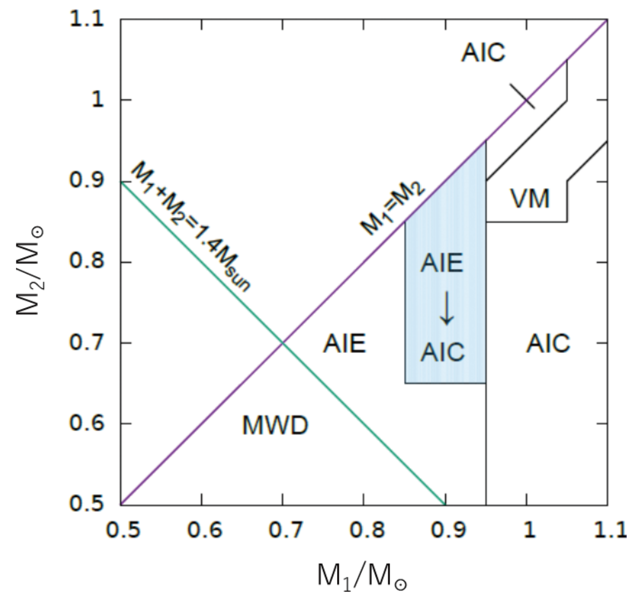

Figure 1: The fate of WD mergers with the mass of the primary star M_1 and the mass of the secondary star M_2. The blue region shows systems which changes their fate depending on the carbon fusion reaction rates.

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The Dust-selected Molecular Clouds in the Northeast Region of the Small Magellanic Cloud

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The Small Magellanic Cloud (SMC) is a dwarf galaxy characterized by a metal-poor environment and active star formation. Because of its proximity (~60 kpc), compared to other nearby galaxies, the SMC provides an invaluable opportunity to investigate physics of theinterstellar medium (ISM) and star formation, along with the Large Magellanic Cloud. The giant molecular cloud (GMC) survey toward the full SMC using CO(J=1–0) line were conducted by the NANTEN 4 m telescope, and 21 GMCs was disocovered [1]. As a complementary approach, Takekoshi et al. [2] attempted a new GMC identification method using 1.1 mm continuum survey data toward the full SMC. However, they did not detect two CO clouds discovered by NANTEN in the northeast (NE) region of the SMC. These CO clouds are characterized by relatively weak star formation activity compared to the other NANTEN GMCs, suggesting that low dust temperature or low surface brightness make it difficult to detect at the 1.1 mm continuum. Therefore, we conducted deep imaging of 1.1 mm continuum toward the NE region in the SMC.

Observation of the 1.1 mm continuum toward the SMC NE region were conducted with the AzTEC camera [3] mounted on the ASTE telescope. Figure 1 shows the obtained image. As a result of clump identification, 20 objects were identified in the observing area. Two NANTEN GMCs consist of two and three compact 1.1 mm objects. This result is consistent with previous high-resolution observation by Mopra toward these GMCs [4].

We estimated dust mass, temperature, index of emissivity of the 1.1 mm objects by a spectral energy distribution (SED) analysis using the Markov Chain Monte Carlo method with the AzTEC, *Herschel*, and *Spitzer* data. Although the gas and dust masses of twelve 1.1 mm objects were estimated as upper limits, the other eight objects show the gas mass range of 5×10^3–7×10^4 $M_\odot$, assuming a gas-to-dust ratio of 1000. The ranges of the dust temperature and index of emissivity were 18–33 K and 0.9–1.9, respectively. We also compared between gas masses estimated by the SED analysis and CO luminosity assuming a conversion factor of 1×10^{21} cm^{-2} (K km s^{-1})$^{-1}$, and confirmed the consistency with uncertainties by a factor of 2.

This result was reported in the Astrophysical Journal [5].

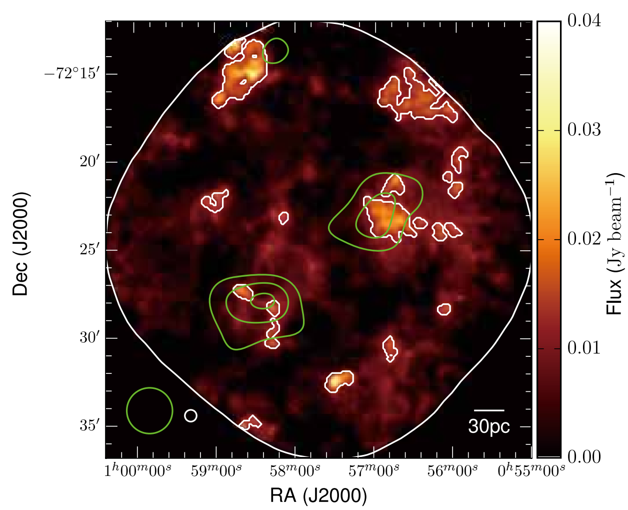

Figure 1: The 1.1 mm image of the SMC NE region. Identified 1.1 mm objects are shown by white contours. Green contours represent the NANTEN CO clouds.

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Relative Velocity Distribution for General Statistics and an Application to Big-bang Nucleosynthesis under Tsallis Statistics

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The distribution function of the relative velocity in a two-body reaction of nonrelativistic uncorrelated particles is derived for general cases of given distribution functions of single particle velocities [1]. As an example, we take the Tsallis distribution [2] that is generally different from Maxwell-Boltzmann (MB) distribution, and show that the distribution function of the relative velocity is different from the Tsallis distribution. Thermonuclear reaction rates are then obtained and adopted for big bang nucleosynthesis (BBN) calculation.

It has been pointed out that if nuclei follow the Tsallis distribution described by one parameter q during BBN, the q value must be close to 1 for light element abundances consistent with observations [3]. A calculation including modifications in two-body reverse reaction rates found that a slightly softer spectrum than the MB distribution leads to some decrease of the ^{7}Li abundance [4].

We derived the exact formulation of relative velocity distribution function, and showed a critical error in equations previously adopted [3,4]. The thermal two-body reaction rate is given by $\langle \sigma v \rangle = [\int d\boldsymbol{v}_1 f(\boldsymbol{v}_1) \int d\boldsymbol{v}_2 f(\boldsymbol{v}_2)] \, \sigma(E) \, v$, where σ is the cross section, $\boldsymbol{v}_i$ is the velocity vector of species $i = 1$ and 2, $f(\boldsymbol{v}_i)$ is the velocity distribution function of i, $v = |\boldsymbol{v}_1 - \boldsymbol{v}_2|$ is the relative velocity, and $E = \mu v^2/2$ is the center of mass (CM) energy with μ the reduced mass of the two-body system.

For MB distributions, the integration part in the above square brackets can be decomposed to functions of the velocity of the center of mass and the relative velocity. That decomposition has been assumed in previous studies [2,3]. However, in general cases including Tsallis distribution, that part cannot be decomposed that way.

Figure 1 shows the relative velocity distribution function versus the CM kinetic energy E for $q = 1.075$ [1].

Adopting calculated reaction rates under the Tsallis statistics, we performed revised BBN calculations. Sensitivities of abundances of all important light nuclei to the parameter q are investigated in detail. The suppression of ^{7}Be production via the change in distribution function [4] is less effective in our exact BBN result than in previous studies [3,4]. Therefore, it is more difficult to reduce the primordial ^{7}Li abundance. However, the q value slightly larger than 1 can increase the D abundance and slightly reduce the Li abundance so that the consistency with observational constraints is maximal [1].

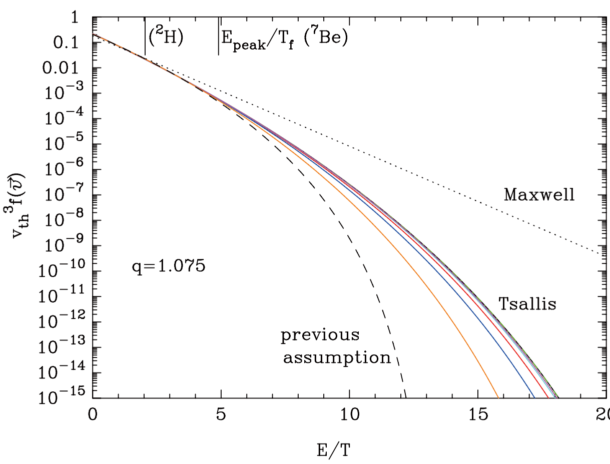

Figure 1: The relative velocity distribution function versus the CM kinetic energy E for $q = 1.075$ [1]. Solid and dash-dotted lines correspond to Tsallis statistics for sets of nuclear mass numbers of reacting nuclei, i.e., (A_1, A_2) =(1,1), (2,2) (dash-dotted line), (4,3), (3,2), (2,1), (3,1), and (7,1) from the top to the bottom, respectively. The dashed and dotted lines correspond to the previous estimate and the MB distribution.

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Supernova Neutrino Process of Li and B Revisited

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A new nucleosynthesis code was developed which involves light to heavy nuclei, neutrino (ν) induced reactions as well as other reactions, and treats neutrino oscillations in supernovae (SNe). Effects of neutrino oscillations on ^{7}Li and ^{11}B synthesis in core-collapse SNe are investigated, and detailed explanation of the ν-process is given focusing on dependencies of yields on the metallicity [1]. The ν-process is an important process for ^{7}Li and ^{11}B in Galactic chemical evolution [2,3,4].

During the propagation of neutrinos from the proto-neutron star, their flavors change and the neutrino reaction rates for spallation of ^{12}C and ^{4}He are affected. In the normal hierarchy case, the charged-current (CC) reaction rates of ν_e are enhanced, and yields of proton-rich nuclei including ^{7}Be and ^{11}C are increased. In the inverted hierarchy case, the CC reaction rates of $\overline{\nu}_e$ are enhanced, and yields of neutron-rich nuclei including ^{7}Li and ^{11}B are increased.

Figure 1 (upper panel) shows the rates of the abundance change of ^{4}He, $|dY(^{4}\mathrm{He})/dt|$, via the ν+^{4}He reactions versus time at the shell with Lagrangian mass $M_r = 4.5\,M_\odot$ [1].

Yields of ^{7}Li, ^{7}Be, ^{11}B, and ^{11}C depend upon the metallicity due to changes in the neutron abundance in SN nucleosynthesis. The metallicity of progenitor stars should then be taken into account in Galactic chemical evolution of Li and B via the ν-process.

Figure 1 (lower panel) shows the nuclear abundances as functions of time at the shell $M_r = 4.5\,M_\odot$ [1].

Figure 2 shows mass fractions of ^{7}Li and ^{7}Be (left panel) and ^{11}B and ^{11}C (right panel) versus M_r [1].

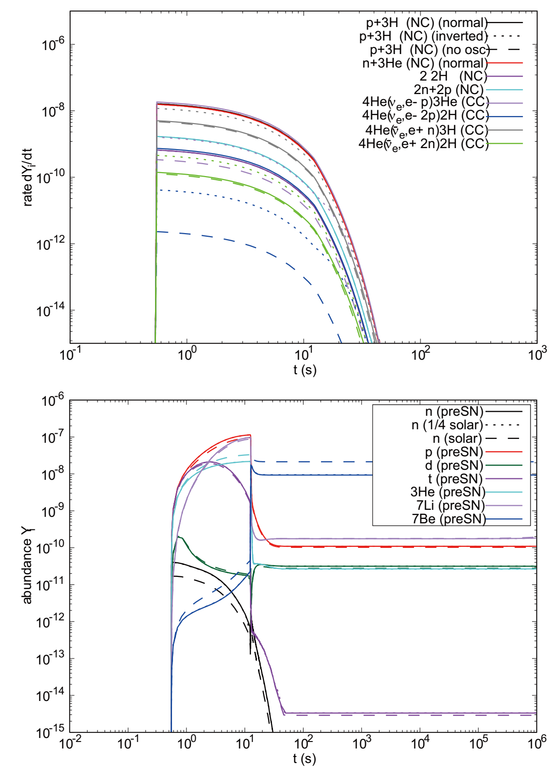

Figure 1: (Upper panel) The rates of the abundance change of ^{4}He, $|dY(^{4}\mathrm{He})/dt|$, via the ν+^{4}He reactions versus time at the shell with Lagrangian mass $M_r = 4.5\,M_\odot$ [1]. Cases of the normal hierarchy (solid lines), inverted hierarchy (dotted lines), and no neutrino oscillation (dashed lines) are shown. (Lower panel) Nuclear abundances as functions of time at the shell $M_r = 4.5\,M_\odot$ [1]. The presupernova s-abundances for $Z = Z_\odot/4$ (1) are adopted for solid lines, while solar abundances (2) are adopted for dashed lines [1].

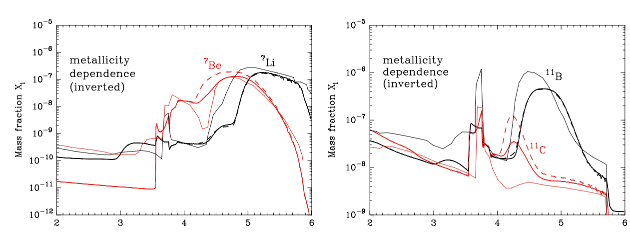

Figure 2: Mass fractions of ^{7}Li and ^{7}Be (left panel) and ^{11}B and ^{11}C (right panel) versus M_r [1]. The updated results [1] (thick lines) and the previous ones [4] (thin lines) are shown. The solid and dashed lines correspond to the cases (1) and (2).

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A Kilometre-sized Kuiper Belt Object Revealed by Stellar Occultation Monitoring Observations

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With the aim of detecting stellar occultation events by kilometer-sized (radii = 1–10 km) Kuiper belt objects (KBOs), we have carried out an optical observation project named Organized Autotelescopes for Serendipitous Event Survey (OASES). Kilometer-sized KBOs are thought to represent a signature of initial planetesimal sizes before their runaway growth phase. Furthermore, these objects are thought to be the source for the observed distribution of the Jupiter family comets. Their size distribution is thus essential for the understanding of the solar system evolution process and the origin of the present-day comets. Since the kilometer-sized KBOs are too faint to be detected directly, the monitoring of stellar occultation events is one possible way to discover them. However, these stellar occultations are extremely unfrequent and short-timescale events and thus are undetectable using existing astronomical instruments.

In this study, we have developed two low-cost observation systems, each consisting of a 280 mm commercial astrograph equipped with a CMOS video camera. We installed these observation systems in different positions on the rooftop of the Miyako open-air school on Miyako Island, Miyakojima-shi, Okinawa Prefecture, Japan, and monitored up to 2000 stars with V-band magnitudes down to ~13 simultaneously with a sampling cadence of 15.4 Hz.

In the 60-hour dataset obtained with the two-year OASES observations, we discovered one occultation candidate event by a KBO with a radius of approximately 1.3 km. Our present detection yields a surface number density of KBOs with radii exceeding 1.2 km is approximately $6 \times 10^5\,\mathrm{deg}^{-2}$. This is the first detection of the stellar occultation event candidate by a kilometer-sized KBO. This surface number density favors a theoretical size distribution model with an excess signature at a radius of 1–2 km. The present results suggest that planetesimals before their runaway growth phase grew into kilometer-sized objects in the primordial outer Solar System and remain as one of the major populations in the present-day Kuiper belt. Our results thus suggest that the number density of kilometer-sized KBOs is sufficient to supply the nuclei of the Jupiter family comets.

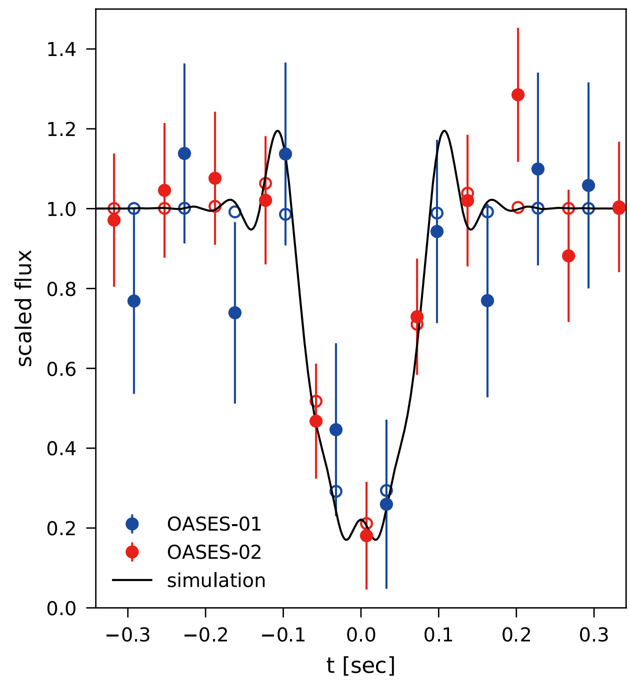

Figure 1: Light curves of an occulted star as a function of the time offset *t* from the central time of the occultation event candidate obtained with OASES-01 (blue line) and OASES-02 (red line) observation systems, respectively. A black line represents the best-fit theoretical light curve.

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Solar Coronal Jets Extending to High Altitudes Observed during the 2017 August 21 Total Eclipse

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Solar coronal jets have been extensively studied using soft X-ray and extreme-ultraviolet (EUV) data, and now they are understood as common phenomena in the low corona. However, from soft X-ray and EUV observations alone, it is difficult to know how high the jets extend. One reason is that there is a gap in the height coverage of the corona by the spaceborne instruments.

At the total solar eclipses, we can observe the corona from the limb to several solar radii under the very low sky background level. At the eclipse on 2017 August 21, we organized a multi-site observation program, and succeeded in taking white-light coronal data with a wide dynamic range at seven sites during a time period of about 70 minutes. Such observations enabled us to trace the time variation of the corona beyond the height coverage by the spaceborne instruments [1].

In the eclipse data, we found coronal jets, which are seen as narrow structures upwardly ejected in polar plumes. Six jets were found in the polar coronal hole regions. They extend from the solar surface to beyond $2\,R_\odot$ with the apparent speed of about $450\,\mathrm{km\,s^{-1}}$. All of the eclipse jets were preceded by EUV jets observed with the Atmospheric Image Assembly of the Solar Dynamics Observatory of NASA. Figure 1 shows an example of the jets observed in the EUV and the eclipse. Conversely, all the EUV jets whose brightness is comparable to ordinary soft X-ray jets and which occurred in the polar regions near the eclipse period were observed as eclipse jets, as shown in Figure 2. From these results, we can conclude that ordinary polar jets generally reach high altitudes and escape from the Sun as part of the solar wind. (The EUV images were provided by courtesy of NASA/SDO and the AIA science team.)

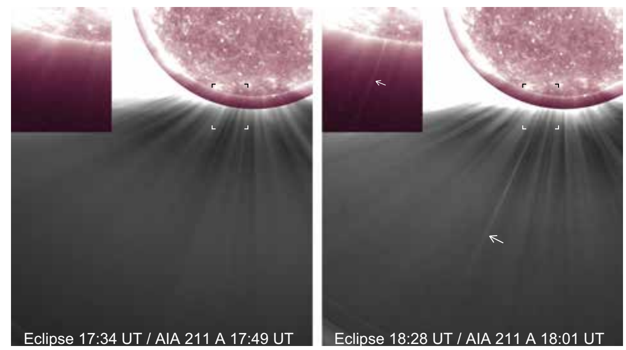

Figure 1: EUV images at 211 Å taken with the AIA of the SDO and eclipse white-light images before (*left*) and after (*right*) the occurrence of a jet. An enlargement of the EUV image in the box is shown at the upper-left corner for each panel. The white-light images are processed to suppress the steep radial brightness gradient and to enhance the jet.

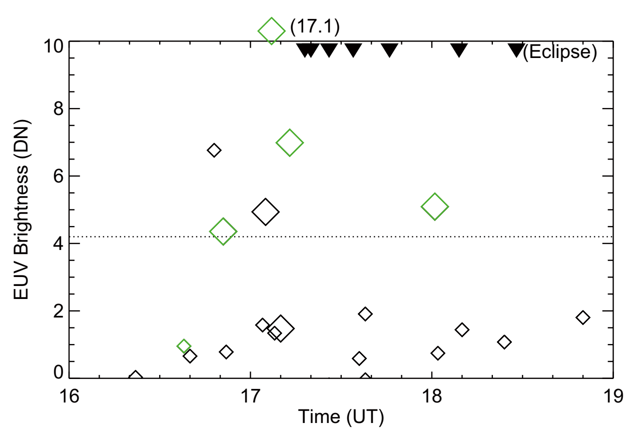

Figure 2: Brightness of the EUV 211 Å jets plotted at their peak times. The jets accompanied by the eclipse jets are displayed with large symbols, and those also observed in the soft X-rays are shown with green symbols. The eclipse observation epochs are marked with triangles.

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ATCA 16 cm Observation of CIZA J1358.9-4750: Implication of Merger Stage and Constraint on Non-Thermal Properties

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In the large-scale structure formation of the Universe, merging galaxy clusters release their huge gravitational energy into thermal energy of the intracluster medium (ICM). A merger sequence of two clusters can be divided into (i) the early stage where the two clusters are getting close, and (ii) the late stage where they are receding from each other. Hydrodynamic simulations suggest that shock waves with position-dependent Mach numbers, M, arise in the merger [1]. Although many late-stage clusters have been observed, there are only several candidates of early-stage clusters, and little is known about shock waves in the early stage.

We conducted the Australia Telescope Compact Array (ATCA) 16 cm observation of a merging galaxy cluster, CIZA J1358.9-4750 (CZ1359). Previous X-ray studies imply that this cluster is composed of binary clusters in the early stage of merger [2]. In the CZ1359 field, we found no significant diffuse radio emission in and around the cluster (Fig. 1) [3]. We obtained a significant upper limit of the total radio power at 1.4 GHz, ~1.1 × 10^{22} Watt/Hz in 30 square arcminutes which is a typical size of radio relics. It is known that an empirical relation holds between the total radio power and X-ray luminosity of the host cluster. The upper limit is about one order of magnitude lower than the power expected from the relation. Therefore, an environment of this merging-cluster system is different from the clusters possessing typical, bright radio halos and relics.

The previous X-ray observation suggested very young (~70 Myr) shocks with low Mach numbers (~1.3), which are often seen at an early stage of merger simulations, at the red-dashed box of Fig. 1. The shocks may generate cosmic-ray electrons with a steep energy spectrum, which is consistent with non-detection of bright (>10^{23} Watt/Hz) relic in this 16 cm band. We derived non-thermal properties at the X-ray shock front and potential shock fronts in CZ1359 as follows. Based on the assumptions of energy equipartition and a model of shock acceleration, the upper limit gives the magnetic-field strength below $0.68 f (D_{\rm los}/1\,{\rm Mpc})^{-1} (\gamma_{\rm min}/200)^{-1}\,\mu$G, where f is the cosmic-ray total energy density over the cosmic-ray electron energy density, $D_{\rm los}$ is the depth of the shock wave along the sightline and $\gamma_{\rm min}$ is the lower cutoff Lorentz factor of the cosmic-ray electron energy spectrum.

Because a steep spectral index is expected due to a low Mach number, low frequency deep observation with MWA and GMRT would be important to further investigate possible diffuse radio emission in the CZ1359 field. In future, the Square Kilometre Array (SKA) and its precursors, ASKAP and MeerKAT, will provide an unprecedented sensitivity in Southern hemisphere. They will advance the study of this cluster significantly.

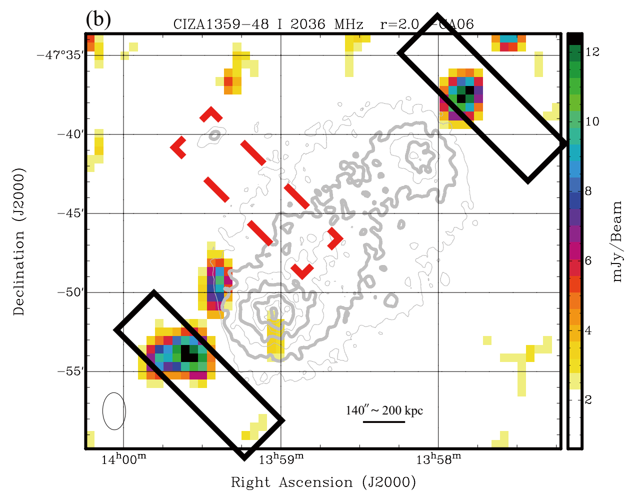

Figure 1: Total intensity map of CZ1359 at 2036 MHz with a 128 MHz bandwidth without CA06 baselines. The color range is shown from 1σ to 10σ rms noise level. Gray contours show the X-ray surface brightness [2]. The black-solid and red-dashed boxes indicate 10′ × 3′ areas in which radio relics are expected in the late- and early-stage of cluster merger, respectively; the latter is associated with the observed X-ray shock front [2].

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Optimum Frequency of Faraday Tomography to Explore the Inter-Galactic Magnetic Field in Filaments of Galaxies

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Magnetic field is a fundamental element of the Universe and it affects formation and evolution of astronomical objects. Even the cosmic web is predicted to be permeated with a large amount of magnetized IGM. This intergalactic magnetic field (IGMF) is thought to play important roles of the thermal history of galaxy clusters, the propagation of ultra-high energy cosmic rays, and the properties of cosmic microwave background. However, there is yet little observational evidence.

Centimeter radio polarimetry is one of the promising tools to study cosmic magnetism [1]. Previously, we studied possible situations to estimate Faraday rotation measure (RM) due to the IGMF, $\mathrm{RM_{IGMF}}$, by means of Faraday tomography. Faraday tomography is a state-of-the-art technique of polarimetry, and it allows us to distinguish multiple polarized sources along a line of sight in theory. In the work, we demonstrated that the broadband data at ultra-high frequency (UHF, 300 MHz – 3000 MHz) is promising to maximize the capability of Faraday tomography [2]. However, obtaining a seamless dataset over broad bandwidth is practically difficult. One of the essential reasons is radio frequency interferences (RFIs), where centimeter wavelength is commonly used in industry. Since RFIs often make signal processing unreliable, persistent RFIs are cut by frequency filters at an early stage of a receiver system. This means that we never obtain astronomical signal at the frequencies.

We investigate optimum frequency coverage of Faraday tomography so as to explore $\mathrm{RM_{IGMF}}$ in filaments of galaxies [3]. We adopt a simple model of the IGMF and estimate confidence intervals of the model parameters using the Fisher information matrix. We find that meaningful constraints for $\mathrm{RM_{IGMF}}$ are available with data at multi-narrow-bands (each 10 MHz – 100 MHz bandwidth) which are scattered over the UHF. The optimum frequency depends on the Faraday thickness of the Milky Way foreground. With data at 1400 MHz, 1600 MHz, and 2700 MHz, $\mathrm{RM_{IGMF}} \sim 10\ \mathrm{rad\ m^{-2}}$ toward a high Galactic latitude is detectable with less than 10 % error, if we choose the center frequency of the lowest band around 600 MHz – 750 MHz with a 40 MHz bandwidth. These results are obtained for a wide brightness range of the background including FRBs.

Cosmic magnetism is one of the key sciences of the Square Kilometre Array (SKA). Thanks to wider frequency coverage in the SKA era, Faraday tomography will be applicable for a wide range of radio sources. Although SKA-MID antennas will be constructed in radio-quiet districts in South Africa, economic growth in South Africa would impact on radio frequency environment at the site in future. This work clarified which frequencies are essential to explore the IGMF. The results can be applicable to any radio telescopes.

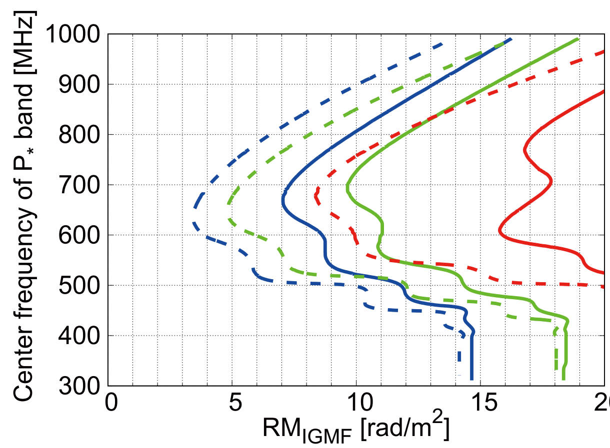

Figure 1: Error profiles between the input $\mathrm{RM_{IGMF}}$ and the chosen center frequency of the lowest band (P_*). Results with data at 1400 MHz, 1600 MHz, and 2700 MHz are shown. The case of the Milky Way thickness of $4\ \mathrm{rad\ m^{-2}}$ and the background brightness of 100 with respect to the foreground are shown. The blue, green, and red lines show the contours on which $\mathrm{RM_{IGMF}}$ is determined with statistical errors of 30 %, 20 %, and 10 %, respectively. The solid and dashed lines are the results with 20 MHz and 40 MHz bandwidths of P_* band, respectively.

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Evaluation of the Vertical Scale Height of L Dwarfs in the Galactic Thin Disk

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Brown dwarfs are object with mass intermediate between stars and planets. Since they do not sustain hydrogen fusion in their cores, they are so fainter than stars. Their effective temperatures are 2200 – 250 K and they are classified under the spectral types of L, T, and Y. Although about 1300 brown dwarfs were discovered so far, their number in our galaxy is comparable to the number of stars (~ 200 billion) [1].

The statistical study on the brown dwarf population has become possible by the advent of the large-area digital surveys. However, the determination of the spatial distribution of brown dwarfs in the context of the Galactic structure is not easy because of their faintness. The previous ground-based surveys are not deep enough to detect brown dwarfs as far as 300 pc, which is roughly the scale height of low mass stars. Only data that reach beyond 300 pc, are obtained by the HST, whose pencil beam surveys have picked up rather small numbers of brown dwarfs, but have given estimates of the vertical scale height, which range from 290 to 400 pc [2,3,4]. The Hyper Suprime-Cam Subaru Strategic Program (HSC-SSP) survey is capable of detecting a large number of new brown dwarfs because of a greater limiting distance and a larger volume for a given spectral type compared with previous surveys.

We have analyzed data release 1 (DR1) of the HSC-SSP data aiming at determining the vertical scale height of L dwarfs in the Galactic thin disk, assuming an exponential disk model. Using the DR1 of the HSC-SSP covering about 130 square degrees at high galactic latitudes, we have obtained L dwarf counts based on the selection criteria on colors, limiting magnitude and PSF morphology using i, z, and y bands. 3665 L dwarfs brighter than $z=24$ have been detected by these criteria. The surface number counts obtained differentially in z magnitude are compared with predictions of an exponential disk model to estimate the thin-disk scale height in the vicinity of the Sun. In the exponential disk model, we first fix the local luminosity function (LLF) to the mean LLF of Cruz et al. (2007) [5] and derive the best fit scale height of 260 pc. However this fit appears to be poor. We then allow the LLF to vary along with the scale height. We use the number densities and their standard deviations of seven magnitude bins of the LLF of Cruz et al. as a starting point of searching for the optimum exponential disk model using a Monte Carlo technique. The best-fit model is found for the vertical scale height of 380 pc. However the χ^2 minimum is rather broad and the 90 % confidence interval is between 320 and 520 pc. We investigate another model by varying the scale height and the density of the brightest magnitude bin, while other magnitude bins are fixed to the mean LLF of Cruz et al.. We find an equally good fit with the two free parameters and the best-fit scale height is again 380 pc, but the 90 % confidence interval is between 340 and 420 pc (Figure 1). The model with the scale height of 380 pc is in principle agreement with the observation (Figure 2). This value of 380 pc appears to be larger than that for M dwarfs (300 pc). This result is qualitatively in accord with the kinematic results by Burgasser et al. [6], in which the velocities of nearby L dwarfs are faster than those of M dwarfs.

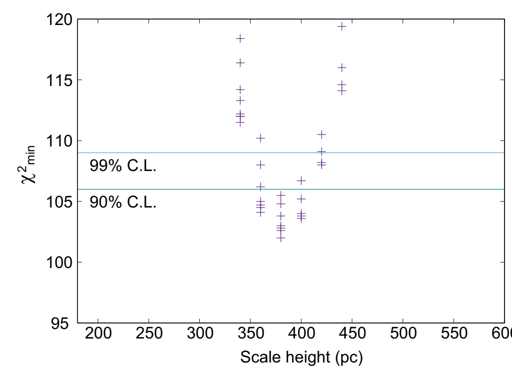

Figure 1: The minimum χ^2 is found at $h=380$ pc. The 90 % and 99 % confidence levels are shown as the green and blue horizontal lines, respectively.

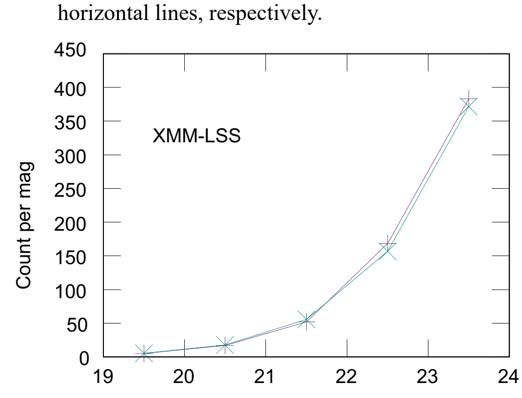

Figure 2: Comparison of observed counts in XMM-LSS (violet) and model predictions (green) that the scale height is 380 pc. The model predictions correspond reasonably well with the observed counts.

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Correction of Near-infrared High-resolution Spectra for Telluric Absorption at 0.90–1.35 μm

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MIZUMOTO, Misaki[2], ARAI, Akira[1], OTSUBO, Shogo[1], TAKENAKA, Keiichi[1], WATASE, Ayaka[1],
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Ground-based near-infrared spectroscopy always suffers from the absorption features on the Earth's atmosphere. Correction for those telluric absorption lines are quite important especially in high-resolution spectroscopy. A traditional method to remove telluric absorption lines is to observe a **"**telluric standard star**"**. For example, an A-type star is often used as a telluric standard star in low-resolution spectroscopy because of its featureless spectrum. In high-resolution spectroscopy, however, a lot of weak metal lines appear on an observed spectrum (e.g., >100 metal lines have been confirmed at 0.90–1.35 μm from a spectrum obtained with the WINERED spectrograph [1]) and distort the real shape of the target spectrum when directly used in spectral division. Because these metal lines are weak and contaminated by telluric absorption lines, to identify and remove them is not a simple task.

Using a synthetic telluric spectrum created by the code `molecfit` [2] as a reference, we have succeeded to remove the weak metal lines from the observed spectrum of an A-type star and obtained a high-quality empirical telluric spectrum. Figure 1 compares the results of telluric correction performed by a model method (`molecfit`) and our empirical method. It is worth noting that the model method achieves a good performance in telluric correction, but the accuracy drops where telluric absorption lines are strong and seriously blended. Our empirical method achieves a quite good performance even at those regions.

We have also checked how the difference in airmass and time between a target and a telluric standard star affect the accuracy of our empirical method. The result is shown in Figure 2. In addition to a naturally expected result that the accuracy of correction increases when the differences in airmass and time decrease, a result that the time variability of water vapor is larger than that of molecular oxygen is quantitatively confirmed. Given that water vapor is the main absorber at 0.90–1.35 μm, minimizing the difference in time between a target and a telluric standard star is especially important for near-infrared spectroscopy.

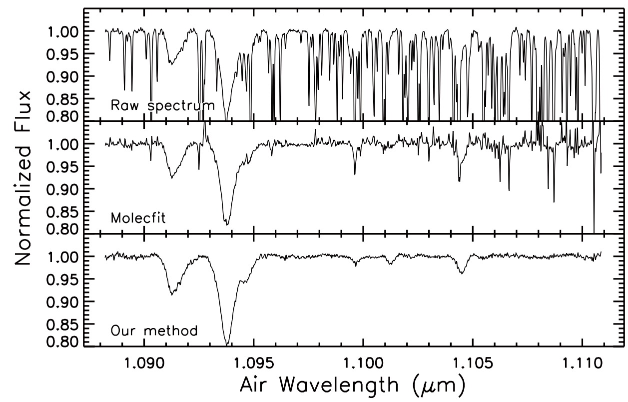

Figure 1: An example of telluric correction for an O-type star at the wavelength region suffered seriously from telluric absorption. From the top, the observed spectrum obtained with WINERED, the same spectrum corrected by `molecfit` for telluric absorption, and that by our empirical method [3].

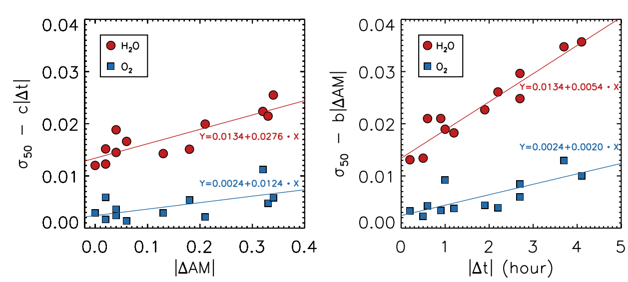

Figure 2: Dependence of the accuracy of telluric correction on the difference in airmass (left) and time (right). The vertical axis indicates the accuracy (the smaller value, the better accuracy). Circles and boxes indicate the results for pixels suffered from H_2O and O_2 absorption, respectively. The dependence on time of H_2O is clearly stronger than that of O_2 [3].

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ALMA Reveals a Misaligned Inner Gas Disk inside the Large Cavity of a Transitional Disk

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Pairs of azimuthal intensity decrements at near symmetric locations have been seen in a number of protoplanetary disks. They are most commonly interpreted as the two shadows cast by a highly misaligned inner disk. Direct evidence of such an inner disk, however, remain largely illusive, except in rare cases. In 2012, a pair of such shadows were discovered in scattered light observations of the near face-on disk around 2MASS J16042165-2130284, a transitional object with a cavity ~60 AU in radius [1]. The star itself is a **"dipper"**, with quasi-periodic dimming events on its light curve, commonly hypothesized as caused by extinctions by transiting dusty structures in the inner disk. Here, we report the detection of a gas disk inside the cavity using ALMA observations with ~0″.2 angular resolution [2]. A twisted butterfly pattern is found in the moment 1 map of CO (3–2) emission line towards the center, which is the key signature of a high misalignment between the inner and outer disks. In addition, the counterparts of the shadows are seen in both dust continuum emission and gas emission maps, consistent with these regions being cooler than their surroundings. Our findings strongly support the hypothesized misaligned-inner-disk origin of the shadows in the J1604-2130 disk. Finally, the inclination of inner disk would be close to −45° in contrast with 45°; it is possible that its internal asymmetric structures cause the variations on the light curve of the host star.

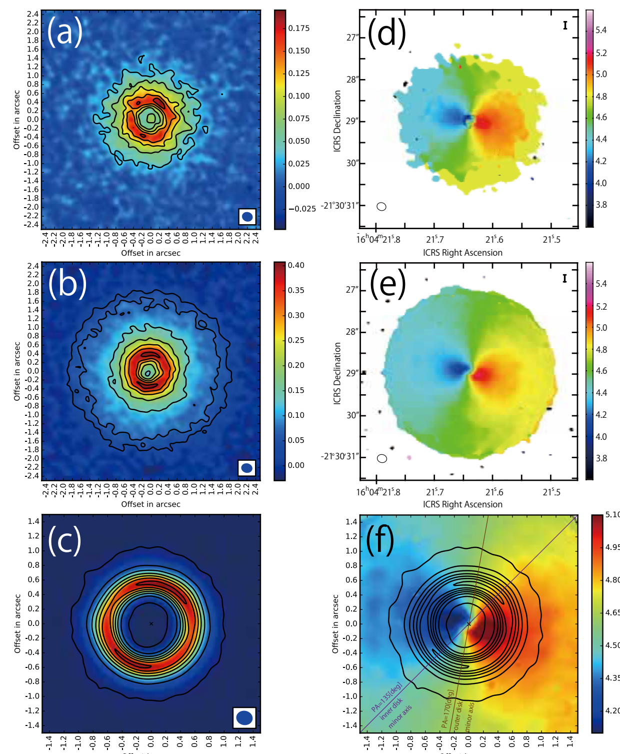

Figure 1: ALMA images of J1604-2130. An ellipse at the bottom right corner for (a), (b), (c), and bottom left corner for (d), (e) denotes the ALMA synthesized beam. The unit of the color bar for (a), (b) and (d), (e), (f) is [Jy/beam.km/s] and [km/s], respectively. (a) HCO^+ (4–3) moment 0 map. Contour levels are (5, 10, 15, 20, 25)×rms. (b) CO (3–2) moment 0 map. Contour levels are (5, 10, 20, 30, 40, 50, 60)×rms. (c) Color map of continuum emission overlaid with and contours at (5, 50, 100, 150, 200, 250, 300)×rms. (d) HCO^+ (4–3) moment 1 map. (e) CO (3–2) moment 1 map. (f) CO moment 1 map is shown in the color map. Continuum in black contours at (5, 50, 100, 150, 200, 250, 300)×rms is overlaid. Purple color line denotes the position angle 135° of inner disk minor axis. Brown color line denotes the position angle 170° of outer disk minor axis.The black cross gives the stellar position.

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Systematic Investigation of the Fallback Accretion-powered Model for Hydrogen-poor Superluminous Supernovae

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Superluminous supernovae are extremely bright supernovae that are started to discover about 10 years ago. They are more than 10 times brighter than canonical supernovae. However, it is still not understood why superluminous supernovae can have such a large luminosity. Especially, the origin of superluminous supernovae without hydrogen signatures has been mystery. One way to explain the huge luminosity is to form an accretion disk around a black hole during a massive star explosion. The accretion disk can result in an outflow that works as a central energy source. This way has been suggested for a while but no attempts have been made to systematically investigate the required accretion parameters. In this study, we systematically investigated the required fallback accretion parameters to explain superluminous supernovae by using the light curve fitting code MOSFiT for the first time [1].

Figure 1 shows an example of the result of light curve fitting. We find that the light curves of superluminous supernovae can be well reproduced by the fallback accretion power model. However, the required mass to accrete to reproduce superluminous supernovae turned out to be too massive. Figure 2 shows the ejecta mass (horizontal axis) and the required central energy (right vertical axis) to put at the center to reproduce superluminous supernovae. All the mass accreted to the black hole does not necessarity converted to the central energy input. It is normally assumed that about 0.1 per cent of the accreted energy is transfered to the ejecta as central energy input and makes light curves bright. The required accretion mass in which this efficiency is taken into account is shown in the right vertical axis of Figure 2. It is found that more than 10 solar masses needs to be accreted to explain superluminous supernovae and we concluded that it is often difficult to explain superluminous supernovae with a fallback accretion power model.

However, we can also find some superluminous supernovae that only require several solar masses of accretion to explain them (red in Figure 2). Therefore, it is possible that there exist some superluminous supernovae powered by the fallback accretion. In such superluminous supernovae, the Fe group elements should be deficit because of the large accretion and we may be able to distinguish them by observing the late-phase spectra to constrain the amount of Fe group elements.

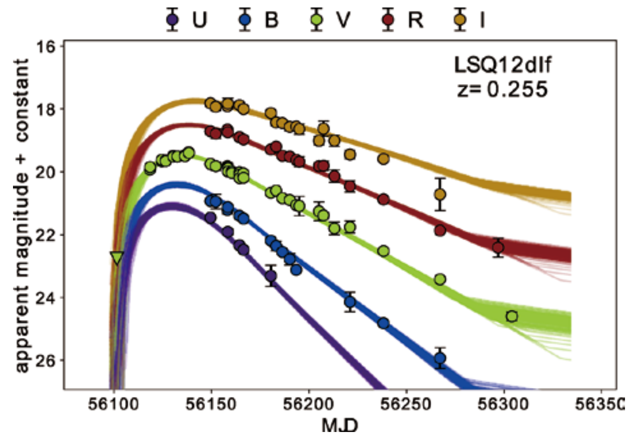

Figure 1: An example of a result of light curve fitting to a superluminous supernova bassed on the fallback accretion powered model [1].

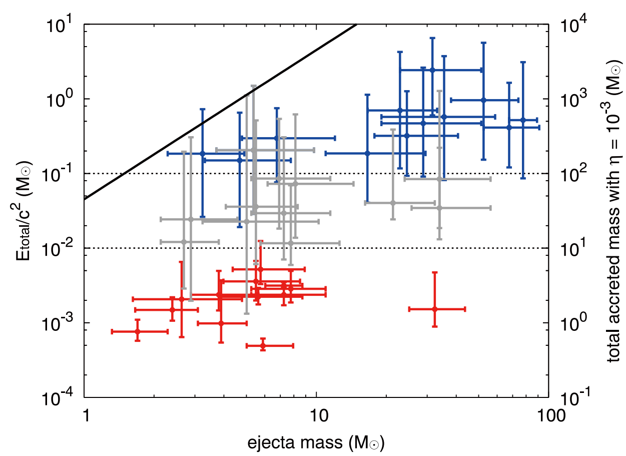

Figure 2: Required ejecta mass and accretion mass estimated for superluminous supernovae [1].

Reference

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Amino Acid Chiral Selection Via Weak Interactions in Stellar Environments: Implications for the Origin of Life

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The formation of biomolecular homochirality currently remains one of the most important, longstanding problems in science today [1].

Magnetochiral phenomena may be responsible for the selection of chiral states of biomolecules in meteoric environments. A model was developed [2] as a possible mode of magnetochiral selection of amino acids by way of the weak interaction in strong magnetic fields. This model was shown to produce an enantiomeric excess (ee) of ~1 % for isovaline, where the enantiomeric excess is defined as the fractional difference in left-handed and right-handed amino acids in a mixture. Quantum chemistry calculations have been performed to evaluate the effects of weak interactions with the nuclei of amino acids to produce an excess of one chiral state. These were performed for both isolated and aqueous states. In some cases, an enhancement was found for aqueous amino acids.

Meteorites with the formed excess of left-handed amino acids may then be responsible for the biochemistry which seeded life on earth, having undergone autocatalysis within the planetary biosphere. Several mechanisms have been postulated to couple a small enantiomeric excess to homochirality [3].

In the model presented here [4,5], amino acids are produced and constrained in meteoroids. These molecules, in the vicinity of strong magnetic fields and anti-neutrino fluxes - as might occur in the vicinity of the nascent neutron star, a Wolf-Rayet supernova, a cooling neutron star, or a neutron star merger - will undergo preferential destruction of one chiral state over the other, producing an excess of left-handed molecules.

Figure 1 shows the results of calculations in this model for cationic isovaline in one example scenario. This scenario might be the high-field and high flux associated with a neutron star merger. Each line in this figure traces out the amino acid enantiomeric excess for a different neutrino flux relative to the nuclear relaxation rate within the molecule.

While the current project has predicted a possible quantitative model for producing left-handed amino acids in stellar environments, future work is now concentrating on predicting differences in isotopic ratios associated with meteoric amino acids [6]. The model presented here is currently the only model capable of predicting chiral amino acids in meteorites while simultaneously predicting anomalous isotopic ratios within the same meteorites.

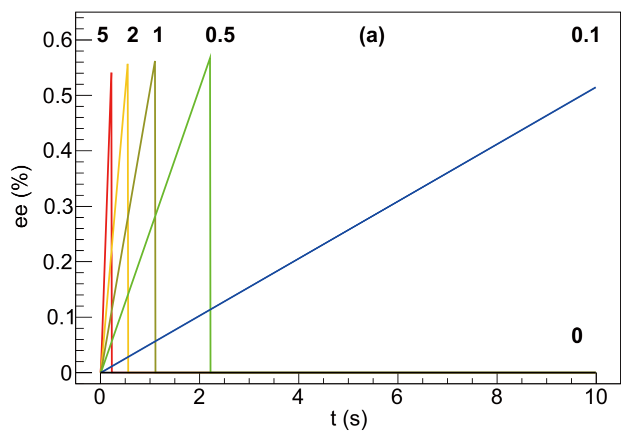

Figure 1: Enantiomeric excess of the isovaline cation vs. exposure time in the vicinity of a high-field, high neutrino flux environment, such as a neutron star merger (for example). Each line corresponds to a different neutrino flux, with zero flux indicated by the black line. The values indicated by each line are the ratio of the neutrino interaction rate to the nuclear magnetic relaxation rate within the molecule.

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Chemical Abundance Analysis of the Capella System

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Capella is a spectroscopic binary, consisting of two G-type giants with similar mass and luminosity. An interesting feature of this system is that, while the slightly more evolved primary (G8 III) is a slowly-rotating normal red-clump giant, the secondary (G0 III) is a chromospherically-active fast rotator showing an overabundance of Li (i.e., Li-rich giant).

Recently, Takeda and Tajitsu ([1]) reported that abundance ratios of specific light elements (e.g., [C/Fe] or [O/Fe]) in Li-rich giants of high activity tend to be anomalously high as compared to normal giants, which they suspected to be nothing but a superficial phenomenon caused by unusual atmospheric structure due to high chromospheric activity. The Capella system is a suitable testbench to verify this hypothesis; that is, if we could detect any apparent difference between the abundances of two stars, it may lend support for this interpretation, since we may postulate that both were originally born with the same chemical composition.

Toward this aim of searching for any apparent disagreement between the abundances of Capella's two components, we carried out a spectroscopic analysis based on the observational data obtained at Gunma Astronomical Observatory to determine the elemental abundances of the primary and the secondary of Capella. The following results were obtained (cf. Figure 1):

— Regarding the heavier elements such as those of the Fe group, the abundances of the primary star turned out somewhat supersolar ([X/H] ~ +0.1–0.2), which is consistent with the expectation because Capella belongs to the Hyades moving group. On the contrary, we found that the [X/H] values of the secondary are appreciably subsolar by several tenths dex (from ~ −0.1 down to ~ −0.5 or even lower).

— However, as to the light elements, such a tendency is not seen. For example, we can state that reasonable abundances of C (from C I 5380) or O (from O I 7771–5) could be obtained for both the primary and the secondary star by our conventional non-LTE analysis.

— Taking these observational facts into consideration, we think we could trace down the reason why anomalously large abundance ratios (such as [C/Fe] or [O/Fe]) were observed in [1] for Li-rich giants of higher rotation/activity. That is, it was not the increase of the numerator (C or O) but the decrease of denominator (Fe) that mainly caused the apparently peculiar abundance ratios. In other words, Fe abundances of active Li-rich giants would have been superficially underestimated.

— We note that lines yielding appreciable underabundances for the secondary star are mostly of minor-population species (e.g., neutral species such as Na I, Fe I, etc.) with comparatively low ionization potential. Accordingly, we suspect that the overionization caused by excessive UV radiation radiated from the active chromosphere is responsible for line weakening, eventually resulting in an apparent underabundance.

— To conclude, the conventional model atmosphere analysis presumably fails to correctly determine the abundances for rotating giants of higher activity. Proper treatment of the chromospheric effect would be required for deriving the photospheric abundances of such stars.

See [2] for more details of this study.

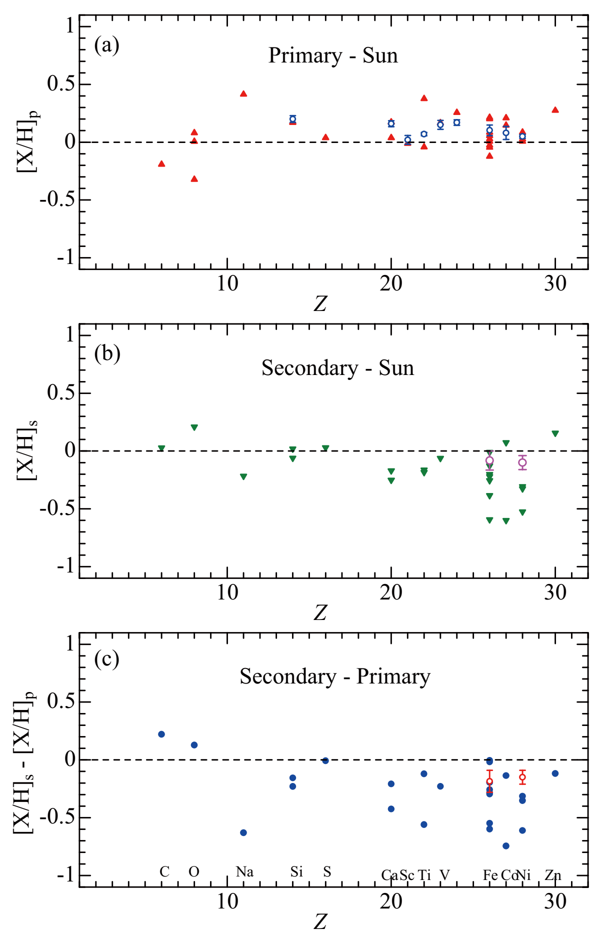

Figure 1: Differential abundances of various elements plotted against the atomic number (Z).

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Photospheric Carbon, Nitrogen, and Oxygen Abundances of A-type Main-sequence Stars

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Despite that many studies have been published regarding the photospheric chemical abundances of normal and chemically-peculiar (CP) A-type stars on the upper main sequence, only a limited number of spectroscopic investigations have been carried out so far concerning CNO (light elements of astrophysical importance), which are known to be generally deficient in CP stars in contrast to many other heavier elements tending to be overabundant.

Motivated by this situation, we conducted a comprehensive spectroscopic study on the abundances of C, N, and O for 100 main-sequence stars of mostly A-type (late B through early F at 11000 K > $T_{\rm eff}$ > 7000 K; cf. Figure 1) comprising normal stars as well as non-magnetic CP stars (Am and HgMn stars) in the projected rotational velocity range of 0 km s^{-1} < $v_{\rm e} \sin i$ < 100 km s^{-1}, based on the high-dispersion spectra obtained at Okayama Astrophysical Observatory (new observations for 29 targets) and Bohyunsan Astronomical Observatory.

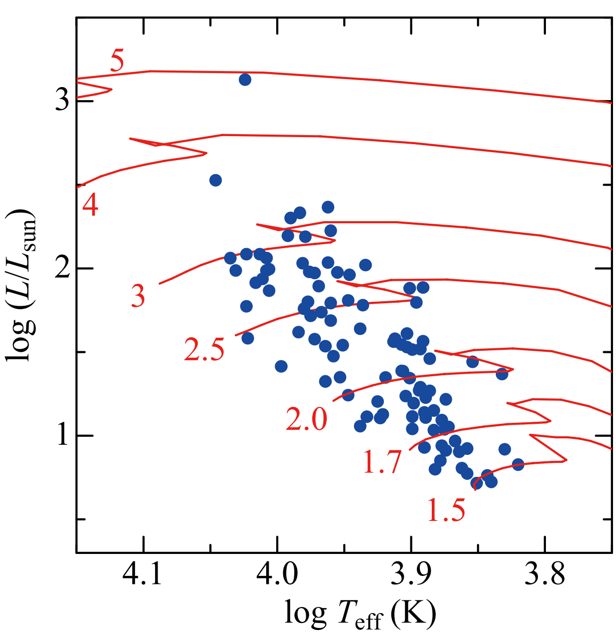

Figure 1: Our 100 program stars plotted on the L vs. $T_{\rm eff}$ diagram, where theoretical evolutionary tracks calculated for various masses are also depicted for comparison.

Our aim was to investigate the abundance anomalies of CNO from qualitative as well as quantitative point of view, especially in terms of their mutual correlations or relation with Fe, dependence upon stellar parameters ($T_{\rm eff}$, $v_{\rm e} \sin i$), and difference between normal and CP stars.

Regarding the method of analysis, we applied the spectrum-fitting technique to C I 5380, N I 7486, and O I 6156–8 lines and evaluated their equivalent widths, from which the non-LTE abundances, non-LTE corrections, and sensitivities to perturbations in atmospheric parameters were derived.

The results of our analysis revealed the following observational characteristics regarding the CNO abundances of our sample stars:

— C, N, and O are underabundant for almost all cases (irrespective of whether classified as peculiar or normal, though with a tendency of larger anomaly for the former case) typically in the range of −1 < [C,N,O/H] < 0), in contrast to [Fe/H] distributing around [Fe/H] ~ 0.

— Moreover, distinctly large deficiencies as much as ~ 2 dex are shown for C or N by some CP stars ([C/H] for late Am stars or [N/H] for HgMn stars of late B-type).

— The inequality relation |[C/H]| > |[N/H]| > |[O/H}]| appears to roughly hold regarding the typical extents of anomaly (deficiency), which is consistent with the prediction from the recent model of atomic diffusion.

— We confirmed that [C/H], [N/H], and [O/H] are anti-correlated with [Fe/H], which means that the sense of chemical anomaly acts oppositely for CNO and heavier metals.

— The extent of CNO abundance peculiarity (deficiency) tends to be larger for lower $v_{\rm e} \sin i$, which becomes especially manifest when we pay attention to 16 Hyades stars of the same primordial composition. This may be in favor of the atomic diffusion theory for the cause of chemical anomaly, which would not work in the existence of efficient mixing by rapid rotation.

— In addition, the dispersions of [C/H], [N/H], and [O/H] tend to grow (with the lower envelope of distribution shifting toward lower values) with a decrease in $T_{\rm eff}$, which is consistent with recent diffusion model predicting that the extent of CNO deficiency increases with decreasing $T_{\rm eff}$.

See [1] for more details of this study.

Reference

[1] Takeda, Y., et al.: 2018, *PASJ*, **70**, 91.

Possibility of Chromospheric Back-Radiation Influencing the Lithium Line Formation in Spite Plateau Stars

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Regarding the so-called "cosmological Li problem", which is the discrepancy between the lithium abundances of metal-poor turn-off dwarfs being nearly constant irrespective of metallicity (Spite plateau) and the primordial BBN value almost established from the CMB observation by *WMAP*, various explanations have been proposed so far, many of which suppose that the observed stellar Li abundance reflects the real composition in the atmosphere and would have been changed (i.e., decreased) from the initial value by some physical mechanisms.

This study has cast doubt on this general belief, suspecting that the problem might be on the technical side of abundance determination; i.e., the surface Li abundances of these stars might have been underestimated. This suspicion was motivated by the observational fact that hot chromosphere exists in metal-poor dwarfs as evidenced by the detection of He I 10830 line with its strength being almost constant irrespective of the metallicity (see [1]). If so, chromospheric UV radiation might induce significant overionization of neutral lithium and considerable weakening of the Li I 6708 line, which could lead to an underestimation of the Li abundance if derived by the conventional method of analysis. The aim of this investigation was to examine this possibility.

As to the modeling of chromospheric radiation, thermal radiation emitted by a uniform slab (characterized by optical thickness τ_0 ($\ll 1$) and temperature T_0) was simply assumed. Incorporating this incident radiation in the surface boundary condition, non-LTE calculations for neutral Li atom were carried out with different combinations of (τ_0, T_0). Further, based on the resulting non-LTE departure coefficients, it was investigated how the equivalent widths and the corresponding abundances are affected by these parameters.

The results turned out rather satisfactory. If parameters are adequately chosen, the equivalent width of Li I 6708 can be considerably reduced by a factor of ~2–3 due to the overionization effect caused by an enhanced UV radiation irradiated from the chromosphere, which eventually leads to an appreciable decrease of the apparent abundance by ~0.3–0.5 dex, being consistent with the discrepancy in question. Moreover, the observed slight metallicity-dependent slope of the plateau (i.e., Li abundance tends to slightly decrease with a decrease in [Fe/H]) can also be reproduced, which is because the overionization stemming from chromospheric irradiation penetrates deeper with an increase of atmospheric transparency (resulting from decreased metallicity). Theoretical predictions for the representative models are compared with the observed data in Figure 1, where we can see a reasonable consistency.

Accordingly, superficial underestimation of Li abundances, which results from an appreciable weakening of Li I 6708 line caused by considerable overionization due to external radiation from the chromosphere, may be regarded as a possible interpretation of the cosmological Li problem and worth further investigation. However, since this calculation is based on a simple parameterized model, successful reproduction of the observed trend established by arbitrarily changing the parameters does not mean that this concept is justified. Therefore, in order to check the validity of this hypothesis, it is important to observationally confirm the existence of UV excess in these Spite plateau stars, which should be detected if such significant overionization is actually operative.

See [2] for more details of this study.

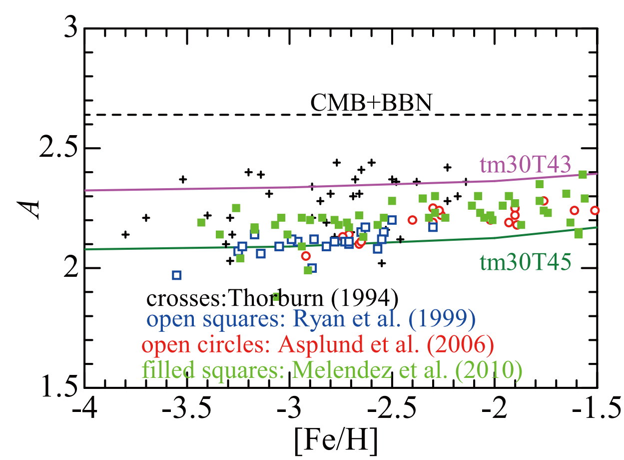

Figure 1: Comparison of the predicted Li abundance vs. metallicity relations (sold lines) for (log τ_0, log T_0) = (−3.0, 4.3) and (−3.0, 4.5) (labeled as tm30T43 and tm30T45) with the observed data (symbols) of Spite plateau stars taken from various previous studies. The horizontal dashed line indicates the primordial Li abundance (predicted from the recent cosmology) of 2.64.

References

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Performance Model Simulation of Ganymede Laser Altimeter (GALA) for the JUICE Mission

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GALA (GAnymede Laser Altimeter) is one of the payload instruments of the JUICE (JUpiter ICy moons Explorer) project to be launched in 2022 to the Jovian icy moons Ganymede, Europa, and Callisto. GALA is developed through an international collaboration between Germany, Japan, Switzerland, and Spain.

With the GALA performance model, we have sought to create the interface conditions that satisfy the science requirements on the probability of false detection (PFD) and the range accuracy [1].

The science requirements on GALA performance can be summarized as involving the following four criteria: [A] for Europa fly-by, PFD is less than 0.2 from an altitude of 1300 km or lower, [B] under the worst observation condition for albedo and surface slope of GCO500 (Ganymede Circular Orbit whose height is 500 km), the accuracy of ranging is less than 10 m and PFD is less than 0.2, [C] under the nominal observation condition of GCO500, the accuracy of ranging is less than 2 m and PFD is less than 0.1, and [D] under the best observation condition of GCO500, the accuracy of ranging is less than 1 m and PFD is less than 0.1. The minimum SNR (R_SNR) which satisfies each requirement from [A] to [D] is summarized in Table 1 through the simulation of output signal of the GALA matched filter (Figure 1), where the range accuracy for [A] is assumed to be '< 10 m'. R_SNR should be less than C_SNR which is evaluated by our GALA performance model for each criterion and summarized in Table 1.

For the assessment, however, we had used literature data as the characteristics of the laser detector of GALA, avalanche photodiode (APD), which should be degraded due to the severe radiation environment around Jupiter. Then we carried out a more realistic model simulation using GALA performance model with these degradation effects of APD. Characteristics of APD, such as gain, quantum efficiency, excess noise index, surface dark current, and bulk dark current, were re-evaluated through radiation tests using the data of dark and photo current of the APD irradiated with 2-MeV-electron and 50-MeV-proton beams, which are the radiation conditions assumed for JUICE-GALA around Jupiter.

These degraded characteristics of APD by radiation were introduced to our performance model of GALA. As a result, our performance simulation of GALA showed again that the science requirements are satisfied even after considering the degraded characteristics of APD (R_SNR < C_SNR). The remaining matter is the effect of noise or digitization in the Analog Electronics Module (AEM), which must be considered for the final specifications of GALA.

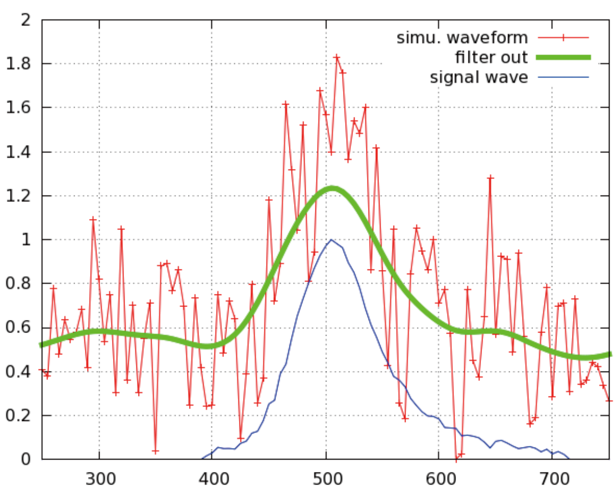

Figure 1: The blue line represents reflected laser signal obtained during HAYABUSA-2 LIDAR ground experiment. The peak value is scaled to 1 at 505 nsec. The red line is the input signal to GALA matched filter shifted vertically from the blue line. The green line is the output of GALA matched filter. The time resolution is 5 nsec.

Table 1: Comparison of C_SNR and R_SNR.

criterion	[A]	[B]	[C]	[D]
C_SNR	23.2	28.8	202	357
R_SNR	22	22	43	122

Reference

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A New Concept for Quasi-Planar Integration of SIS Heterodyne Mixer Array and the Concept-proof Experiment

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Spectral lines measured by millimeter and submillimeter(mm/sub-mm) astronomical heterodyne receivers contain rich information about the chemical composition, the dynamics and red-shift of sources, which are missing in the broadband imaging done by mm/sub-mm cameras. However, the pixel counts of heterodyne arrays, especially those based on Superconductor-Insulator-Superconductor (SIS) mixers, is much less than that of cameras. The SIS array receivers that have advanced features such as sideband separation (2SB) and dual-polarization have not outnumbered handful pixels. One of the major difficulties in building a large format heterodyne array lies in the fact that a waveguide local-oscillator (LO) distribution network routed in a 3D space can not be manufactured with conventional split-block machining. In addition, in order to conduct dual-polarization observation, one has to rely on non-planar polarization-separation components, like wire-grids or waveguide orthomode transducers (OMTs), which are inherently difficult to be incorporated into a compact array.

We push forward the planar-integration idea to enable a quasi-planar heterodyne array by introducing on-chip membrane-based LO and signal waveguide probes, which greatly facilitate the LO distribution. This approach breaks the structural entanglement between the mixer circuits and the LO distribution network, so that the LO distribution network and the SIS mixers can be respectively accommodated in physically independent layers. As a consequence, multiple pixels can be put on a single chip (called integrated circuit or IC hereafter), like in direct-detection cameras. To prove the concept, we designed and fabricated a single-pixel prototype with a dual-polarization and balanced mixing scheme, which is assumed to be readily expansible to many pixels. The experimental results show expected performance, which as comparable to the state-of-the-art performance that a traditional SIS mixer has achieved. The concept and the concept-proof experiment are concluded in [1].

The fabrication of the ICs is different from the conventional SIS mixer fabrication process in several aspects because of new features and components being introduced and incorporated. In particular, very flat silicon membranes that mechanically support the planar OMT and the waveguide probes for local oscillator coupling were formed with a combination of dry and wet etching methods to completely remove the handle layer and the buried oxide layer of the silicon on insulator substrates. We also applied an anodization passivation of the surface of the ground plane and a via-hole etching process with an i-line stepper in the formation of low-leakage SIS junctions. The SIS junctions of moderately good quality have been fabricated with an average quality factor as high as 18, which indicate the integrity of the junction definition with the complex fabrication of ICs. The fabrication process is concluded in [2].

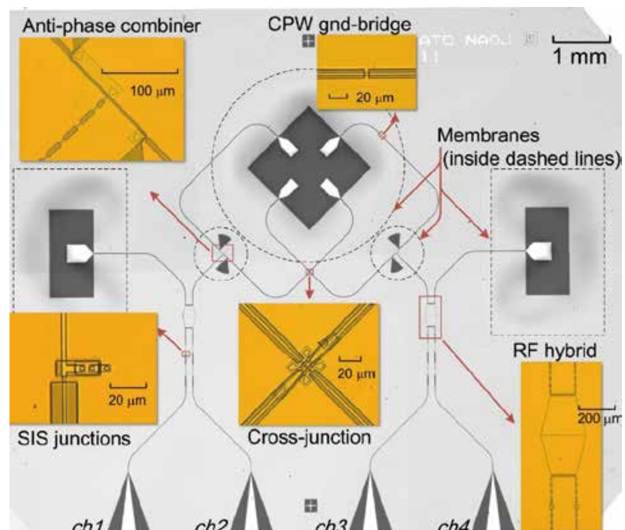

Figure 1: The image of the front side of the mixer chip with a size of 13 mm × 10 mm × 0.4 mm. Critical parts are enlarged in the insets to show fine structures.

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Axion Production from Landau Quantization in the Strong Magnetic Field of Magnetars [1]

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The axion is a hypothetical pseudoscalar particle. It is a pseudo-Goldstone boson associated with the Peccei-Quinn symmetry [2] and has been introduced as a solution to the strong CP-violation problem [3].

Axions are candidates for the cold dark matter of the universe because they have non-zero mass and their interactions with normal matter should be small. In view of the lack of detections in recent WIMP searches, the study of axion production or detection is well motivated and axions become a compelling candidate for cold dark matter.

In this work we utilize an exact quantum calculation to explore axion emission from electrons and protons in the presence of the strong magnetic field of magnetars.

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

$$\Big[\gamma_\mu \cdot (i\partial^\mu - \zeta e A^\mu - M + U_s - \frac{e\kappa}{4M}\sigma_{\mu\nu}(\partial^\mu A^\nu - \partial^\nu A^\mu)\Big] \psi_a(x) = 0, \quad (1)$$

where κ is the AMM, e is the elementary charge, and $\zeta = \pm 1$ is the sign of the particle charge. U_s is the scalar mean-field. The vectror field plays the role of shifting the single particle energy and does not contribute to the result of the calculation, so that we omit it.

In our model charged particles are protons and electrons. The mean-fields are taken to be zero for electrons, while for protons they are given by the relativistic mean-field theory. The single particle energy is then written as

$$E = \sqrt{p_z^2 + (\sqrt{2eBn + M^{*2}} - se\kappa B/M)^2} \quad (2)$$

with $M^* = M - U_s$, where n is the Landau number, p_z is a z-component of momentum, and $s = \pm 1$ indicates the spin-direction.

We calculate an axion emission from a transitions between the Landau levels by using the following interaction:

$$\mathcal{L}_{int} = -ig_{aff}\tilde{\Psi}_f \gamma^\mu \gamma_5 \Psi_f \phi_a, \quad (3)$$

with ψ and φ being the fermion (proton or electron) and axion fields, respectively. We choose the axion-nucleon and axion-electron couplings to be $g_{aNN} = 6 \times 10^{-12}$ and $g_{aee} = 9 \times 10^{-15}$, respectively.

In Fig. 1 we show the density dependence of the total axion luminosity for $B = 10^{15}$ G. The solid lines show the results at $T = 0.7$ keV, 2 keV and 5 keV from below to above. For comparison, we plot the neutrino luminosities in the MU process (dashed lines), which are independent of the magnetic field strength.

We find that cooling by axion emission is much larger than neutrino cooling by the Urca processes. Consequently, axion emission in the crust may significantly contribute to the cooling of magnetars.

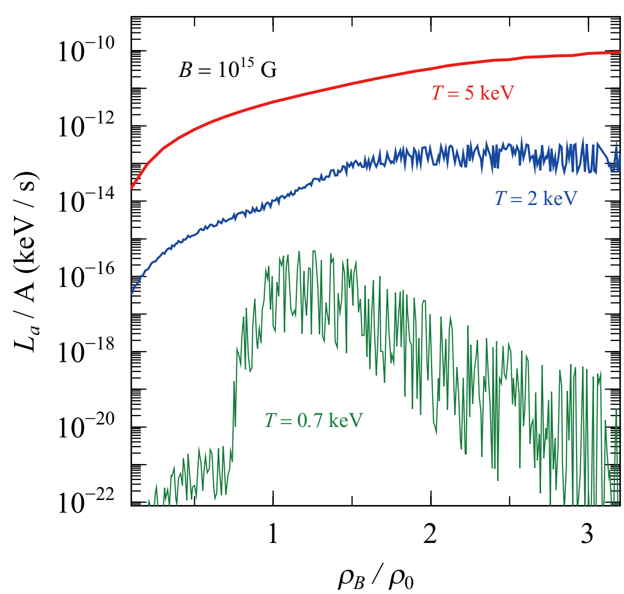

Figure 1: Axion luminosity per nucleon versus baryon density at temperatures $T = 0.7$ keV, $T = 2$ keV and $T = 5$ keV (from bottom to top) for $B = 10^{15}$ G. The dashed the results of the MU processes.

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Identification of Gamma-Ray Vorticies with Compton Scattering [1]

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Photon vortices caring orbital angular momentum (OAM) [2] are one of most interesting topics in various fields of physics. It is expected to create in astronomical systems such as black holes [3].

Gamma-ray bursts (GRBs) are one of the most energetic explosive phenomena in the universe. One of remarkable features for observed rays is a fact that high linear (circular) polarization was observed for some gamma-rays, whcih may be generated by synchrotron radiations from relativistic electrons under strong magnetic fields. Katoh et al. [4] showed that higher harmonic photons radiated from spiral motion electrons under magnetic fields are the photon vortecies. Thses facts imply that the gamma-ray vortex may be generated in the astronomical system with strong magnetic field such as neutron-star surface and GRBs.

Recently it has been planed to generate gamma-ray vortices in the MeV region experimentaly [5]. However, there is a question, how to verify the gamma-ray vortex in actual experiments. In this work we consider the coincidence measurement of photon vortices on rest electron because the angular momentum of the incident gamma-ray vortices should be conserved into the scattered photon-electron system. The differential cross section of the scattered photon measured simultaneously with the scattered electron for the incident photon with wave function of Laguerre Gaussian (LG) is calculated in the framework of relativistic quantum mechanics [1].

Here, we set the coordinate that the photon beam direction is z-direction, and the scattered electron in the zx-plane. When the initial photon is the plane wave, the final photon is also scattered in zx-plane and its energy is fixed. When the initial photon is gamma-vortex, its momentum has y-component, and its energy is not fixed. Here, we define the angle θ_y as the angle between the final photon momentum and zx-plane, and ΔE as the energy difference in the final photon between the vortex wave and the plane wave for the initial photon. In Fig. 1 we show the contour plots of the differential cross sections as functions of θ_y and ΔE when the energy of the initial photon is 0.5 MeV, its z-component of the OAM for is 1 $\hbar$, and the polar angle θ_e for the scattered photon is given by $\cos\theta_e = 0.95$. We see that it has annulus structures which maps the strength distribution of the incident photon with LG wave function The result shows that this method is powerful tools to investigate the angular momentum of the wave function of incident gamma-ray vortices.

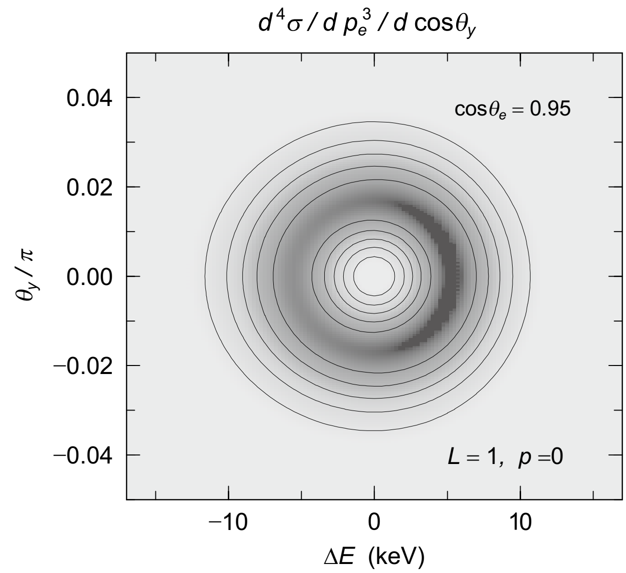

Figure 1: The contour plots of the differential cross-section of Compton scattering at $\cos\theta_e = 0.95$. The horizontal axis shows the energy difference ΔE from that in standard Compton scattering, and the vertical axis shows the polar angle between zx-plane and the scattered photon angle.

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EoS Dependence of the Relic Supernova Neutrino Spectrum

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The Relic Supernova Neutrino (RSN) Spectrum is studied based on a variety of astronomical scenarios, which include different supernova occurance, the cosmic star formation history, and metallicity dependent initial mass function. It reveals the signature of nuclear equation of state (EoS) dependence, which appears robustly in spite of the different scenarios [1].

Two EoS, soft EoS (LS-EoS) and stiff EoS (Shen-EoS), are applied for failed supernovae (fSNe). It has been noticed that fSNe with these EoS produce prominent difference in the neutrino spectrum especially in the high energy tail. Therefore it is expected that the RSN spectrum offers valuable information about EoS of the proto-neutron stars. We estimate the detection rate of the RSN by assuming 10 years run of the Hyper-Kamiokande detector.

Not only the EoS but also many astrophysical aspects influence the RSN spectrum. Types of SNe and their occurence are obvious examples. Recent progress of the numerical simulation provides insight into the SN explosion mechanism and gives the complicated picture about the criteria for successful explosions in terms of their progenitor mass. This aspect is included in this work.

The RSN spectrum also strongly depends upon the cosmological star formation rate (SFR). The observational SFR is mostly estimated by the UV light from galaxies.

A new cosmic SFR is recently proposed considering the star burst galaxies at high redshift, which makes SFR lager than UV-based SFR and is considered in this study.

SFR also depends upon the initial mass function (IMF), which is usually assumed universal. It is, however, possible that IMF varies according to the metallicity. Metal-poor molecular cloud tends to form more massive stellar objects selectively leading to the top-heavy IMF at high redshift. Metalicity dependent IMF is also studied in this work. We investigate RSN spectrum based on many astrophysical scenarios as mentioned above, and they are summarized below and presented in Figure 1.

For fiducial case, a standard SFR by Madau & Dickinson and Salpeter-A IMF are adopted. Non-monotonic SNe/fSNe occurence is used for progenitors in the mass range of 10–40 $M_{\odot}$. The case with another SNe/fSNe occurence, which is motivated by RSG-problem, is labeled as Case A. For Case B, starburst and quiescent star formation phases are considered with the different IMF for each phase. Metalicity-dependent variable IMF, which is also redshift dependent, is used for Case C. Observationally it is suggested that the SFR for starburst galaxies at high redshift is underestimated. This possibility along with metallicity-dependent IMF is considered in Case D. All cases without the neutrino oscillation are presented in Figure 1, which shows clear EoS-dependence of RSN spectrum, especially the location of their peak and tail even when a variety of astrophysical scenarios are considered. Even with the neutrino oscillation, similar results are obtained. Threrefore this could be a valuable tool to get insight about the nuclear EoS.

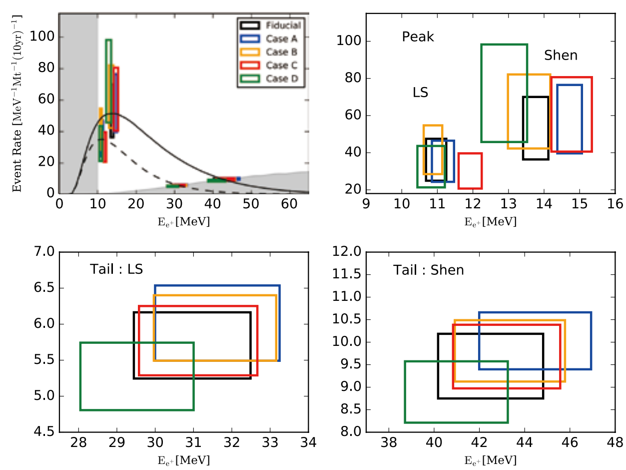

Figure 1: RSN spectrum for different astrophysicsl scenarios. Fiducial RSN spectrum with Shen-EoS and LS-EoS are shown as solid and dashed lines respectively. The error boxes are placed at the peak and tail of the spectrum for each cases.

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Formation of Super-Earths and Their Atmospheres

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Recent exoplanet surveys that include the Kepler project have revealed a significant number of super-Earths. As of May 2019, over 2000 super-Earths have been confirmed, and hence we can discuss their statistical properties. One of the most important properties is the period-ratio distribution of adjacent planets. It is revealed that super-Earths are generally not in mean-motion resonances. However, previous studies of super-Earth formation showed that super-Earths undergo rapid inward orbital migration in a protoplanetary disk. As a result, super-Earths are captured in mean-motion resonance at the final state (e.g., Ogihara et al. 2015), which is inconsistent with observed non-resonant period-ratio distribution.

In previous simulations, a simple power-law distribution is used for the distribution of gas surface density of the protoplanetary disk. However, recent magneto-hydrodynamical simulations showed that the distribution of the protoplanetary disk can be quite complicated due to effects of magnetically driven disk winds (e.g., Suzuki et al. 2016). In this study, we adopt a more realistic disk evolution model that takes into account effects of disk winds, and investigate formation of super-Earths by *N*-body simulations. As a result of simulation, we find that orbital migration can be significantly suppressed in such a disk. Although super-Earths are once captured in mean-motion resonances, they undergo orbital instability after gas depletion, leading to non-resonant configurations [1]. We also find that the observed period-ratio distribution is well reproduced by results of our simulations (Figure 1).

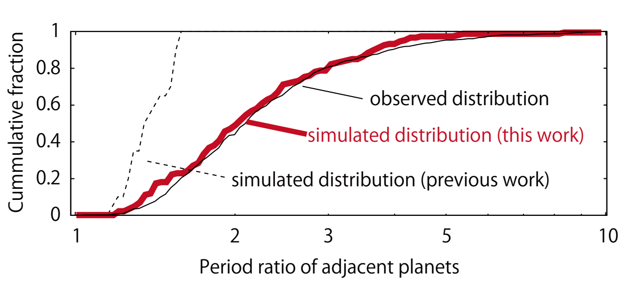

Figure 1: Comparison of period-ratio distributions of adjacent planets. The observed distribution is well reproduced by results of simulations, in which more realistic disk evolution model is used.

As another observed property of super-Earths, the amount of H/He atmosphere is also important. Using theoretical calculation of atmospheric structure, it is estimated that super-Earths typically possess 0.1–10 % of H/He atmospheres. On the other hand, the standard theory of atmospheric evolution suggests that super-Earths should accumulate massive H/He atmospheres from the gas component of the protoplanetary disk. This is inconsistent with the estimated amount of the super-Earth atmosphere (i.e., 0.1–10 wt%).

Regarding this problem, we focus on the fact that there can be a rapid gas flow driven by disk winds in the surface region of the protoplanetary disk. We perform simulations of atmospheric evolution, and find that the rapid gas flow in the disk surface may not contribute to the accretion of atmosphere onto super-Earths. When the atmospheric accretion is limited by this effect, the amount of accreted H/He atmospheres can be regulated to 0.1–10 wt%, which is consistent with observations [2].

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Size Evolution of Giant Ellipticals from Redshift z = 4 Based on the High Resolution Near-infrared Imaging with AO188 on Subaru Telescope

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One of the largest problems of galaxy evolution is the size evolution of galaxies. Hubble space telescope has revealed morphologies of galaxies at high redshift and shows that the typical size of galaxies has become smaller with redshift [1]. Especially, giant ellipticals at $z > 2$ have already been as massive as but a tenth smaller in size than those of giant ellipticals today [2]. Though it is an interesting topic, it is hard to observe the size evolution of giant elliptical galaxies at $z > 3$; Deep and wide multi-wavelength observations are required to discover progenitors of giant ellipticals and Hubble cannot observe their rest-frame optical light shifted at > 1.7 μm.

In this study [3], first, we select the candidate massive galaxies stopped star formation (quiescent) at $z \sim 4$ from the Subaru/XMM-Newton Deep Survey (SXDS) based on the photometric redshifts obtained by spectral energy distribution (SED) fitting. Then we conduct the high resolution *K*-band imaging for the five targets by using AO188 and Infrared Camera and Spectrograph (IRCS) on Subaru telescope to show the morphologies. Fig. 1 shows the observed images in *K*-band, models, and observed images subtracted with models. They are fitted by models with an effective radius $r_e \sim 0.5$ kpc on average. Our result confirms that the strong size evolution of giant ellipticals continues at up to $z = 4$. It is the first time to show the size evolution of giant ellipticals at up to $z = 4$ properly in rest-frame optical.

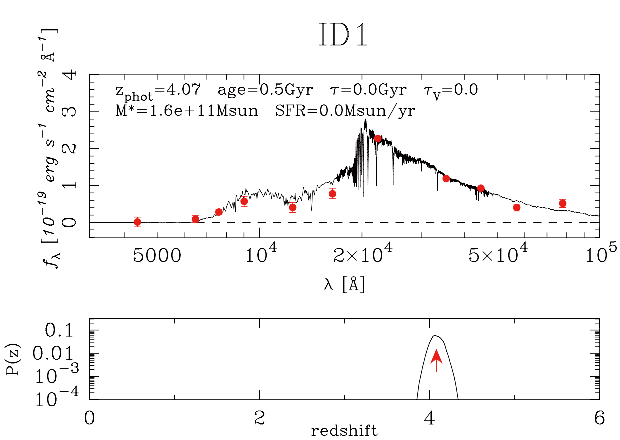

Figure 1: The SED fit and redshift probability distribution of one of our targets.

Fig. 2 shows the size-stellar mass evolution of the most massive giant ellipticals today drawn assuming that the most massive quiescent galaxies at each redshift are the progenitors. It suggests that minor mergers plausibly drive the size evolution of the most massive ellipticals.

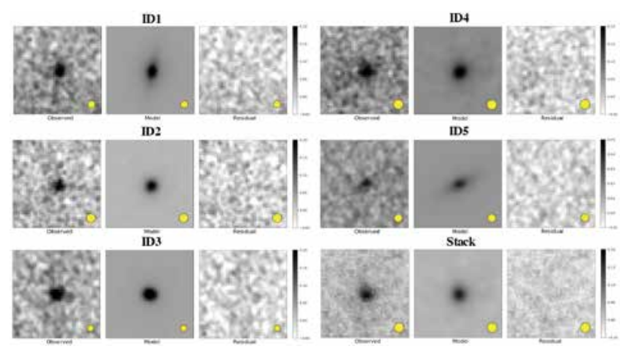

Figure 2: The observed *K*-band, best-fit model and observed - model images of the five objects and their stacked image. The model fit is performed with GALFIT [4].

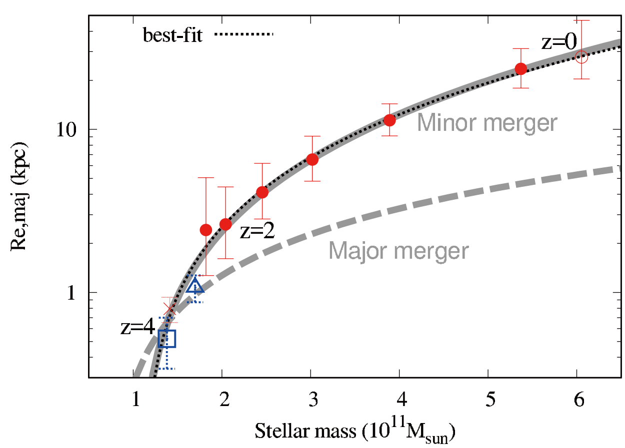

Figure 3: The red and blue points show the size and stellar mass evolution history of the most massive galaxies obtained based on this study at $z = 4$ and previous studies. The dotted line shows their best-fit model. The gray solid and dashed lines show the toy models for size evolution in case of minor mergers and major mergers.

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Multi-wavelength Light Curve Modeling of the Low-luminosity Gamma-ray Burst 171205A

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Gamma-ray bursts are instantaneous gamma-ray point sources appearing in the sky. GRBs with the duration longer than 2 sec are classified into long GRBs and are related with the gravitational collapse of massive stars. GRBs are considered as emission from highly relativistic jets. The afterglow following the prompt gamma-ray emission is indeed well explained by synchrotron emission from non-thermal electrons accelerated in the blast wave driven by a relativistic jet. Among long GRBs, busts with their gamma-ray luminosity much lower than those of normal GRBs are called low-luminosity GRBs (llGRBs). Because of their dim prompt gamma-ray emission, only nearby events have been detected, which makes it difficult to investigate their origin. We consider that llGRBs can be explained by energetic supernova ejecta interacting with their immediate ambient gas and have been developing an emission model for llGRBs [1]. In this study, we have applied our theoretical light curve model to the newly discovered llGRB 171205A [2].

The theoretical light curve depends on the ejecta kinetic energy $E_{\rm rel}$, the CSM density parameter $A_\star$ ($A_\star = 1$ corresponds to the wind of normal Wolf-Rayet stars), and the density slope n of the relativistic ejecta. In Figure 1, we plot several theoretical light curves with different parameter sets, which are compared with the gamma-ray light curve of GRB 171205A. We found that relativistic ejecta expanding with the kinetic energy of $E_{\rm rel} = 5 \times 10^{50}$ erg and the CSM mass of $10^{-4}\,M_\odot$ most successfully explain the observed gamma-ray emission. In Figure 2, we show the radiated energy $E_{\rm rad}$ versus duration $t_{\rm burst}$ diagram and the region occupied by theoretical models, which is compared with Swift GRBs. The theoretical model successfully explains the population of llGRBs in this diagram.

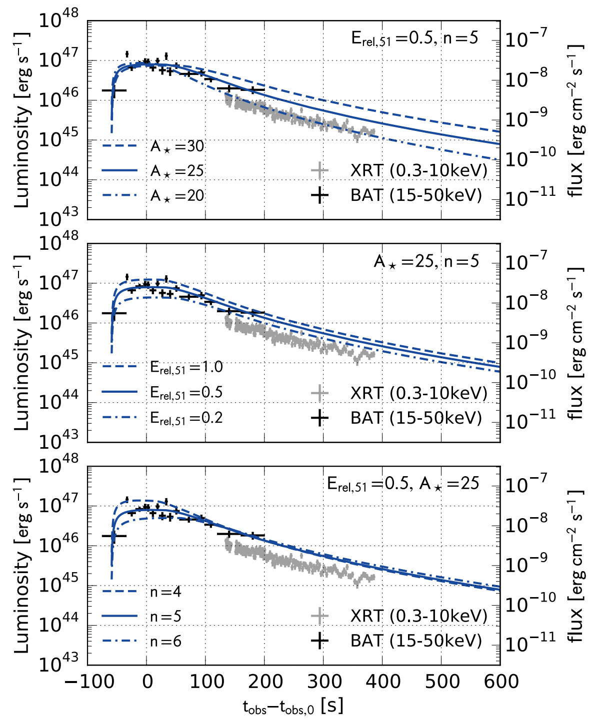

Figure 1: Theoretical light curve model for the gamma-ray and X-ray emission. In each panel, model light curves with different sets of the parameters, $A_\star E_{\rm rel}$, and n are plotted.

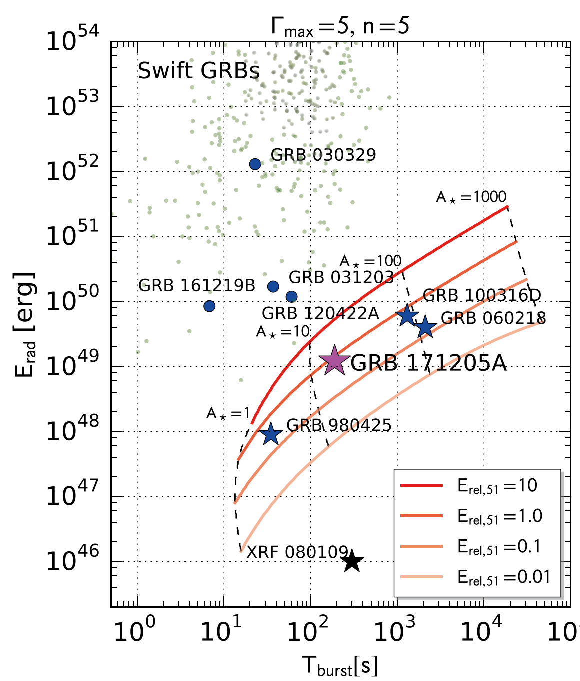

Figure 2: Gamma-ray radiated energy vs duration diagram.

References

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Observations of Photospheric Magnetic Structure below a Dark Filament Using the Hinode Spectro-Polarimeter

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The structure of the photospheric vector magnetic field below a dark filament on the Sun is studied using the observations of the Spectro-Polarimeter attached to the Solar Optical Telescope onboard *Hinode* [1]. Special attention is paid to discriminate the two suggested models, a flux rope or a bent arcade. “Inverse-polarity” orientation is possible below the filament in a flux rope, whereas “normal-polarity” can appear in both models. We study a filament in active region NOAA 10930, which appeared on the solar disk during 2006 December (Figure 1).

The transverse field perpendicular to the line of sight has a direction almost parallel to the filament spine with a shear angle of 30 deg, whose orientation includes the 180-degree ambiguity. To know whether it is in the normal orientation or in the inverse one, the center-to-limb variation is used for the solution under the assumption that the filament does not drastically change its magnetic structure during the passage.

When the filament is near the east limb, we found that the line-of-site magnetic component below is positive, while it is negative near the west limb. This change of sign indicates that the horizontal photospheric field perpendicular to the polarity inversion line beneath the filament has an “inverse-polarity”, which indicates a flux-rope structure of the filament supporting field.

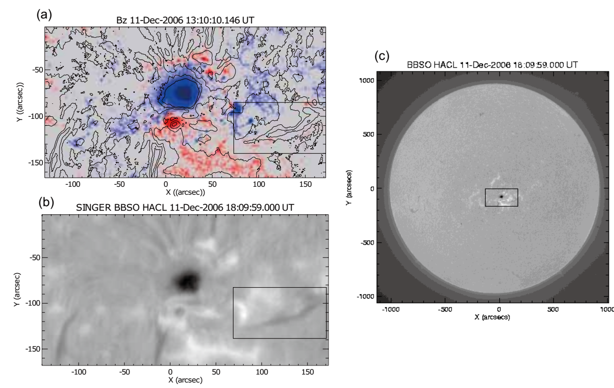

Figure 1: Active region NOAA 10930 on 2006 December 11. Color map in (a): LOS component of the magnetic field obtained by the Milne-Eddington fitting procedure from the *Hinode* SOT/SP observations. Red (blue) color indicates the positive (negative) polarity. The color plot is saturated at an absolute strength at 3 kG with dark blue (red) for negative (positive) field. Contours in (a) and gray-scale in (b) : Brightness in the Hα band taken at the Big Bear Solar Observatory. The square insets in panels (a) and (b) indicates the filament studied in this paper. (c) The same data as (b) but in full observational field of view. The square line indicates the field of view of panels (a) and (b).

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New Predicted Primordial Lithium Abundance from an Inhomogeneous Primordial Magnetic Field Model

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There is a long-standing cosmic Lithium Problem in the standard Big Bang Nucleosynthesis (BBN) model that the predicted primordial ^{7}Li abundance is 4 times higher than the observational constraint from Pop.II stars. Previous study [1] introduced a constant scale invariant (SI) PMF strength within a co-moving radius 1 Mpc during the BBN epoch which corresponds to a super horizon magnetic field but virtually did not solve the Lithium Problem. Theoretically, the length scale of the PMF fluctuations inside the co-moving horizon scale in its energy density can survive during the BBN epoch [2], therefore, it is possible for PMF to have an energy density fluctuations.

In this work [3], we simply assume that the distribution function of magnetic energy density ρ_B follows $f(\rho_\mathrm{B})$ which is a gaussian distribution with a peak located at the mean value ρ_Bc, the summation of radiation energy density ρ_rad and ρ_B, i.e., $\rho_\mathrm{tot} = \rho_\mathrm{rad} + \rho_\mathrm{B}$, is presumed to be a homogeneous quantity. Since temperature is proportional to $\rho_\mathrm{rad}^{-1/4}$, it is also inhomogeneous in our model. The nuclear reactions occur locally, this means that the local velocity distribution function for baryons at a certain temperature is described by *Maxwell-Boltzmann* (MB) distribution; Globally, due to the existence of temperature inhomogeneity, it would finally lead to an effective non-MB distribution function for baryonic velocities during the BBN epoch.

We encode the temperature averaged reaction rates into the BBN network calculation and compare the results with the observationally inferred abundances for D, ^{4}He and ^{7}Li as shown in Fig. 1. We plot the light element abundance as a function of baryon-to-photon ratio $\eta_{10} = \eta \times 10^{10}$. In the range of Planck constraint (light blue vertical band): η_{10} =6.10±0.04, in the grey region of the figure, the model parameters ρ_Bc and σ_B are ranged from $\rho_\mathrm{Bc}/\rho_\mathrm{tot}$ = 0.08–0.13 and ρ_B = 0.04–0.17 respectively. This region shows that the calculated D/H and Y_p (^{4}He mass fraction) are consistent with observations, and the ^{7}Li/H value is reduced to (3.18–3.52) × 10^{-10} compared with standard BBN (shown by solid lines).

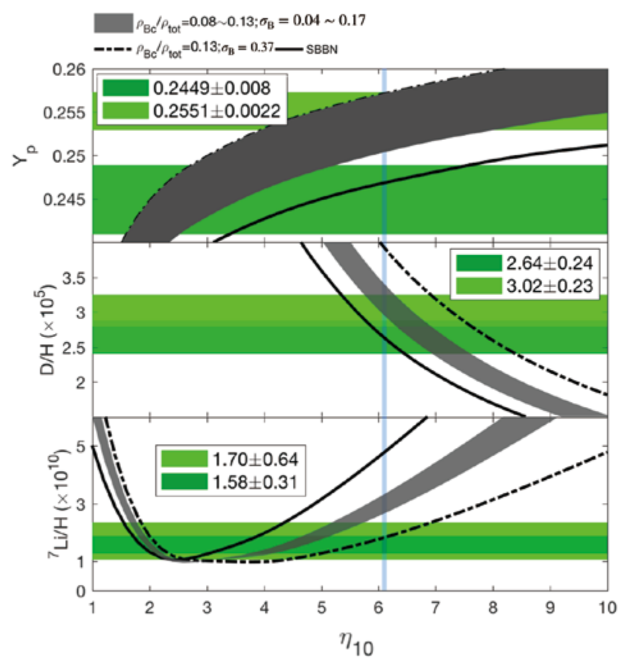

Figure 1: Y_p, D/H and ^{7}Li/H prediction as a function of baryon-to-photon ratio $\eta_{10} = \eta \times 10^{10}$. The green bands show the adopted observational constraints for each elements. The vertical blue band shows the Planck constraint on η_{10}. The light orange band shows the possible η_{10} region for which concordance is possible for all three elements.

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β-decay Rates for Exotic Nuclei and r-process Nucleosynthesis up to Thorium and Uranium

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Study of beta-decays at waiting-point nuclei at neutron magic numbers of N = 50, 82 and 126 is important to clarify the origin of the r-process elements. Beta decay rates for exotic nuclei with N = 126 relevant to r-process nucleosynthesis are studied up to Z = 78 by shell model calculations [1]. The half-lives are obtained by including contributions from both the Gamow-Teller (GT) and first-forbidden (FF) transitions. Calculated half-lives are shown in Fig. 1 together with those obtained in Refs. [2,3]. The present results are found to be short compared with the standard values by FRDM (finite-range-droplet model) [2], while they are close to another shell-model evaluation [3]. The contributions from the FF transitions become more important for larger Z, and dominant at $Z > 72$. They are essentially important at $Z > 75$ to get reasonable half-lives compatible with the observation. Calculated half-life for Z = 78 (^{204}Pt), $\tau_{1/2}$ = 38.3 s, is found to be fairly consistent with the recent experimental data; 16+6/-5 s [4].

The half-lives for the waiting-point nuclei obtained, which are short compared to a standard FRDM, are used to study r-process nucleosynthesis in core-collapse supernova explosions and binary neutron star mergers [1]. The CCSN models adopted here are the neutrino-driven wind (νDW) supernova explosion model and the magnetohydrodynamic jet (MHDJ) supernova explosion model, and the binary NSM model is the dynamical mass ejection model. The element abundances are obtained up to the third peak as well as beyond the peak region up to uranium and thorium The position of the third peak is found to be shifted toward a higher mass region due to shorter shell-model half-lives in both core-collapse supernova explosions and binary neutron star mergers. We find that thorium and uranium elements are produced more with the shorter shell-model half-lives and their abundances come close to the observed values in core-collapse supernova explosions. In case of binary neutron star mergers, thorium and uranium are produced as much as consistent with the observed values independent of the half-lives.

Further extensive knowledge on the nuclear input properties on and near the r-process flow path on the nuclear chart are expected to help identify both the r-process site and the nucleosynthesis mechanism.

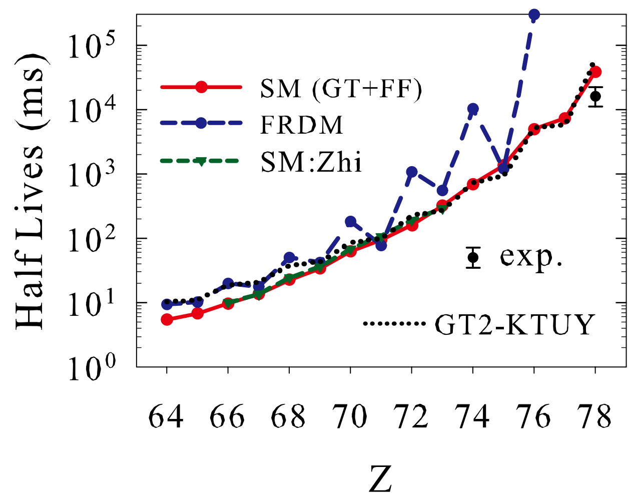

Figure 1: Calculated half-lives for the isotones with N = 126 as well as the experimental half-life value for Z = 78 [4]. Half-lives obtained by the present shell-model (SM) calculations with GT+FF contributions (solid curve), those of FRDM [2] (dashed curve), another SM calculation [3] (short-dashed curve) as well as the GT2-KTUY [5] (dotted curve) model are shown. Taken from Ref. [1].

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Global *N*-body Simulation of Galactic Spiral Arms

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The formation mechanism of galactic spiral arms is one of the important unsolved problems in galactic astronomy. The swing amplification is one of the theories to explain galactic spiral arm formation. If the leading wave is excited, it rotates to a trailing wave due to the shear. If the self-gravity is sufficiently strong compared to the stabilizing effect due to the random velocity, the rotating wave is amplified during the rotation.

Based on the swing amplification, the azimuthal wavelength, the pitch angle, and the number of spiral arms can be estimated. From the local and linear analyses, it was found that the pitch angle, the amplification factor, and the number of spiral arms are given as a function of disk parameters [1]. The number of spiral arms and the pitch angle formulae are

$$\bar{m} = 0.922C\frac{(2-\Gamma)^2}{fQ}, \tag{1}$$

$$\tan\bar{\theta} = \frac{1}{7}\frac{\kappa}{A} = \frac{2}{7}\frac{\sqrt{4-2\Gamma}}{\Gamma}. \tag{2}$$

where C is the order of unity, Γ is the shear rate, f is the disk mass fraction, Q is the Toomre's Q, κ is the epicycle frequency, and A is Oort constant.

$$\bar{m} \simeq \frac{0.230C}{Qf}\left(\frac{14\tan\bar{\theta}}{1+\sqrt{1+49\tan^2\bar{\theta}}}\right)^4. \tag{3}$$

These predictions have not yet been confirmed by global simulations in detail.

In this research, we have performed the global *N*-body simulations of disk galaxies in order to compare the spiral structure with those by the swing amplification theory [2]. We introduced the simple simulation model for dark halo and disk. For the halo, we adopted the power-law model to control the shear rate directly. The stellar disk surface density is given by an exponential model.

The mean pitch angle and number of spiral arms were calculated in the disks with various shear rates and mass fractions. Results are shown in Figure 1. The number of spiral arms decreases with both increasing the shear rate and the disk mass fraction. The pitch angle decreases with increasing the shear rate and is independent of the disk mass fraction. It follows that the pitch angle tends to increases with the number of spiral arms if the disk mas fraction is fixed, which is shown in Figure 2. We confirmed that the dependencies of the spiral structure in *N*-body simulations on disk parameters agree with those in the swing amplification theory.

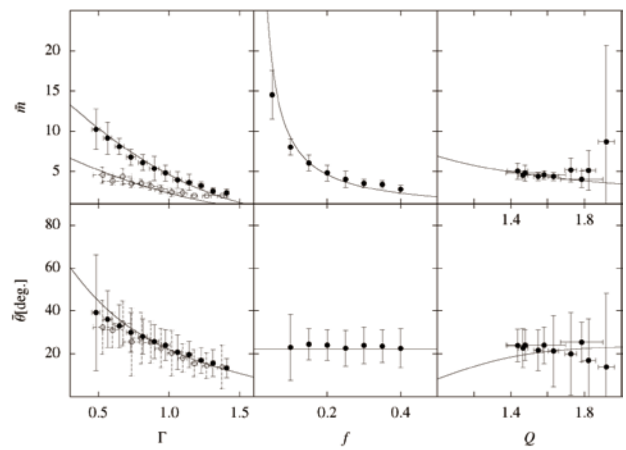

Figure 1: Number of spiral arms $\bar{m}$ and the pitch angle $\bar{\theta}$ against Γ, f, and Q. The solid curves show the equations (1) and (2). In the left panels, the filled and open circles correspond to the models of $f = 0.2$ and $f = 0.4$, respectively.

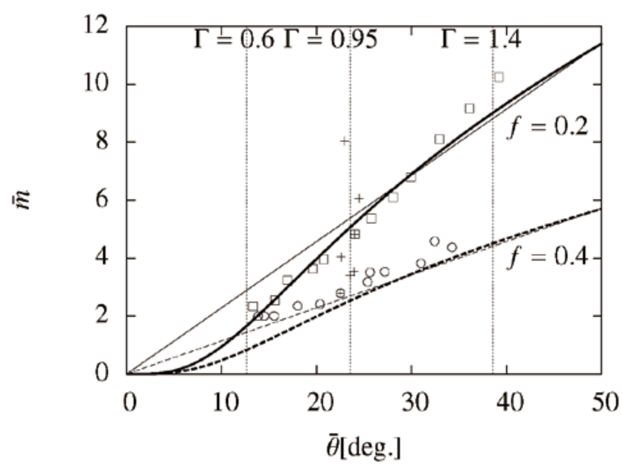

Figure 2: Pitch angle $\bar{\theta}$ against the number of the spiral arms $\bar{m}$ for the models of $f = 0.2$, $f = 0.4$, and $\Gamma_h = 1.0$. The solid and dashed curves show the estimates given by equation (3).

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Size Distribution of Small Hilda Asteroids

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The Hilda group is an asteroid population located in the 3:2 mean motion resonance with Jupiter, near ~4.0 au from the Sun. The taxonomic distribution of Hildas (mainly consisting of C-, P-, and D-type asteroids) is similar with that of Jupiter Trojans (JTs) rather than that of main-belt asteroids (MBAs). Recent dynamical models for the solar system formation claimed that the JTs were transported from the outer planet region by gravitational perturbation. Based on the scenario, the similarity of taxonomic distribution between Hildas and JTs indicates that the two populations have a common origin. If this is correct, their size distributions should be analogous to one another. However, the size distribution of Hildas smaller than 10 km was still unknown.

Our previous study [1] has detected 631 of small JTs from the data obtained by a survey observation around the Jupiter L4 points with Subaru/HSC, which allowed us to derive the size distribution of JTs down to 2 km in diameter. Using the same data, we additionally detected 130 Hildas from the area of ~29 deg^2 [2]. The detection limit is 24.4 mag in the r band, which corresponds to diameter of ~1 km assuming an albedo of 0.055.

As the results of our data analysis in the same manner as we did for JTs, we selected 91 objects as an unbiased sample of small Hildas and found that its absolute magnitude distribution can be approximated by a single-slope power law with an index of $\alpha = 0.38 \pm 0.02$ ($N(H) \propto 10^{\alpha H}$, where H is the absolute magnitude). This value well agrees with that of JTs in the same size range. Direct comparing the size distributions between Hildas and JTs also indicates that they are similar to one another in shape in the km size range. Considering that these asteroids in such size range seem to be in collisional equilibrium and the shape of size distribution depends on the characteristic of impact strength law, this result suggests similarity of the bulk composition and inner structure between Hildas and JTs, which strongly supports that the two populations have a common origin.

References

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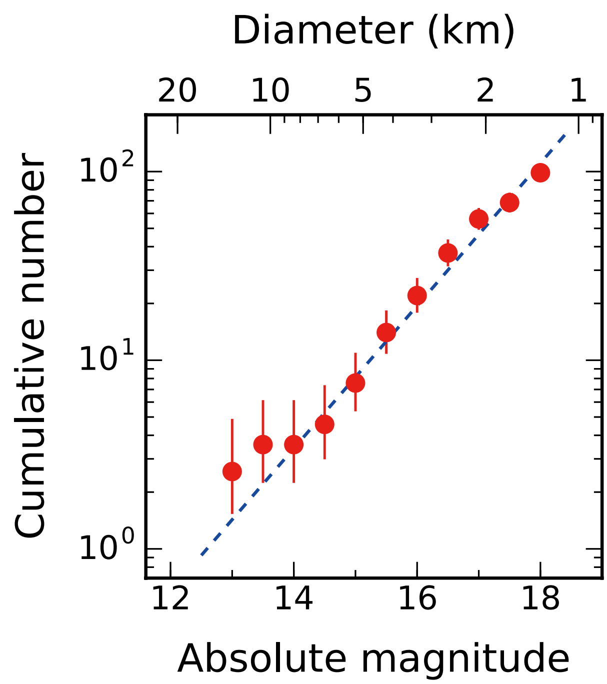

Figure 1: Cumulative size distribution of Hilda group asteroids observed by our observations. The cumulative numbers are corrected by the detection efficiency function. The geometric albedo is assumed to be 0.055. The dashed line shows the best-fit power law.

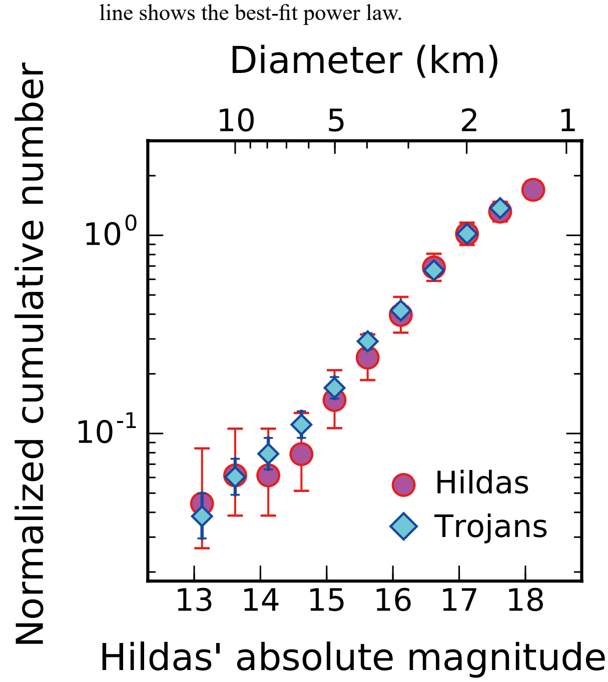

Figure 2: Cumulative size distributions derived from the Hilda (circles) and JT (diamonds) samples in our survey, both of which are normalized at 2 km in diameter. The geometric albedos are assumed to be 0.055 for Hildas and 0.07 for JTs.

ALMA Observations of the ρ Ophiuchus B2 Region
I. Molecular Outflows and Their Driving Sources

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We present the results of ALMA mosaic observations of 1.3 mm dust continuum and ^{12}CO (J=2–1) molecular line toward the ρ Ophiuchus B2 region. The 1.3 mm dust continuum image made from the combined 12 and 7 m array data reveals not only the dense cores identified by past single-dish observations but also their detailed internal substructures. The ^{12}CO (J=2–1) images show very complex structures of the gigantic outflow observed in Oph B2 [1]. The 1.3 mm continuum image and the blueshifted and redshifted component images of the ^{12}CO line are compared with Spitzer 24 μm and Herschel 70 μm images. The comparison suggests that the protostellar outflow lobes are presumably driven at least by two known protostars, flat-spectrum objects EL 32 and EL 33, as indicated in Figure 1. We do not detect clear high-velocity components associated with other known protostars, a Class I protostar SST c2d J162730.9.242733 and a flat-spectrum object SST c2d J162721.8.242727. In the ALMA 1.3 mm image, 28 condensations are identified under the condition whose peak intensity larger than 6σ, and each condensation is individually enclosed at least with a contour at an interval of 3σ. However, neither ^{12}CO outflow, 24 μm nor 70 μm is associated with the dust condensations without the known protostars. It seems that these condensations are still in the pre-stellar phase. In addition, we find interesting striations with ~1900 au separations in the ^{12}CO channel images as shown in Figure 2. The CO striations appear to be roughly parallel to the magnetic field direction, and we speculate that the directions of the striations may follow the magnetic field in the envelope of Oph B2 [2].

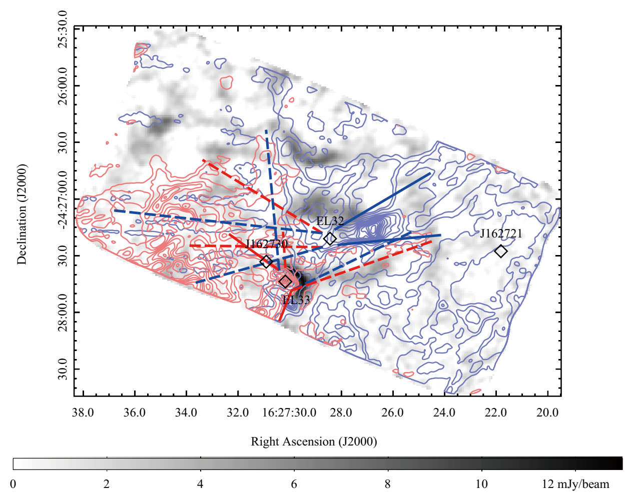

Figure 1: Figure 16 in [2]. ^{12}CO outflow structures (blue and red contours) of the Oph B2 region overlaid on ALMA 1.3 mm continuum image. The positions of the four protostars are indicated with diamonds. The blue and red solid/dashed lines show the edges of blueshifted and redshifted lobes of our proposed outflows, respectively.

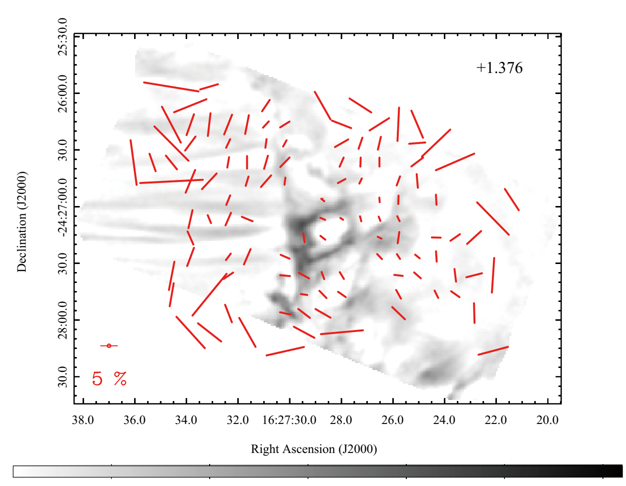

Figure 2: Figure 17 in [2]. SCUPOL polarization map overlaid on the ^{12}CO channel map at $V_{\rm LSR}$ = +1.376 km s^{-1}. The plane-of-sky magnetic field direction should be perpendicular to the SCUPOL polarization vectors, which indicates that the CO striations are parallel to the magnetic field direction.

References

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Extremely High Excitation SiO Lines in Disk-Outflow System in Orion Source I

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As one of the nearest star forming regions, Orion Source I has been studied via the high-resolution observations with millimeter and submillimeter wavelengths. The observations of SiO and H_2O lines revealed the rotating disk and outflow around Source I, which support the star formation via accretion. The mass of Source I is estimated to be ~8 $M_\odot$ with the observed velocity gradients [2,3]. On the other hand, the proper motion measurements of young stellar objects in Orion KL suggested that the dynamical interaction between multiple stars occurred ~500 years ago. In this scenario, Source I is thought to be a binary system with a mass of ~20 $M_\odot$ [4]. The study of the physical properties of Source I requires the high angular resolution observations of the inner disk/outflow region.

In this study, we present the results of ALMA observation at 0.1″ resolution to investigate the properties of hot and dense gas near Source I. The observations were conducted as one of the science projects in cycle 2 at band 8.

We detected 465 GHz ^{29}SiO v=2 J=11–10, 464 GHz SiO v=4 J=11–10, and 428 GHz SiO v=2 J=10–9 lines towards Source I (v and J represent the vibrational and rotational excitation level, respectively). In particular, this is the first time the SiO emission with the high vibrational excitation level (SiO v=4 J=11–10 with the excitation temperature ~7000 K) has been detected in star forming regions.

SiO v=2 J=10–9 emission shows a bipolar structure in the direction of northeast-southwest with ~200 au scale. In contrast, SiO v=4 J=11–10 and ^{29}SiO v=2 J=11–10 lines have a compact structure with a diameter of < 80 au (Figure 1). The observed SiO emissions have the velocity gradients in the direction of northwest-southeast, which is consistent with those of other high-frequency lines and masers [2,3]. The morphologies and the velocity distributions suggest that the SiO v=2 J=10–9 emission traces the base of rotating outflow, and the SiO v=4 J=11–10 and ^{29}SiO v=2 J=11–10 emissions are located at the surface of the disk where the disk wind is launching.

Assuming Keplerian rotation, the rotation curve of SiO v=4 J=11–10 emission is well reproduced by the ring structure with an inner radius of 12 au, the outer radius of 26 au and the central mass of 7 $M_\odot$, which yields a lower limit of the mass of Source I.

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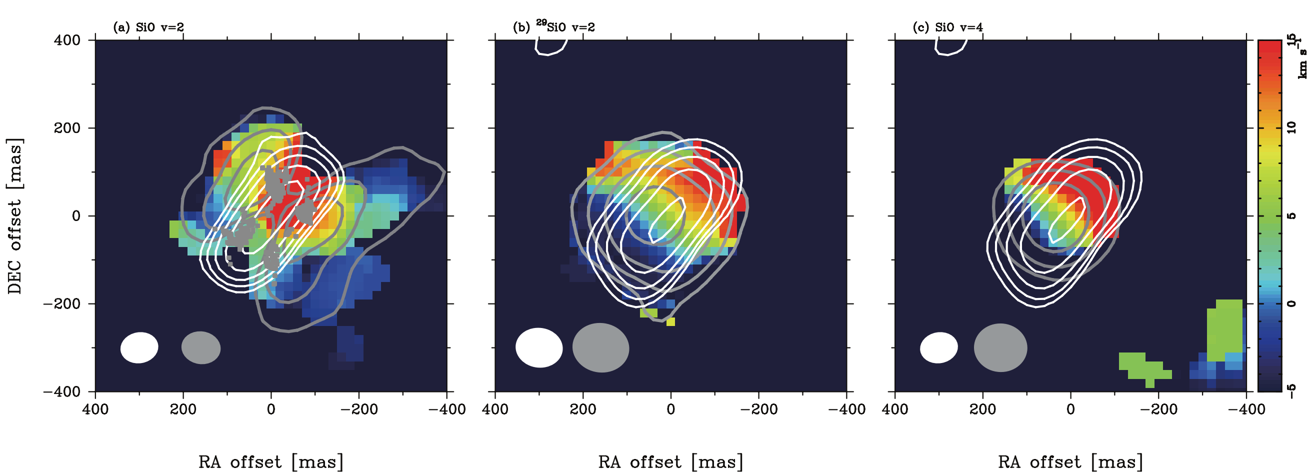

Figure 1: Moment 0 (grey contour) and moment 1 maps (color) of observed SiO lines superposed on the continuum map (white contour). (a) Map of SiO v = 2 J = 10–9 and 430 GHz continuum emission. Grey dots represent the position of SiO v = 1 and 2 J = 1–0 maser emission [3]. (b) Map of ^{29}SiO v = 2 J = 11–10 and 460 GHz continuum emission. (c) Map of SiO v = 4 J = 11–10 and 460 GHz continuum emission.

A Wide and Deep Exploration of Radio Galaxies with Subaru HSC (WERGS): The Optical Counterparts of FIRST Radio Sources

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Radio galaxies (RGs) have an active galactic nucleus (AGN) with powerful radio-jets driven by a harbored supermassive black hole. Radio-jets can control and quench star formation in galaxies through energy injections into interstellar and intergalactic medium. Host galaxies of RGs are typically as massive as $M_* > 10^{11}\,M_\odot$. Therefore, RGs are a key population for understanding the formation and evolution of massive galaxies.

We started a survey of RGs based on the wide and deep optical photometric data of Hyper Suprime-Cam Subaru Strategic Program (HSC-SSP) [1]. This project is called “Wide and Deep Exploration of Radio Galaxies with Subaru HSC (WERGS)”.

In Yamashita et al. (2018) [2], we reported the first result on HSC counterparts of radio sources detected with the Very Large Array FIRST 1.4 GHz survey [3]. We performed a cross-match between two catalogs of FIRST and HSC-SSP, and we identified ~3600 radio-AGNs in the 156 deg^2 field. The number of the matches accounts for more than 50 % of the FIRST sources in the field, and is higher than that of SDSS counterparts (~30 % [3]). 9 % among the matched sample are optically unresolved sources such as radio-loud quasars.

The 1.4 GHz source counts of the optically faint RGs ($i > 21$) among the matched sources are fitted with a linear function of a slope that is flatter than that of the bright RGs. On the other hand, the source counts of the optically faint radio quasars show a slope steeper than that of the bright radio quasars. The i-band number counts of the optically faint RGs show a flat slope down to 24 mag, implying possibilities that there are less massive or distant RGs beyond 24 mag. The photometric redshifts derived from the HSC-SSP photometries show that most of the RGs are distributed at redshifts from 0 to 1.5. Particularly, the sub-sample of the optically faint RGs are distributed at $z > 1$. These optically faint RGs at $z > 1$ have higher radio/optical ratios ($> 10^4$) than the optically bright RGs at lower z (Figure 1). This study gives RGs which are at the optically faint end and high-redshift regime and have not been probed by previous searches.

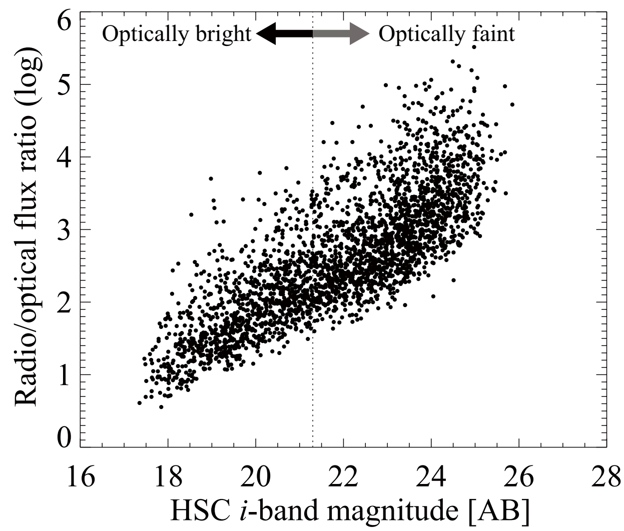

Figure 1: Radio/optical flux ratio as a function of apparent i-band magnitude of the HSC-FIRST RGs. The dotted line indicates the border separating the optically bright and faint RGs by their i-band magnitude (21 mag).

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Spectroscopic Identication of the Most Distant Galaxies by a Doubly-ionized Oxygen Emission Line

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FLETCHER, Thomas[3], HARIKANE, Yuichi[11], HATSUKADE, Bunyo[11], HAYATSU, Natsuki H.[11/12]
MATSUDA, Yuichi[2/13], MATSUO, Hiroshi[2/13], OKAMOTO, Takashi[14], OUCHI, Masami[11], PELLÓ, Roser[4]
RYDBERG, Claes-Erik[15], SHIMIZU, Ikkoh[16], TANIGUCHI, Yoshiaki[17], UMEHATA, Hideki[11/17/18]
YOSHIDA, Naoki[11], CHRISTENSEN, Lise[19], BINGGELI, Christian[5], TAKEUCHI, Tsutomu T.[7]
ASANO, Ryosuke S.[7], SUNAGA, Kaho[7], LEE, Minju M.[7/2], SHIBUYA, Takatoshi[20]
KOHNO, Kotaro[11], OTA, Kazuaki[21/22], MORIWAKI, Kana[11], NAGAO, Tohru[23]

1: Osaka Sangyo University, 2: National Astronomical Observatory of Japan, 3: University College London, 4: Université de Toulouse, 5: Uppsala University, 6: Johns Hopkins University, 7: Nagoya University, 8: Pontificia Universidad Católica de Chile, 9: Millennium Institute of Astrophysics, 10: Space Science Institute, 11: University of Tokyo, 12: European Southern Observatory, 13: Graduate University for Advanced Studies, 14: Hokkaido University, 15: Universität Heidelberg, 16: Osaka University, 17: Open University of Japan, 18: RIKEN, 19: University of Copenhagen, 20: Kitami Institute of Technology, 21: University of Cambridge, 22: Kyoto University, 23: Ehime University

A far-infrared emission line was used to spectroscopically identify the most distant galaxy at redshift 9.11. The radiation traveled a distance of 13.28 billion light years before arriving our telescopes [1]. This finding of a doubly ionized oxygen was made by ALMA, after the first detection of the ionized oxygen line from SXDF-NB1006-2 [2] followed by many observations. Observation of the ionized oxygen emission using ALMA has become a standard tool to study the most distant galaxies.

Until now, many high-redshift galaxies have been identified by Hubble Space Telescope (HST), and many of them were spectroscopically identified by a Ly-α emission line. However, when redshift is larger than 6, neutral intergalactic gas component increases and Ly-α emission is partly absorbed, which made the redshift identification more difficult at higher redshift. Ionized carbon emission line at 158 μm in far-infrared was found strong, and ALMA have identified the emission from many distant galaxies. However, at redshift larger than 7, ionized carbon emission were rarely been detected.

We have been focusing on the doubly ionized oxygen emission line at 88 μm, which is typically observed from massive starforming regions and from low metallicity galaxies. Ionized oxygen emission from high-redshift sources can be observed by ALMA, especially from massive starforming galaxies with short stellar lifetime and quick metal enrichment through supernovae explosion.

The two observational results show spectroscopic identification of starforming galaxies by far-infrared radiation without use of optical spectroscopy [1,3]. Both galaxies, MACS1149-JD1 and MACS0416_Y1, were magnified by gravitational lens of massive clusters of galaxies, and their photometric redshifts were measured by HST. With four receiver setups of ALMA to cover the candidate frequency range, the ionized oxygen emission were detected in two hours for single receiver setup to obtain significance of 7.4σ and 6.3σ, respectively. Optical identification by Ly-α was made toward MACS1149-JD1, but significance was higher for the ionized oxygen line. Optical emission line survey was made toward MACS0416_Y1, which resulted in null. On the other hand, large dust mass was measured toward this galaxy [3]. From the analyses on the stellar spectra and the dust mass show that star-forming activities in both galaxies started about 300 Myrs earlier.

Another paper we introduce here is a simulation studies of the ionized oxygen emission line at 88 μm, based on a cosmological hydrodynamic simulations [4]. We have identified 32 galaxies with their stellar mass larger than $10^8\,M_\odot$ and 270 galaxies larger than $10^7\,M_\odot$ in the redshift range from 7 to 9. Luminosities of the ionized oxygen relative to the starformation rates are analyzed and redshift dependence is shown, where relative luminosity of the ionized oxygen increases at larger redshift, which is consistent with our ALMA observations. The simulation studies show structures within each galaxies, which will be compared with higher angular resolution ALMA observations.

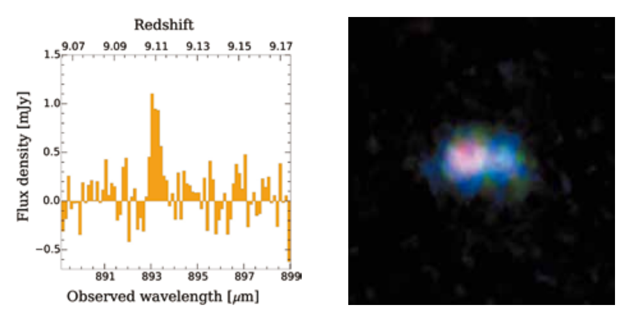

Figure 1: (left) ALMA spectrum of [OIII]88 μm toward MACS1149-JD1. (right) ALMA images of MACS0416_Y1 by [OIII]88 μm (green) and dust (red) overlaid on HST image of stellar distribution (blue).

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Development of Terahertz Photon Detectors with Low Leakage SIS Junctions

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In terahertz frequency region, consisting of submillimeter-wave and far-infrared radiation, both wave and particle nature of radiation play important roles. Technically, both optical and microwave technologies can be applied, and terahertz frequency region is a field of interest in quantum optics. We are developing fast photon detectors in the terahertz frequency region, and proposing to apply them to future astronomical observations [1]. The first application is to measure terahertz photon statistics from astronomical sources and obtain precise measure of temperature or deviation from thermal equilibrium comparing to Bose-Einstein statistics. The application includes measurements of photon statistics of cosmic background radiation and non-thermal sources to study physical states of these emission.

Intensity fluctuation caused by photon bunches can be used to realize intensity interferometry. The interferometry is known by the name Hanbury-Brown and Twiss, and is a basis of the quantum optics. However, application to astronomical interferometry have been limited due to low efficiencies in optical and requirements of large dynamic range in radio-wave. These difficulties can be solved in terahertz frequencies by introduction of fast photon detectors, and future applications to astronomical interferometers are foreseen.

In terahertz frequencies, a photon rate of about 100 M photons/s is expected from bright astronomical sources [2]. To resolve each photon arrival, time resolution less than 1 ns, or bandwidth larger than 1 GHz, is required to detectors. To realize photon counting sensitivities, the noise equivalent power (NEP) less than $10^{-17}\,\mathrm{W}/\sqrt{\mathrm{Hz}}$ is needed. We are developing such detectors using superconducting tunnel junctions (SIS photon detectors).

Performance of the SIS photon detectors are limited by leakage current through the SIS junctions. When the leakage current is decreased to 1 pA, NEP can be less than $10^{-17}\,\mathrm{W}/\sqrt{\mathrm{Hz}}$. Figure 1 show the measured leakage current of SIS junctions fabricated in the Clean Room for Analog & Digital superconductiVITY (CRAVITY) in the National Institute of Advanced Industrial Science and Technology (AIST). The figure shows the leakage current of three different sizes of SIS junctions measured at a bias voltage of 600 μV. The critical current density of the junctions are 300 A/cm^2. The 3 μm size junction achieves leakage current of about 1 pA. The normal impedance of the junction is about 100 Ω, which is good for impedance matching to antenna.

Although, SIS junctions for leakage current measurements do not have antenna structure, we have illuminated the junction with a cryogenic blackbody source to measure their far-infrared response. In spite of low quantum efficiency due to surface reflection, NEP was evaluated to be about $10^{-16}\,\mathrm{W}/\sqrt{\mathrm{Hz}}$ at around 10 THz.

Using the same type of SIS junctions, we have designed SIS photon detectors with antenna at 500–650 GHz as shown in Figure 2. The detector consists of twin-slot antenna, coplanar waveguide and PCTJ-type SIS junctions, with characteristic impedance of 50 Ω. Although RF bandwidth of the detector is as small as 4 GHz due to the low current density junctions, it is appropriate to limit the number of incoming photons and to readout as fast as 1 ns.

In FY2018, fabrication and evaluation of SIS photon detectors were made and their results were presented in international workshops and society meetings.

This work is supported by a Grant-in-Aid for Exploratory Research of JSPS KAKENHI 15K13469 and a budget for Basic R&D on onboard equipment for future space science missions from ISAS/JAXA.

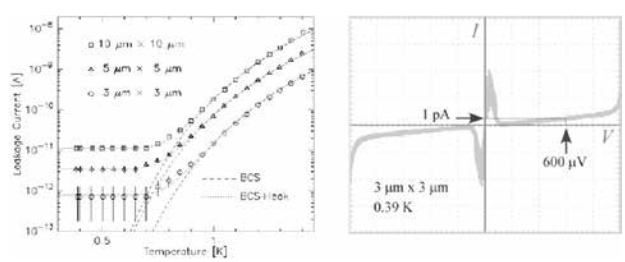

Figure 1: (left) Temperature dependence of leakage current of SIS junctions with three different sizes. (right) I-V characteristics of a 3×3 μm^2 junction.

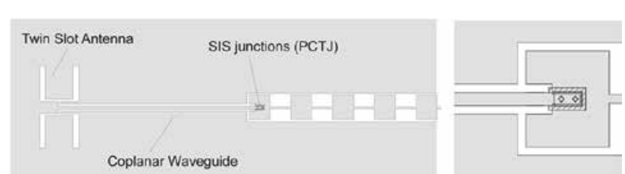

Figure 2: The design of an SIS photon detector. (left) A twin-slot antenna, a coplanar waveguide, PCTJ-type SIS junctions and a choke filter. (right) Enlarged view of the PCTJ-type SIS junctions.

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Terahertz Atmospheric Windows for High Angular Resolution Terahertz Astronomy from Dome A, Antarctica

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1: NAOJ, 2: Purple Mountain Observatory, CAS, 3: Smithonian Astrophysical Observatory

Ground-based astronomical observations have been made between optical and middle infrared wavelengths and between submillimeter to microwave frequencies. Atmosphere absorbs or reflect incoming radiation from space, and water is a dominant absorber in infrared to submillimeter-wave. Astronomical telescopes are hence built on high altitude sites such as Mauna Kea in Hawaii and Atacama in Chile. However, supra-terahertz frequencies or far-infrared radiation longer than 30 μm is not easy to observe from ground.

Antarctica can be an ideal site for astronomy due to low temperature and low water content in the atmosphere. Especially on Antarctic Domes, or icy mountains, one of which exceeds 4000 m in altitude, would show the most transparent atmosphere on earth. The paper we introduce here discusses the feasibility of astronomical observations in far-infrared and terahertz waves based on atmospheric transmission measurements from Dome A at 4093 m altitude [1].

The measurement of atmospheric transmission from Dome A is already reported in the research highlight in 2016, where wide-band Fourier transform spectrometer is used to measure atmospheric transmission spectra covering 1–15 THz during 2010–2011 [2]. In this paper we focus on 4 atmospheric windows (1.5 THz, 3.4 THz, 5.8 THz and 7.1 THz) to show observational feasibility in winter season. The 1.5 THz window is for observations of an ionized nitrogen line, 3.4 THz and 5.8 THz for doubly ionized oxygen lines, and 7.1 THz for a water ice-feature from protoplanetary disks.

Figure 1 shows the most transparent atmospheric spectrum measured during 2010–2011. Comparing to the Atacama altiplano, where ALMA is situated, transmission at 1.5 THz is more than twice and 3.4 THz window is clearly identified, which is difficult to be identified in Atacama. The wide atmospheric window at 7.1 THz will be most suitable for studies of exoplanet formation through observations of the water ice feature.

Transmission at winter season is represented by the measurements at 3.4 THz, which is the least transparent window, during two months (July–August, 2010), as shown in Figure 2. It is expected that atmospheric transmission is stable for several consecutive days at a level of 10 %. Comparing to the past observations at 1.5 THz from the south pole when atmospheric transmission was 3–6 %, observational feasibility is relatively high even at 3.4 THz window under stable atmosphere at Dome A.

Two telescopes (DATE5 and KDUST) are proposed for future instruments in Dome A. The DATE5 is a 5-m terahertz telescope and KDUST is a 2.5-m optical telescope. With the DATE5, whose aperture is larger than Herschel Space Observatory, will achieve the highest angular resolution in supra-terahertz frequencies. To achieve much higher angular resolution, astronomical interferometry, either with heterodyne or intensity interferometers could be implemented on these telescopes. The intensity interferometry could be advantageous because of their stability against atmospheric phase fluctuation, and longer baseline could be possible. In near future, these telescopes and interferometers will be used to make high angular resolution observations of massive starforming regions and exoplanet forming sites from Antarctica.

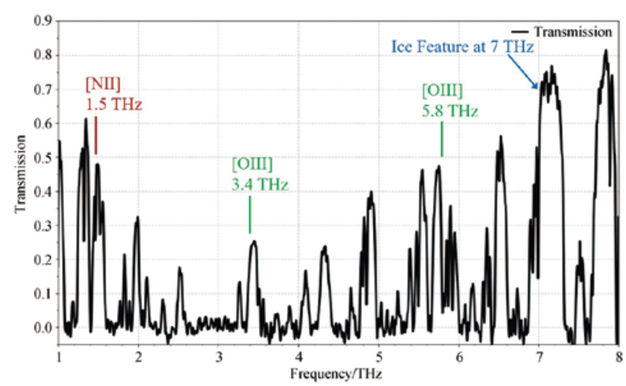

Figure 1: Zenith atmospheric transmission spectra measured at Dome A, Antarctica at 12–18h UTC on August 9th 2010.

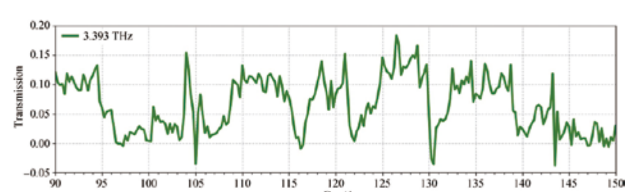

Figure 2: Atmospheric transmission during July-August, 2010 at 3.393 THz for the doubly ionized oxygen observations.

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II Status Reports of Research Activities

1. Subaru Telescope

1. Subaru Telescope Staff

As of the end of FY 2018, the Subaru Telescope staff consisted of 23 dedicated faculty members including seven stationed at Mitaka and two stationed at Okayama, four engineering staff members, three senior specialist, and three administrative staff members. Additional staff members include one project research staff member, seven senior specialist, one research expert, and four administration associates, all of whom are stationed at Mitaka. Additional staff members include one administrative maintenance staff member, one administrative staff member and two administration associates, all of whom are stationed at Okayama. Moreover, 14 research-education staff members, 13 of whom are stationed at Mitaka and one of whom is stationed at Pasadena, and three engineering staff members, 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 by Grants-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 2018, Subaru Telescope produced many outstanding scientific outcomes which were published in major international journals. Below are some examples:

(1) Using the very wide field optical camera, Hyper Suprime Cam (HSC), the deepest wide field map of the three-dimensional distribution of matter in the Universe was created and analyzed. The precise measurement of the lumpiness of matter in the Universe was successfully made, by using the gravitational distortion of images of about 10 million galaxies. By combining this measurement with previously conducted observations, the properties of the "dark energy" that dominates the energy density of the Universe have been further constrained.

(2) Based on high spatial resolution near-infrared imaging observations at ~2 micrometer using the near-infrared camera (IRCS) and adaptive optics (AO188), the morphologies of massive quiescent galaxies (without active formation) located 12 billion light-years away from the Earth have been investigated. It was found that these galaxies (probable progenitors of giant elliptical galaxies seen in the local universe) are very compact, only about 5 % the size of present-day elliptical galaxies with comparable stellar masses. Comparing the observations and those in the literature with models, the obtained results could be explained if the growth of galaxy size was driven by minor mergers where a large galaxy cannibalizes smaller ones.

(3) Using HSC, the most-distant body ever observed in our Solar System was discovered at about 120 astronomical units (AU), where 1 AU is defined as the distance between the Earth and the Sun. This was interpreted to be a dwarf planet with a spherical shape with about 500 km in diameter located more than three-and-a-half times more distant than the Solar System’s most-famous dwarf planet, Pluto, and also even more distant than the previously detected second-most-distant Solar System object, Eris, at about 96 AU.

(4) Based on the analysis of the mid-infrared spectrum of Comet 17P/Holmes during its outburst taken with the mid-infrared instrument (COMICS), it has been discovered that Comet 17P/Holmes was formed in a cold region of the solar nebula far from the Sun and probably includes highly volatile species abundantly.

3. Open-use

In S18A, 45 programs (94 nights) were accepted out of 155 submitted proposals, requesting 347.3 nights in total. In S18B, 50 proposals (84.5 nights) were accepted out of 156 submitted proposals, requesting 415.7 nights in total. Service observations were made for 9 nights. In S18A and S18B, 7 and 5 accepted open-use proposals were by foreign principal investigators, excluding the University of Hawai‘i and Australian observing time. The number of applicants in submitted proposals was 2423 for Japanese researchers (Japanese astronomers at any institute and non-Japanese astronomers belonging to Japanese institutes) and 893 for foreign researchers. The number of researchers in accepted proposals was 902 for Japanese astronomers and 893 for foreign astronomers. In S18A and S18B, the number of open-use visiting observers was 312, of which 54 were foreign astronomers. A total of 130 astronomers observed remotely from Mitaka. In S18A and S18B, 84.42 % of the open use time (including University of Hawai‘i time) was used for actual astronomical observations, after excluding the weather factor and scheduled maintenance downtime. About 1.93 %, 0.11 %, 13.4 %, and 0.14 % of observing time was lost due to instrument trouble, communication trouble, telescope trouble, and operation trouble, respectively. In S18A and S18B, remote observations from Hilo were conducted for 23 programs with 23.5 nights.

On the other hand, remote observations from Mitaka were conducted for 48.4 nights with 27 programs including HSC SSP. The number of telescope time exchange nights between Subaru Telescope and Keck were 5.5 nights in S18A and 9.0 nights in S18B. About those between Subaru Telescope and Gemini, Subaru Telescope users used Gemini time 2.5 nights in S18A and 5.5 nights in S18B (not including Fast Track programs) while Gemini users used Subaru time 4.0 nights in S18A and 5.2 nights in S18B.

4. Telescope Maintenance and Performance Improvement

At the Subaru Telescope, although we have conducted maintenance and upgrade work which is concentrated on telescope control, there are coming into prominence some elements, for example movable large structures and the heat exhaust system which have aged because we have conducted only irregular and/or emergency maintenance on them. Also, because Subaru has been used for over 20 years since the start of regular operation, we have to replace or upgrade its drive system and controller, and inspect the dome structure for longer stable operation. In Fiscal Year 2018, because of the reduced budget we have conducted some scheduled maintenance, and made a ranked list of other maintenance and renovations for the future. The Telescope Engineering Division has provided two engineers for the work. In this work, we established the Technology Planning Development Office in Subaru Telescope for investigating and negotiating with some companies for efficient budget spending. They have already started arranging to renovate the main shutters, which are the most dangerous of the movable large structure; renovations are expected to start summer 2019.

Currently, although our observation style is “Onsite Observation,” we are going to start "Remote Observation" in the near future. For the future, we have built up the system which is able to monitor and safely control from offsite. We believe that this system can make for efficient staffing and fast troubleshooting. We also upgraded the surveillance camera system to provide clear site survey at night too. In addition, we are preparing to upgrade the dome control system to survey the situation of all large movable structures remotely at anytime.

There were many incidents in FY 2018. There is a list of incidents caused by external circumstances and maintenance items below.

May;
- Kilauea Volcano eruption (May - September)
  * No damage from the eruption itself.
- Large scale earthquakes associated with volcanic activity (M6.9)
  * Stopped observation temporary due to the structure, mainly the Telescope and Main shutters, having been shaken. Observation was resumed with limited abilities after casual inspection.

August;
- Multiple places damaged due to rain leakage and water condensation due to passing Hurricane Rane.
- Annual Mechanical Maintenance.

September;
- Conducted technological collaboration with Mizusawa Observatory.
- Two large UPS damaged due to power interruption.
  * Resumed by using “By-pass mode” temporarily.
  * Resuming observation using slow AZ/EL speed to preventing telescope damage.
  * Restored UPSs by April.

November;
- Maintenance for Top Unit Exchanger system.
- Scheduled power outage in Maunakea Summit Area by electric company.

December;
- Upgrade for Serial-Parallel Communication Unit.
- Upgrade Telescope control computer to accommodate abilities of PFS.

February;
- Replacement of a part of Primary Mirror control card.
- Annual Electrical maintenance.

In Fiscal Year 2019, we expect to conduct main shutter renovation and recoating of the Infrared Secondary Mirror. We are assuming two months of downtime to conduct anti-aging activities for extending the telescope lifetime. We may also suffer the effects of natural disasters due to the increased chances of volcanic activity.

We are really sorry about that. Thanks to you all for your understanding and cooperation.

5. Instrumentation

In FY 2018, the following seven facility instruments were provided for the open-use observations : Hyper Suprime-Cam (HSC), 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). Among them, FOCAS and COMICS were damaged by Hurricane Lane, and it took more than half a year to recover FOCAS. COMICS was recovered quickly from the damage by the hurricane but its operation was stopped for several months due to the facility UPS trouble.

In these years, there have been discussions on how we maintain or stop the operation of the facility instruments. In FY 2018, it was decided to decommission COMICS after the semester S20A, and this was reported to the users. In addition, FOCAS is planned to be decommissioned after PFS starts science operation.

Due to the volcanic activity and earthquakes, the top-unit exchange was cancelled from May to October which resulted in cancellations of HSC observing runs. However, the operation of the HSC instrument itself has been stable similarly to the last fiscal year.

Among the ongoing upgrade projects for the other facility instruments, the FOCAS Integral Field Units has successfully completed engineering observations and has been provided for the open-use observations from May 2019. For AO188, the upgrades of the real-time control system and laser guide star system, and installation of the Transponder-Based Aircraft Detector system are ongoing. We expect them to be in operation from around the end of FY 2019 or in FY 2020. Other projects include the upgrade of the dispersing element, grism, of MOIRCS and upgrades of the aging control computers and devices of the first generation instruments. In addition, we have completed the preliminary design of the NsIR beam switcher, which will enable switching NsIR instruments without physically moving the instruments, by collaborating with Australian institutes.

As carry-in (PI-type) instruments, SCExAO (Subaru Coronagraphic Extreme Adaptive Optics), CHARIS (high-contrast integral-field spectrograph), and VAMPIRES (visible aperture masking interferometer with differential polarimetry), which are used in combination with AO188, have been offered for the Subaru Telescope open-use program. MEC (MKID Exoplanet Camera, ultra-fast energy-resolving camera), which is one of the instrument modules on SCExAO, has been successfully installed on SCExAO and conducted on-sky engineering observations.

In addition, IRD (InfraRed Doppler instrument) has continued its commissioning observations, and was eventually offered to normal open-use programs since S18B.

Two other PI-type instruments proposed by the University of Tokyo teams, SWIMS (Simultaneous-color Wide-field Infrared Multi-object Spectrograph) and MIMIZUKU (mid-infrared multi-field imager and spectrograph), which were carried-in in FY 2017, solved issues on the mechanical interface with the telescope in S18A and conducted engineering observations in S18A and S18B.

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. The engineering first-light is scheduled in FY 2020 and science operation is expected to be started in FY 2021. In FY 2018, the metrology camera system (MCS), which measures the location of each optical fiber, was delivered to Subaru Telescope and we performed on-telescope adjustment and testing. We defined the route and method for fixing optical fiber cables along the telescope and dome through investigations using their prototype cable. The construction of the Spectrograph Clean Room (SCR) was almost finished and optimization of the temperature control system was performed. The modification of telescope control system software was also conducted and is now waiting for the real PFS system to be delivered on-site. The data analysis system and the science database which combines HSC and PFS data was being developed with US collaborators. The prototype science database was already released and is now being revised for the version 2.

We are currently promoting the ULTIMATE-Subaru project, aiming to extend the wide-field capability to near-infrared wavelengths by developing a ground-layer AO (GLAO) system and wide-field near-infrared instruments. ULTIMATE-Subaru will be a new flagship facility instruments after HSC and PFS, and will offer a new survey capability in bright nights in the mid-2020s. In FY 2018, we have completed conceptual design studies of the GLAO system in collaboration with Australian and Taiwanese research institutes. The GLAO design successfully passed the external review by domestic and international experts and is now ready to enter preliminary design phase. In the JSPS funded project, ULTIMATE-START, we have proceeded with the preliminary design of the multiple Shack-Hartmann wavefront sensor system and laser guide star facility, both of which can be demonstrators of the technologies used in the future GLAO system. We have applied for the NAOJ's A-project status to complete the design for ULTIMATE-Subaru. The application has been approved for the GLAO part. The GLAO project will start from FY 2019 with the aim to complete the preliminary design in FY 2021.

6. Computer and Network

Subaru Telescope completed its first year of STN5. Collaboration between Fujitsu Engineers and CoDM members achieved stable transition of core system and network services, STARS data archive, and implementation of new sub-systems. Toward the end of this fiscal year, CoDM is working to expand the Summit VM environment, to support Instrumentation OBCPs such as IRCS, MOIRCS, and HDS, and analysis and monitoring servers; creating a system that will be robust and recoverable in case of hardware failures.

The Observation Data Archive has been ongoing from the previous year, continual planning for the inclusion of data from other instruments observing with the Subaru Telescope. The archive is operational without serious problem. The data archive system in Mitaka also showed stable performance. The STARS administrator has also successfully prototyped a near-real-time delivery system for HSC observation.

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. Subaru Telescope scheduled 181 nights of Mitaka Remote between April 1, 2018 and March 31, 2019.

Subaru Telescope has accepted support of PFS instrument and HSC data analysis (HSC On-site Data Analysis System). Installation of new hardware, and support of existing hardware continues. HSC Admins continue prototyping high speed filesystems to improve computation to support observation. Success in this prototype is possibly a baseline for future instruments requiring near-real-time analysis of data. PFS infrastructure installation of the core network, storage, and virtual server environment is being supported.

Subaru Telescope has been developing and operating web applications that support open-use observations. The Proposal Management System (ProMS) supporting calls for proposals changed. Subaru Telescope is planning to develop a web application to help the referees who score the proposals. Online visitor forms support visiting on-site or remote observers, engineers, and support contractors for Hilo and Mitaka Campuses. Subaru Telescope continues support of other web-based applications: HSCQ (HSC Queue observation) and HSCOBSLOG (HSC Observation Log).

In Mitaka, the HSC off-site data analysis system and HSC data archive system are in operation. The HSC data archive provides the reduced data from HSC to researchers worldwide.

As of March 1, 2018 Subaru Telescope has successfully migrated to new network hardware under contract with Fujitsu. Network support of Base and Summit Facilities has been very stable. The Subaru Telescope network uses a direct network connection to Mitaka, supporting Mitaka remote observation, STARS archive data transfer, and communication between NAOJ facilities. Subaru Telescope is researching methods for future enhancement to transfer large observational data sets over high-speed networks in collaboration with the University of Hawaii-Institute for Astronomy.

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 nine. The number of SOKENDAI students who had primary supervisors affiliated with Subaru Telescope (including those concurrently belonging to Subaru Telescope) was eleven, which constituted about half of the total 24 Sokendai students hosted in NAOJ. Of those, three had supervisors who belonged primarily to Subaru Telescope.

In FY 2018, Subaru Telescope hosted four 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 19 and 14, 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 2018, we hosted a Subaru Autumn School in Mitaka. There were 13 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 ten undergraduate students from all over Japan held in October 2018, and the other for six new SOKENDAI students at NAOJ held in January 2019. 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 throughout the general population. Raising positive awareness of Subaru Telescope — within the local community, in particular — is critical for the success of the Subaru Telescope project as well as the next generation telescope project on Maunakea. PIO has three major tasks to achieve its goal.

Task 1: Provide information about activities and scientific results from Subaru Telescope by effectively using websites and social media platforms. Subaru Telescope provides press releases to the Japanese, local, and international media and holds press conferences. During Fiscal Year 2018, there were 14 web-postings (7 in Japanese and 7 in English) about discoveries from Subaru Telescope. Articles about instrument development, the work and activities at the Subaru Telescope, and other announcement totaled 48 (26 in Japanese, 22 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 18 from Japanese media and 9 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 Hawai'i, 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 2018, 554 people visited the summit facility through the public tour program. This number does not include tours that were suspended due to poor weather conditions, earthquakes, power failures, and winter time tour-suspensions. An additional 109 groups visited the summit facility via the special tour programs. In total, 1099 people visited the summit facility in Fiscal Year 2018. In addition to that, 8 special tours dedicated for the residents of Hawai‘i were conducted and 96 local people participated. 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 Telescope staff provide comments and advice. A total of 16 groups (472 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 2018, PIO provided/coordinated a total of 49 lectures at the Subaru Telescope Hilo Base Facility or at nearby locations, such as ‘Imiloa 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 Telescope staff also conducted 22 lectures outside Hawai‘i and 10 remote lectures for Japanese schools.

Other than that, PIO also conducted 12 outreach activities including exhibitions and interacted with about 7000 people.

In addition to providing lectures, Subaru Telescope actively participates in various outreach events and career fairs on Hawai‘i 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 ‘Imiloa Astronomy Center, Maunakea Visitor Information Station, and the University of Hawai‘i at Hilo participate. AstroDay was also held in Kona, on the west side of the island.

Another major outreach event on Hawai‘i Island is the annual Onizuka Science Day at the University of Hawai‘i at Hilo. 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 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 Telescope 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. In recent years, 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. Nobeyama Radio Observatory

1. Nobeyama 45-m Radio Telescope

(1) Open Use Observations

The 37th open use observations period started on December 15, 2018. The statistics of the successful proposals are as follows, “General Programs”: 20 programs were accepted out of 47 submitted proposals including ten programs from abroad (out of 22 submitted), “Large Program”: one program was accepted out of three submitted, “Short Programs”: four were accepted out of nine submitted, “Backup Programs,” which are to be carried out when weather is not good enough for the main observations: two programs were accepted (out of two submitted). “GTO (Guaranteed Time Observation) programs”: no proposals were submitted. “DDT Programs”: no proposals were submitted. VLBI open use observations including the 45-m telescope: four proposals were accepted out of 16 submitted.

Remote observations were conducted from Mitaka, Iriki, Kagoshima University, Osaka Prefecture University, Nagoya University, Institute of Astronomy The University of Tokyo, University of Tsukuba, Hokkaido University, and ASIAA (Taiwan).

(2) Improvements and Developments

Taking into account the reduction of the human and budgetary resources of Nobeyama Radio Observatory, we continued a call for Nobeyama Development Proposals. 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 (technical assessor) also attended the review as observers from the observatory side. A total of five proposals were received, and three of them (3-band simultaneous observing system HINOTORI, frequency-modulation local oscillation FMLO, and Band 1 receiver by Taiwan) were accepted, and two (“Millimetric Adaptive Optics: Development of a Wave-front Sensor” and “100-GHz, 109-element camera”) were “accepted with conditions attached.”

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

- A malfunction in the sub-reflector driving system was repaired.
- Preventive and corrective paint to the antenna main-reflector structure was done.
- The replacement of a mirror exchange system (old one) was completed. The design work for the replacement of the beam switching system was conducted.
- Development of the data reduction procedure with the CASA pipeline is continued. This will lead to an automated observing system in the future.
- Simultaneous observations of the 22 and 43 GHz bands were realized by installing a frequency selective filter developed by the HINOTORI program, and made available for open use.

(3) Scientific Results

A total of 34 refereed journal papers were published on the basis of research using the 45-m radio telescope.

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 CO shells and outflows were discovered in the Orion A giant molecular cloud and Aquila Rift. It was shown that stellar feedback by stellar winds and outflows can help maintain the turbulence in molecular clouds (Feddersen et al., Nakamura et al.).

(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 yet using FOREST on the 45-m telescope. Hints of evidence for cloud-cloud collisions were obtained toward RCW166 (Ohama et al.), N35 (Torii et al.), and Sh2-48 (Torii et al.).

(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. It was found that the star formation efficiency is suppressed in the bar (Yajima et al.) but it may be enhanced in some cases (Muraoka et al.), and the bar becomes longer and the bar pattern speed decreases with increasing galaxy size (Salak et al.).

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

- It was found that the gas distribution is better described by the dust distribution rather than by CO emission distribution (Komugi et al.).
- Complex Organic Molecules were studied (Suzuki et al.).
- Massive young stellar objects and massive star forming regions were astrochemically studied (K. Taniguchi et al.).
- High-velocity emissions were discovered toward the galactic Center, and were suggested to indicate the formation site of an intermediate-mass black hole (Takekawa et al.).
- Broad emissions were detected in the Galactic Center CMZ region (Tokuyama et al.).
- A line survey toward the WCCC region was made (Yoshida et

al.).

- Astrochemical study was made on the basis of the C_2H/CH_3OH ratio (Higuchi et al.)
- Hints of evidence for cloud-cloud collision were obtained toward the Orion A giant molecular cloud (Fukui et al.), and the giant molecular cloud Cyg OB7 (Dobashi 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 2017. To avoid the interference, we modified the front-end system in 2018 and are doing the commissioning now.
- 9.4 GHz: Data unavailability had continued due to the malfunction of an amplifier starting from late June 2017. It was recovered in April 2018, and the observations resumed.
- 34 GHz and 80 GHz: Due to the malfunction of the sensor for adjusting the pointing, observation has been suspended since November 2018.

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 in the 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, this year we again carried out synergetic observations with the Atacama Large Millimeter/Submillimeter Array, and Japanese Venus Climate Orbiter AKATSUKI (JAXA/ISAS), and 1.6-m Pirka Telescope (Nayoro Observatory, Faculty of Science, Hokkaido University) employing a Near Infrared Echelle Spectrograph (The University of Tokyo). These studies of the Venusian atmosphere allow us to address the links between photochemistry and dynamical circulation of material in the Venusian atmosphere and the space weather environment. In addition, in the NINS Nobeyama Exhibition Room, we started to show the status of the remote operation and the SPART observations on the computer display.

(2) 1.85-m Radio Telescope (Osaka Prefecture University)

In 2018, one peer reviewed paper was published using data from this telescope.

(3) 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. Using data of NoRH, four refereed papers were published in Fiscal Year 2018.

4. Public Outreach

(1) PR activities at Nobeyama Campus

The Nobeyama Campus received a cumulative total of 44,481 visitors throughout the year, including participants in the Special Open House event. Staff members conducted 40 guided tours, including ones for Super Science High School (SSH) students and the Campus Tour Week, while 3 requests for outside lectures and 42 requests for on-site filming and interviews were granted. The Campus Tour Week for educational institutions was scheduled during the summer. Three groups took advantage of this opportunity. For the workplace visits, 5 students from 2 schools, local junior-high schools, visited the observatory. For the SSH initiative, 4 schools and groups visited NRO and participated in lectures. The filming and interview requests, especially those by some local broadcast stations in Nagano Prefecture, increased due to efforts to strengthen cooperation with local communities, especially the “Nagano Prefecture is Astro-Prefecture” promotion. Moreover, those focusing on the future of NRO increased in the last half of the year.

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

Moreover, we received and answered about 220 phone calls this year from the public regarding the regular opening of the observatory, observatory events, and general astronomy (including 21 interviews).

(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, with a contribution from NRO, “Jimoto Kansha Day (Thanks Day for the Locals) & Open Symposium” was held as the Special Open House for locals (Minamimaki and Kawakami Village) at Vegetaball With, Minamimaki Village Rural Exchange Center by Yatsugatake Forest, Mountain Science Center, University of Tsukuba 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.

Moreover, a “Nagano Prefecture is Astro-Prefecture” stamp-rally 2018 was carried out following the last year by the “Nagano Prefecture is Astro-Prefecture” liaison council, which was founded in 2016 through cooperation with Kiso Observatory and other organizations. The third meeting was held at Kiso—town culture center on February 23–24 with about 60 participants. Some activity reports and discussion on the future activities were presented. Meanwhile, associated open lectures were also held with about 120 participants.

(3) NINS Nobeyama exhibition room

The former building of the Nobeyama Millimeter Array, NINS Nobeyama exhibition room was officially opened thorough the year in cooperation with NINS and the institutes. It was open to the public at the same time as the open time of Nobeyama Campus. 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

SOKENDAI held the workshop on Radio Astronomical Observation using the Nobeyama 45-m Radio Telescope from June 4 to 8, with 8 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) Agreement on the mutual cooperation between NAOJ and Minamimaki Village

NAOJ and Minamimaki Village made an agreement on mutual cooperation to support PR activities for scientific results of NAOJ and the utilization of the facilities of NRO for the tourist and education activities of Minamimaki Village. The activities based on the agreement will be determined by an operation committee to be founded following the agreement.

(2) Hiring, Transfer (incoming)

Kiyotaka Takeda: Leader of Accounting Unit, from Shinshu University

Tosikazu Takahashi: Engineer, from Advanced Technology Center

Shunya Takekawa: Project Research Staff, hired

(3) Retirement, Transfer (outgoing)

Yasuhide Miyabara: Leader of Accounting Unit, moved to NINS

Tomio Kanzawa: Senior Research Engineer, moved to Advanced Technology Center

Hiroshi Mikoshiba: Research Engineer, retired

Takuya Wada: Engineer, retired

Masaaki Oya: Senior Specialist, retired

Mitsuhiro Matsuo: Research Supporter, retired

(4) NRO Conference Workshops and Users Meeting

- December 26-27, 2018, NAOJ Mitaka, Large Seminar Room ALMA/45-m/ASTE Users Meeting 2018 (Organizing Committee: Hiroshi Nagai (NAOJ Chile Observatory) Ken'ichi Tatematsu, Tomofumi Umemoto (NRO), Daisuke Iono (NAOJ Chile Observatory))

3. Mizusawa VLBI Observatory

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

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 2018, a total of 479 (3972 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) and EAVN (East Asian VLBI Network) observations, and others. These VLBI data, except for KaVA and EAVN, 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 calls-for-proposals with the 43, 22, and 6.7 GHz bands for semester 2018B and 2019A were released in April and September, respectively. A total of 3 proposals, which requested a total time of 84 hours, were submitted, all 3 proposals from overseas. Based on the evaluations by referees elected from scientists in related fields, the VLBI program committee decided to accept a total of 3 proposals (84 hours) in 2018B and 2019A.

(2) Science Research

In FY 2018, Mizusawa VLBI Observatory published a total of 46 refereed journal papers for scientific achievements. Among them, six papers were published by the Observatory staff and one by a student in the Observatory as PIs. Three papers were scientific results from VERA observations, two were the results from Korea-Japan international collaboration, KaVA (KVN and VERA Array), and 10 were from other domestic and international VLBI arrays based on previous studies with VERA and KaVA and from related engineering works. The most important observational result from VERA is astrometry observations of a semi-regular variable star SV-Peg. The distance of 333 pc determined by observing the H2O masers associated with SV-Peg is about three times smaller than that from the European astrometry satellite, GAIA Data Release (DR) 2, of 893 pc. The difference between VERA and GAIA DR2 could be due to the significant size of stellar photospheres which affects the error in the GAIA DR2. Thus, our results provide useful hints to improve the accuracy of Galactic astrometry based on VERA and GAIA results.

In addition, observational results from VERA are also published for detailed studies of active galactic nuclei (AGNs), such as jet motions and the evolution of a famous radio galaxy 3C84. As further extension of VERA and KaVA observations, several VLBI-related papers were published for the results from VLBA and KVN, VLBI arrays in the USA and Korea, respectively. There are also publications related to development of imaging techniques and preparatory millimeter VLBI observations for EHT (Event Horizon Telescope). Other than VLBI, the Observatory staff published results from a combination of VLBI and ALMA (Atacama Large Millimeter/Submillimeter Array) observations of high-mass star-forming regions and theoretical studies for a future international project SKA (Square Kilometer Array).

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 90 hours in total in FY 2018. 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) VLBI observation of a flare star, 2) Compact radio sources in the galactic center, 3) High-z AGNs, and 4) Fermi gamma-ray sources, have been carried out.

Some papers, proceedings, and an ATel alert were published in FY 2018 by using JVN, such as a multi-messenger observation for an NS-NS merger (Tominaga et al.), presentations in IAU Symposium 336 dedicated to astrophysical masers (Sugiyama et al., Motogi et al., Takefuji et al., Kojima et al.), ATel alert on a flare of UX Ari through collaboration between X-ray and VLBI (Iwakiri et al.). It is worth mentioning collaborating observations with X-ray groups (MAXI, NICER, etc.) indicates that JVN has potential for flexible observation along with alerts issued by transient monitoring groups.

For development study, Professor Imai (Kagoshima University) and Professor Niinuma (Yamaguchi University) are up-grading the VLBI observation system at the Nobeyama 45-m Radio Telescope by obtaining a Grant-in-Aid for Scientific Research (A). 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 2018, a total of 153 (1060 hours) VLBI observations, common use observations, large program observations, and test observations, were conducted by KaVA (KVN and VERA Array) with the 43 and 22 GHz bands. The data of the seven VLBI stations were correlated at the Korea-Japan Correlation Center at KASI Daejeon Campus in Korea.

KaVA common-use calls-for-proposals for semester 2018B and 2019A were made in April and September of 2018, respectively. In total, 22 proposals requesting a total time of 444.5 hours were submitted. Through the evaluations by referees elected from scientists in related fields and the subsequent decision made by the EAVN combined Time Allocation Committee, a total of 9 proposals (330 hours) were accepted in 2018B and 2019A.

(2) Results of Research

Science output based on KaVA is steadily increasing since the opening of the KaVA common use in FY 2014. In FY 2018, two research papers that made use of KaVA common-use data were published in peer-reviewed journals, three proceeding for an international conference were published, and one paper has just been accepted for a peer-reviewed journal in the end of March. These include the discovery of jet-cloud interaction in 3C84 (Kino et al. 2018), detailed maser monitoring for massive star-forming regions (Kim J.S. et al. 2018), and initial results from KaVA experiments with the 22/43 GHz simultaneous dual-frequency receiving system (Zhao et al. 2018). Moreover, performance evaluation of the KaVA astrometry mode has been successfully completed, demonstrating that parallax measurements within 2 kpc are now possible. The presence of KaVA is expanding in various astronomical contexts thanks to these outcomes for a variety of topics.

The three KaVA Large Programs (LP), which were launched in late FY 2015, started the 2nd term of their monitoring observations from FY 2018. Papers on various topics are currently in preparation such as M87, SgrA, and massive star formation regions (Kim J.H. 2018, Kim K.T. 2018) thanks to the accumulated data and results. These papers are planned to be submitted in the next year.

4. East Asian VLBI and Global VLBI

(1) Observations and Common Use Observations of EAVN

EAVN (East Asian VLBI Network) consists of KaVA, the Tianma 65-m, Nanshan 26-m, and Nobeyama 45-m radio telescopesIn FY 2018, a total of 41 (352 hours) VLBI observations, common use observations, and test observations, were conducted by EAVN with the 43 and 22 GHz bands. The recorded data were correlated at the Korea-Japan Correlation Center at KASI Daejeon Campus in Korea.

EAVN common-use calls-for-proposals for semester 2018B and 2019A were made in April and September of 2018, respectively. In total, 22 proposals requesting a total time of 444.5 hours were submitted. Through the evaluations by referees elected from scientists in related fields and the subsequent decision made by the EAVN combined Time Allocation Committee, a total of 13 proposals (237.5 hours) were accepted in 2018B and 2019A.

Regarding global mm-VLBI, we supported the operation of open use observations of the Event Horizon Telescope, and developed software to analyze the EHT data.

(2) Results of Research

To expand the capability of international VLBI throughout East Asia, the commissioning of the East-Asian VLBI Network (EAVN) is actively ongoing through collaboration between Japan, the Republic of Korea, and China. In FY 2018, EAVN commissioning progressed significantly, and finally EAVN open-use observations (at 22 and 43 GHz) started from late 2018, with a total of 10 stations (KaVA, NRO45, Tianma65, Urumqi).

Prior to this, the EAVN Workshop 2018 was held in PyeongChang in September, and the EAVN MoU was also concluded among NAOJ, KASI, SHAO, and XAO, which became a milestone in EAVN collaborative efforts over the past years. So far EAVN calls-for-proposals have been made twice, and several observation proposals were submitted from all over the world. Along with the commissioning, continuous efforts have been made to produce early EAVN science results by collaborating with the Event Horizon Telescope and other multi-wavelength facilities in the world, detecting active flaring events in M87.

From FY 2018, not only centimeter VLBI but also experiments for millimeter VLBI have been started in collaboration with VLBI astronomers in East Asia ("EAVN high"). The first East Asia millimeter VLBI experiment was performed using the GLT, SRAO, and SPART in March. The observations were successful and this activity will complement the global EHT observations and also EAVN at low frequencies.

5. Future Plans for SKA

In the 2018 fiscal year, the observatory established a new section, Section of Future Projects, to develop a plan for a future projects of the observatory. Three observatory staff members are in charge of this development as their main duties. They studied the Square Kilometre Array (SKA) project as a future plan of the observatory.

Since the application of the SKA sub-project submitted last year was not approved by the executive committee, the Section reconsidered the plan through continuous discussion with the stakeholders such as the SKA headquarters, the Japanese science community, and the executive committee. The Section members visited the SKA headquarters in June 2018 and obtained the understanding of the SKAO staff about Japanese minor participation and possible engineering items. A Section member also continued to attend the SKA board meetings as an observer and obtain new information about the project. The status of Japan was reported to the SKA board. The Section members discussed the participation plan with the Japan SKA consortium, and applied for the master plan 2020 of the Science Council of Japan with a strong recommendation by the Radio Astronomy Forum. The application was selected as a candidate for the next important large project by the astronomy and astrophysics committee of the council.

In parallel, the Section conducted searches for the signs of interests from universities about participation in the SKA1 construction, and made efforts to understand the community's requests. In October 2018, the Section proposed a new A-class project for the SKA to NAOJ. Through reviews by the executive committee, the SKA1 Study Group, which aims to become a project in the future, was established.

Toward development of a Japanese SKA regional center, the Section members visited Shanghai in May 2018 and had a discussion with core members of SKA-China. As one of the East Asian collaboration, through a meeting in Korea in September 2018, we decided to hold the East-Asia SKA science workshop in Shanghai in May of next year. Many Japanese scientists will attend this workshop. Regarding SKA precursors, the community hosted an international conference on ASKAP at Miyazaki in May 2018, and on MWA at Nagoya in December 2018. The Section supported them. A Section member visited Murchison, the site of MWA and ASKAP, and gathered information. About VLBI, the Section supported the organization of a VLBI Forum symposium at Mitaka in July 2018, and led the investigation of VLBI science in the SKA era. The Section also led EAVN use case development in the Japan SKA consortium.

The Section proceeded with engineering development through tight conversations with the community including participation in the community's engineering meetings. The Section intensively addressed the receiver, VLBI system, and assembly integration verification (AIV) as pragmatic options. In the receiver development, we performed the concept design study including simulations in collaboration with universities. We attended the receiver workshop held at Oxford in March 2019, and investigated the status of state-of-the-art design works. In the VLBI development, a Section member visited the SKA headquarters and clarified the work sub-packages. In the AIV development, the Section had significant progress in collaboration with the Australian team. The Section had several tele-conferences with the team, read the many documents for the critical design review, pointed out engineering issues of the AIV described in the documents, and contributed to the review as an observer.

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-T2 and AOV sessions using S and X-bands on a once per-month basis. We adopted 2 Gbps recording as the recording mode of VERA internal geodetic sessions, and the improved accuracy of geodetic solutions was confirmed by geodetic parameter estimation. In AOV sessions, wideband observation using OCTAD-OCTADISK2 was newly standardized.

In FY 2018, we participated in 8 IVS sessions and performed 20 VERA internal geodetic sessions including a joint VERA and KVN geodetic session. The final estimations of geodetic parameters were 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 has continued by post-seismic creeping, and the position of Mizusawa station moved 6.0 cm toward the South-South-West during FY 2018. And, in Ogasawara and Ishigakijima, fluctuations of the displacement by slow slip events were detected.

We carried out continuous GPS observations at VERA stations in order to monitor short term coordinate variations and to estimate atmospheric propagation delays. The propagation delays (excess pass delays) vary irregularly in time. We produce essential correction data for VERA accurate astrometry through GPS observations. The result of GPS positioning at Mizusawa shows a post-seismic motion to the East-Southeast direction even though 8 years have passed since the occurrence of the 2011 Earthquake off the Tohoku Pacific coast. The gravity change observation at Ishigakijima continued through joint work with other institutes and universities. That observation contributes to the precise field gravity survey. 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 2018, we developed two down-converters for dual polarization receiving of the K, Q-band. We installed these instruments at Ishigaki and performed VLBI experiments. In a result, we obtained good fringes and started scientific test observations with KaVA. We installed new RF direct A/Ds “OCTAD” and high-speed recorders “OCTADISK2” developed by NAOJ at all VERA stations and performed international geodetic broad band VLBI experiments. We obtained good geodetic results and it became possible to participate in international geodetic observations stably. We have developed and installed the GP-GPU correlators at the Mizusawa correlation center. 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, and VLBI back-end system development as potential items to be contributed from Japan. As a technology related to SKA, we developed the L-band patch antenna arrays, receivers with a superconductor filter, and OCTADs systems. These systems were installed at Mizusawa and Ishigaki. With regard to high frequency VLBI, we performed various development and AIV for balloon-borne radio interferometry. The system was completed and was ready to be launched in the 2018 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 Mizusawa VERA Station. The facilities have been operating stably, contributing to the determination of UTC (Coordinated Universal Time) through continuous management and operation of the time system. The NTP (Network Time Protocol) server at the Timekeeping Office provides “Japan Central Standard Time” on a network. This service has been in great demand; 5 or 6 million daily visits were recorded last year.

9. Ishigakijima Astronomical Observatory

FY 2018 was the 13th year of Ishigakijima Astronomical Observatory (IAO). Three refereed papers using the observational data of IAO were published, and the total number has reached 26. The number of visitors was 13,564 and exceeded 10,000 for the past 6 years in a row. The establishment purpose of observational study, public outreach, and regional promotion has been accomplished. The total number of visitors since FY 2006 reached 130,000 in October. The number of foreign tourists has increased from 795 in the previous year to 858.

In terms of the research, we observed 73 objects for 114 nights including joint observations with Japanese universities and two international projects of JOVIAL for detection of Jupiter oscillation with Japan, France, and the United States and GROWTH with Tokyo Institute of Technology (Tokyo Tech), California Institute of Technology (Caltech) and others. As the achievements of these studies, refereed papers on X-ray binary black hole MAXI J1820+070, comet 2P/Encke, and Near-Earth Objects were published.

In regards to education, more than 1,000 people visited IAO in group visits of elementary and junior high schools and inspections by government offices. The lifelong study for Okinawa prefectural inhabitants, 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. We contributed to regional education through the support of the graduation research of two students and the lectures for “Certification of Astronomy Guides” (77 participants) held in the university.

As for the public outreach, five special events were held. A total of 675 people attended the Golden Week event in seven days. The star party for Mars, Jupiter, and Saturn welcomed 68 people in two days. Also, 475 people visited IAO during the “Southern Island Star Festival” event in nine days. The star party for Comet 46P/Wirtanen welcomed 33 people in two days. A total of 63 people attended the spring vacation event “Urizun Starry Sky Class” in two days.

A total of 3,098 people took part in the 17th year of the “Southern Island Star Festival” which is co-hosted with Ishigaki City held from August 11 to 19. And 400 people attended the star festival held in Iriomote Island co-sponsored with the Yeayama Greater Metropolitan Area Affairs Association. Also 100 people joined in the weather class for families co-hosted with Ishigakijima Local Meteorological Observatory.

On the other hand, the “Stamp Rally” was held in July through collaboration between IAO and Nayoro Observatory KITASUBARU with which IAO concluded an exchange agreement.

By the deadline at the end of February, 17 people who collected the stamps of both observatories applied. The anniversary gifts were presented to 6 people among them by lottery. We cooperated with conferences held in Ishigaki Island including the “48th Comet Conference” (45 participants) in June and “Cosmic Shadow 2018” (44 participants) in November, and a lot of astronomers joined in the group visit of IAO. Thus, IAO plays a part in research exchange promotion.

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 15, 2018: the Ninth Open Observatory Event held at the Ibaraki University Center for Astronomy, and NAOJ Mizusawa VLBI Observatory, Ibaraki Station, with a cumulative total of 473 visitors in attendance.

From August 11 to August 19: “The Southern Island Star Festival 2018” held together with special open house events at the VERA Ishigakijima Station and Ishigakijima Astronomical Observatory with approximately 3,000 visitors to the whole “Star Festival.” Events included the astronomical observation party at Ishigakijima Astronomical Observatory, attended by 475 visitors; and the special public opening of the VERA Station attended by 306 visitors.

On August 11: Special open house of VERA Iriki station held jointly with “The Yaeyama Highland Star Festival 2018,” with approximately 3,800 visitors in attendance.

On August 18: “Iwate Galaxy Festival 2018,” open house of NAOJ Mizusawa Campus, held with 1,521 visitors in attendance.

On February 10, 2019: “Star Island 18,” open house event of VERA Ogasawara Station held, with 248 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. except during the New Year’s season and other closures.

The numbers of visitors to each facility is as follows,

a) VERA Mizusawa Observatory 19,666
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 1,388

c) VERA Ogasawara Station 9,580

d) VERA Ishigakijima Station 2,844

e) Ishigakijima Astronomical Observatory 13,564
[including Stargazing sessions (5,077): Evenings on Saturdays, Sundays, and Holidays. and “The Starry Sky Study Room” (featuring the 4D2U “Four-Dimensional Digital Universe”, 4503) in Ishigakijima Astronomical Observatory]

11. Education

(1) University and Post-Graduate Education

Regarding postgraduate education, Mizusawa VLBI Observatory assisted 1 doctor and 2 master course graduate students from the University of Tokyo, and 2 doctor and 1 master course graduate students from SOKENDAI with their research. Three of them are from foreign countries. In addition, one master course student from Yamaguchi University was accepted for education and got his master's degree. One undergraduate student from the University of Tokyo was accepted as a summer student of SOKENDAI in Mizusawa and Mitaka. 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 14-17 at the Nishihara main campus and were opened to the public at the satellite campuses. Observational workshops were held at Ishigakijima Astronomical Observatory from August 27-29, with about 26 participants. Two undergraduate students of the University of the Ryukyus got support of their graduate studies in Ishigakijima Astronomical Observatory.

The lectures for “Certification for Astronomy Guides” held in the University of the Ryukyus were given. 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. (2) Research experience for high school students

During August 13-15, the VERA Ishigakijima Station and the Ishigakijima Astronomical Observatory held “The Churaboshi Research Team Workshop” for 11 local high school students including 6 from locations outside of Ishigaki Island, such as the Okinawa main island and Tochigi Prefecture. It was organized under support from JSPS, and an Observatory staff member was honored by JSPS for this continuous promotion activity. “The 12th Z Star Research Team Event” was held August 13-15 to use the VERA Mizusawa antenna for observation. A total of 12 high school students from the Tohoku region were accepted for research experience.

4. 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 pursue cutting-edge solar science through 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 have joined in 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 three from SSO: Y. Katsukawa as secretary, Y. Suematsu for SOT, and H. Hara for EIS. The Science Schedule Coordinators (SSC) have been organized to leverage the open-use observation system. Two Japanese members from NAOJ (T. Sekii for SOT and T. Watanabe, professor emeritus, for EIS) join the SSC activity. The SSC serve as a contact point for observation proposals from world solar physics researchers to use Hinode and promote joint observations between Hinode and the other science satellite or ground-based observatories.

FY 2018 corresponds to the second year of the third mission-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 and 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 filtergraphic instrument which was terminated in February 2016. New science results have been obtained via joint observations with SDO, IRIS, and ALMA as well as long-term standalone observation by Hinode. The number of Hinode related refereed papers published in FY 2018 is 105, and further achievements are expected in the coming years. The power switch of EIS suddenly turned off on January 21, 2018 and its science operation was suspended for a long time beyond the end of the fiscal year in order to prepare for the recovery procedure with careful event analysis and to prioritize joint observations with ALMA. The recovery operation of EIS was successfully completed in May 2018. Since then, the science observations keep running without any issues.

The 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 past 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 (MDAS), and the new SDAS: Solar Data Archive System, has started since FY 2018 for the archiving and public release of the solar data. SSO is jointly operating SDAS with ADC and the open-use data analysis system of Hinode data is maintained under MDAS.

2. Ground-based Observations in Mitaka Campus

Full-disk observations of the Sun have been carried out in the western area of 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), Grant-in-Aid for Scientific Research on Innovative Areas. In FY 2018, we introduced a polarization modulation device synchronized with the H2RG camera, and conducted actual polarization observation of the Sun at the Hida Observatory, Kyoto University.

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 2018 corresponds to the 101st year 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.

3. Nobeyama Solar Radio Polarimeters

Although 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 radio polarimeter 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. It is noted that starting from FY 2019, SSO will take over responsibility for the operation and maintenance of the radio polarimeter in place of NRO.

4. Cooperation with SOLAR-C Project Office

SSO jointly worked for the proposal of the UV-EUV Spectroscopic Telescope (Solar-C_EUVST) mission to JAXA in January 2018 by using the opportunity provided by the JAXA Competitively-chosen Middle-class Satellite Mission and for the update of the proposal documents to proceed to the next mission definition phase; Pre-Phase-A2 in FY 2019. SSO also supported technical studies for CLASP-2; scheduled to launch in the spring of 2019, and the Sunrise-3 balloon-borne experiment scheduled in the summer of 2021.

5. Educational Activity

SSO staff accepted and is supervising three Ph.D. course students and two Master course students from University of Tokyo and Tohoku University, and two postdocs (Specially Appointed Research Staff) belong to SSO. Two members (Y. Katsukawa and H. Hara) contributed to the undergraduate course lectures in astronomy at the University of Tokyo.

6. 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 interview requests, and providing materials to the media, etc. Since solar VR contents developed for the exhibition at the FY 2017 NAOJ open house were well-received by visitors, SSO started the distribution of the software for smartphones from July 2018. The campaign observations with Hinode joined by Japanese junior-high/high (JH/H) school students: titled as “Let’s observe the Sun with Hinode 2018” were carried out twice from July 23 to 28 and from August 6 to 11.

7. 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 12th meeting held September 10 to 13, 2018 in Granada, Spain. The number of participants and papers were 142 and 143, respectively. SSO co-organized a solar physics community meeting: ‘JSPC (Japan Solar Physics Community) Symposium’ (February 18–20, 2019 at Nagoya University).

8. Others

The 10-cm coronagraph of the former Norikura Solar Observatory relocated to Yunnan, China and is used for corona observation in China. The observational situation is disclosed on a web page. In Fiscal Year 2018, staff from both Japan and China visited each other to advance the improvement of the coronagraph.

In Peru, astronomical instruments from SSO have been installed, and SSO is promoting the use of a coelostat and spectrograph at Ica University in collaboration with Kyoto University for astronomical education and research in Peru. In addition, it is also under discussion to transfer to Peru the so-called “new coronagraph” (diameter 10 cm) of the former Norikura Solar Observatory.

Y. Katsukawa of SSO has been a member of the Science Working Group of the Daniel K. Inouye Solar Telescope (DKIST), a 4-m telescope under construction at Haleakala, Hawai‘i. Aiming at participating in DKIST, SSO staff cooperated for the development of the Critical Science Plan of DKIST. In addition, a taskforce team for DKIST participation was established with members including university staff, and applied for a research fund to promote research personnel exchange with DKIST. Furthermore, with the aim of providing DKIST focal plane equipment, we are working for the development of new instruments, applying for external research grants.

In Europe, another 4-m solar telescope (EST) is now in the planning stage. SSO is participating in the board meetings as an observer to watch the progress, and joining the SOLARNET project (January 2019 to December 2022) of the European solar community to develop a proto-type IFU for EST.

Three visiting professors, Prof. K. Kuzanyan from Russia, Dr. J. Shin from Korea, and Dr. M. J. Thompson from the USA (who passed away during the stay), stayed at NAOJ over an extended period for collaborative studies of the Sun. For one month from February 10, 2019, Dr. M. Demidov from Russia stayed as a resident researcher and conducted joint research on solar magnetic field and polarization measurement.

Regarding personnel affairs, T. Iju was assigned from April as a Specially Appointed Senior Specialist, in place of K. Yaji. Specially Appointed Research Staff, Dr. K.-S. Lee retired at the end of December 2018 and Dr. A. Joshi retired at the end of March 2019. In their place, Dr. T. Matsumoto has been appointed as Specially Appointed Research Staff from April, 2019.

5. NAOJ Chile Observatory (NAOJ ALMA Project / NAOJ Chile)

The ALMA Project is a global partnership of East Asia (led by Japan), Europe, and North America (led by the United States) in cooperation with other regions 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.

As of January 1, 2019, the NAOJ ALMA Project was spun off from NAOJ Chile Observatory, which was renamed NAOJ Chile. The mission of the NAOJ ALMA Project includes: executing the functions of the East Asian ALMA Regional Center to provide support to East Asian users; coordinating activities in Chile; preparing future project plans; and making budget requests. On the other hand, the main mission of NAOJ Chile is to manage and oversee the NAOJ researchers working for the Joint ALMA Observatory (JAO) and to support the on-site operations of ALMA in Chile. From October 2018, the NAOJ ALMA Project is led by Alvaro Gonzalez as Project Manager. On January 1st 2019, Shin'ichiro Asayama was appointed Head of NAOJ Chile.

1. Progress of the ALMA Project

ALMA scientific observations and commissioning observations are currently underway. Commissioning observations include new capabilities in solar and polarization observations. In these activities, Masumi Shimojo has led the planning of the interferometric part of the solar observations as well as the performance verifications, leading to the opening of the Band 7 capability for ALMA open-use. Koichiro Nakanishi and Hiroshi Nagai have contributed to the polarization tests. Also, Hiroshi Nagai has participated in the international working group established to realize “The ALMA Development Roadmap” to expand ALMA’s capabilities and to produce more exciting science in the coming decade. In addition, the sub-components developed by Japan such as the antennas, correlators, and receivers (Bands 4, 8, and 10) are all working properly.

2. ALMA Open-Use and Scientific Observations

The seventh round of ALMA open-use observations commenced in October 2018 as Cycle 6. The main capabilities of Cycle 6 include: interferometric observations using at least forty-three 12-m antennas; Atacama Compact Array (ACA) observations (interferometric observation with at least ten 7-m antennas and single-dish observations with at least three 12-m antennas); eight frequency bands (Bands 3, 4, 5, 6, 7, 8, 9 and 10); and maximum baselines are 16.2 km for Bands 3, 4, 5, and 6, 8.5 km for Band 7, and 3.6 km for Bands 8, 9, and 10. In addition to these, Cycle 6 continuously provides: open-use opportunities for Target of Opportunity (ToO) Observations; Large Programs that exceeds 50 hours on the 12-m array or 150 hours on ACA in stand-alone mode; millimeter-wavelength VLBI; ACA stand-alone mode, solar observations, and polarization observations. Furthermore, Cycle 6 provides circular polarization observations for Bands 3 to 7 and ACA in stand-alone mode for Band 8, as well as extended IF bandwidth for Band 6. In response to the Cycle 6 Call for Proposals, there were submissions of 1,836 proposals from all over the world.

The call for the eighth round of open-use observations was issued as Cycle 7. The Cycle 7 capabilities will include: interferometric observations using at least forty-three 12-m antennas; and ACA observations (interferometric observation with at least ten 7-m antennas and single-dish observations with at least three 12-m antennas). Cycle 7 will cover eight receiver bands (Bands 3, 4, 5, 6, 7, 8, 9, and 10), and the maximum baselines will be 16.2 km for Bands 3 to 7, and 3.6 km for Bands 8 to 10. Especially notable new capabilities of Cycle 7 are: Band 7 observations with the maximum baseline of 16.2 km which will provide an improved spatial resolution of 10 milli-arcsec; solar observations in Band 7; and improved observing efficiency for spectral scans. The Call for Proposals for Cycle 7 was closed at 24:00 JST on April 17, 2019, and Cycle 7 observations are scheduled to start from October 2019. Meanwhile, a stand-alone ACA supplemental call for proposals is scheduled to be issued during the period of Cycle 7 aiming to maximize the scientific output of ACA. The proposal submission deadline is set at 24:00 JST on October 1, 2019 and the start of observations is scheduled in January 2020.

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

An international team of astronomers led by Takuya Hashimoto at Osaka Sangyo University/the National Astronomical Observatory of Japan observed the distant galaxy MACS1149-JD1 and detected an emission line of doubly ionized oxygen [OIII]. From the measured redshift $z = 9.11$, they found that the observed galaxy is located 13.28 billion light-years away. It was the most distant galaxy with oxygen ever detected by any telescope, and also the most distant galaxy ever whose distance was accurately derived from spectral observations. Combining their results with the data taken with the Hubble Space Telescope indicated that the star formation in the galaxy started approximately 250 million years after the Big Bang. These research results will be key to unveiling the star forming process at the early stage of the Universe.

A research group led by Nami Sakai at RIKEN observed the protostar IRAS 04368+2557 and revealed that the planetary planes in the inner and outer parts of the gas disk around the star are misaligned. This is the first time such a warped disk structure has been found in an infant protostar that has no companion star. Although it was already known that many extrasolar systems have planets that are not lined up in a single plane, these findings imply that the misalignment of planetary orbits in many planetary systems may be caused by distortions in the planet-forming disk early in their existence.

The research team led by Jeong-Eun Lee at Kyung Hee University (Korea) and Yuri Aikawa at the University of Tokyo observed the young star V883 Ori and detected complex organic molecules including methanol, acetaldehyde, and acetone in the protoplanetary disk around the star. Also, they successfully obtained the spatial distribution of methanol and acetaldehyde inside the disk. It is assumed that various molecules are being released into space from the sublimation of ice in the disk by a sudden flare-up of this young star. These findings have been attracting scientific attention as a key to unveiling the chemical composition of ice in protoplanetary disks that has yet to be explored in detail.

3. Educational Activities and Internship

During summer holidays of universities, the NAOJ Chile Observatory accepted six undergraduate students, four of which were involved in research activities in Mitaka and other two in Chile. Also, the NAOJ Chile Observatory accepted one post-doctoral fellow as a visiting researcher for a month from the University of Concepción (Chile).

A website called “ALMA Kids” was opened to provide fun, educational content about the ALMA telescope and its scientific outcomes for kids. Following the debut in English, Spanish, and Chinese, the Japanese version became available in FY 2018. ALMA Kids will introduce various scientific observation results as well.

4. Public Outreach Activities

Achievements of ALMA scientific observations and test observations were covered by over 70 newspaper/journal articles and 9 television/radio programs, featuring observation results with ALMA achieved in various fields of astronomy. In particular, the detection of oxygen in a galaxy located 13.28 billion light-years away with ALMA was reported on news programs called “Ohayo Nippon” on NHK G channel, “FNN Prime News” on Kansai Television, and “Hiruobi” on MBS in May 2018. It was also covered by over 980 news websites worldwide. As represented by these figures, scientific results made by Japanese researchers are becoming increasingly visible overseas.

The NAOJ ALMA website posted 30 news articles and 12 press releases this year. In addition to these, many articles were added to the site such as review articles about ALMA research themes and interviews with ALMA staff members. A mailing-list-based newsletter has been issued on a monthly basis with approximately 2,500 subscribers. Updated, detailed information is provided on Twitter (@ALMA_Japan), with nearly 42, 900 followers as of the end of FY 2018.

In May 2018, the NAOJ Chile Observatory hosted a week-long ALMA booth at the Japanese Geoscience Union Meeting held in Makuhari Messe. The public lectures and Science Cafe events were organized on 17 occasions in FY 2018 to make the current status and achievements of ALMA widely known through dialogue with visitors.

From the mid-March 2015, ALMA started to accept public visitors to the ALMA Operations Support Facility (OSF) at an altitude of 2,900 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 watching videos on ALMA. The registration often reaches the full capacity soon after the start of registration every weekend. Public visits to ALMA are good opportunities to provide many people with live experience at the workplace of ALMA researchers. The number of public visitors in FY 2018 was 3,904 people.

On August 17, 2018, 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 (a small piece of colored paper), TANABATA star festival was celebrated with tanzaku decorations on bamboo stalks and a star party. The event was a great opportunity to make more people in the local community familiar with the ALMA project and NAOJ while promoting international friendship.

5. International Collaboration (committees, etc.)

In the international ALMA project, meetings are held frequently by various committees. In FY 2018, 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 respective tasks in the international project

6. Workshops and Town Meetings

- April 4, 2018 ALMA Cycle 6 Town Meeting and Proposal Workshop at Mitaka
- December 14 to 15, 2018 East Asian ALMA Development Workshop 2018 at Osaka Prefecture University
- December 17 to 19, 2018 East Asian ALMA Science Workshop at I-site Namba
- December 26 to 27, 2018 ALMA/45m/ASTE Users Meeting at Mitaka

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. Project Research Staff Changes

(1) Hired
- Benjamin Wu: Project Research Staff
- Nguyen Duc Dieu: Project Research Staff
- Tomoko Sato: Project Research Staff (secondment to Tohoku University)
- Tom Bakx: Project Research Staff (secondment to Nagoya University)
- Yuichi Higuchi: Project Research Staff (secondment to Kindai University)
- Seokho Lee: Project Research Staff (secondment to Tokyo Institute of Technology)

(2) Departed or transferred
- Salinas Nicolas: Project Research Staff
- Minju Lee: Project Research Staff
- Takuya Hashimoto: Project Research Staff

9. Main Visitors

- November 30, 2018
  Ambassador of the Republic of Korea to Chile and his party visited the ALMA site.

10. Progress of ASTE Telescope

The ASTE telescope has been operated by a consortium including universities mainly for the purpose of promoting full-fledged submillimeter astronomical research in the southern hemisphere and developing/verifying observational equipment and methods required for the submillimeter astronomy. As the ALMA telescope started its operation phase in FY 2012, the operation policy of ASTE was revisited to utilize ASTE as a telescope to provide observational evidence for strengthening ALMA observation proposals and promote development for the enhancement of ALMA's future performance too. 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. Also, ASTE is making a significant contribution to developing the skills of young researchers who will play key roles in the equipment development for the next generation.

Due to the failure of the azimuth drive that occurred on November 21, 2017, the open-use program in FY 2018 was suspended as scheduled in the annual plan in order to focus on the repair work of the drive mechanism for the operation in FY 2019. The drive mechanism was recovered by the end of March 2019 using high-price, long-lead items that were purchased by saving the operating costs. On the other hand, the malfunction of the subreflector control computer that was found in mid-March 2019 remained unsolved and will be carried over to the next fiscal year.

In the development, there were improvements in the functions of the mixer and the reference signal input system of the new 345 GHz heterodyne receiver. In particular, the receiver noise was improved from 400 K to 90 K in the 330 GHz band which affects the observations of the ^{13}CO (J=3–2) emission line and in the 355–365 GHz band as well.

Although the open-use program was not carried out in FY 2018, the project drove forward preparations for the observations not implemented either in FY 2017 or FY 2018 and issued the call for proposals for the first semester of FY 2019. For the limited 200-hour observation time, nine proposals were received from the East Asian community. As a result of the proposal evaluation by the Millimeter/submillimeter Program Subcommittee, three proposals were fully and another three were partially adopted. In addition to these, two proposals were adopted for the time allocated to Chile.

In 2018, a total of 17 peer-reviewed papers were published, which far exceeds the average number over the past years (approximately 10 papers a year on average). It was a comparable level to the number achieved in FY 2011 (19 papers) and in FY 2012 (18 papers). Among the published 17 papers, 11 papers were written by Japanese researchers outside NAOJ and three by overseas researchers, while the remaining three are related to instrument development.

In accordance with the new internal policy to make small projects more visible, ASTE reviewed its project goals and recalculated the required number of personnel and costs to make an application as an A project (to operate a small-scale telescope).

6. 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, the special-purpose computer for gravitational many-body problems, and a general-purpose PC clusters for small-scale calculations, carrying out research and development of computational astrophysics, and performing astronomical research with simulations. The new main supercomputer of the present system renewed in 2018, ATERUI II (Cray XC50), has a theoretical peak performance of 3 Pflops, which is the world's fastest supercomputer for astronomy. CfCA also continued operation of other computers such as GRAPE-DR and GRAPE-9 that are dedicated to gravitational many-body problems, in addition to the reinforcement of the general-purpose PC cluster. Efforts in visualizing astronomical data also continue.

2. Open Use

(1) Computer Systems

This year marked the first year of the upgraded astronomical simulation system, which includes the new open-use supercomputer Cray XC50. It is installed and under operation at Mizusawa VLBI Observatory. The users have been making academically significant progress as before.

While XC50 is leased for six 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) together with several GPU nodes; 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. The center undertook development, improvement, and maintenance for both hardware and software for the system this year.

Computational resources are allocated to the XC50, GRAPE’s including GPU, 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 141 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 XC50)

● Operating Hours
  Annual operating hours: 7108.8
  Annual core operating ratio: 92.71 %

● Number of Users
  Category S: 2 adopted in the first term, 1 in the second term; total 3
  Category A: 9 adopted at the beginning of the year, 0 in the second term; total 9
  Category B+: 21 adopted at the beginning of the year, 3 in the second term; total 24
  Category B: 106 adopted at the beginning of the year, 16 in the second term; total 122
  Category MD: 15 adopted at the beginning of the year, 5 in the second term; total 20
  Category Trial: 53, year total

(Statistics on the GRAPE system)

● Number of Users
  5 (at the end of the fiscal year)

(Statistics on PC cluster)

● Operation stats
  Total number of submitted PBS jobs: 393,071
  Annual core operation ratio by users’ PBS jobs: 87.73 %

● Number of Users
  48 (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 XC50 workshop for beginning users:
  August 1, 2018, 16 attendees

● Cray XC50 workshop for intermediate users:
  August 2, 2018, 20 attendees

● iSALE tutorial sessions
  August 6–8, 2018, 10 attendees

● Hydrodynamics simulation school
  February 19–21, 2019, 33 attendees

● Users meeting:
  January 15–16, 2019, 65 attendees

● *N*-body simulation Spring School
  February 4-6, 2019, 12 attendees

3. PR Activity

In FY 2018, the following press releases were issued from the center:

- "Supercomputer Astronomy: The Next Generation"
  June 1, 2018, Center for Computational Astrophysics
- "New Mystery Discovered Regarding Active Asteroid Phaethon"
  June 29, 2018, Takashi Itoh (CfCA) et al.
- "Veiled Supernovae Provide Clue to Stellar Evolution"
  September 4, 2018, Takashi Moriya (Division of Theoretical Astronomy, NAOJ) et al.
- "Cosmological Constraints from the First-Year Subaru Hyper Suprime-Cam Survey"
  September 26, 2018, Chiaki Hikage (Kavli IPMU, the University of Tokyo) et al.
- "Little Supernova is Big Discovery: the Origin of Binary Neutron Stars"
  October 12, 2018, Takashi Moriya (Division of Theoretical Astronomy, NAOJ) et al.
- "Black Hole 'Donuts' are Actually 'Fountains'"
  November 30, 2018, Takuma Izumi (Subaru Telescope) and Keiichi Wada (Kagoshima University) et al.
- "Fusion Science and Astronomy Collaboration Enables Investigation of the Origin of Heavy Elements"
  March 12, 2019, Daiji Kato (National Institute for Fusion Science) and Masaomi Tanaka (Tohoku University) et al.

In FY 2018, as the operation of the new supercomputer system "ATERUI II" started, communication activities for media and general public were vigorously conducted. On June 1, 2018, we had a press conference at NAOJ Mizusawa Campus (Presenters: Prof. Eiichiro Kokubo/CfCA, Prof. Mareki Honma/Mizusawa VLBI Observatory, Mr. Mamoru Nakano/Cray Japan Inc.) and showed ATERUI II to the journalists. On June 13, 2018, CfCA and the Public Relations Center held the astronomy lecture for science reporters "The Universe depicted by simulations — Five Years of the Supercomputer ATERUI and the Next Generation System —" in Tokyo. Three researchers (Prof. Eiichiro Kokubo/CfCA, Dr. Tomoya Takiwaki/CfCA, Dr. Tomoaki Ishiyama/Chiba University) gave talks about the research results from ATERUI and the progress expected with ATERUI II. The press conference and lecture resulted in a lot of coverage about ATERUI II, not only in the local media in Mizusawa but also on television and in newspapers and scientific magazines across the country. Furthermore, on July 8, 2018, the NAOJ Public Lecture "ATERUI's Challenge to The Unknown Universe — The Universe Depicted by a Supercomputer —" was held at the Oshu City Cultural Hall with 156 guests in attendance. Three researchers (Prof. Eiichiro Kokubo/CfCA, Dr. Masaomi Tanaka/Tohoku University, Dr. Junichi Baba/JASMINE Project) reported the results of ATERUI. In addition to these events, we also produced a video introducing ATERUI II, and published a CfCA special issue of NAOJ News in August 2018.

The center took part in the special open house of Mizusawa Campus, Iwate Galaxy Festival 2018, held on August 18, 2018. About 160 visitors attended the ATERUI II guided tours and experienced a close-up view of the facility. At the Mitaka open house held on October 27, 2018, CfCA made the computer room accessible to the public and introduced simulation astronomy with GRAPE and the PC cluster. A Twitter account @CfCA_NAOJ and YouTube channel have been operated to provide the information on CfCA.

4. 4D2U Project

In FY 2018, the 4D2U project continued to develop and provide movie contents and software. A simulation movie titled "Collisional Growth of Dust" was released on the 4D2U website in December 2018, and "Chariklo's Double Rings" was released in January 2019. These movies were also published on the 4D2U YouTube channel with a format for VR on smartphones. A domemaster version for planetariums was also distributed.

The updated version 1.5.0 of the four-dimensional digital universe viewer, "Mitaka," was released in July 2018. This version of Mitaka included new functions, e.g. displaying the Milky Way map generated by Gaia DR2 data and the all sky map of H-alpha emissions. In addition, other updates were made such as making it easier to change the line of sight. Version 1.5.1 of Mitaka was released in January 2019. The position accuracy of the Sun, planets, and the Moon over long periods of time was improved, which makes it possible to reproduce past and future solar and lunar eclipses with better accuracy.

In FY 2018, demonstrations of Mitaka VR were given during the open campus days of Mizusawa. In addition, at the open campus of Mitaka, in cooperation with the Division of Theoretical Astrophysics, we gave a mini lecture entitled "Theoretical Astronomy Frontiers" using 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 and Tomohisa Kawashima were engaged as project assistant professors. A Boltzmann based general relativistic radiation-MHD code was developed, and some test problems were successfully solved by the code. It was found that our new code can give more accurate radiation fields in the regions above the accretion disks than the conventional code base on the moment method. In addition, the spectra of the super-Eddington flows around black holes as well as neutron stars were calculated by a general relativistic radiation transfer code (RAIKOU). We found that the hard X-rays are diluted via the electron scattering which occurs above the disks. The reduction of the hard X-rays is more effective for the neutron star case than for the black hole case. RAIKOU succeeded in calculating the black hole shadow of M87.

Representing CfCA, Professor Kohji Tomisaka and Project Visiting Professor 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 detailed hardware specifications of the Post-K system were finally opened to the public, and broad discussions are now underway about the kinds of software applications that should/could be run on it.

6. Staff Transfers

● Staff members hired in this FY
(Assistant Professor) Iwasaki, Kazunari
(Project Assistant Professor) Kawashima, Tomohisa
(Specially Appointed Research Employee) Ishikawa, Shogo; Taki, Tetsuo
(Senior Specialist) Fukushi, Hinako; Hohokabe, Hirotaka
(Research Supporter) Ideguchi, Shinsuke; Hohokabe, Hirotaka
(Dispatch Staff) Osada, Noriko

● Staff members who departed in this FY
(Project Assistant Professor) Takahashi, Hiroyuki
(Senior Specialist) Oshino, Shoichi
(Research Expert) Kato, Tsunehiko
(Research Supporter) Ideguchi, Shinsuke; Hohokabe, Hirotaka
(Dispatch Staff) Osada, Noriko

7. Gravitational Wave Project Office

Since the first direct detection of gravitational waves from a black hole merger in 2015, the field of gravitational wave astronomy has been expanding at ever increasing speed. The detection of gravitational waves from the merger of binary neutron stars in 2017 together with the intense follow-up observations marked the beginning of multi-messenger astronomy. The Gravitational Wave Project Office (GWPO) has been putting most of its resources into the construction of KAGRA, a large-scale Japanese gravitational wave detector. By the end of FY 2018, most of the KAGRA components were installed and the project entered the commissioning phase, aiming to start observations in the fall of FY 2019.

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 has been divided into several phases which gradually upgrade the interferometer to its final configuration. In April 2018, KAGRA demonstrated the first operation of a km-scale cryogenic interferometer with a simple Michelson configuration. This test operation provided us with critical information regarding cryogenic operation of a large underground interferometer. Throughout the rest of FY 2018, the NAOJ GWPO worked hard to install all the remaining components necessary to operate the full-configuration KAGRA interferometer.

The NAOJ GWPO is contributing to several aspects of the project. 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 optical components from the ground vibrations. We have developed four different types of vibration isolation systems, of different complexities, to meet varied isolation requirements of different components. In this fiscal year, we completed the assembly and installation of all the isolation systems necessary for the operation of the full-configuration KAGRA interferometer. In particular, in FY 2018, we have installed two of the world's largest isolation systems, for the cryogenic mirrors, each suspension with a length of 13.5 m, and three large isolation systems for room temperature mirrors. Basic damping control of those isolation systems has been implemented and the optimization of the performance is ongoing.

(2) Auxiliary Optics

The auxiliary optics subsystem (AOS) is responsible for providing optical components for stray light control, optical angular sensors, beam reducing telescopes (BRTs), beam-monitoring cameras and optical windows. Highlights of the activities in FY 2018 include the large optical baffles such as wide-angle baffles (WABs) and narrow-angle baffles (NABs) for stray light mitigation and the BRTs. We have completed the installation of four WABs and four NABs on schedule without impacting the KAGRA schedule. We have also installed a BRT at the end of the X-arm of KAGRA on time. Combined with the other BRT installed at the Y-end in the last fiscal year, all the required BRTs are ready now for KAGRA, and they have been indispensable for commissioning milestones such as the first optical resonance in KAGRA's arm cavity. Moreover, we installed a vibration isolation stage for one of the BRTs earlier than previously planned. ATC provided us with great support in mechanical/thermal/optical design, assembly work, and modifications.

(3) Mirror Characterization

In FY 2018 we completed the upgrade of the PCI (photothermal common-path interferometer) system. This system is used to measure the optical absorption of mirrors and coatings. Low absorption is critical for the cryogenic operation of KAGRA. In FY 2018, several different sapphire samples were measured to gather statistics and understand the physical processes that lead to high absorption. During the characterization process we collaborated with three different Japanese crystal makers; their crystals were successfully characterized, and the results were shared with the crystal makers so as to improve the production process. Thanks to these measurements, our understanding of the relationship between the crystal lattice properties and the absorption losses greatly improved.

2. R&D

(1) R&D for upgrades to 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 capability to develop a 300-meter-long high-finesse filter cavity, which in the last year has been extensively characterized, showing results that exceed expectations. Those results were published in July in PRD. The frequency-independent squeezed light source has been finalized in this FY and the first frequency-independent squeezing was measured at the end of

January. Thanks to this experiment, we established long-term collaborations and welcomed many visitors from abroad.

The absorption measurement bench developed to characterize the KAGRA mirrors is also used to study the performance of crystalline coatings, a possible solution to reduce coating thermal noise. We characterized various mirrors (different size, coating transfer method, etc.). The implementation of a self-calibration technique for GaAs crystalline coating has been started and will continue in the next FY.

We are also developing a facility to directly measure the coating thermal noise at cryogenic temperatures using a folded cavity with multiple higher-order modes. In order to gain experience in this scheme, we collaborated with the MIT group to measure room-temperature coating thermal noise using their system.

(2) Space GW detectors

Just like electromagnetic observations, different wavelengths of gravitational waves give different pictures of the Universe. This motivates us to build GW detectors capable of detecting lower frequency gravitational waves. There are already several proposals around the world for low frequency GW detectors like spaceborne detectors and atomic interferometers. In this fiscal year, a few members of the group joined the Japanese LISA consortium to be led by JAXA to contribute to the LISA project (target: ~mHz) and/or acquire experience in space gravitational-wave detectors. At the same time, discussion on how to bring forward the DECIGO project (target: ~0.1 Hz) continues. Some discussions with new members for expanding the project collaborators were held in the annual DECIGO workshop. Such a large project needs international collaborations, and we also expect to gain experience on that from LISA.

3. Education

During FY 2018 the GWPO included among its members two graduate students from the University of Tokyo and three from SOKENDAI. Two of them successfully defended their PhD theses and graduated by the end of March 2019. During the same period the office hosted in total 6 students from the University of Tokyo, the Sapienza University of Rome (Italy), National Tsing Hua University (Taiwan), Beijing Normal University (China) and Université Savoie Mont Blanc (France). All of them worked at NAOJ for six months. The office also hosted an undergraduate student with the SOKENDAI summer student program. The members of the office gave lectures at the University of Tokyo and SOKENDAI on gravitational waves and at Hosei University on fluid mechanics.

4. Outreach

In FY 2018, members of our office joined a press release on an ultra-sensitive gravity measurement device, gave 4 public lectures at a public library, public schools and so on, and wrote an article for a popular science magazine. We also accepted many visitors to TAMA300 (over 700 people) and KAGRA (over 140 people), including a BBC team shooting an interview about KAGRA.

5. International Collaboration and Visitors

During FY 2018, a PhD student from the Chinese University of Hong Kong visited the Kamioka branch of NAOJ for approximately 5.5 months to work on the topic of optimizing the control systems/schemes for the KAGRA VIS. The Kamioka branch also received visits from one researcher from the Center for Measurement Standards (Taiwan) for two weeks, and from one PhD student from the Wuhan Institute of Physics and Mathematics (China) for 3 months. Apart from KAGRA, the GWPO continued its collaborations with CNRS/APC (France), Beijing Normal University (BNU, China), and National Tsing Hua University (NTHU, Taiwan) on the development of a frequency dependent squeezed vacuum source at TAMA. For this research, we received visits by scientists/engineers from CNRS, BNU and NTHU. The office also received visits from PhD students from BNU, Institut d'Optique Graduate School (France), and Université Savoie Mont Blanc (France) for a total duration of four months. One postdoc each from the Max Planck Institute (Germany) and the Università degli Studi di Padova (Italy) visited our office under the NAOJ Visiting Joint Research Program. One of our PhD students visited MIT (US) for 3.5 months under the SOKENDAI Student Dispatch Program and another spent one month at Laboratori Nazionali Di Legnaro (Italy) under the SOKENDAI Overseas Travel Fund.

6. Publications, Presentations and Workshops Organization

The office members were authors of 22 publications in international journals and of 9 presentations at international conferences. There were also 20 presentations given at conferences in Japan.

During FY 2018, the 21st KAGRA Face to Face Meeting was held on December 5 and 6, 2018 at NAOJ Mitaka campus, and 118 scientists from around the world participated in this international conference.

7. Acquisition of External Funds

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

8. Staff

During FY 2018 one project research staff (project research fellow) was hired as a researcher at the Institute for Cosmic Ray Research (ICRR), University of Tokyo after the expiration of his term of office at the GWPO. Another project research staff (project research fellow) moved to a JSPS foreign research fellow position. As of March 31, 2019, the total number of GWPO staff reached a count of 21 members, including 11 research and academic staff (including 1 specially appointed and 1 affiliated researcher), 1 engineer, 1 project research staff (project research fellow), 1 project research staff member, 2 senior specialists, 1 research supporter, 1 administrative expert, and 2 administrative supporters.

8. 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; the construction was subsequently commenced. Japan is responsible for the fabrication of the telescope primary mirror, the design and fabrication of the telescope structure as well as its onsite installation and adjustment, and the design and production of science instruments.

In Hawai‘i where TMT is slated to be built, the State of Hawai‘i approved a new Conservation District Use Permit (CDUP) for TMT construction on Maunakea in September 2017, which was then challenged in court. In October 2018, the Hawai‘i State Supreme Court ruled the permitting process had been duly carried out. Having gained the court’s affirmation, preparation commenced for onsite construction. With activities ongoing by all the partners, Japan initiated fabrication of the telescope structure in FY2018, and also made continued efforts for production of the primary mirror segments, and for design and development of science instruments.

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, as well as the US Association of Universities for Research in Astronomy (AURA) participating as an Associate Member. In the United States, a program called the US Extremely Large Telescope (US-ELT) Program was embarked on to allow all-sky observation by coordinating work between TMT and the Giant Magellan Telescope (GMT, a telescope with an aperture of 22 m currently under construction in Chile). The US-ELT announced its blueprint, and made preparations for the US National Science Foundation’s participation in the TMT Project.

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. In FY2018, the board focused on steps to be taken for the restart of onsite work in Hawai‘i, scheduling and budgetary planning for a term up to the telescope completion, and further definition of its decision-making process, among other matters.

Going through the permit process that the Hawai‘i State Board of Land and Natural Resources (BLNR) commenced to redo in 2016, a new CDUP was approved for the planned TMT site on Maunakea in September 2017. Several parties appealed this decision, but in October 2018, the State Supreme Court found that due process was followed for issuance of the CDUP. Another lawsuit was filed against a sublease. With the consent given by BLNR in 2014, this sublease had been issued by the University of Hawai‘i, which is responsible for management of the summit area of Maunakea, to allow the use of the site for TMT construction. As a result of the Supreme Court ruling handed down for this case in June 2018, the sublease was found to be valid.

The TMT International Observatory worked toward the resumption of onsite work through a series of discussions with the State of Hawai‘i, the University of Hawai‘i, and local stakeholders. During this process, the TMT-J Project Office put in its own effort as well to garner more understanding by holding dialogues with the community of Hawai‘i.

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

For the construction of TMT, Japan is responsible for essential components of the telescope: the design and fabrication of the telescope structure and its control system, and the manufacturing of the primary mirror in accordance with the executed agreements. It also takes part in production of a portion of the science instruments which are developed through international partnerships. In FY2018, the following progress was made.

(1) Fabrication of the primary mirror segments

The TMT primary mirror, comprised of 492 segment mirrors,

Figure 1: Conceptual image of TMT when constructed.

requires the fabrication of 574 segment mirror in all with the replacements included. The processes in the fabrication 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 shaping, and mounting of the mirror segments onto support assemblies. These processes are followed by final surface finish to be completed in the U.S. and coating with reflective metal to be performed onsite, before the mirror segments are finally installed on the telescope.

Of these processes, the plan calls for Japan to fabricate all the mirror blanks and to perform spherical grinding on all 574 segment mirrors. In FY2018, 63 mirror blanks were fabricated and spherically ground. The running total rose to 277 blanks that have been spherically ground by the end of FY2018. We are continuing to ship them to overseas partners for polishing.

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, Japan is leading this work for 175 of the mirror segments. In FY2018, nine segments were aspherically ground.

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

Japan is responsible for 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. Following the baseline and detailed designs developed by FY2016 and preparation for fabrication in FY2017, FY2018 saw the launch of the fabrication process for the telescope structure; work on the structure mainly entailed the production of fabrication drawings of key components in the elevation and azimuth structures, as well as prototype tests for the purpose of reducing risks, and coordination of interfaces with other subsystems. It is noteworthy that a drive test, which was carried out on the prototype of an azimuth cable wrap system, confirmed that the vibration produced from the azimuth cable wrap system was satisfactorily small, and provided the prospect of meeting strict requirements for vibration.

(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, which stands for Infrared Imaging Spectrograph. Being in charge of its imager, Japan currently engages in development including designing and prototyping in cooperation with the Advanced Technology Center. Having entered the detailed design phase in FY2017, IRIS made further progress in its development and design in FY2018, which mainly constitutes: final confirmation of required specifications; work toward determination of interface specifications; analysis of tolerances and stray light in the optics in the imager; analysis of effects of vibrations that the telescope and other systems generated against the optical mechanics; a number of tests, including bond strength tests with the use of prototypes, mechanical drive system durability tests, motor heat generation tests, and other tests; and preparation for measuring the deformation of a 165-mm square spherical mirror caused by cryogenic cooling.

With its planned primary role in the camera system of the Wide-Field Optical Spectrograph (WFOS), Japan examined and developed the optical part. It also contributed to the development of the overall system design which had started in the previous fiscal year.

3. Planning of TMT Science, Instrumentation and Operation

In December 2018, the TMT Science Forum, which is convened annually for international stakeholders together with all the TMT members for discussion of science programs and science instrumentation envisioned with TMT, was held in Pasadena, California. With the US-ELT Program's submission of a proposal to the National Science Foundation on the horizon, the forum deliberated on key science achievable with TMT, and intensively discussed science instruments and telescope operation required for the expected science programs.

An international committee called the TMT Science Advisory Committee, which is responsible for formulation of TMT's instrumentation plan with international parties, found a rise in the importance of extrasolar planet observations, which led to its detailed proposal for a near infrared spectroscopy required to meet this demand. Also, the international committee reviewed white papers on second-generation instruments that had been put forward in FY2017, and laid out a map of the future instruments with consideration given to the proposals.

The TMT-J Science Advisory Committee, which is a domestic committee established for Japanese stakeholders, reviewed efforts both in Japan and overseas that aimed to enable Japanese researchers to make scientific achievements by using TMT. The discussion centered on key science programs that were developed overseas, Japan's efforts to develop science instruments for the purpose of research on extrasolar

Figure 2: Participants of the TMT Science Forum held in December 2018 toured the TMT International Observatory's laboratory, where a truss frame for the primary mirror cell partially prototyped in Japan has been built as a test bed with the first Segment Support Assembly integrated.

planets, and the direction that should be followed for science cases in collaboration with the Subaru Telescope. Also, the TMT-J Project Office continued to provide support funding for research and development of element technology, with an aim of development and design of second-generation science instruments. In FY2018, the development funding was made available to five universities and other institutions selected through the public call.

4. Public Relations, Outreach, and Education

Information on the TMT Project is provided on the TMT-J Project Office website, including updates particularly regarding the situation at the Maunakea construction site and the work share progress made by Japan. Additionally, TMT Newsletters No. 57 through 61 were delivered. Efforts for public outreach were made through lectures and exhibitions in various regions of Japan. A total of 45 lectures and classes on demand were held for the public.

Contributions were also made by making available an on-demand lecturer for the science/technology education and PR event "Journey Through the Universe" (March 2019) held in Hawaiʻi where TMT is to be constructed.

TMT has an international team that consists of Japan and other overseas members, known as WEPOC (workforce development, education, public outreach, and communications), and holds regular meetings for education, development of human resources, and other purposes. As part of its efforts, WEPOC organizes international workshops designed for early-career researchers and engineers. In December 2018, it hosted the third workshop in Pasadena, California, attended by about 50 graduate students and researchers in the early stages of their careers, including eight people from Japan. The workshop offered practical learning opportunities, such as small projects of research and development where participants collaborated in groups to work through specific case studies and issues presently faced by the TMT Project.

With donations toward the TMT Project raised continually, 109 individuals provided donations from January to December in 2018. These donations were utilized for a program named *Fureai Tenmongaku*, which offers children opportunities to learn about astronomy directly from astronomers who visit schools throughout Japan on demand.

5. Organization

By the end of the fiscal year, three Professors, five Associate Professors, an Assistant Professor, a Research Engineer, a Project Professor, a Project Associate Professor, a Project Assistant Professor, five Senior Specialists, a URA employee, a Special Senior Specialist, three Project Research Staff members, and two Administrative Supporters held full-time positions for the TMT-J Project Office. In addition, a Professor, four Associate Professors, and two Assistant Professors from the Advanced Technology Center, Subaru Telescope, and NAOJ Chile 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.

A detailed staffing plan was formulated to increase personnel based in Pasadena, California, with an aim of strengthening collaboration with the TMT International Observatory.

9. 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 arc-second (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 related to the Galactic Center Archeology etc. 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 2018

1) Organization of the office

The JASMINE Project Office is composed of six full-time staff members, six staff members with concurrent posts, one project research staff, two research supporters, one technical supporter, 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; and the University College London.

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 be actually launched into space was completed in FY 2010.

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 as the highest precision annual parallaxes at a precision of less than or equal to 25 μas and proper motions, or transverse angular velocities across the celestial sphere, at a precision of less than or equal to 25 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 supermassive black hole at the Galactic Center; the gravitational field in the Galactic nuclear bulge; the activity around the Galactic Center; star cluster formation; 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 M-class scientific satellite mission proposals and the Small-JASMINE mission is going through the ISAS selection process. Small-JASMINE successfully passed the review for the selection of pre-project candidate/Planning review held by the space science committee at ISAS in August 2018. As a result, a JASMINE-team has been established in ISAS and Small-JASMINE has entered into the Mission Definition Phase (Pre-Phase A2). Furthermore, we have been preparing for the next review at ISAS to upgrade to the development phase.

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

1. Project Overview

In FY 2018, a future plan for the RISE Project Office was forwarded. A workshop to discuss a new proposal for asteroid exploration was held at Wuhan University in China between December 17 (Mon.) and 19 (Wed.). Four members of the RISE Project Office attended the workshop and started joint research with Chinese scientists. Also, the project organized the second workshop on lunar landing exploration at Mizusawa Campus on February 22 (Fri.) and 23 (Sat.). Based on discussions regarding lunar sciences, a roadmap plan for an international space exploration mission was proposed.

Second, the RISE Project Office led the operation of the Laser Altimeter (LIDAR) of Hayabusa2. The mission phase started with arrival at the target asteroid at the end of June. The RISE Project Office (1) coordinated science operations and prepared operation procedure documents every week, (2) organized operators meetings, (3) prepared data for publication, (4) determined the Hayabusa2 spacecraft's position, and (5) discussed the landing site selection routinely. At the same time, the project members attended the special operations at the Operation Center at Sagamihara campus of ISAS to monitor telemetry downlinked from the spacecraft. Furthermore the science members continued analyzing and interpreting LIDAR data to accomplish scientific goals.

Third, the RISE Project Office supported future exploration projects of Japan. A RISE member examined the twist elasticity of the thermal strap of the Ganymede Laser Altimeter (GALA) EM for the Jupiter Icy Moon Explorer (JUICE) mission to help the German Aerospace agency (DLR) revise the ICD. For the Martian Moons eXploration (MMX), in order to constrain image acquisition conditions in Quasi-Satellite Orbit (QSO), influences of solar angle and viewing geometry on estimates of Phobos shape model and rotation state were investigated. Also, accuracies of spacecraft orbits and attitude, data rate, and simultaneous observations by multiple instruments were examined in the view of system requirements.

Fourth, the project commenced providing laboratory equipment for joint use by researchers outside of NAOJ. A small vacuum chamber was used for thermal vacuum tests of a lunar and planetary seismometer in a low-temperature environment, and data necessary for the development of new seismometers were obtained.

2. Educational Activities/Internship

Seven RISE members delivered lectures in turn at the graduate 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. A student of SOKENDAI was accepted for the "Experimental radio astronomy class."

3. Outreach/PR

In FY 2018, the Office members volunteered for Kirari Oshu City Astronomy School as well as four times for Fureai Astronomy classes. RISE members attended both Mizusawa and Ogasawara Campus open house days. At Mitaka Campus open house day, they not only interacted with the guests, but also provided special lectures.

4. Joint Research/International Collaborations

In May, the RISE members held a summer school for lunar and planetary science and exploration in east Asia in Fuchu City, Tokyo. Five, seven, and nine students from China, Korea, and Japan, respectively, participated in the summer school and promoted international exchange.

5. Career Development

A new research expert joined the Office in September.

11. Solar-C Project Office

The SOLAR-C Project Office has engaged in planning the next solar observation satellite mission 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. Through these activities, we are researching and inheriting technologies required for satellite mission development and management methods for international joint projects.

1. SOLAR-C Project

SOLAR-C is a planned project and may become Japan's fourth solar observation satellite, after Hinotori, Yohkoh, and Hinode. The plan is to realize the launch in the mid-2020s. 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, satellite bus, and telescope assembly; and the science instruments will be developed through the international collaborations with the U.S. and European space agencies and institutions.

In order to realize a part of the SOLAR-C science as early as possible, we proposed the UV-EUV Spectroscopic Telescope (Solar-C_EUVST) mission to JAXA in January 2018 by using the opportunity provided by the JAXA Competitively-chosen Middle-class Satellite Mission. In short, the EUVST is a mission aiming at elucidating the universal processes of the magnetic plasma which drive solar activity, by attaining an order of magnitude higher spatial resolution and throughput than Hinode/EIS with a wide temperature sensitivity from the chromosphere to the 10 million degree corona and by coordinated observations with ground-based large aperture solar telescopes.

The EUVST proposal received a high assessment from the Mission Selection Committee, and was recommended as a pre-candidate for the Competitively-chosen Middle-class Satellite Mission No. 3 or 4 by the ISAS Science and Engineering Committee in July, 2018. Then, we started studies, updating the proposal document to clear an international review in December and then to proceed to the next mission definition phase; Pre-Phase-A2 in FY 2019. In order to solve some issues raised by the committee, we clarified the scientific objectives and conducted a technical investigation of critical elements with a space telescope manufacturer. In the study, we proceeded with an optical and structural design integrating the telescope and spectrograph into one unit, clarified the conceptual design, and determined issues that arise when we adopt a standard bus for the middle-class satellite. In addition, with relevant overseas institutes, we held meetings a few times and established the baselines.

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 successfully carried out the first flight experiment in September 2015.

Since publishing the science results from the first flight experiment, the CLASP project has been preparing for the second flight experiment, changing the observed spectral line from HI Lyα to the chromospheric MgII h & k lines at 280 nm. The Japanese CLASP team led by J-side PI, Dr. R. Ishikawa, fabricated new flight components, which are needed to observe a different spectral window, and started the assembly of the telescope and the spectrograph toward the launch in April 2019. After the completion of the assembly of the flight telescope and spectrograph and the performance evaluation tests, the flight instrument was shipped to the U.S. on November 19, 2018. Then, the team integrated the flight components provided by the U.S. side, performing the final end-to-end verification test. At the launch site, they carried out the health-check of the optics before and after the vibration test and decided the observation target, while waiting for the launch.

(2) Sunrise-3 Project

The Sunrise-3 project is the third balloon-borne experiment in the German-led Sunrise program. The preparation of the plan started in FY 2015 for the flight experiment scheduled in the early 2020s. Under the international collaboration, the Japanese team has been jointly developing 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.

The proposal for the gondola for Sunrise-3 has been approved by NASA in this fiscal year, and Sunrise-3 is scheduled to be flown in the summer of 2021. We made the optical, mechanical, and thermal designs of the Sunrise

Chromospheric Infrared spectroPolarimeter (SCIP, PI: Dr. Y. Katsukawa), developing mechanisms for the polarization modulator and image scanner. The interfaces with various European components were clarified. We should note that about half of the total budget for CLASP-2 and Sunrise-3 was funded by JAXA through the Small-sized Mission Program.

(3) FOXSI-3 Project

The FOXSI-3 project is the approved third observational sounding rocket experiment in the U.S. FOXSI program with focusing hard X-ray telescopes. One of the hard X-ray detectors was 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 obtained at each CMOS imaging pixel by a photon counting method. 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 U.S. team was performed. The observation flight was conducted on September 7, 2018, in White Sands, U.S., and succeeded in acquiring innovative data with the high-speed CMOS camera for soft X-ray photon counting. The world's first coronal two-dimensional spectral data captures an X-ray micro-brightening phenomenon with unprecedented sensitivity. The detailed data analysis is in progress for the presentation of scientific results. It is noted that to carry out this experiment, a Grant-in-Aid for Scientific Research (A) was acquired.

3. Others

Dr. R. Ishikawa of this project, received the Young Scientist Award from the Minister of Education, Culture, Sports, Science and Technology in this fiscal year.

Although the SOLAR-C Project Office is reimbursed by NAOJ for its general operation and contingencies, a large part of the expenses for supporting the project preparation is funded by other external sources including Grants-in-Aid for Scientific Research (Kiban-S for Sunrise-3, Kiban-A, for FOXSI-3, Kiban-B for CLASP-2), JAXA’s strategic R&D fund for basic development, and the Small-sized Mission Program.

With regard to personnel affairs, Ms. H. Uekiyo, Administrative supporter, was assigned from April, 2018 in place of Ms. M. Fujiyoshi.

12. 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, JVO Project, HSC Data Analysis/Archiving Software Development Project, and open-use computer system and service. The functions/staff of the network project moved to the IT Security Office in July 2018.

2. DB/DA Project

The DB/DA-project conducts research and development on astronomical DataBases (DB) and Data Analysis (DA). 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, the former Okayama Astrophysical Observatory 188-cm telescope, Kiso 105cm Schmidt telescope (the University of Tokyo), MITSuME 50-cm telescopes (Tokyo Institute of Technology), and KANATA 150-cm telescope (Hiroshima University). The total amount of opened data is about 23 million frames (185 TB) as of May 2019. SMOKA contributes to many astronomical products. The total number of refereed papers using SMOKA data is 237 as of May 2019.

In this year we've started to release the data of new instruments, CHARIS of Subaru Telescope, and MuSCAT of the Subaru Telescope Okayama Branch Office. We also continued the improvement of the system for implementing new functions needed by users, and for more effective operation.

3. JVO Project

FITS WebQL v4 was released. FITS WebQL is a web based quick-look service for generic FITS data. In this release, a new feature called "Cube Slicer" was implemented, which enables a user to look at each frequency channel image in the FITS cube. Gaia Data Release 2 was released on the JVO portal. Gaia is a spacecraft for astrometry, which was launched and is operated by the European Space Agency. The Gaia catalog consists of about 1.7 billion objects. Additionally, Nobeyama Legacy data sets of FUGIN, COMING, and the Star Formation project were released on the JVO portal.

An on-going collaboration between JVO and C-SODA of JAXA/ISAS has been taking place, aiming to distribute the data obtained by astronomical satellites of ISAS through the VO interface.

The progress on the development of the JVO portal was presented at the IAU General Assembly, Astronomical Society of Japan meetings, Astronomical Data Analysis Software & Systems (ADASS).

A lecture about the usage of the JVO ALMA FITS archive was presented at an ALMA data analysis school and ALMA user's meeting.

We attended the International Virtual Observatory Alliance (IVOA) meeting and discussed the operation and standard protocol of VO.

Total access count for the JVO services was 3.5 million and the download amount was 12 TB in the 2018 fiscal year.

4. HSC Data Analysis/Archiving Software Development

This project, started in January 2009, primarily develops the data analysis pipeline and data archiving software for Hyper Suprime-Cam (HSC) equipped with 104 CCDs. Our main subject is implementation of the software for effective data analysis/archiving. We have been discussing ways of correcting various effects originating from the camera system for precise photometry and astrometry, and introducing parallel processing for better performance. The data operation has been stable, generating a large volume (300–400 GB/night) of data.

In the Subaru Strategic Program (SSP) with HSC (March 2014–), we perform data analysis and produce databases for the processed results. We made the 7th internal data release (S18A) to the SSP team collaborators in June 2018, which covers ~305 sq. degree areas in all bands to the full depth with 420 TB of files. The catalog database includes 450 million objects. We have continued developing various user interface software for getting images or catalog products using the database through web browsers. The public data release (PDR) 1 (February 2017) hosts over 900 registered users from 40 countries. The computing hardware and software for the data releases are in a stable operation, and we have been working on improvements to the pipeline functions to achieve better calibration accuracy. The on-site data analysis system has been assisting SSP and general observations including queue-mode observations.

Commissioning of some instrumental components for the next-generation multi-object spectrograph PFS started in summer 2018. We have been involved in discussions of data formats, and development of science data archives which are tied to the HSC products.

5. 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 the "Multi-Wavelength data analysis subsystem (MDAS)", "Large data archive and service subsystem (MASTARS, SMOKA, HSC science, ALMA, VERA, NRO, Okayama and Solar data archives)", "JVO subsystem", "Data analysis subsystem in Mizusawa campus", "Development subsystem", and "Open-use terminals and printers in Mitaka campus".

In JFY 2018, we have been constructing the "Large Scale Cluster (LSC)" for analyzing the big astronomical observation data such as HSC, and the system will be provided as an open-use system (in preparation). This computer system is an in-house product of ADC.

The number of CPU cores and total memory in LSC are 280 cores and 5 TB, respectively. In addition, the working disk area of LSC is the distributed file system of 5 PB. The system will exceed 1,000 cores by cooperating with an existing computer system, and will ultimately extend to 2,000 cores by expanding the system.

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 2018 were as follows.

1. The briefing session of MDAS, Apr. 24, 2018; 13 users
2. IRAF/PyRAF installation school, June 5, 2018; 5 users
3. IDL School for Beginners, July 26–27, 2018; 6 users
4. SOKENDAI summer student program (Support), July 31–Aug. 31, 2018; 7 users
5. Python + Jupyter notebook data analysis school, Aug. 30–31, 2018; 11 users
6. HSC data analysis school, Sep. 13–14, 2018; 6 users
7. Subaru Autumn School 2018 (Co-host), Sep. 25–28, 2018; 13 users
8. IDL School for FITS data analysis, Nov. 1–2, 2018; 6 users
9. ALMA Data Reduction Tutorial for Beginners, Dec. 3–4, 2018; 12 users
10. ALMA (Solar) workshop, June 14–17, 2019; 9 users
11. *N*-body simulation school, Feb. 4–6, 2019; 13 users
12. Database school, Feb. 14–15, 2019; 12 users
13. SOKENDAI Spring School (Support), Mar. 4–6, 2019; 22 users

The total number of participants of the schools in JFY 2018 was 135 users.

6. Others

As part of outreach and promotions activities, 135 issues of "ADC News" were published from No. 709 to No. 843 in JFY 2018. The newsletters were distributed by E-mail to users and appeared on the ADC web pages.

13. Advanced Technology Center (ATC)

1. Organization and Summary of Activities in ATC

The Advanced Technology Center (ATC) is the core research organization of the technological development at the National Astronomical Observatory of Japan (NAOJ), and is the research and development (R&D) center for advanced astronomical observation instruments, from radio waves to visible and ultraviolet light, both on the ground and in space. We position the development of the instruments for ongoing astronomical projects driven by the NAOJ as "prioritized area development" and development research contributing to the future astronomical projects as "advanced technology development." We also organize "Workshops and Development Support Facilities" to support development and production activities of astronomical observation instruments for various internal and external NAOJ technology development groups by offering open use of ATC facilities such as experimental facilities and measurement equipment. ATC promotes joint R&D aimed at developing new astronomical observation instruments and observation technologies in cooperation with not only NAOJ, but also universities and other research institutes. In this fiscal year, the ATC placed only the development of the observation instruments related to the Solar-C project office (which is one of the ATC's annual goals) as "advanced technology development," in order to proceed to the discussion to clarify how the themes to be addressed at the ATC should be selected. Other developments were basically carried out using external budgets such as Grants-in-Aid for Scientific Research. The outline of the activity is shown below.

As one of the "high priority areas of development," development of the observation instruments of the Infrared Imaging Spectrograph (IRIS) and Wide-Field Optical Spectrometer (WFOS) for the Thirty Meter Telescope (TMT) were promoted. As for IRIS, the design and development of the critical design phase are being carried out through cooperation almost as scheduled. In the development of WFOS, the design and studies to support the selection of the observing method of WFOS has been conducted. As a result, at the TMT board meeting in November 2018, it was decided to consider only the multi-slit method that WFOS-J has mainly considered, and the conceptual design phase of WFOS began.

As another "high priority area of development," development of ALMA receivers (Bands 4, 8, 10) has been done with the highest priority. Failed cartridge receivers returned from ALMA have been repaired and shipped back to Chile so as not to affect the operation of ALMA. In addition, ALMA future development has been being conducted to further enhance the observation capability of ALMA. A wideband receiver using a high critical current density SIS (superconductor-insulator-superconductor) junction was successfully demonstrated. For this achievement, our researcher was awarded the IEEE Microwave Theory and Techniques Society Japan Young Engineer Award. Furthermore, as key parts of the gravitational wave telescope KAGRA under construction in Kamioka Gifu, the design, manufacturing, evaluation, and installation of the auxiliary optics equipment has been completed without delay for tight and fluid schedule requests. Some of the equipment was installed earlier than scheduled. We also made improvements to the anti-vibration system.

As "advanced technology development," the development of space-borne solar observation telescopes CLASP2, FOXSI-3, and SUNRISE-3, has been done including mechanical design, production, performance evaluation, environmental tests, etc. as scheduled.

In the shop / open-use support, in the above-mentioned priority area development and advanced technology development, each shop/unit, including the mechanical engineering shop, made large contributions to instrument development such as mechanical design / production, performance evaluation, environmental testing, etc. In particular, for the optical design of IRIS, our engineer was awarded the Optical Design Excellence Award from the Optical Design Research Group of Japan Optical Society. It also contributed to support R&D activities in the development of astronomical observation instruments of internal and external groups, which brought the number of adopted joint development research and facility use jobs to 32 in total. It should be also mentioned that it was decided in the Advanced Technology Center to introduce the latest large-scale machine tools, specifically a 3-dimensional metal printer and a 5-axis machining center, and preparations were carried out aiming for installation in the 2019 fiscal year. Details are described below.

2. Workshops and Development Support Facilities

(1) Mechanical Engineering Shop (ME shop)

The ME shop engages in a comprehensive manufacturing process to fabricate experimental and observational instruments, from design to fabrication and verification. Three teams (design team, machining team, and measurement team) cooperate with each other to meet the various needs from NAOJ projects and other institutions by leveraging their expertise.

1) Design team

The design team has worked on mechanical design and related measurement, assembly, and installation for TMT/IRIS, KAGRA, CLASP2, and SUNRISE3.

[TMT/IRIS]

In parallel with the final design of the IRIS imager, the design team focused on prototype tests of the mechanisms. There also was a collaboration with the neighboring instrument (NFIRAOS) to work on coupled loads analysis.

- Design

  Final design for IRIS imager

  NFIRAOS-IRIS coupled loads analysis (seismic response analysis)

Test equipment for cryogenic motor test

50 K Cryostat with 230 mm diameter window for 160 mm square mirror test

CAD model migration from Inventor to SolidWorks

- Testing

Heat generation from cryogenic motor

Cryogenic thermal deformation of glass piece with bonded metal pad

- Meetings and Reviews

IRIS mechanical team meeting (monthly telecon)

IRIS face to face meeting @ Mitaka

[KAGRA]

Mainly worked for assembly and on-site installation of the instruments designed in the previous year.

- Design

Design update on Wide Angle Baffle suspension

Narrow Angle Baffle suspension

- Assembly and installation

Narrow Angle Baffle suspension

TMS Vibration Isolation System

Beam Reducing Telescope

[CLASP2]

Structural integrity assessment of new flight components, design, and implementation of opto-mechanical parts, and field operations at the launch side were carried out for re-flight in April 2019.

- Design

Detailed design and production progress control for the slit holder

- Testing

Support for vibration test of magnifier and grating

Assessment of structural integrity of the spectropolarimeter by using finite element analysis correlated with vibration test results

- Assembly and verification

Assembly, production progress control, and implementation of the slit holder

Support for the rocket payload vibration test and field operations at the launch site

[SUNRISE3]

Detailed design of the opto-mechanical parts of the spectrometer was completed through optical and structural analysis. All parts were delivered on schedule in close cooperation with the machining team.

- Design

Detailed design and production progress control of SCIP opto-mechanics

Detailed design and production progress control of SMM-TM

Structural-thermal-optical analysis for SCIP structure

Detailed design of metal spring with heat exhaust capability

- Assembly and verification

Optical element implementation and bonding effect evaluation of SMM-TM

2) Machining team

The machining team has widely responded to fabrication requests ranged from major NAOJ projects to open-use users. In FY 2018, the main contribution was to manufacture the components for CLASP2, SUNRISE3, and the Tomo-e Gozen project.

- For TMT/IRIS, mechanical parts were manufactured for mechanical element tests conducted by design team.
- For KAGRA, large and small sized blade springs used for vibration isolation devices were fabricated.
- For airborne instrumentation, precision shim plates (flight model) to be loaded into CLASP2 were fabricated. Test parts for SUNRISE3 and FOXSI3 were manufactured as well.
- In open use programs, the Base Plate (BP) and Height Adjuster Plate (HAP) fabrication for the Tomo-e Gozen project under development by Institute of Astronomy, the University of Tokyo were finished. With this completion, all fabrication over several years from trial to the final item to be loaded was completed.

Fabrication correspondence by Ultra-precision Section

- Trial production of profiled horn for ALMA Band 10

As we succeeded in getting data for the narrow groove process in the last fiscal year, we worked on the goal of finishing production as an element. (Continued to next period.)

- Trial fabrication of metal spring for heat exhaust from optical elements

In cooperation with the design team, we succeeded in fabricating a thin wall section with the same spring characteristics as the analysis results.

- Other experimental mirrors

Regarding a malfunction of an ultra-precision machine under certain condition discovered last period, we determined the cause and presented our results at the 38th Symposium on Engineering in Astronomy. In addition, the 721-pixel Silicon lens array with AR-coating was submitted to the Cutting Dream Contest Awards 2018 by DMG Mori. The production was exhibited at JIMTOF 2018 (Japan International Machine Tool Fair), and it was an opportunity to introduce the machining techniques of NAOJ.

3) Measurement team

The measurement team has responded to general requests and supported fabrication in order to assure required quality.

- SUNRISE3

Shape measurement of SMM-TM prototype mirror holder

- Tomo-e Gozen

Surface measurement of the detector base processed by milling machine

- Next generation CMOS camera

Diameter and position measurement of pins of the detector base

- TMT/IRIS

Measurement of CMM probe contact effect on high precision optical surface made of fused silica assuming optical alignment of IRIS imager.

Table 1: The requests in FY 2018.

From FY 2017	4
NAOJ	
ATC	6
TMT/IRIS	6
ALMA	7
KAGRA	9
SOLAR-C,CLASP2,SUNRISE3,FOXSI3	15
Subaru	4
Public Relations Center	1
External Organizations	
IoA, Univ. of Tokyo	5
Univ. of Tsukuba	2
Univ. of Hyogo	3
Total	62
To FY 2019	2

4) Installation of new equipment

In FY 2018, the budget requested for a 5-axis machining center was been approved to reinforce the core manufacturing facilities. The ME shop has started the preparation for its installation. Expected time for its delivery is September 2019.

The activities are as follows.

- Preparation for its competitive bidding, selection of needed options, accessories and other devices, and specification check
- Schedule planning and preparation for the factory renovation (renovation work will be carried out in FY 2019)

5) Future technology development

From a long-term perspective, the ME shop has been developing the underlying technologies that will be needed for the future, based on the technology demands from the various projects. The activities in FY 2018 are as follows.

- Opto-mechanical element with heat exhaust capability

In response to a demand for next solar observing satellite development, we started prototyping of an opto-mechanical element, a metal spring, that can not only retain an optic component by friction, but also conduct the heat caused by direct solar radiation, from the optic component to the structure.

- Opto-mechanical design optimization for high-resolution optical system

In order to optimize the design across optical and structural fields, we established an analytical environment and workflow that enables cooperative verification of opto-mechanical design at the Advanced Technology Center.

- Development of cryogenic application non-optical contactless linear encoder

We started to develop a cryogenic application non-optical contactless linear encoder to use for positioning mechanisms in radio and infrared frequency instruments. In FY 2018, the first cooling test was conducted and future plans were examined based on the test result.

(2) Preparation for metal 3D printer installation

We have decided to introduce a metal 3D printer for new technology developments toward future astronomy. The budget was approved by the executive agency of NAOJ on July, 2018, and the machine is scheduled to be delivered in August, 2019. The 3D printer will be collaboratively managed and operated by design, fabrication, and measurement teams in the ME shop.

In the 2018 fiscal year, the following preparation has proceeded:

- Bidding: machine selection, specification confirmation, and paperwork
- Rearrangement in the Instrument Development Buildings No. 1 and No. 2 to ensure space for the machine
- Preparation work for construction of installation environment
- Organizing the operation team
- Market research for operation

(3) Thin Film Processing Unit

Continued from last year, fundamental experiment has continued to improve the concrete processes for coating using inhomogeneous multilayers.

The interface program between the inhomogeneous multilayer design software and the coater was developed, and the total design-to-fabrication system with some limitations has been built, and is under evaluation. New development of the in-situ optical monitor during deposition is under consideration.

(4) Space Chamber Shop and Space Optics

Acquisition and accumulation of key 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 2018, in collaboration with the SOLAR-C Project Office and the ME Shop, we have assisted the development activities of solar observation projects (CLASP2, Sunrise-3) that are situated as Advanced Technology Developments in ATC. Concerning the CLASP2 sounding-rocket experiment in which observations of the solar chromospheric magnetic fields are planned at ultraviolet wavelengths, we have supported the development activities of the flight components for the second flight. Among these activities, the facilities of Space Chamber Shop were frequently used for the vacuum bakeout of the flight parts and outgassing measurements before assembly. The light source for polarization calibration, which was developed through the activity of the Space Optics Shop, was used for the CLASP2 spectro-polarimeter, and the polarization calibration on the ground was completed as scheduled. In the Sunrise-3 project aiming at observing high-resolution chromospheric magnetic fields from a balloon altitude, facilities of the Space Chamber Shop were used for the outgassing and CTE measurements of the structure materials.

(5) Optical Shop

Activity of optical shop in FY 2018

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) Repairs and upgrades for measurement systems
- Installation of the variable-angle absolute-reflectance attachment for SolidSpec-3700 (SHIMADZU)
- Proofreading of LEGEX910 (Mitutoyo)

3) Open use
- The number of annual user: 221
  NAOJ: 196 (including 167 from ATC)
  External organizations: 25 (including 6 from Institute of Astronomy, University of Tokyo)
- Use of LEGEX910 (large-scale 3-D measurement machine): 26
  Number of operating days: 28
- Technical consulting for users: 44

(6) Optical and Infrared Detector Group

Near infrared image sensors for astronomical observation are currently supplied only by a US company. They are extremely expensive, and it takes much time to import the near infrared image sensors to Japan. We have developed a 1280 x 1280 pixel near infrared image sensor using an Indium Gallium Arsenide compound semiconductor as an alternative near infrared image sensor in collaboration with a domestic company. In this year, a small prototype image sensor using a finer CMOS manufacturing process to reduce the readout noise more has been manufactured experimentally. The prototype sensor worked as designed, and results measured at a cryogenic temperature were nearly as expected.

(7) Telescope Receiver Developments

Based on the technical skills acquired through the ALMA receiver development, the “telescope receiver development” team has provided support and development for the telescope receivers of other projects and institutes.

We have supported the integration of ASTE’s new receiver and the cryostat. We also developed a new Band 10 receiver for ASTE by refurbishing the ALMA prototype receiver which had been developed in the ALMA construction phase. In this development, we successfully reduced the “sideband noise” (the noise from the local oscillator).

We maintain good collaboration with other radio telescopes being developed by universities (Nagoya University, Osaka Prefecture University, Kwansei Gakuin University). We also provided technical support for the 7-mm receiver that is being developed mainly by ASIAA.

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.

(8) Facility Management Unit

The Facility Management Unit conducts the management of ATC facilities including the building and electrical 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 SIS clean room, we have re-renovated one unit that did not meet the regulation values, and refurbish the water-cooled air conditioner. As a result, the temperature stabilized in the SIS clean room. The water line of the circulating cooling water facility has been polluted due to aging, so inspection and cleaning work were carried out to prevent deterioration of the water quality.

Because positive-pressure drop occurred in the clean room, the filter unit of the external air conditioner was replaced to prevent the positive-pressure drop and the deterioration of cleanliness. We implemented outdoor storage of flammable gas cylinders (ME shop east, clean room air conditioner room west) based on the High Pressure Gas Safety Act.

In the newly built No.3 building (TMT building), construction of the circulating cooling water facilities was completed so that refrigerators could be used in each laboratory, and construction of a large clean room is in progress. In addition, construction for piping from the existing cold evaporator (CE) has been completed so that now nitrogen gas can be used in each laboratory. Furthermore, the gas-liquid separator in the CE tank yard used for liquid collection was replaced with a new one. The conference room, staff room, and some laboratories of the No. 3 building started to be used.

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 (Astrobiology Center), Subaru Telescope, Hinode Science team, SOLAR-C / CLASP2. Projects that require high cleanliness in instrument development use clean rooms. In the 110 cleanroom of the No.1 building and the 101 large cleanroom of the No.2 building, instrumentation related to KAGRA was developed. In addition, the main body of the CLASP telescope successfully launched in the United States in 2015 returned, and was refurbished as CLASP2 in the No.2 building. The CLASP2 instrument development was completed in the 101 large cleanroom and sent to the United States.

3. Prioritized Area Developments

(1) TMT

1) IRIS

The R&D activities and analyses for TMT/IRIS in FY 2018 are as follows:

(1) Final confirmation of the design requirement documents, (2) finalization of the interfaces of IRIS, (3) optical analysis on tolerance of IRIS imager and stray light analysis, (4) analysis of effects of vibrations in the opto-mechanical system of IRIS

caused by the telescope structure, (5) prototype tests on bonding strength, durability of the movable components, heat generation from motors etc., (6) preparation of testing setup for the large mirror, whose size is 165 mm square, to measure the deformation under the cryogenic condition.

2) WFOS

Over several years, we have been working on the design of the camera for the multi-object spectrograph and the action item of Fiscal Year 2018 was the study of the tradeoff between the cost and performance. In collaboration with NIKON, we reduced the diameter of the lens by allowing 20 % vignetting at the field edge (equivalent to HSC). We also made the feasibility studies of holography for the optical methodology. These enabled targeted cost reduction with minimum impact on the performance.

The tradeoff study between the multi-slit spectrograph and fiber spectrograph was made in the fiscal year 2018 and the multi-slit type, which WFOS-J has been working on, was selected by the TMT SAC and approved by the TMT board. We are also proposing an Integral Field Unit (IFU) using image slicers based on the prototyping experiences at the Subaru Telescope. Once it is realized, the IFU will enable unique functions on the 30 m telescope. Although the budget is tight for WFOS, the proposal of IFU was appreciated by the TMT SAC, in particular by the SAC chair Chuck Steidel.

(2) ALMA receiver maintenance of Bands 4, 8, 10

The Bands 4, 8, and 10 receiver cartridges of ALMA developed and mass-produced by Japan completed shipment of 73 units for each band, for a total of 219 units during FY 2013. Most of the receivers have been installed and operated in the ALMA antennas for scientific observation. At ATC, the ALMA receiver maintenance team has been repairing the receiver cartridges that failed during operation since FY 2014. In FY 2018, one Band 4 and one Band 10 receiver were repaired. These failures were caused by a temperature sensor indication error in Band 4 and the mixer performance of Band 10. We repaired the wiring and the mixer board respectively.

Fig. 1 shows the number of repairs by each band and the classification of failure cause (initial failure, aging failure) from the start of shipment in FY 2012 to FY 2018. The number of repairs has been reduced to 4 or less annually since FY 2016, and the initial failures have decreased. Although the frequency of repairs caused by aging failure is currently kept low, they have not been through enough time to predict the future. In order to continue stable operations of ALMA, it is important to maintain a maintenance system in ATC that can quickly respond to ALMA receiver failures.

In the operation support for the Chile site, in order to determine whether failures that occur in the receivers of other bands similarly occur in Band 4, 8, and 10, the record of assembly work was checked and presented to the local engineer. With regard to the receiver tuning problems in Chile, we solved the problems through cooperation such as examining the performance evaluation test data. The ALMA receiver

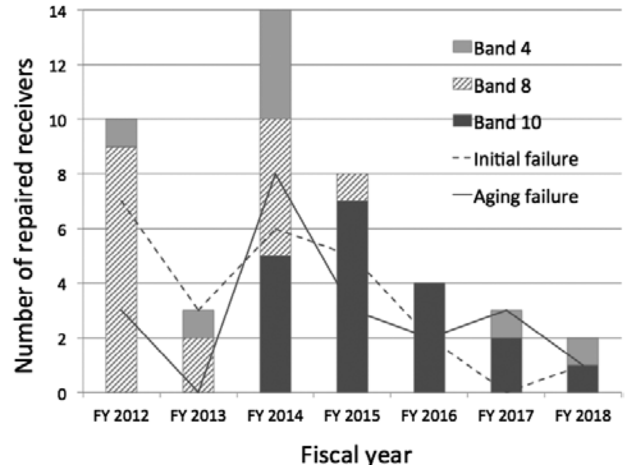

Figure 1: Annual changes in number of repaired receivers.

maintenance team at ATC will continue to maintain close contact with local engineers in Chile and support smooth operation.

(3) ALMA future development

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 a frequency band not implemented in the array yet: 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 2 receivers

The original ALMA Band 2+3 project has decided to move forward to the Band 2 (RF: 67–116 GHz) development, which will be led by ESO. ATC has contributed to the Band 2 receiver development with design and development for waveguide components and receiver optics based on a dielectric lens. We sent a corrugated horn and OMT designed at ATC and manufactured by a domestic company in Japan to ESO, and Band 2 receivers utilizing these components delivered from three institutes were characterized and compared. The evaluation result showed that the receiver using our components had the highest performance.

ATC is also developing a dielectric lens for the Band 2 receiver. We established a material characterization system equipped with a network analyzer and well-designed wideband optics in the frequency range, and evaluated dielectric materials to be used as a lens. Based on the measured dielectric properties, the lens shape and anti-reflection structure fabricated on its surface were redesigned in order to improve the performance. We also rebuilt our beam measurement system and improved the reliability for the optics evaluation.

2) Ultra-Wideband receiver

ATC has developed a wideband RF and IF receiver for the future ALMA receiver upgrade. 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, the matching circuit of the SIS mixer was renewed to improve the RF coverage. The evaluation result showed extremely low-noise performance within 2 to 3 times the quantum noise (hf/k_B). This is the first demonstration in the world where a single-end SIS mixer fully covers both the original ALMA bands. We also have demonstrated low-noise performance with a wide IF bandwidth covering 3–22 GHz, using an SIS mixer-preamplifier module. Based on the developed RF components, we established a 2SB mixer measurement setup which allows us to evaluate across the wide ranges of RF 275–500 GHz and IF 3–22 GHz and demonstrated the wideband 2SB mixer.

3) Terahertz receiver

We evaluated the ALMA Band 10 receiver which has SIS mixers employing high critical current density (high J_C) SIS junctions based on an Aluminum Nitride barrier. The receiver fully satisfies the current ALMA specifications at Band 10 frequencies (787–900 GHz) and offers a large margin when compared to the receivers using the SIS mixer around J_C = 10 kA/cm^2.

4) Multibeam receiver

Based on our original concept of the planar integration SIS mixer array we have designed, fabricated, and fully evaluated a dual polarization balanced mixer on a single chip operating at a frequency range of 125–163 GHz. Test results show high sensitivity comparable to the state-of-the-art of a conventional SIS mixer with low cross-talk between the two polarizations. In addition, this balanced mixer demonstrates a noise rejection ratio as high as 15 dB, which is a favorable consequence of the high accuracy of micro-fabrication techniques. With these results, the feasibility of the concept has been successfully proven at millimeter wavelengths.

5) SIS junction development

During the past year our junction technology based on Nb/AlN$_x$/Nb tri-layers has been maintained and mixers incorporating high quality junctions with current densities of J_C = 10–60 kA/cm^2 are now fabricated on a regular basis. SIS mixers based on our high-J_C junction technology are already being used in various types of low noise receivers, either as part of an upgrade or demonstrating advanced receiver capabilities. The more conventional junction technology based on Nb/AlO$_x$/Nb tri-layers has been further investigated with respect to barrier growth conditions. This resulted in an improved reproducibility for tri-layers in the current density regime of J_C = 10–20 kA/cm^2. The excellent degree of reliability in the fabrication process is possible through access to high-end equipment in the ATC clean room, maintained by our group, for thin film deposition, lithography, and dry etching, among others.

In parallel with the development of high-J_C junctions, encouraging progress in fabricating SIS mixers on silicon membranes has been made, which is the key technology for the planar integration of multibeam SIS mixers. In the past year two major improvements have been achieved. The plasma-enhanced chemical vapor deposition (PE-CVD) has been applied rather than the more conventional magnetron sputtering for better side-wall coverage. A machine-aligned via-hole etching process has been established to improve the uniformity in the junction definition and therefore has led to good balance in the symmetrical circuit configuration.

(4) KAGRA

We have developed KAGRA's auxiliary optics subsystem (AOS) and vibration isolation subsystem (VIS) with the Gravitational-Wave Project Office (GWPO).

For the AOS, we have completed the assembly, test, and installation of every planned component on schedule. The components in the schedule are as follows: four units of wide-angle baffles (WABs) with vibration isolation systems, four units of narrow-angle baffles (NABs) with vibration isolation systems, and a transmission monitor system (TMS). All of them have been installed in the vacuum chambers. We modified the WABs after reflecting on the lessons learned from a cooling test performed from the end of the last fiscal year to the beginning of this fiscal year. We performed tests for the assembly and installation of the NAB, and modified the design by reflecting on the findings from the tests. In addition, we addressed an unplanned request from KAGRA to modify the NABs so that each of them holds four photo detectors to pick off part of the power from the resonating light beam in the arm cavity. The TMS took an important role in operating KAGRA's 3-km arm cavities, in which we at last achieved a resonant light beam in this fiscal year. Moreover, we were able to ship a vibration isolation system for the TMS (TMS-VIS), and install it at the site. It is worth emphasising that we have achieved these results on schedule, including unplanned jobs, without major accidents. At the same time another TMS-VIS is being assembled at Mitaka. We will ship it in the next fiscal year.

The VIS is a subsystem to suspend mirrors required for the KAGRA interferometer to isolate them from seismic disturbances. 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.

We mostly completed the major VIS work, especially design work, assigned to ATC in the last fiscal year. In this fiscal year, we addressed a few maintenance issues, and performed fabrication of large blade springs. The original blades had been imported from abroad, but the workers at KAGRA found that they were broken when they were about to install them. KAGRA wanted to immediately produce the blade springs in Japan, and we addressed the request by taking advantage of our established know-how about blade springs.

4. Advanced Technology Developments

(1) CLASP2/SUNRISE/SOLAR-C

ATC has assisted the design, assembly, and verification of the instrument in the development activities of the solar observation projects (CLASP2, Sunrise-3). In CLASP2 aiming at the measurement of chromospheric magnetic fields in ultraviolet wavelengths, the design of the new optical system and the updated structures have been confirmed through verification tests. By taking charge of the bonding process between optical elements and each supporting structure, we have also gained a bonding technique that is to be applied to space instrumentation. In Sunrise-3 aiming at the measurement of solar chromospheric magnetic fields from a balloon altitude, the final optical design, the preparation of specification documents, and the design of holders and mount structures for optical components were carried out. The mechanical support structures have been fabricated in the ME shop as an in-house development activity.

5. Open-Use Programs, Joint Research and Development

We categorize open use programs as facility use programs or collaboration programs depending on the ATC facilities and commitment of ATC members.

In FY 2018, we made calls for open use programs twice, receiving applications for 9 collaboration programs and 23 facility use programs.

Later in the year, major modifications of the laboratory assignments were made to accommodate installation of a metallic 3D printer and a 5-axis machining center. Many users contributed to the laboratory rearrangements.

Applicant names and program titles are listed in the section "Open Use Programs, etc." The results of the programs can be found on the ATC homepage.

6. Others

(1) HSC

In FY 2018, although HSC did not encounter any major troubles, the filter exchangers experienced malfunctions several times, possibly due to aging degradation. The ME shop at ATC responded to those issues. We will have to make the regular maintenance cycle of the exchanger more frequent than we had originally planned. As for the newly developed calibration system of HSC, we installed the components including the fiber cable, projector, light source, and monochrometer. We planned to start the regular operation from the FY 2018, but the light source failed, and we brought the unit back to Japan. We then identified the failure of the power unit. We will resume the operations from FY 2019.

We could not make the expected progress on HSC SSP observations because the observing time from May through October was canceled due to the volcanic activity and the frequent earthquakes on the island of Hawai‘i. The achievement rate of survey observing reached 75 % compared with the original plan. This is mainly due to the extremely bad weather since Fall 2017 through Spring 2018. We submitted a request to add 30 nights to reach the 80 % level of achievement rate to the Subaru Scientific Advisory Committee and Subaru User's meeting and the request is being reviewed.

This year, we published the first results on estimates of cosmological parameters. A press release was issued in September 2018 jointly with KIPMU and was picked up by major newspapers. Our constraints on cosmological parameters are equivalent with what our rival survey DES showed, eventhough the HSC survey field was only 1/13 that of DES. This clearly demonstrates that HSC did indeed do a better job in the precise shape measurements of faint small galaxies and this leads to an advantage in scientific observations.

7. Awards

The following staff in ATC have received awards for their development activity:

T. Tsuzuki: 21th optical design award by the Optical Society of Japan

T. Kojima: 2018 IEEE Microwave Theory and Techniques Society Japan Young Engineer Award

14. 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 2018, 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 2018, 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 senior engineer, 1 engineer, 1 section leader, 6 senior specialists, 2 research experts, 21 public outreach staff members, and 2 administrative supporters.

On April 1, public outreach officials (English translation of the job title changed to "public outreach staff members" in August) Yumi Hibino and Natsuki Yonetani arrived in the Outreach and Education Office.

On August 1, Administrative Supporter Makiko Aoki was transferred to IT Security Office. On September 1, Administrative Supporter Sayumi Noguchi was promoted to Administrative Expert.

On March 31, senior engineer Ko Matsuda, senior specialist Sze-leung Cheung and public outreach staff member Shiomi Nemoto resigned.

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. We conduct not only public outreach activities using SNS and movies, but also new forms of public outreach such as exhibits at international events and Citizen Astronomy in response to the mid-term goals and suggestions from the External Review. To improve the skills of outreach personnel, the staff members attended workshops.

(1) Online-Based Information Sharing

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

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

Month	Access counts	Month	Access counts	Month	Access counts
April 2018	391,479	August 2018	2,147,940	December 2018	1,503,156
May 2018	490,279	September 2018	740,226	January 2019	1,075,677
June 2018	508,191	October 2018	781,932	February 2019	536,671
July 2018	1,654,974	November 2018	535,890	March 2019	491,852
Total: 10,858,267					

Table 1: Monthly website access statistics for the Public Relations Office website, NAOJ Public Relations Center (April 2018–March 2019).

Operation Guide for the HSC Viewer	French/Spanish versions
Exploring the Universe with "Subaru"	French/Spanish versions
Mars Makes the Closest Approach in 2018	Japanese Version
Mars's Close Approach to Earth	Japanese/English Versions
Mars	Japanese Version
Project PR movie "Advanced Technology Center"	Japanese/English Versions
A partial solar eclipse captured by the Solar Flare Telescope on January 6, 2019	Japanese Version
NAOJ PR movie	Japanese Version

Table 2: Summary of Produced Videos.

June 29, 2018	New Mystery Discovered Regarding Active Asteroid Phaethon
July 2, 2018	New IR Instrument Searches for Habitable Planets
July 13, 2018	Subaru Telescope Helps Pinpoint Origin of Ultra-High Energy Neutrino
September 4, 2018	Falling Stars hold Clue for Understanding Dying Stars
September 10, 2018	Asteroid Science Observations from Stargazing Party Telescope
October 12, 2018	Little Supernova is Big Discovery: the Origin of Binary Neutron Stars
November 22, 2018	ALMA's Highest Frequency Receiver produces its First Scientific Result on Massive Star Formation
November 30, 2018	Black Hole 'Donuts' are Actually 'Fountains'
December 3, 2018	Combination of Space-based and Ground-based Telescopes Reveals more than 100 Exoplanets
December 17, 2018	MuSCAT2 to find Earth-like Planets in the TESS Era
December 18, 2018	Mystery of coronae around supermassive black holes deepens
January 1, 2019	Early protostar already has a warped disk
February 5, 2019	Retreating Snow Line Reveals Organic Molecules around Young Star
February 28, 2019	Hiding Black Hole Found
February 26, 2019	Two-Gun Baby Star Solves Stellar Mystery
March 12, 2019	Cross-Disciplinary Collaboration Enables Investigation of the Origin of Heavy Elements
March 14, 2019	Astronomers Discover 83 Supermassive Black Holes in the Early Universe
March 14, 2019	ALMA Observes the Formation Sites of Solar-System-like Planets
March 20, 2019	The Rise and Fall of Ziggy Star Formation and the Rich Dust from Ancient Stars
March 28, 2019	Spiraling giants: witnessing the birth of a massive binary star system

Table 3: Web Releases.

May 16, 2018	ALMA Finds Oxygen 13.28 Billion Light-Years Away - Most Distant Oxygen Indicates Mature Nature of a Young Galaxy
June 1, 2018	Supercomputer Astronomy: The Next Generation
August 28, 2018	Unstoppable Monster in the Early Universe
September 20, 2018	Cosmological Constraints from the First-Year of Hyper Suprime-Cam
January 27, 2019	Missing-Link in Planet Evolution Found

Table 4: Press Conferences.

2019, the number of Japanese version twitter followers exceeds 180,000. 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.189–202 were issued, introducing research results and NAOJ hosted events.

We produced a NAOJ PR movie, videos explaining astronomical phenomena, and videos introducing outreach activities. Including foreign language versions, 12 original videos were produced. The videos are uploaded mainly on YouTube. As of the end of March 2019, these videos have accumulated a total of 2,886,000 minutes of play time and 600,000 views. Continued from last year, our office performed live stream broadcasting seven times of heavenly bodies with the 50-cm Telescope for Public Outreach. There were about 105,000 viewers in total. We have been approved as an official program by DWANGO Co., Ltd. which manages a live broadcast for niconico, and our viewers are increasing. In addition, we conducted live internet broadcasts of lectures on the Special Open House Day for Nobeyama Radio Observatory and Mitaka Open House Day.

(2) Research Result PR

There were 26 research result announcements (compared to 25 in FY 2018 and 20 in FY 2017). We released all the research releases in both English and Japanese. In addition to press conferences and continuing to mail press releases to an original media list for domestic audiences and using the delivery services of the American Astronomical Society, AlphaGalileo, and EurekAlert! from AAAS for overseas audiences, this year we started experimenting with ResearchSEA and started to mail press releases to a new original media list.

In the perennially popular Astronomy Lectures for Science Journalists program, the 25th lecture entitled "The Universe Depicted by Simulations — Five Years of the Supercomputer ATERUI and the Next Generation System —" was held on June 13, 2018, with 19 people (16 companies) in attendance.

(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 July 8, 2018, the NAOJ lecture meeting titled "ATERUI's Challenge to The Unknown Universe — The Universe Depicted by a Supercomputer —" was held at Oshu City Cultural Hall (Z Hall) with 156 guests in attendance.

We also made a new NAOJ PR video.

To publicize NAOJ abroad, we co-hosted a booth at an overseas meeting where the press, researchers, and educational officials gather (AAAS Annual Meeting in Washington, DC February 2019). We also held media tours "Subaru Telescope:

20 Years Wishing Upon a Star" for domestic and oversea media and embassy officials. Tours were held in Japanese and English separately (on November 15 and 19 respectively) and a total of 35 participants (14 media companies) attended.

(4) New Astronomical Objects

Four staff members, including one full-time and three contract employees, handled reports of new astronomical objects and other communications submitted to NAOJ. In this fiscal year, there were a total of 18 reports including confirmation requests for new celestial object candidates and other reports. The contents were: 2 novae, 6 variable stars/transient objects, 4 comets, 2 planets/asteroids, 2 objects with high proper motion, 2 others. Among the many examples of reporting a ghost image or known asteroid as a new object, the reports in April 2018, were communicated via NAOJ to the IAU Central Bureau for Astronomical Telegrams and were recognized as an independent discovery of Nova Sagittarii 2018 (V5857 Sgr) and a detection of an outburst of a dwarf nova V392 Per. In addition, the reports in November and December 2018, were communicated via NAOJ to the IAU Minor Planet Center (MPC) and were recognized as independent discoveries of COMET C/2018 V1 (Machholz-Fujikawa-Iwamoto) and COMET C/2018 Y1 (Iwamoto).

(5) Citizen Astronomy (Shimin Tenmongaku)

From FY 2016, the Public Relations Office has promoted "Citizen Astronomy," in which the public participates in astronomical research activities using observational data released by NAOJ. "Citizen Astronomy" ("Shimin Tenmongaku" in Japanese) conducted at NAOJ is an example of "Citizen Science" in which researchers / research institutes and the public collaborate on scientific activities. Through cooperation with the Subaru Telescope, we developed a program to determine the shapes of colliding galaxies by using data released by the Hyper Suprime-Cam Subaru Strategic Program (HSC-SSP). In this fiscal year, Citizen Astronomy was selected as one of the "Open Lab" projects of the National Museum of Emerging Science and Innovation (hereafter Miraikan) in which the public participate in experiments. On August 1, 2018, a citizen astronomy program "What Kinds of Galaxies are There in the Universe? Classifying the 'Shapes' of Galaxies" was held at Miraikan and data were obtained from 245 participants. In addition, by having participants classify the shapes of galaxies on touch panels, we collected data set 1 from December 6, 2018, to January 6, 2019 (990 participants), and data set 2 from January 11 to January 21, 2019 (599 participants) and used them to refine the content. We are also constructing our website with the cooperation of the Subaru Telescope and aiming to launch early in FY 2019.

4. Outreach and Education Office

(1) Public Visits

A total of 25,648 people participated in Mitaka Campus Public Visits (former name was Visitors' Area) in FY 2018. In addition, the group tours in 2018 consisted of 108 general tours (3,945 guests), and 15 workplace visits by schools (71 guests), and 4 others such as inspections (107 guests), for a total of 131 tours accommodating 4,182 guests. Therefore, 25,648 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. We installed audio guides (Japanese/English versions) for most of the Visitors' Area.

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 22 sessions were held with 4,477 participants this year. In addition to this, the telescope was used by 15 groups (993 people) for group tours, inspections, etc.; so a total of 5,470 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 47 screenings were held this year, with 5,621 guests participating. For four 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 93 groups (2,929 people). In addition, 93 group tours (1,156 people) were organized and a total of 9,706 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 10, November 11, March 23, and March 24, no reservations needed) were held with 1,040 attendees.

(2) Telephone Inquiries

The office received inquiries from the media, government offices, and the general public. The Outreach and Education Office responded to 5,209 telephone inquiries (Table 5) and 130 letters, 42 of which were official documents.

(3) Media Reception

We received 144 interview and filming requests from various media. Among these, we dealt with 127 requests. The contents were: 27 news-paper articles; 49 TV programs (15 news programs, 12 science programs, 2 dramas, 20 others); 35 publications (28 magazines, 6 books, 1 other); 6 websites (6 news sites); 4 radio programs; 1 movie; 5 others.

(4) Educational and Outreach Activities

The "FUREAI (Friendly) Astronomy" project, now in its 9th year, provided lectures to 80 schools. In this fiscal year, a minimum of 3 and a maximum of 694 students participated in each lecture and a total of 54 lecturers provided events for 7,424

	Solar Ephemeris	Lunar Ephemeris	Ephemeris	Time	Solar System	Universe	Astronomy	Other	Total
April–June	133	68	28	10	124	102	81	581	1,127
July–September	105	112	40	12	349	115	97	832	1,662
October–December	120	98	37	12	221	95	89	671	1,343
January–March	138	103	30	5	174	84	89	454	1,077
Total	496	381	135	39	868	396	356	2,538	5,209

Table 5: Telephone inquiries made to the Outreach and Education Office of the NAOJ Public Relations Center (April 2018–March 2019).

students. In nine years, 54,480 students in total have attended the lectures in 561 schools from Hokkaido in the north to Okinawa, Hachijō-jima, and Ogasawara in the south.

"Summer Nights: Let's Count Shooting Stars 2018 (August 2018)" and "Let's Gaze at the Geminid Meteor Shower 2018 (December 2018)" were held and we received 1,316 reports and 1,397 reports respectively. (These events were discontinued in this fiscal year.)

On July 23 (Monday) and August 24 (Friday), "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 and three-dimensional Mars handcrafts) with 92 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 26 (Fri) and October 27 (Sat) with the theme "Rediscover the Solar System." 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: 490 guests attended on pre-open day, and 3,247 guests attended on open day, so 3,737 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.

We held lectures and workshops with the theme "Planet Formation" for teachers, museum staff, and science media at the "Workshop for Communicators" from December 2 to 3. We provided useful knowledge for future astronomy outreach activities to the 64 participants who gathered from all over the country.

(5) Community Activities

The "Mitaka Picture Book House in the Astronomical Observatory Forest" welcomed 40,338 visitors in FY 2018. The Office supervised an exhibition "Journey to the Moon" (July 2018 to June 2019). 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 10th "Mitaka Solar System Walk" from September 21 (Fri) to Sunday, October 28 (Sun) in cooperation with Mitaka City and the non-profit organization (NPO) Mitaka Network University. Stamps were placed at 249 shops and facilities around Mitaka City. Adding 21 limited event stamps, 270 stamps were placed and this is a record number. Approximately 20,000 guide-maps/stamp sheets were distributed, of which 3,518 people turned theirs in for a prize. The number of participants who collected all of the stamps was 493. 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 fourth year since its opening and seven exhibitions were held in FY 2018. The Public Relations Center had proposed three of these exhibitions and helped with two lectures and workshops. Also, the office offered outreach and monthly astronomical information images through largescale 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 "M Marche Project" conducted on the 4th Sunday of every month. We welcomed 16,916 guests in the 2018 fiscal year and celebrated 50,000 visitors since the opening. It has been acknowledged as a location in town where science can be easily accessed.

(6) Merchandizing Business

Continued from the last fiscal year, the Office cooperated with merchants who organized the NAOJ original goods and aided in making them, and there was an effort that made use of NAOJ's intellectual property such as packaged products of teaching materials developed for Astronomy Classes for Kids in Summer. We also offer two vending machines dispensing capsule toys which are already in place for weekend visitors. 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 more than 3000 items of these goods were sold in the fiscal year.

(7) International Activities

The Office edited and published the proceedings of CAP2018 in Fukuoka held in March 2018. The administrators of the international conference received "the Prize for Holding International Conferences" from the Fukuoka Convention & Visitor Bureau on December 5, 2018, and "the Prize for Attracting and Holding International Conferences" from the Japan National Tourism Organization on February 28, 2019.

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 2019 edition of the Calendar and Ephemeris, the 2019 version of the calendrical section of the Rika Nenpyo (Chronological Scientific Tables), and the 2020 edition of the Reki Yoko (posted in the official gazette on February 1, 2019). The Calendar and Ephemeris webpage was updated to match what was published in the Reki Yoko. We also updated the web version of Reki Yoko 2019 in accordance with the establishment of holidays related to the Imperial succession.

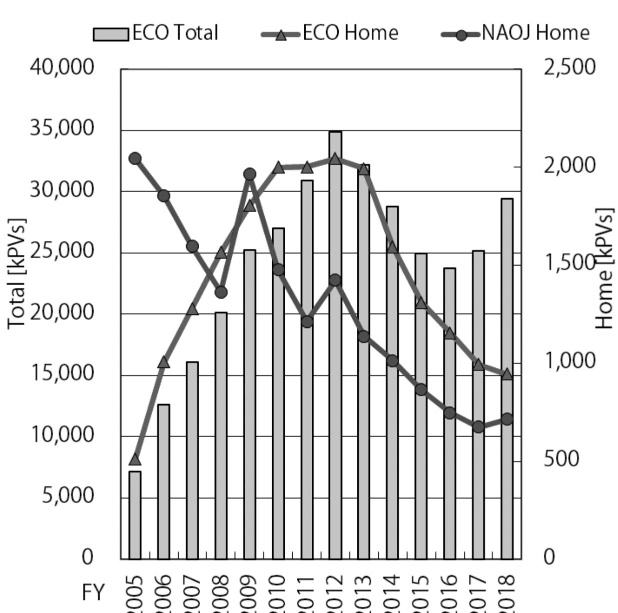

Figure 1: Pageviews for ECO Website.

(2) As for the website (https://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 29 million page views for this fiscal year.

(3) The Japan Association for Calendars and Culture Promotion hosted its 8th 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 57th permanent exhibition was "The Solar System Described in Rare Documents." This exhibit can also be viewed at the Rare Materials Exhibition of the Library's website, in Japanese only (https://eco.mtk.nao.ac.jp/koyomi/exhibition/).

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 2018, 421 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 2018, photocopies or loans were provided in a total of 125 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. We also lent our documents to history and art museums for exhibitions. These items have appeared in various external publications.

During the Mitaka Open House Day festivities in October, we opened part of the Mitaka Library to the public as in the past. Most of the reading room on the first floor was opened to the public. 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 30 Fiscal 2017 (Japanese)
- Annual Report of the National Astronomical Observatory of JAPAN Volume 20 Fiscal 2017 (English)
- NAOJ Pamphlet (Japanese)
- NAOJ Pamphlet (English)
- NAOJ News, No. 297 – No. 308 (April 2018 – March 2019)
- NAOJ Calendar (The 14th in the series)
- Radio Astronomy Public Relations Comic "ALMAr's Adventure" (#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 are nearing publication. In digitalization efforts, we installed an "Archive" shelf at the Publications Office's digital publication website for e-books and posted "Teaching of Astronomy in Asian-Pacific Region." We also published the first English Composition Style Guide for internal use to strengthen our international publication ability. In addition, we provided native check services to the NAOJ Directorate, Public Relations Office, etc. for English language publications. We also contributed to holding international media tours. In normal business, the Office produced and distributed the Annual Report of the NAOJ (Japanese/English versions) and the NAOJ pamphlets (Japanese/English/Spanish versions). 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. 04 Special Edition" June; "ALMA 04 Special Edition" November; "Subaru HSC Special Edition part one" February; and "Subaru HSC Special Edition part two" March) were printed and these aided the outreach efforts of each project. We also published sub-special articles "Communicating Astronomy with the Public 2018" (May) and "The 6-m Millimeter-Wave Telescope Returns to Mitaka" (January). 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 2019 calendar "NAOJ ALMA 2019" (the 14th since 2005) was created. In addition, like in other years editing support was also given to the publication of the "Rika Nenpyo 2019 (Chronological Scientific Tables, Astronomy section)."

8. International Astronomical Union Office for Astronomy Outreach (IAU/OAO)

In FY 2018, the International Astronomical Union (IAU) Office for Astronomy Outreach (OAO) mainly focused on expanding the list of National Outreach Contacts in each country, reorganizing it and ensuring its effectiveness, and supporting international communication through interaction and translation to achieve one of the goals of the IAU Strategic Plan 2020–2030 (Goal 4) which was approved at the IAU General Assembly held at Vienna in August 2018.

We also published the CAP Journal Vol. 24 on October 31 and Vol. 25 on March 21, 2019. The online editions can be freely browsed at the IAU webpage (https://www.capjournal.org/).

For international information provision, the office posted a total of 320 postings on the IAU/OAO social media accounts which were managed by OAO during FY 2018. The Facebook community grew by 43 % and the Twitter followers increased by 16 %. OAO also manages the social media accounts of the headquarters of the IAU and posted a total of 553 posts. As a result, the Facebook community grew by 20 % and the Twitter followers increased by 24 %. Meanwhile, the IAU Astronomy Outreach Newsletter (e-mail news) was delivered 24 times and 264 items of information were provided to 4,362 subscribers all over the world. The newsletter has been translated and redistributed into seven different languages by collaborators in the respective countries. The Office also dealt with the construction of the contents (Themes) of the IAU website for the public and the inquiries from the public (about 300 inquiries).

We are promoting the Astronomy Translation Network (translation work by volunteer network) as an NAOJ proposal project for OAO activities. There are 382 registered volunteers. They are divided into nine groups and translate each language. An intern, Berenice Himmelfarb, came and worked as a project manager from May to November.

At the IAU General Assembly, the Office ran the first "Inclusion Day" and Focus Meeting 14 on global astronomy outreach, and hosted "Inspiring Stars" with tactile exhibitions and workshops for everyone regardless of whether or not they have visual impairment. Together with the IAU Secretariat and the Office of Astronomy for Development (OAD) for social development based in South Africa, we contributed to the booth exhibition and the overall flow of the event as well. The OAO Sub-Coordinator was in charge of making the proceedings of CAP2018 in Fukuoka. For the details of the conference, please refer to the Outreach and Education Office section. The Sub-Coordinator also played an important role in inviting IAU Symposium 358 and served as a valued member of the organization committee.

In addition, OAO is preparing the IAU 100 projects as one of the implementing organizations of the IAU 100 anniversary project in cooperation with the IAU 100 Secretariats established at the IAU secretariat and Leiden University. The Office supported the development and production of a telescope kit and is mainly responsible for three Global Projects "Inspiring Stars", "Dark Skies for All", and "Name ExoWorlds II".

We started a partnership with the National Astronomical Research Institute of Thailand (NARIT) and invited a NARIT officer, Pisit Nitiyanant, in December 2018 as a six-month intern to support the Astronomy Translation Network.

15. 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 by maintaining an environment suitable for the individual research purposes. While enabling challenging exploratory research with observations and/or instrumentation, the Division of Optical and Infrared Astronomy furthers these goals by allowing new research projects to launch as the natural course of growth. The Division also actively engages in post-graduate education to foster the next-generation professionals in the field. 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 offers open use observations, and universities and research institutes throughout Japan that focus on new instruments and observational approaches. This fundamental principle has been developed since the Subaru Telescope was constructed.

The Division of Optical and Infrared Astronomy oversees the following projects in NAOJ: Subaru Telescope (C Project), the TMT-J Project Office and the Gravitational Wave Project Office (B Projects), and the JASMINE Project (A Project). The Extrasolar Planet Detection Project Office grew to become the Astrobiology Center (ABC) of the National Institutes of Natural Sciences on December 31, 2017. This transition extends the vision to explore "life in the Universe" and uncover its mysteries. Most of the ABC staff contiued to hold concurrent positions in 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 this Division with either the Division or one of the A, B, or C Projects as their primary appointment. At times, they may also have concurrent positions in other projects in NAOJ. The primary staff of the Division of Optical and Infrared Astronomy in FY 2018 consisted of one professor, four assistant professors (including one on sabbatical in a domestic institution), eight research affiliates, and one JSPS postdoctoral fellow.

The Division coordinates educational, research, and administrative activities with Subaru Telescope Mitaka Office. Since personnel transfer often occurs within the Division of Optical and Infrared Astronomy, the Division plays an increasingly important role in coordinating with the Subaru Telescope and the TMT-J Project Office. The Division as a whole maintains and operates facilities/services which are auxiliary to research, for example, the mailing lists and the web servers for the Division of Optical and Infrared Astronomy and related projects such as the Subaru Telescope, the TMT-J Project Office, the Gravitational Wave Project Office, and the 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. This Division, stemming from a long history as central to NAOJ and its predecessor will merge into the new Division of Science in FY 2019. Therefore, the report from the division of "Optical" and "Infrared" will cease to exist. The staff of this Division will move either to the new Division, or to Subaru Telescope or the TMT-J Project.

2. Research Based on Observation

(1) Observational Research Using Various Types of Telescopes

Observational research utilizing the Subaru Telescope is the primary approach, covering a wide variety of subjects including cosmology, the formation and evolution of galaxies, the formation of stars and planets, the structure and evolution of the Milky Way, stellar spectroscopy, Solar System bodies, and the search for the exoplanets.

One highlight from the Subaru Telescope is a very intriguing filamentary structure in the imaging data from Hyper-Suprime Camera. Very careful inspection of the ghost features in the HSC images led to this serendipitous discovery.

Staff on sabbatical summarized the performance of the wide-field infrared camera attached to the 91-cm telescope at the former Okayama Astrophysical Observatory, and studied the Cepheids in the Milky Way Galaxy.

Research by combining multi-wavelength data goes on. A JSPS researcher used the hard X-ray telescope NuSTAR to study dwarf galaxies with star bursts. Despite the presence of active galactic nuclei suggested by the mid-infrared observations, X-ray data do not show such activities. A research paper based on these findings is now submitted to a journal.

A study on protoplanetary disks by using both the Subaru Telescope and ALMA observations is on-going. Now the obtained ALMA data are being analyzed.

Optical and Infrared Synergetic Telescopes for Education and Research (OISTER) is a NAOJ-led 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.

(2) International Collaboration in Observational Research

The Division continues to nurture the international collaborative studies with researchers and facilities abroad.

A study on excess ultraviolet regions around galaxies continues with researchers in the USA. Research on the removal of material by ram pressure in galaxy clusters is in progress with collaborators in the USA, Czech Republic, UK, Italy, France, Germany, Mexico, and Canada.

Site survey continues in the western Tibet area for a future large infrared telescope site in cooperation with the National Astronomical Observatories in China (NAOC) of the Chinese Academy of Sciences. Based on the past meteorological data in China, clear-sky probabilities in the area were evaluated.

(3) Research Using Archived Data

Analysis of the Sun-rise and Sun-set times in the Chongxiu-Daming Calendar that was developed in 12th century China is in progress. Research on the multiplicity of stars is being carried out by using stellar and lunar occultation data.

Digitization the Schmidt plates used in the Kiso Ultraviolet-Excess Galaxies (KUG) catalog continued. These data are archived in the Astronomical Data Archive Center (ADAC), NAOJ, and are opened for public access.

3. Observational Instrument Development

Studies of coronagraph masks for the Subaru Telescope, WSOUV, WFIRST, etc. were conducted. Using a laser frequency comb to calibrate the instrument drift, open use and strategic observations with the Infrared Doppler Instrument (IRD) at the Subaru Telescope started.

The detailed analysis of ghosts in Hyper Suprime-Cam images continued at Subaru Telescope.

For the Hosei Twin Astronomical Telescopes (HOTATE), we supported observations, improvement, and the construction of the data archive.

Developers for the Subaru Telescope and related software published a book (in Japanese) which is available electronically as well as through print-on-demand. This book covers the software development at Okayama Astrophysical Observatory; telescope and instrument control software for the Subaru Telescope; data acquisition software; data archives; and the connections between various programs.

4. Support for Subaru Telescope Operation

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 Infrastructure Support

Web servers and mailing lists, both fundamentally essential infrastructure for research activities, were maintained. We also managed the printers and rented multi-function photocopiers, sub-networks, and data backup servers for Subaru Telescope Mitaka Office. In addition, we assisted new administrative staff with setting-up computers. As part of the preparation for the demise of the Division, unused data storage units were nulled.

Information and network security became more serious issues. Division staff members have been encouraged to take the training offered/requested at NAOJ, and more knowledgeable staff has helped to remedy the situation.

6. Information for the Public and Outreach, and Support for 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 the Open House event held at Mitaka Campus (Mitaka Open House Day).

At the Symposium of the Inter-University Research Institute Corporations in 2018, staff talked about the Division’s activities.

7. Hosting Scientific Conferences and Meetings

The Division co-hosted the 9th OISTER workshop held at Saitama University on December 25 and 26, 2018.

8. Visitors

Dr. Jin Koda of Stony Brook University visited for discussion on a research project.

9. Educational Activities

The Division of Optical and Infrared Astronomy provided postgraduate education to 14 graduate students and research student from SOKENDAI (the Graduate University of Advanced Studies), the University of Tokyo, and Tokyo University of Science.

Division staff members made active contributions to formal and informal seminar. Since April 2015, a half an hour presentation/discussion session has been organized 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.

At the end of the 2019 academic year the Division was terminated and the graduate students were assigned to the groups (Divisions or Projects) to which their respective advisors belong.

16. 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 provided in each project's section and in the research highlights. The Radio Astronomy Frequency Committee has been established within the division, renamed to The Radio Astronomy Frequency Committee from September 2018, engaging in discussions on protection against artificial interference generated by electrical equipment, which causes major obstacles in radio astronomical observations.

1. Radio Astronomy Frequency Committee

The mission of the Radio Astronomy Frequency Committee 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 the achievements made in the field of radio astronomy so far.

Just as light pollution from artificial light sources becomes an obstacle in optical observation, artificial radio interference generated by the electronic devices surrounding us could be 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, regardless of whether active or passive, 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 Committee 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 understanding 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 2018 the Committee 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 Committee 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 applicable rules and regulations have been established to address the issue of interference cooperatively. The Radio Astronomy Frequency Committee 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. For example, 76 GHz automobile radars became 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 in use. 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 Committee is regularly involved in the WP7D (radio astronomy) and WP1A (frequency management) meetings. The Committee also takes part in various international conferences, representing the Japanese community of radio astronomy researchers.

In FY 2018, the Committee participated in the ITU-R WP7D meetings held in May and September in Geneva. In these meetings, the following items were discussed as major agenda items related to radio astronomy: interference from the MSS system in the HIBLEO-2 network (Iridium NEXT) to radio astronomy at 1.6 GHz; impact of spurious signals from the autonomous maritime radio devices (AMRD) on the 320 MHz band; and allocation of frequencies above 275 GHz. Also, the Committee attended the Conference Preparatory Meeting (CPM) in Geneva in February 2019 for a trend study prior to the WRC-19 meeting in 2019.

(4) Activities in Japan

The three major domestic activities of the Radio Astronomy Frequency Committee are: participation in various committees and working groups hosted by the MIC, direct negotiations with wireless operators regulated by the MIC, and information activities to raise public awareness about radio interference in radio astronomical observations. Negotiations with wireless operators to reduce interference sources represent a major part of the Committee'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 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 aiming to observe 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 be important 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 carried out 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 a satellite launched in December 2017 verified that the filter provides proper protection 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 Communications Inc. (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 Committee. 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 Committee continues to monitor their progress and shares the information with related radio astronomers.

Moreover, the Committee 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 an important part of the activities. To raise public awareness about “Interference to Radio Astronomy,” these collected cases are effectively used in presentations by our community members. Various tutorial materials are also being prepared for the general public. As optical astronomers are actively working on the protection of their observation environment against artificial light, radio astronomers will also make an increased effort to promote better understanding of radio interference for maintaining a good environment for radio observations in future years.

17. 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 solar physics 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 both 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 theoretical research in the Division 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 solar-type 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 four papers in refereed journals as a co-author. The work was about the comparative study of active solar-type stars' spots and sunspots regarding their lifetimes and evolution and about research related to 18th Century Japanese sunspot sketches and space weather event records. The Division organizes 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), one from the University of Tokyo and one from Tohoku University. The Division, in cooperation with Kyoto University and Nagoya University, supported the annual "Leading-edge Solar Research-Experience Tour" in March, 2019 for undergraduate students; nine students visited solar-related research organizations and experienced the latest research in the field.

3. Others

The NAOJ Fellow Toriumi retired at the end of March, and has been appointed as an ISAS Top Young Fellow since April, 2019. With the abolition of the NAOJ research divisions, the Division of Solar and Plasma Astrophysics will be abolished and integrated into the new Division of Science.

18. 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 2018 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 Telescope, ALMA, and Nobeyama radio telescope; and interdisciplinary research on the 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, research affiliates, and visiting joint 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 2018, the dedicated faculties of the Division of Theoretical Astronomy included two professors, two associate professors, and three assistant professors in addition to one adjunct professor and one adjunct assistant professor who concurrently held a primary position at the Center for Computation Astrophysics. In addition to these research and educational members, the division was served by six project assistant professors, four project research staff, two EACOA fellows, and in addition one administrative supporter who gave full support to all activities of the division. Among them Takashi Moriya, an assistant professor, joined our division from February in 2019.

3. Research Results

The research papers and presentations in the international conferences carried out by the division members as authors or presenters are more than 150 in number. 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:

- Multi-wavelength light curve modeling of the low-luminosity gamma-ray burst 171205A (Suzuki, A)
- Global N-body Simulation of Galactic Spiral Arms (Kokubo, E. et al.)
- Systematic Investigation of the Fallback Accretion-powered Model for Hydrogen-poor Superluminous Supernovae (Moriya, T. et al.)
- Formation of super-Earths and their atmospheres (Ogihara, M., Kokubo, E. et al.)
- Nucleosynthesis Constraints on the Explosion Mechanism for Type Ia Supernovae (Mori, K., Kajino, T., Famiano, M. et al.)
- Impacts of the New Carbon Fusion Cross Sections on Type Ia Supernovae (Mori, K., Kusakabe, M., Kajino, T., Famiano, M. et al.)
- β-decay Rates for Exotic Nuclei and r-process Nucleosynthesis up to Thorium and Uranium (Kajino, T. et al.)
- New Predicted Primordial Lithium Abundance from an Inhomogeneous Primordial Magnetic Field Model (Luo, Y., Kajino, T., Kusakabe, M. et al.)
- EoS Dependence of the Relic Supernova Neutrino Spectrum (Kajino, T. et al.)
- Supernova Neutrino Process of Li and B Revisited (Kusakabe, M., Kajino, T. et al.)
- Relative velocity distribution for general statistics and an application to Big-Bang nucleosynthesis under Tsallis statistics (Kusakabe, M., Kajino, T., Luo, Y. et al.)
- Axion Production from Landau Quantization in the Strong Magnetic Field of Magnetars (Kajino, T. et al.)
- Identification of Gamma-Ray Vortices with Compton Scattering (Hayakawa, T., Kajino, T. et al.)
- Many others.

The following research results are released on the division's website (http://th.nao.ac.jp/) as research highlights:

- New simulations of terrestrial planet formation (Ogihara, M., Kokubo, E. et al.)
- Why are we all left handed? – Theory of elementary particle origin (Famiano, M., Kajino, T. et al.)
- Veiled Supernovae Provide Clue to Stellar Evolution (Moriya, T. et al.)
- Nucleosynthesis Constraints on the Explosion Mechanism for Type Ia Supernovae (Mori, K., Kajino, T., Famiano, M. et al.)
- Cosmochronometer ^{98}Tc is produced abundantly by supernova electron antineutrinos (Hayakawa, T., Kusakabe, M., Kajino, T. et al.)
- Little Supernova is Big Discovery: the Origin of Binary Neutron Stars (Moriya, T. et al.)
- Ignition of Type Ia Supernovae with Recent Experimental Carbon Fusion Cross Sections (Mori, K., Kusakabe, M., Kajino, T., Famiano, M. et al.)
- Can the inhomogeneous primordial magnetic field solve the "Big-Bang lithium problem"? (Luo, Y., Kajino, T., Kusakabe, M. et al.)
- Relativistic quantum mechanical description of "photon vortices" and cosmological observation (Hayakawa, T., Kajino, T. et al.)

4. International and Domestic Collaborations

The Division of Theoretical Astronomy played a leading role in research activities in the fields of theoretical astronomy and astrophysics, observational astronomy, and experimental physics. This division organized numerous cross-disciplinary international conferences, domestic meetings, and seminars in various related fields of astronomical science:

International meetings
- International Conference on "Filament Paradigm in Star Formation," Nagoya University, November 5–9 in 2018.
- International Workshop on "Nucleosynthesis of heavy elements: roles of supernovae and neutron star mergers," Beihang University, People's Republic of China, December 13–15 in 2018.
- 2nd International Workshop on "Subaru-WFIRST Synergistic Observations," JAXA, December 17–18 in 2018.
- International Workshop on "Cosmo-Nuclear Physics of Heavy Element Genesis and Nuclear Data," Hokkaido University, March 3–8 in 2019.

Domestic meetings
- Workshop on "Neutrino-induced Nucleosynthesis in Supernovae," Kyushu University, June 9–11 in 2018.
- 9th TDA Symposium on "Dark Matter Halo," NAOJ Mitaka, August 27–28 in 2018.
- Workshop on "100 years from Hirayama Family: Present status of research for the understanding of collisions and evolutionary processes in the Solar System," Chiba Institute of Technology, Sky-Tree Campus, November 4 in 2018.
- 31st RIRONKON Symposium, University of Kyoto, December 19–21 in 2018.
- 10th TDA Symposium on "Variety and Origin of Stellar Death Processes," NAOJ Mitaka, January 21–23 in 2019.
- Workshop on "Gravity and Cosmology" for Young Astronomers and Astrophysicists, YITP Kyoto University, February 27–31 in 2019.
- Workshop on "Polarimetry in the ALMA era: a new crossroad of astrophysics," NAOJ, March 25–29 in 2019.

Eiichiro Kokubo served on the organizing committee of Commission A4 (Celestial Mechanics and Dynamical Astronomy) of IAU. Toshitaka Kajino performed the 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). He also 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. Educational and Outreach Activities

The members of the Division of Theoretical Astronomy actively engaged in both graduate and undergraduate lectures at the University of Tokyo and many other institutes and universities including classes at Super Science High Schools. They also engaged in public promotions and outreach activities by offering lectures to the general public.

6. Awards

A research group including Akimasa Kataoka received the PASJ Excellent Paper Award (April 27 in 2018). Tomoya Takiwaki received the NINS Young Researcher Award (May 7 in 2018). Toshitaka Kajino received the honor of Best Science Award from Beihang University in the People's Republic of China (December 1 in 2018).

7. 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 2018 to the division are listed below:

BALANTEKIN, Akif B. (University of Wisconsin–Madison, USA)
CHEOUN, Myung-Ki (Soongsil University, South Korea)
DELIDUMAN, Cemsinan (Mimar Sinan University of Fine Art, Turkey)
EKINCI, Basak (Mimar Sinan University of Fine Art, Turkey)
FAMIANO, Michael A. (Western Michigan University, USA)
FUJIMOTO, Keizou (Beihang University, People's Republic of China)
KIM, Soo-Bong (Seoul National University, South Korea)
KUSAKABE, Motohiko (Beihang University, People's Republic of China)
LAI, Shih-Ping (National Tsing Hua University, Taiwan)
MATHEWS, Grant J. (University of Notre Dame, USA)
MATSUMOTO, Yuhshi (ASIAA, Taiwan)
MAZZALI, Paolo (Liberpool John Moores University, UK)
NORMAN, Colin Arthur (Johns Hopkins University, USA)
OKADA da SILVA, Hector (Montana State University, USA)
PAPPAS, Georgios (University of Rome, Italy)
PEHLIVAN, Yamac (Mimar Sinan University of Fine Art, Turkey)
PIAN, Elena (Italian National Institute of Astrophysics/Institute of Space Astrophysics and Cosmic Physics, Italy)
YAO, Xingqun (Beihang University, People's Republic of China)
YEH, You-Ting (National Tsing Hua University, Taiwan)

19. 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.

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 2018, 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 236 cases (507 items). A security export control briefing was held two times at Mitaka (June 4: 19 attendants, June 24: 25 attendants) for improving the knowledge and awareness of NAOJ staff. In addition to these briefings, an explanation hosted by NINS was held at NAOJ on March 22, 2019.

2. Liaison Work for Overseas Astronomical Research Organizations

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 and interview of the 2019 EACOA/EAO postdoctoral fellowship program recipients.

We hosted an NAOJ booth at the IAU General Meeting held at Wien during August 20-31, 2018 and AAS meeting at Seattle during January 6-11, 2019 to promote research results and to explain the current status of each project.

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 x 3 days each shift since October 2017. Thus, on Thursday when both of the SD staff members are at the office, we hold 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 2018, 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 (49 documents).

III Organization

1. Organization

- Advisory Committee for Research and Management
- Director General
  - Vice-Director General (on General Affairs)
  - Vice-Director General (on Program)
  - Director of Engineering
  - Director of Research Coordination
  - Executive Advisors to the Director General
  - Projects
    - (C Projects)
      - Subaru Telescope
      - Nobeyama Radio Observatory
      - Mizusawa VLBI Observatory
      - Solar Science Observatory
      - ALMA Project
      - NAOJ Chile
      - Center for Computational Astrophysics
    - (B Projects)
      - Gravitational Wave Project Office
      - TMT-J Project Office
    - (A Projects)
      - JASMINE Project Office
      - RISE Project
      - SOLAR-C Project Office
  - Centers
    - Astronomy Data Center
    - Advanced Technology Center
    - Public Relations Center
  - Divisions
    - Division of Optical and Infrared Astronomy
    - Division of Radio Astronomy
    - Division of Solar and Plasma Astrophysics
    - Division of Theoretical Astronomy
  - Research Enhancement Strategy Office
    - Research Evaluation Support Office
  - Office of International Relations
  - Human Resources Planning Office
  - Safety and Health Management Office
  - Engineering Promotion Office
  - IT Security Office
  - Administration Department

2. Number of Staff Members

		(2019/3/31)
Director General		1
Research and Academic Staff		145
	Professor	24
	Executive Engineer	0
	Associate Professor	37
	Senior Research Engineer	9
	Assistant Professor	62
	Research Associate	0
	Research Engineer	13
Engineering Staff		38
Administrative Staff		59
Research Administrator Staff		10
Employees on Annual Salary System		145
Employees on Annual Salary System Transferring to the Mandatory Retirement System		1
Full-time Contract Employees		35
Full-time Contract Employees Transferring to the Mandatory Retirement System		3
Part-time Contract Employees		94
Part-time Contract Employees Transferring to the Mandatory Retirement System		16

3. Executives

Director General	Tsuneta, Saku
Vice-Director General	
on General Affairs	Watanabe, Jun-ichi
on Program	Iguchi, Satoru
Director of Engineering	Takami, Hideki
Director of Research Coordination	Saito, Masao
Executive Advisor to the Director General	Fukushima, Toshio
Executive Advisor to the Director General	Hiramatsu, Masaaki
Executive Advisor to the Director General	Ogasawara, Ryusuke
Executive Advisor to the Director General	Sekiguchi, Kazuhiro
Executive Advisor to the Director General	Takami, Hideki

4. Research Departments

Projects

C Projects

Subaru Telescope

Director	Yoshida, Michitoshi
Professor	Ohashi, Nagayoshi
Professor	Yoshida, Michitoshi
Affiliated Professor	Kashikawa, Nobunari
Associate Professor	Iwata, Ikuru
Associate Professor	Noumaru, Junichi
Associate Professor	Takato, Naruhisa
Associate Professor	Takeda, Yoichi
Associate Professor	Tanaka, Masayuki
Project Associate Professor	Kambe, Eiji
Chief Research Engineer	Iwashita, Hiroyuki
Assistant Professor	Imanishi, Masatoshi
Assistant Professor	Komiyama, Yutaka
Assistant Professor	Koyama, Yusei
Assistant Professor	Minowa, Yosuke
Assistant Professor	Okamoto, Sakurako
Assistant Professor	Okita, Hirofumi
Assistant Professor	Ono, Yoshito
Assistant Professor	Onodera, Masato
Assistant Professor	Pyo, Tae-Soo
Project Assistant Professor	Hayashi, Masao
Project Assistant Professor	Izumi, Takuma
Research Engineer	Bando, Takamasa
Engineer (Gishi)	Namikawa, Kazuhito
Engineer (Gishi)	Omata, Koji
Engineer (Shunin Gijyutsuin)	Tamura, Tomonori
Engineer (Gijyutsuin)	Sato, Tatsuhiro
Project Research Staff	Yamashita, Takuji
Senior Specialist (Tokuninsenmonin)	Ikeda, Hiroyuki
Senior Specialist (Tokuninsenmonin)	Kakazu, Yuko
Senior Specialist (Tokuninsenmonin)	Koike, Michitaro
Senior Specialist (Tokuninsenmonin)	Mineo, Sogo
Senior Specialist (Tokuninsenmonin)	Nakajima, Masayo
Senior Specialist (Tokuninsenmonin)	Okura, Yuki
Senior Specialist (Tokuninsenmonin)	Taniguchi, Akimitsu
Senior Specialist (Tokuninsenmonin)	Takita, Satoshi
Senior Specialist (Tokuninsenmonin)	Yamada, Yoshihiko
Senior Specialist (Tokuninsenmonin)	Yamanoi, Hitomi
Research Expert	Kawanomoto, Satoshi
Administrative Supporter	Kuwata, Hitomi
Administrative Supporter	Shibata, Junko
Administrative Supporter	Suehiro, Yoko
Administrative Supporter	Yoshida, Chie

Administration Department

Manager	Seto, Yoji
General Affairs Unit	
Leader	Chiba, Satoko
Accounting Unit	
Leader	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	Guyon, Olivier
RCUH	Hand, Derek
RCUH	Harakawa, Hiroki
RCUH	Hasegawa, Kumiko
RCUH	Hattori, Takashi
RCUH	Hora, Brendan
RCUH	Inagaki, Takeshi
RCUH	Jeschke, Eric
RCUH	Kackley, Russell
RCUH	Kerns, Michael
RCUH	Koshida, Shintaro
RCUH	Kudo, Tomoyuki
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	Namiki, Shigeru
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	Sai, Jinshi
RCUH	Schubert, Kiaina
RCUH	Shimakawa, Rizumu
RCUH	Spencer, Robin
RCUH	Suh, Hyewon
RCUH	Sur, Ryoko
RCUH	Tait, Philip
RCUH	Tajitsu, Akito
RCUH	Takagi, Yuhei
RCUH	Takiura, Koki
RCUH	Tamae, Richard
RCUH	Tanaka, Yoko
RCUH	Tanaka, Makoto
RCUH	Terai, Tsuyoshi
RCUH	Tomono, Daigo
RCUH	Toyofuku, Ralph
RCUH	Tsang, Emiko
RCUH	Vievard, Sebastien
RCUH	Villegas-Villeza Jr., Loreto
RCUH	Wahl, Matthew
RCUH	Weber, Mark
RCUH	Winegar, Tom
RCUH	Wung, Matthew
RCUH	Yoshida, Hiroshige
RCUH	Yoshiyama, Naomi

Okayama Branch Office

Director	Izumiura, Hideyuki
Associate Professor	Izumiura, Hideyuki
Assistant Professor	Maehara, Hiroyuki
Engineer (Gijyutsuin)	Tsutsui, Hironori

Administration Office

Leader	Tanabe, Keizo
Administrative Supporter	Shibukawa, Hiroko
Administrative Supporter	Yamashita, Ayako
Administrative Maintenance Staff	Watanabe, Noriaki

Nobeyama Radio Observatory

Director	Tatematsu, Ken'ichi
Professor	Tatematsu, Ken'ichi
Chief Research Engineer	Kanzawa, Tomio
Assistant Professor	Ishizuki, Sumio
Assistant Professor	Minamidani, Tetsuhiro
Assistant Professor	Umemoto, Tomofumi
Project Assistant Professor	Torii, Kazufumi
Research Engineer	Mikoshiba, Hiroshi
Engineer (Gishi)	Handa, Kazuyuki
Engineer (Gishi)	Kurakami, Tomio
Engineer (Gishi)	Miyazawa, Chieko
Engineer (Gishi)	Miyazawa, Kazuhiko
Engineer (Gishi)	Shinohara, Noriyuki
Engineer (Gishi)	Takahashi, Toshikazu
Engineer (Gijyutsuin)	Nishitani, Hiroyuki
Project Research Staff	Kaneko, Hiroyuki
Project Research Staff	Kim, Gwanjeong
Project Research Staff	Takekawa, Shunya
Senior Specialist (Tokuninsenmonin)	Hamada, Kaname
Senior Specialist (Tokuninsenmonin)	Kinugasa, Kenzo
Senior Specialist (Tokuninsenmonin)	Takahashi, Shigeru
Research Expert	Maekawa, Jun
Technical Expert	Hayashi, Mitsuru
Technical Expert	Ide, Hidemi
Technical Expert	Inoue, Norio
Technical Expert	Inoue, Norio
Research Supporter	Matsuo, Mitsuhiro
Administrative Supporter	Hatakeyama, Eiko

Administration Office

Deputy Manager	Otsuka, Tomoyoshi

General Affairs Unit

Leader	Otsuka, Tomoyoshi
Administrative Supporter	Kikuchi, Kikue
Administrative Supporter	Shingai, Hisako
Administrative Supporter	Yoda, Chizuko
Administrative Maintenance Staff	Fuji, Shigeru
Administrative Maintenance Staff	Hinata, Shigeto
Administrative Maintenance Staff	Kikuchi, Tsuyoshi
Administrative Maintenance Staff	Yokomori, Yasuyuki

Accounting Unit

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Administrative Supporter	Kodaira, Toshiko
Administrative Supporter	Takasawa, Mitsue
Administrative Supporter	Takemura, Miwako

Mizusawa VLBI Observatory

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Professor	Honma, Mareki
Professor	Kobayashi, Hideyuki
Associate Professor	Shibata, Katsunori
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
Engineer (Shunin Gijyutsuin)	Ueno, Yuji
Engineer (Gijyutsuin)	Hirano, Ken
Project Research Staff	Akahori, Takuya
Project Research Staff	Hanayama, Hidekazu
Project Research Staff	Horiuchi, Takashi
Project Research Staff	Sugiyama, Koichiro
Project Research Staff	Sakai, Daisuke
Project Research Staff	Tazaki, Fumie
Senior Specialist (Tokuninsenmonin)	Adachi, Yuki
Senior Specialist (Tokuninsenmonin)	Kim, Mi Kyoung
Senior Specialist (Tokuninsenmonin)	Miura, Mitsuo
Senior Specialist (Tokuninsenmonin)	Nagayama, Takumi
Senior Specialist (Tokuninsenmonin)	Oyama, Tomoaki
Senior Specialist (Tokuninsenmonin)	Ozawa, Tomohiko
Senior Specialist (Tokumeisenmonin)	Terasawa, Toshio
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	Yamauchi, Aya
Technical Supporter	Konishi, Satoru
Administrative Supporter	Komori, Akiyo
Technical Supporter	Konishi, Satoru
Administrative Supporter	Katsukawa, Marie
Administrative Supporter	Komori, Akiyo

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Administrative Supporter	Oizumi, Yuka
Administrative Supporter	Sasaki, Mie
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Accounting Unit

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Ishigakijima Astronomical Observatory

Director	Honma, Mareki

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Solar Science Observatory

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Associate Professor	Hanaoka, Yoichiro
Associate Professor	Katsukawa, Yukio
Associate Professor	Suematsu, Yoshinori
Associate Professor	Sekii, Takashi
Engineer (Gishi)	Shinoda, Kazuya
Research Expert	Hagino, Masaoki
Project Research Staff	Joshi, Anand Diwakar
Senior Specialist (Tokuninsenmonin)	Iju, Tomoya
Senior Specialist (Tokuninsenmonin)	Morita, Satoshi
Administrative Supporter	Sugimoto, Junko
Research Expert	Yaji, Kentaro
Technical Expert	Inoue, Naoko
Research Supporter	Ishii, Shuichi
Administrative Supporter	Kano, Kaori
Administrative Supporter	Sugimoto, Junko

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Professor	Iguchi, Satoru
Professor	Ogasawara, Ryusuke
Project Professor	Hasegawa, Tetsuo
Associate Professor	Gonzalez Garcia, Alvaro
Associate Professor	Iono, Daisuke
Associate Professor	Kiuchi, Hitoshi
Associate Professor	Kosugi, George
Project Associate Professor	Espada Fernandez, Daniel
Project Associate Professor	Nagai, Hiroshi
Project Associate Professor	Nakanishi, Koichiro
Project Associate Professor	Tafoya Martinez, Daniel
Senior Research Engineer	Kikuchi, Kenichi
Senior Research Engineer	Watanabe, Manabu
Assistant Professor	Ezawa, Hajime
Assistant Professor	Hiramatsu, Masaaki
Assistant Professor	Kamazaki, Takeshi
Assistant Professor	Matsuda, Yuichi
Assistant Professor	Shimojo, Masumi
Project Assistant Professor	Indriolo, Nicholas
Project Assistant Professor	Miura, Rie
Project Assistant Professor	Miyamoto, Yusuke

Project Assistant Professor	Okamoto, Joten
Project Assistant Professor	Saigou, Kazuya
Project Assistant Professor	Ueda, Junko
Research Engineer	Ashitagawa, Kyoko
Research Engineer	Nakazato, Takeshi
Research Engineer	Yamada, Masumi
Engineer (Gishi)	Kato, Yoshihiro
Engineer (Gishi)	Nakamura, Kyoko
Engineer (Gijyutsuin)	Shizugami, Makoto
Project Research Staff	Bakx Tom, Johannes Lucinde Cyrillus
Project Research Staff	Guzman Fernandez, Andres Ernesto
Project Research Staff	Hashimoto, Takuya
Project Research Staff	Higuchi, Yuichi
Project Research Staff	Kroug, Matthias Nils
Project Research Staff	Lee, Seokho
Project Research Staff	Lu, Xing
Project Research Staff	Nguyen, Duc Dieu
Project Research Staff	Nishimura, Yuri
Project Research Staff	Sanhueza Nunez, Patricio Andres
Project Research Staff	Takahashi, Sanemichi
Project Research Staff	Tanaka, Kei
Project Research Staff	Tokuda, Kazuki
Project Research Staff	Wang, Tao
Project Research Staff	Wu, Benjamin
Project Research Staff	Wu, Yu-Ting
Project Research Staff	Zahorecz, Sarolta
Senior Specialist (Tokuninsenmonin)	Fujimoto, Yasuhiro
Senior Specialist (Tokuninsenmonin)	Fukui, Hideharu
Senior Specialist (Tokuninsenmonin)	Furutani, Akio
Senior Specialist (Tokuninsenmonin)	Ikeda, Emi
Senior Specialist (Tokuninsenmonin)	Kawasaki, Wataru
Senior Specialist (Tokuninsenmonin)	Matsui, Takayuki
Senior Specialist (Tokuninsenmonin)	Miel, Renaud Jean Christophe
Senior Specialist (Tokuninsenmonin)	Miyachi, Akihira
Senior Specialist (Tokuninsenmonin)	Morita, Eisuke
Senior Specialist (Tokuninsenmonin)	Nakamoto, Takashi
Senior Specialist (Tokuninsenmonin)	Nakanishi, Takashi
Senior Specialist (Tokuninsenmonin)	Niizeki, Yasuaki
Senior Specialist (Tokuninsenmonin)	Nishie, Suminori
Senior Specialist (Tokuninsenmonin)	Nishikawa, Tomoko
Senior Specialist (Tokuninsenmonin)	Otawara, Kazushige
Senior Specialist (Tokuninsenmonin)	Shimoda, Takanobu
Senior Specialist (Tokuninsenmonin)	So, Ryoken
Senior Specialist (Tokuninsenmonin)	Uemizu, Kazunori
Senior Specialist (Tokuninsenmonin)	Yoshino, Akira
Senior Specialist (Tokuninsenmonin)	Morita, Satoshi
Technical Expert	Tanaka, Rie
Administrative Expert	Kanda, Masako
Research Supporter	Ban, Makiko
Administrative Supporter	Kono, Izumi
Administrative Supporter	Otawara, Hikaru
Administrative Supporter	Saito, Naoko
Research Assistant	Michiyama, Tomonori

NAOJ Chile

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Associate Professor	Asayama, Shinichiro
Associate Professor	Okuda, Takeshi
Assistant Professor	Hirota, Akihiko
Assistant Professor	Ishii, Shun
Assistant Professor	Sawada, Tsuyoshi
Assistant Professor	Takahashi, Satoko
Project Assistant Professor	Hull, Charles Lindsay Hopkins
Engineer (Gishi)	Kobiki, Toshihiko
Engineer (Shunin Gijyutsuin)	Ito, Tetsuya
Project Research Staff	Izumi, Natsuko
Project Research Staff	Silva Bustamante, Andrea Ludovina
Project Research Staff	Walker, Daniel Lewis

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

Acting Manager	Asayama, Shinichiro

General Affairs Unit

Staff	Isozaki, Yuka

Accounting Unit

Staff	Yamafuji, Yasuto

Center for Computational Astrophysics

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Professor	Kokubo, Eiichiro
Assistant Professor	Ito, Takashi
Assistant Professor	Iwasaki, Kazunari
Project Assistant Professor	Kawashima, Tomohisa
Project Research Staff	Ishikawa, Shogo
Project Research Staff	Ohtani, Yukari
Project Research Staff	Taki, Tetsuo
Senior Specialist (Tokuninsenmonin)	Fukushi, Hinako
Senior Specialist (Tokuninsenmonin)	Hohokabe, Hirotaka
Research Expert	Kato, Tsunehiko
Research Expert	Nakayama, Hirotaka
Research Supporter	Hasegawa, Satoki
Research Supporter	Oshigami, Shoko

B Projects

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Assistant Professor	Akutsu, Tomotada
Assistant Professor	Leonardi, Matteo
Assistant Professor	Takahashi, Ryutaro
Project Assistant Professor	Shoda, Ayaka
Research Engineer	Ishizaki, Hideharu
Engineer (Shunin Gijyutsuin)	Tanaka, Nobuyuki
Project Research Staff	Barton, Mark Andrew
Project Research Staff	Zeidler, Simon
Senior Specialist (Tokuninsenmonin)	Hirata, Naoatsu
Senior Specialist (Tokuninsenmonin)	Tapia, San Martin Enzo Nicolas
Administrative Expert	Ohyama, Megumi
Research Supporter	Harada, Mikiko
Administrative Supporter	Yoshizumi, Mizuho

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Assistant Professor	Ohishi, Naoko
Administrative Supporter	Sakamoto, Eri

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Professor	Usuda, Tomonori
Professor	Yamashita, Takuya
Associate Professor	Aoki, Wako
Associate Professor	Hayashi, Saeko
Associate Professor	Sugimoto, Masahiro
Project Associate Professor	Oya, Shin
Assistant Professor	Nishikawa, Jun
Assistant Professor	Yasui, Chikako
Project Assistant Professor	Hattori, Masayuki
Research Engineer	Tazawa, Seiichi
Project Research Staff	Hamano, Satoshi
Project Research Staff	Kubo, Mariko
Project Research Staff	Ozaki, Shinobu
Project Research Staff	Schramm, Malte
Senior Specialist (Tokuninsenmonin)	Chapman, Junko
Senior Specialist (Tokuninsenmonin)	Endo, Tatsuki
Senior Specialist (Tokuninsenmonin)	Ishii, Miki
Senior Specialist (Tokuninsenmonin)	Kusumoto, Hiroshi
Senior Specialist (Tokuninsenmonin)	Shindo, Miwa
Senior Specialist (Tokuninsenmonin)	Sugiyama, Motokuni
Senior Specialist (Tokumeisenmonin)	Inatani, Junji
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Administrative Supporter	Tatsugi, Tomoko

Pasadena Branch Office

Associate Professor	Terada, Hiroshi

A Projects

JASMINE Project Office

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Assistant Professor	Tatsumi, Daisuke
Assistant Professor	Tsujimoto, Takuji
Assistant Professor	Ueda, Akitoshi
Assistant Professor	Yano, Taihei
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Research Supporter	Mase, Ichiro
Research Supporter	Utsunomiya, Shin
Technical Supporter	Kashima, Shingo

RISE Project

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Associate Professor	Matsumoto, Koji
Senior Research Engineer	Tsuruta, Seiitsu
Assistant Professor	Araki, Hiroshi
Assistant Professor	Noda, Hirotomo
Research Engineer	Asari, Kazuyoshi

Project Research Staff	Higuchi, Arika
Project Research Staff	Nomura, Reiko
Project Research Staff	Yamamoto, Keiko
Administrative Supporter	Uemura, Yuiko

SOLAR-C Project Office

Director	Ichimoto, Kiyoshi
Professor	Ichimoto, Kiyoshi
Associate Professor	Hara, Hirohisa
Associate Professor	Kano, Ryouhei
Affliated Associate Professor *	Goto, Motoshi
Assistant Professor	Ishikawa, Ryoko
Assistant Professor	Kubo, Masahito
Assistant Professor	Narukage, Noriyuki
Senior Specialist (Tokuninsenmonin)	Nodomi, Yoshifumi
Project Research Staff	Song, Donguk
Research Supporter	Tsuchiya, Chie
Administrative Supporter	Uekiyo, Hatsue

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Centers

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Associate Professor	Oishi, Masatoshi
Associate Professor	Takata, Tadafumi
Assistant Professor	Furusawa, Hisanori
Assistant Professor	Shirasaki, Yuji
Project Research Staff	Honma, Hidetomo
Project Research Staff	Sorahana, Satoko
Senior Specialist (Tokuninsenmonin)	Isogai, Mizuki
Senior Specialist (Tokuninsenmonin)	Kamegai, Kazuhisa
Senior Specialist (Tokuninsenmonin)	Makiuchi, Shinichiro
Senior Specialist (Tokuninsenmonin)	Ozawa, Takeaki
Senior Specialist (Tokuninsenmonin)	Tanaka, Nobuhiro
Senior Specialist (Tokuninsenmonin)	Zapart, Christopher Andrew
Research Expert	Furusawa, Junko
Research Supporter	Fujikawa, Makiko
Administrative Supporter	Ishii, Yuko

Advanced Technology Center

Director	Uzawa, Yoshinori
Professor	Uzawa, Yoshinori
Project Professor	Takami, Hideki
Associate Professor	Hayano, Yutaka
Associate Professor	Matsuo, Hiroshi
Associate Professor	Miyazaki, Satoshi
Associate Professor	Shan, Wenlei
Senior Research Engineer	Fukushima, Mitsuhiro
Senior Research Engineer	Fujii, Yasunori
Senior Research Engineer	Okada, Norio
Assistant Professor	Kojima, Takafumi
Assistant Professor	Nakaya, Hidehiko
Assistant Professor	Oshima, Tai
Assistant Professor	Suzuki, Ryuji
Research Engineer	Obuchi, Yoshiyuki
Research Engineer	Sato, Naohisa
Engineer (Gishi)	Kamata, Yukiko
Engineer (Gishi)	Kubo, Koichi
Engineer (Gishi)	Uraguchi, Fumihiro
Engineer (Shunin Gijyutsuin)	Fukuda, Takeo
Engineer (Shunin Gijyutsuin)	Ikenoue, Bungo
Engineer (Shunin Gijyutsuin)	Inata, Motoko
Engineer (Shunin Gijyutsuin)	Iwashita, Hikaru

Engineer (Shunin Gijyutsuin)	Kaneko, Keiko
Engineer (Shunin Gijyutsuin)	Mitsui, Kenji
Engineer (Shunin Gijyutsuin)	Tamura, Tomonori
Engineer (Shunin Gijyutsuin)	Waseda, Koichi
Engineer (Gijyutsuin)	Ezaki, Shohei
Engineer (Gijyutsuin)	Sakai, Ryo
Engineer (Gijyutsuin)	Shimizu, Risa
Engineer (Gijyutsuin)	Tsuzuki, Toshihiro
Project Research Staff	Nagai, Makoto
Project Research Staff	Uchiyama, Mizuho
Senior Specialist (Tokuninsenmonin)	Saito, Sakae
Technical Expert	Aiba, Kazukiyo
Technical Expert	Katsumoto, tatsuo
Research Supporter	Nakajima, Shizuka
Administrative Supporter	Kuroda, Kyoko
Administrative Supporter	Murakami, Hiromi
Administrative Supporter	Sato, Takashi

Public Relations Center

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Professor	Fukushima, Toshio
Professor	Watanabe, Jun-ichi
Associate Professor	Agata, Hidehiko
Associate Professor	Yamaoka, Hitoshi
Research Engineer	Katayama, Masato
Senior Engineer	Matsuda, Ko
Engineer (Shunin Gijyutsuin)	Nagayama, Shogo
Senior Specialist (Tokuninsenmonin)	Cheung, Sze Leung
Senior Specialist (Tokuninsenmonin)	Ishikawa, Naomi
Senior Specialist (Tokuninsenmonin)	Lundock, Ramsey Guy
Senior Specialist (Tokuninsenmonin)	Pires Canas, Lina Isabel
Senior Specialist (Tokuninsenmonin)	Tsuzuki, Hiroko
Senior Specialist (Tokuninsenmonin)	Usuda-Sato, Kumiko
Research Expert	Ono, Tomoko
Research Expert	Takata, Hiroyuki
Public Outreach Staff	Endo, Isao
Public Outreach Staff	Fujimura, Ayako
Public Outreach Staff	Fujita, Tokiko
Public Outreach Staff	Hamura, Taiga
Public Outreach Staff	Hatano, Satomi
Public Outreach Staff	Hibino, Yumi
Public Outreach Staff	Ishizaki, Masaharu
Public Outreach Staff	Ito, Hironori
Public Outreach Staff	Koike, Akio
Public Outreach Staff	Kubo, Maki
Public Outreach Staff	Kume, Kaori
Public Outreach Staff	Mikami, Naotsugu
Public Outreach Staff	Naito, Seiichiro
Public Outreach Staff	Natsugari, Satomi
Public Outreach Staff	Nemoto, Shiomi
Public Outreach Staff	Oguri, Junko
Public Outreach Staff	Shibata, Yukiko
Public Outreach Staff	Shioya, Yasuhisa
Public Outreach Staff	Takabatake, Noriko
Public Outreach Staff	Takeda, Takaaki
Public Outreach Staff	Yonetani, Natsuki
Administrative Expert	Noguchi, Sayumi

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Ephemeris Computation Office

Director	Katayama, Masato

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Director	Fukushima, Toshio

The Office for Astronomy Outreach of the IAU

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Director	Matsuda, Ko

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Professor	Saito, Masao
Professor	Sekiguchi, Kazuhiro
Professor	Usuda, Tomonori
Professor	Yamashita, Takuya
Professor	Yoshida, Michitoshi
Project 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	Noumaru, Junichi
Associate Professor	Sugimoto, Masahiro
Associate Professor	Takato, Naruhisa
Associate Professor	Takeda, Yoichi
Associate Professor	Tanaka, Masayuki
Associate Professor	Terada, Hiroshi
Senior Research Engineer	Iwashita, Hiroyuki
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	Maehara, Hiroyuki
Assistant Professor	Minowa, Yosuke
Assistant Professor	Miyoshi, Makoto
Assistant Professor	Morino, Jun-ichi
Assistant Professor*	Nakajima, Tadashi
Assistant Professor	Nishikawa, Jun
Assistant Professor	Ohishi, Naoko
Assistant Professor	Okamoto, Sakurako
Assistant Professor	Okita, Hirofumi
Assistant Professor	Ono, Yoshito
Assistant Professor	Onodera, Masato
Assistant Professor	Pyo, Tae-soo
Assistant Professor	Soma, 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
Project Assistant Professor*	Hashimoto, Jun
Project Assistant Professor*	Hori, Yasunori
Research Engineer	Bando, Takamasa
Research Engineer	Ishizaki, Hideharu
Research Engineer	Tazawa, Seiichi
Engineer (Gishi)	Namikawa, Kazuhito
Engineer (Gishi)	Omata, Koji
Engineer (Shunin Gijyutsuin)	Tamura, Tomonori
Engineer (Shunin Gijyutsuin)	Tanaka, Nobuyuki
Engineer (Gijyutsuin)	Sato, Tatsuhiro
Engineer (Gijyutsuin)	Tsutsui, Hironori
Project Research Staff *	Komatsu, Yu
Project Research Staff *	Konishi, Mihoko
Project Research Staff *	Kuzuhara, Masayuki
Project Research Staff *	Omiya, Masashi
Project Research Staff *	Suzuki, Taiki
Senior Specialist (Tokuninsenmonin)*	Kusakabe, Nobuhiko
Administrative Supporter	Kimura, Hiroko
Research Assistant	Kikuta, Satoshi
Research Assistant	Matsuno, Tadafumi

*concurrently appointed in NINS

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Professor	Kobayashi, Hideyuki
Professor	Mizuno, Norikazu
Professor	Namiki, Noriyuki
Professor	Ogasawara, Ryusuke
Professor	Sakamoto, Seiichi
Professor	Tatematsu, Ken'ichi
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	Matsumoto, Koji
Associate Professor	Okuda, Takeshi
Associate Professor	Shibata, Katsunori
Senior Research Engineer	Kanzawa, Tomio
Senior Research Engineer	Kikuchi, Kenichi
Senior Research Engineer	Tsuruta, Seiitsu
Senior 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	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	Yamada, Masumi
Engineer (Gishi)	Handa, Kazuyuki
Engineer (Gishi)	Kato, Yoshihiro
Engineer (Gishi)	Kobiki, Toshihiko
Engineer (Gishi)	Kurakami, Tomio
Engineer (Gishi)	Miyazawa, Chieko
Engineer (Gishi)	Miyazawa, Kazuhiko
Engineer (Gishi)	Nakamura, Kyoko
Engineer (Gishi)	Shinohara, Noriyuki
Engineer (Gishi)	Takahashi, Toshikazu
Engineer (Shunin Gijyutsuin)	Ito, Tetsuya
Engineer (Shunin Gijyutsuin)	Ueno, Yuji
Engineer (Gijyutsuin)	Hirano, Ken
Engineer (Gijyutsuin)	Nishitani, Hiroyuki
Engineer (Gijyutsuin)	Shizugami, Makoto
Research Supporter	Tsuneyama, Junko
Administrative Supporter	Mashiko, Kyoko
Engineer	Nishitani, Hiroyuki
Engineer	Shizugami, Makoto
Engineer	Wada, Takuya
Specially Appointed Senior Specialist	Takebayashi, Yasuo
Research Supporter	Tsuneyama, Junko
Research Assistant	Taniguchi, Kotomi

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Associate Professor	Katsukawa, Yukio
Associate Professor	Sekii, Takashi
Associate Professor	Suematsu, Yoshinori
Assistant Professor	Ishikawa, Ryoko
Assistant Professor	Kubo, Masahito
Assistant Professor	Narukage, Noriyuki
Project Assistant Professor	Toriumi, Shin
Engineer (Gishi)	Shinoda, Kazuya
Senior Engineer	Shinoda, Kazuya
Research Supporter	Ishii, Shuichi

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Assistant Professor	Hamana, Takashi
Assistant Professor	Iwasaki, Kazunari
Assistant Professor	Kataoka, Akimasa
Assistant Professor	Moriya, Takashi
Assistant Professor	Takiwaki, Tomoya
Project Assistant Professor	Nozawa, Takaya
Project Assistant Professor	Ogihara, Masahiro
Project Assistant Professor	Shirasaki, Masato
Project Assistant Professor	Sotani, Hajime
Project Assistant Professor	Suzuki, Akihiro
Project Research Staff	Kusune, Takayoshi
Administrative Supporter	Izumi, Shioko

5. Research Support Departments

Research Enhancement Strategy Office

Director	Iguchi, Satoru
Senior Specialist (Tokuninsenmonin)	Asaga, Akitaka
Senior Specialist (Tokuninsenmonin)	Chapman, Junko
Senior Specialist (Tokuninsenmonin)	Fukui, Hideharu
Senior Specialist (Tokuninsenmonin)	Hasuo, Ryuichi
Senior Specialist (Tokuninsenmonin)	Hori, Kuniko
Senior Specialist (Tokuninsenmonin)	Lundock, Ramsey Guy
Senior Specialist (Tokuninsenmonin)	Miura, Mitsuo
Senior Specialist (Tokuninsenmonin)	Noda, Noboru
Senior Specialist (Tokuninsenmonin)	Okamoto, Koichi
Senior Specialist (Tokuninsenmonin)	Suzui, Mitsukazu

Research Assessment Support Office

Director	Watanabe, Jun-ichi
Senior Specialist (Tokuninsenmonin)	Hori, Kuniko

Office of International Relations

Director	Watanabe, Jun-ichi
Senior Specialist (Tokuninsenmonin)	Hasuo, Ryuichi
Senior Specialist (Tokuninsenmonin)	Haruki, Mutsumi
Senior Specialist (Tokuninsenmonin)	Matsumoto, Mizuho

Support Desk

Research Supporter	Shirato, Reiko
Research Supporter	Yamanaka, Wakana

Human Resources Planning Office

Director	Noda, Noboru
Senior Specialist (Tokuninsenmonin)	Noda, Noboru

Safety and Health Management Office

Director	Okamoto, Koichi
Senior Specialist (Tokuninsenmonin)	Okamoto, Koichi
Technical Expert	Tsuchiya, Tatsumi

Engineering Promotion Office

Director	Takami, Hideki
Senior Specialist (Tokuninsenmonin)	Suzui, Mitsukazu

IT Security Office

Director	Watanabe, Jun-ichi
Deputy Director	Oe, Masafumi
Senior Research Engineer	Nakamura, Koji
Assistant Professor	Oe, Masafumi
Engineer (Gijyutsuin)	Matsushita, Sayaka
Administrative Expert	Aoki, Makiko

Administration Department

General Manager	Sasagawa, Hikaru

General Affairs Group

Manager	Harada, Eiichiro
Deputy Manager	Furuhata, Tomoyuki
Senior Specialist (Senmonin)	Yamanouchi, Mika
Senior Specialist (Tokuninsenmonin)	Ito, Yuko
Senior Specialist (Tokuninsenmonin)	Murakami, Sachiko
Senior Specialist (Tokuninsenmonin)	Takahashi, Hidehiro
Senior Specialist (Tokuninsenmonin)	Yamamoto, Chieko
Specialist (Information Technology)	Chiba, Yoko
Specialist (Personnel Accounting)	Ishii, Katsuhiko

General Affairs Unit

Leader	Chiba, Yoko
Staff	Matsukura, Koji
Staff	Mochimaru, Shiori
Staff	Morita, Akitsugu
Administrative Expert	Shishido, Rie
Administrative Supporter	Kobayashi, Kayo
Administrative Supporter	Seki, Kumi
Re-employment Staff	Amemiya, Hidemi

Personnel Unit

Leader	Yamanouchi, Mika
Senior Staff	Iida, Naoto
Staff	Iwasaki, Yumi
Staff	Kayamori, Shinji
Staff	Sakamoto, Misato

Payroll Unit

Leader	Ishii, Katsuhiko
Staff	Furukawa, Shinichiro
Staff	Inoue, Miyuki
Administrative Supporter	Aiba, Narukazu
Administrative Supporter	Kawabata, ritan
Administrative Supporter	Takase, Kazuhiko

Employee Affairs Unit

Leader	Yamaura, Mari
Staff	Ouchi, Kaori
Staff	Saito, Masahiro
Administrative Expert	Noguchi, Megumi
Research Promotion Group	
Manager	Ishibashi, Kazuya
Senior Specialist (Senmonin)	Onishi, Tomoyuki
Administrative Supporter	Torii, Makiko
Research Support Unit	
Leader	Goto, Michiru
Staff	Nakagawa, Yukie
Administrative Expert	Tanaka, Midori
Administrative Expert	Yoshizawa, Mariko
Administrative Supporter	Komoda, Chizuru
Administrative Supporter	Suzuki, Yoshiko
Administrative Supporter	Urushibata, Kozue
Graduate School Unit	
Leader	Fujimori, Mihiro
Administrative Expert	Inoue, Mizuho
Administrative Supporter	Omura, Yumiko
International Academic Affairs Unit	
Leader	Tsukano, Satomi
Administrative Supporter	Ito, Yoshihisa
Financial Affairs Group	
Manager	Honda, Daisuke
Deputy Manager	Ikeda, Hiroshi
Specialist (Audit)	Ishikawa, Junya
Staff	Hiramatsu, Naoya
General Affairs Unit	
Leader	Yamamoto, Shinichi
Administrative Supporter	Sasaki, Sayuri
Budget Unit	
Leader	Tanigaichi, Takuya
Staff	Masuda, Akio
Administrative Supporter	Yano, Kumiko
Asset Management Unit	
Leader	Kikkawa, Hiroko
Staff	Takahashi, Sachiko
Receiving Unit	
Leader	Kikkawa, Hiroko
Administrative Supporter	Nakagomi, Kimitoshi
Administrative Supporter	Onuki, Yasue
Administrative Supporter	Shibui, Junko
Administrative Supporter	Tsukamoto, Satoko
Accounting Group	
Manager	Tanaka, Masaru
Accounting Unit	
Leader	Sato, Yoko
Staff	Okubo, Kazuhiko
Administrative Supporter	Kobayashi, Rina
Administrative Supporter	Nakayama, Keiko
Administrative Supporter	Suzuki, Yukiko
Procurement Unit	
Leader	Yamazaki, Go
Staff	Sugimoto, Naomi
Staff	Takada, Miyuki
Administrative Expert	Sato, Masako
Administrative Supporter	Ochiai, Nana
Re-employment Staff	Hyuga, Tadayuki
MEXT Trainee	
Staff	Takai, Tetsuya
Facilities Group	
Manager	Takahashi, Kazuhisa
General Affairs Unit	
Leader	Kawashima, Ryota
Staff	Tamura, Makoto
Administrative Supporter	Hagino, Hiromichi
Planning Unit	
Leader	Murakami, Kazuhiro
Administrative Supporter	Nagata, Yomogi
Administrative Supporter	Takizawa, Minoru
Maintenance Unit	
Leader	Narisawa, Hiroyuki
Administrative Supporter	Kurose, Takahiro

6. Personnel Change

Director General

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2018/4/1	Tsuneta, Saku	Appointed	Director General	(Japan Aerospace Exploration Agency Institute of Space and Astronautical Science, Director General)

Research and Academic Staff

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2018/4/1	Hayashi, Masahiko	Hired	Division of Optical and Infrared Astronomy, Professor	(Director General)
2018/5/1	Uzawa, Yoshinori	Hired	Advanced Technology Center, Professor	(National Institute of Information and Communications Technology, Permanent Staff, Terahertz Technology Research Center, Director of Collaborative Research Laboratory of Terahertz Technology)
2018/8/1	Okamoto, Sakurako	Hired	Division of Optical and Infrared Astronomy (Subaru Telescope), Assistant Professor	(Subaru Telescope, Project Research Staff)
2018/10/1	Fukagawa, Misato	Hired	Division of Radio Astronomy (NAOJ Chile Observatory), Professor	(Nagoya University Graduate School of Science, Associate Professor)
2018/11/1	Maehara, Hiroyuki	Hired	Division of Optical and Infrared Astronomy (Subaru Telescope), Assistant Professor	(Kyoto University Graduate School of Science, Program-Specific Associate Professor)
2019/2/1	Moriya, Takashi	Hired	Division of Theoretical Astronomy, Assistant Professor	(Division of Theoretical Astronomy, Project Assistant Professor)
2019/3/1	Iwasaki, Kazunari	Hired	Division of Theoretical Astronomy (Center for Computational Astrophysics), Assistant Professor	(Osaka University Graduate School of Science, Specially-appointed Assistant Professor)

2018/4/30	Kashikawa, Nobunari	Resigned	(The University of Tokyo Graduate School of Science, Professor)	Division of Optical and Infrared Astronomy (TMT-J Project Office), Associate Professor
2018/9/30	Hayashi, Masahiko	Resigned	(JSPS Bonn Office, Director)	Division of Optical and Infrared Astronomy, Professor
2018/10/31	Inoue, Goki	Resigned	(The Graduate University for Advanced Studies)	IT Security Office, Research Engineer
2019/3/31	Kobayashi, Hideyuki	Resigned	(Mizusawa VLBI Observatory, Project Professor (Distinguished Professor))	Division of Radio Astronomy (Mizusawa VLBI Observatory), Professor
2019/3/31	Ogasawara, Ryusuke	Resigned		Division of Radio Astronomy (ALMA Project), Professor
2019/3/31	Oishi, Masatoshi	Resigned	(Public Relations Center, Project Professor)	Astronomy Data Center, Associate Professor
2019/3/31	Oishi, Naoko	Resigned		Division of Optical and Infrared Astronomy (Gravitational Wave Project Office), Assistant Professor

2019/3/31	Mikoshiba, Hiroshi	Retired		Division of Radio Astronomy (Nobeyama Radio Observatory), Research Engineer

2018/7/1	Fukushima, Mitsuhiro	Promoted	Advanced Technology Center, Senior Research Engineer	Advanced Technology Center, Research Engineer

Engineering Staff

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2018/4/1	Shimizu, Risa	Hired	Advanced Technology Center, Engineer	
2018/5/1	Matsushita, Sayaka	Hired	Astronomy Data Center, Engineer	
2019/3/20	Wada, Takuya	Resigned		Division of Radio Astronomy (Nobeyama Radio Observatory), Engineer
2019/3/31	Matsuda, Ko	Retired	(Public Relations Center, Re-employment Staff)	Public Relations Center, Senior Engineer

Administrative Staff

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2018/4/1	Onuma, Toru	Hired	Mizusawa VLBI Observatory, Head of Administration Office and General Affairs Unit, Leader	(National Institutes for the Humanities National Institute for Japanese Language and Linguistics)
2018/4/1	Kurose, Takahiro	Hired	Administration Department Facilities Group Maintenance Unit, Staff	(The University of Tokyo)
2018/7/1	Tanigaichi, Takuya	Hired	Administration Department Financial Affairs Group Budget Unit, Leader	(The University of Tokyo)
2018/8/1	Takeda, Kiyotaka	Hired	Nobeyama Radio Observatory Administration Office Accounting Unit, Leader	(Shinshu University)
2018/6/30	Akaike, Makoto	Resigned	(The University of Tokyo)	Administration Department Financial Affairs Group Budget Unit, Leader
2019/3/31	Ishibashi, Kazuya	Resigned	(Nagoya University)	Administration Department Research Promotion Group, Manager
2019/3/31	Ikeda, Hiroshi	Resigned	(The University of Tokyo)	Administration Department Financial Affairs Group, Deputy Manager
2019/3/31	Ishii, Katsuhiko	Resigned	(Tokyo Gakugei University)	Administration Department General Affairs Group Payroll Unit, Leader
2019/3/31	Sato, Yoko	Resigned	(Tokyo Medical and Dental University)	Administration Department Accounting Group Accounting Unit, Leader
2019/3/31	Yamazaki, Go	Resigned	(Tokyo Gakugei University)	Administration Department Accounting Group Procurement Unit, Leader
2019/3/31	Tanabe, Keizo	Resigned	(Okayama University)	Subaru Telescope Administration Unit, Leader
2019/3/31	Todoriki, Tatsuya	Resigned	(The University of Tokyo)	Public Relations Center Administration Office Library, Leader
2019/3/31	Otsuka, Tomoyoshi	Retired	(Nobeyama Radio Observatory, Re-employment Staff)	Nobeyama Radio Observatory, Head of Administration Office
2018/4/1	Yamanouchi, Mika	Promoted	Administration Department General Affairs Group, Senior Specialist (Personnel) and Personnel Unit, Leader	Administration Department General Affairs Group Personnel Unit, Leader
2018/4/1	Iida, Naoto	Promoted	Administration Department General Affairs Group Personnel Unit, Senior Staff	Mizusawa VLBI Observatory Administration Office General Affairs Unit, Staff

2018/8/1	Miyabara, Yasuhide	Reassigned	National Institutes of Natural Sciences Administrative Bureau Financial Affairs Division, Chief of Accounting Section	Nobeyama Radio Observatory Administration Office Accounting Unit, Leader

Employee on Annual Salary System

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2018/4/1	Takami, Hideki	Hired	Advanced Technology Center, Project Professor (Distinguished Professor)	(Advanced Technology Center, Professor)
2018/4/1	Kambe, Eiji	Hired	Subaru Telescope, Project Associate Professor	(Okayama Astrophysical Observatory, Project Associate Professor)
2018/4/1	Miyamoto, Yusuke	Hired	NAOJ Chile Observatory, Project Assistant Professor	(Nobeyama Radio Observatory, Project Research Staff)
2018/4/1	Tsukagoshi, Takashi	Hired	Division of Radio Astronomy, Project Assistant Professor	
2018/4/1	Suzuki, Akihiro	Hired	Division of Theoretical Astronomy, Project Assistant Professor	
2018/4/1	Sakai, Daisuke	Hired	Mizusawa VLBI Observatory, Project Research Staff	
2018/4/1	Takekawa, Shun'ya	Hired	Nobeyama Radio Observatory, Project Research Staff	
2018/4/1	Okamoto, Sakurako	Hired	Subaru Telescope, Project Research Staff	
2018/4/1	Ishikawa, Shogo	Hired	Center for Computational Astrophysics, Project Research Staff	
2018/4/1	Suzuki, Tomoko	Hired	NAOJ Chile Observatory, Project Research Staff	
2018/4/1	Lee, Minju	Hired	NAOJ Chile Observatory, Project Research Staff	
2018/4/1	Takahashi, Shigeru	Hired	Nobeyama Radio Observatory, Senior Specialist	(Nobeyama Radio Observatory, Research Expert)
2018/4/1	Iju, Tomoya	Hired	Solar Science Observatory, Senior Specialist	
2018/4/1	Takita, Satoshi	Hired	Subaru Telescope, Senior Specialist	
2018/4/1	Fukushi, Hinako	Hired	Center for Computational Astrophysics, Senior Specialist	(Center for Computational Astrophysics, Research Supporter)
2018/4/1	Ishii, Miki	Hired	TMT-J Project Office, Senior Specialist	(TMT-J Project Office, Research Expert)
2018/4/1	Nodomi, Yoshifumi	Hired	SOLAR-C Project Office, Senior Specialist	
2018/4/1	Isogai, Mizuki	Hired	Astoronomy Data Center, Senior Specialist	(Astoronomy Data Center, Research Expert)
2018/5/1	Nishie, Suminori	Hired	NAOJ Chile Observatory, Senior Specialist	
2018/6/1	Ito, Yuko	Hired	Administration Department General Affairs Group, Senior Specialist	
2018/7/15	Kimura, Atsushi	Hired	NAOJ Chile Observatory, Senior Specialist	
2018/9/1	Nguyen Duc Dieu	Hired	NAOJ Chile Observatory, Project Research Staff	
2018/9/18	Nomura, Reiko	Hired	RISE Project Office, Project Research Staff	
2018/10/1	Taki, Tetsuo	Hired	Center for Computational Astrophysics, Project Research Staff	
2018/10/1	Murakami, Sachiko	Hired	Administration Department General Affairs Group, Senior Specialist	(Administration Department General Affairs Group General Affairs Unit, Administrative Expert)
2018/10/22	Wu, Benjamin	Hired	NAOJ Chile Observatory, Project Research Staff	

2018/11/26	Bakx, Tom Johannes Lucinde Cyrillus	Hired	NAOJ Chile Observatory, Project Research Staff	
2018/12/17	Hohokabe, Hirotaka	Hired	Center for Computational Astrophysics, Senior Specialist	(Center for Computational Astrophysics, Research Supporter)
2019/1/1	Kawashima, Tomohisa	Hired	Center for Computational Astrophysics, Project Assistant Professor	(Division of Theoretical Astronomy, Project Research Staff)
2019/1/1	Kakazu, Yuko	Hired	Subaru Telescope, Senior Specialist	
2019/2/1	Yamashita, Takuji	Hired	Subaru Telescope, Project Research Staff	
2019/2/1	Higuchi, Yuichi	Hired	ALMA Project, Project Research Staff	
2019/2/1	Hayashi, Yohei	Hired	ALMA Project, Senior Specialist	
2019/3/1	Indriolo, Nicholas	Hired	ALMA Project, Project Assistant Professor	
2019/3/1	Lee, Seokho	Hired	ALMA Project, Project Research Staff	
2019/3/1	Hamano, Satoshi	Hired	TMT-J Project Office, Project Research Staff	

2018/5/31	Harakawa, Hiroki	Resigned		TMT-J Project Office,Project Research Staff
2018/5/31	Oishi, Yukie	Resigned		Subaru Telescope, Senior Specialist
2018/6/30	Egusa, Fumi	Resigned		NAOJ Chile Observatory, Project Assistant Professor
2018/7/6	Okumura, Yuji	Resigned		NAOJ Chile Observatory, Senior Specialist
2018/7/31	Okamoto, Sakurako	Resigned	(Division of Optical and Infrared Astronomy (Subaru Telescope), Assistant Professor)	Subaru Telescope, Project Research Staff
2018/8/31	Takahashi, Hiroyuki	Resigned		Center for Computational Astrophysics, Project Assistant Professor
2018/8/31	Salinas Poblete, Vachail Nicolas	Resigned		NAOJ Chile Observatory, Project Research Staff
2018/8/31	Oshino, Shoichi	Resigned		Center for Computational Astrophysics, Senior Specialist
2018/9/29	Capocasa, Eleonora	Resigned		Gravitational Wave Project Office, Project Research Staff
2018/11/24	Lee, Minju	Resigned		NAOJ Chile Observatory, Project Research Staff
2018/11/30	Niino, Yu	Resigned		Subaru Telescope, Project Research Staff
2018/11/30	Kimura, Atsushi	Resigned		NAOJ Chile Observatory, Senior Specialist
2018/12/31	Lee, Kyoung Sun	Resigned		Solar Science Observatory, Project Research Staff
2018/12/31	Kawashima, Tomohisa	Resigned	(Center for Computational Astrophysics, Project Assistant Professor)	Division of Theoretical Astronomy, Project Research Staff
2018/12/31	Oya, Masaaki	Resigned		Nobeyama Radio Observatory, Senior Specialist
2019/1/31	Moriya, Takashi	Resigned	(Division of Theoretical Astronomy, Assistant Professor)	Division of Theoretical Astronomy, Project Assistant Professor
2019/3/18	Sakai, Nobuyuki	Resigned		Mizusawa VLBI Observatory, Project Research Staff
2019/3/31	Tafoya Martinez, Daniel	Resigned		ALMA Project, Project Associate Professor
2019/3/31	Hashimoto, Takuya	Resigned		ALMA Project, Project Research Staff
2019/3/31	Sorahana, Satoko	Resigned	(TMT-J Project Office, Project Research Staff)	Astronomy Data Center, Project Research Staff

2019/3/31	Pires Canas, Lina Isabel	Resigned	(Public Relations Center, Senior Specialist)	Public Relations Center, Senior Specialist
2019/3/31	Yamamoto, Chieko	Resigned	(Administration Department General Affairs Group, Employee on Annual Salary System Transferring to the Mandatory Retirement System Senior Specialist)	Administration Department General Affairs Group, Senior Specialist

2018/12/20	Kobayashi, Tsuyoshi	Quit		NAOJ Chile Observatory, Senior Specialist

2018/4/30	Pena Arellano, Fabian Erasmo	Contract Expired		Gravitational Wave Project Office, Project Research Staff
2018/5/31	Ao, Yiping	Contract Expired		NAOJ Chile Observatory, Project Research Staff
2018/5/31	Noguchi, Koki	Contract Expired		Administration Department General Affairs Group, Senior Specialist
2018/6/30	Wu, Benjamin	Contract Expired		Division of Theoretical Astronomy, Project Research Staff
2018/7/31	Kawakami, Kazuyuki	Contract Expired		NAOJ Chile Observatory, Senior Specialist
2018/8/31	Takebayashi, Yasuo	Contract Expired		Division of Radio Astronomy, Senior Specialist
2018/9/30	Fukui, Akihiko	Contract Expired		Subaru Telescope, Senior Specialist
2018/11/30	Horie, Yosaku	Contract Expired		NAOJ Chile Observatory, Senior Specialist
2019/3/31	Toriumi, Shin	Contract Expired		Division of Solar and Plasma Astrophysics, Project Assistant Professor
2019/3/31	Nozawa, Takaya	Contract Expired	(Division of Science, Project Research Staff)	Division of Theoretical Astronomy, Project Assistant Professor
2019/3/31	Joshi, Anand Diwakar	Contract Expired		Solar Science Observatory, Project Research Staff
2019/3/31	Izumi, Natsuko	Contract Expired		NAOJ Chile, Project Research Staff
2019/3/31	Kubo, Mariko	Contract Expired	(Subaru Telescope, Project Research Staff)	(TMT-J Project Office, Project Research Staff)
2019/3/31	Homma, Hidetomo	Contract Expired		Astronomy Data Center, Project Research Staff
2019/3/31	Taniguchi, Akimitsu	Contract Expired		Subaru Telescope, Senior Specialist
2019/3/31	Furutani, Akio	Contract Expired		ALMA Project, Senior Specialist
2019/3/31	Shimoda, Takanobu	Contract Expired	(ALMA Project, Project Research Staff)	ALMA Project, Senior Specialist
2019/3/31	Morita, Eisuke	Contract Expired	(ALMA Project, Senior Specialist)	ALMA Project, Senior Specialist
2019/3/31	Matsui, Takayuki	Contract Expired	(ALMA Project, Senior Specialist)	ALMA Project, Senior Specialist
2019/3/31	Kawasaki, Wataru	Contract Expired	(ALMA Project, Senior Specialist)	ALMA Project, Senior Specialist
2019/3/31	Tapia San Martin, Enzo Nicolas	Contract Expired		Gravitational Wave Project Office, Senior Specialist
2019/3/31	Cheung, Sze Leung	Contract Expired		Public Relations Center, Senior Specialist

Employees on Annual Salary System Transferring to the Mandatory Retirement System

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2018/4/1	Ishikawa, Naomi	Hired	Public Relations Center, Senior Specialist	(Public Relations Center, Employee on Annual Salary System Senior Specialist)

Research Administrator Staff

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2019/3/31	Lundock, Ramsey Guy	Contract Expired	(Public Relations Center, Employee on Annual Salary System Senior Specialist)	Research Enhancement Strategy Office (Public Relations Center), Senior Specialist
2019/3/31	Chapman, Junko	Contract Expired	(Research Enhancement Strategy Office (Office of International Relations), Research Administrator Staff Transferring to the Mandatory Retirement System Senior Specialist)	Research Enhancement Strategy Office (TMT-J Project Office), Senior Specialist

Foreign Visiting Researcher

Name	Period	Affiliated Institute
Kuzanyan, Kirill	2018/9/5 ~ 2018/12/14	Institute for Terrestrial magnetism, Ionosphere and Radiowave Propagation, Russian Academy of Sciences(Russia)
Shin, Junho	2018/4/6 ~ 2018/7/5	Kyung Hee Astronomical Observatory, College of Applied Science, Kyung Hee University(Korea)
Thompson, Michael John	2018/10/1 ~ 2018/10/15	National Center for Atmospheric Research(USA)
Famiano, Michael	2018/4/23 ~ 2018/5/30	Western Michigan University(USA)
Kawata, Daisuke	2018/7/23 ~ 2018/8/31	Mullard Space Science Laboratory, University College London(UK)
Kusakabe, Motohiko	2018/4/17 ~ 2018/6/29	Beihang University(China)

Secondment Staff

Name	Term of Secondment	Main Institute, Position	Secondment Institute, Position
Ando, Masaki	2018/4/1 ~ 2019/3/31	The University of Tokyo Graduate School of Science, Associate Professor	Gravitational Wave Project Office, Affiliated Associate Professor
Kashikawa, Nobunari	2018/6/13 ~ 2019/3/31	The University of Tokyo Graduate School of Science, Professor	Subaru Telescope, Affiliated Professor
Ichimoto, Kiyoshi	2016/4/1 ~ 2019/3/31	Kyoto University Graduate School of Science, Professor	SOLAR-C Project Office, Professor
Flaminio, Raffaele	2017/9/1 ~ 2019/3/31	The French National Centre for Scientific Research, First Class Researcher	Gravitational Wave Project Office, Project Professor
Fukagawa, Misato	2018/4/1 ~ 2018/9/30	Nagoya University Graduate School of Science, Associate Professor	NAOJ Chile, Professor

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	Kwasan and Hida Observatories, Graduate School of Science, Kyoto University
Kawakita, Hideyo	Faculty of Science, Kyoto Sangyo University
Kusano, Kanya	Institute for Space-Earth Environmental Research, The University of Nagoya
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
Ohashi, Masatake	Institute for Cosmic Ray Research, The University of Tokyo

From NAOJ

Fukagawa, Misato	ALMA Project
Gouda, Naoteru	JASMINE Project Office
Honma, Mareki	Mizusawa VLBI Observatory
Iguchi, Satoru	Vice-Director General (on Program)
Kokubo, Eiichiro	Center for Computational Astrophysics
Saito, Masao	Director of Research Coordination
Takami, Hideki	Director of Engineering
Tomisaka, Kohji	Division of Theoretical Astronomy
Usuda, Tomonori	TMT-J Project Office
● Watanabe, Jun-ichi	Vice-Director General (on General Affairs)
Yoshida, Michitoshi	Subaru Telescope

● Chairperson ○ Vise-Chairperson

Period: April 1, 2018 - March 31, 2020

8. Professors Emeriti

Professors Emeriti (NAOJ)

Arimoto, Nobuo
Ando, Hiroyasu
Chikada, Yoshihiro
Fujimoto, Masakatsu
Hayashi, Masahiko
Hiei, Eijiro
Hirayama, Tadashi
Inoe, Makoto
Ishiguro, Masato
Iye, Masanori
Kaifu, Norio
Kakuta, Chuichi
Karoji, Hiroshi
Kawaguchi, Noriyuki
Kawano, Nobuyuki
Kinoshita, Hiroshi
Kobayashi, Yukiyasu
Kodaira, Keiichi
Manabe, Seiji
Miyama, Shiyoken
Miyamoto, Masanori
Mizumoto, Yoshihiko
Nakano, Takenori
Nariai, Kyoji
Nishimura, Shiro
Nishimura, Tetsuo
Noguchi, Kunio
Noguchi, Takashi
Oe, Masatsugu
Okamoto, Isao
Sakurai, Takashi
Shibasaki, Kiyoto
Watanabe, Tetsuya
Yamashita, Yasumasa
Yokoyama, Koichi

IV Finance

Revenue and Expenses (FY2018)

(Unit: ¥1,000)

Revenue	Budget	Final Account	Budget − Final Account
Management Expenses Grants	10,598,039	11,282,054	−684,015
Facilities Maintenance Grants	562,500	334,080	228,420
Subsidy Income	1,315,611	1,315,611	0
Miscellaneous Income	50,890	52,525	−1,635
Industry-Academia Research Income and Donation Income	283,848	551,937	−268,089
Reversals of Reserves for Specific Purposes	0	0	0
Total	12,810,888	13,536,207	−725,319
Expenses	Budget	Final Account	Budget − Final Account
Management Expenses	10,648,929	10,316,561	332,368
Employee Personnel Expenses	3,608,606	3,570,797	37,809
Operating Expenses	7,040,323	6,745,764	294,559
Facilities Maintenance Expenses	562,500	334,080	228,420
Subsidy Expenses	1,315,611	1,315,611	0
Industry-Academia Research Expenses and Donation Expenses	283,848	315,899	−32,051
Total	12,810,888	12,282,151	528,737
Revenue-Expenses	Budget	Final Account	Budget − Final Account
	0	1,254,056	−1,254,056

V KAKENHI (Grants-in-Aid for Scientific Research)

1. Series of Single-year Grants for FY 2018

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)	7	107,400	32,220	139,620
Scientific Research (S)	2	47,600	14,280	61,880
Scientific Research (A)	11	110,000	33,000	143,000
Scientific Research (B)	7	29,100	8,730	37,830
Young Scientists (A)	2	2,200	660	2,860
Grant-in-Aid for Challenging Research (Pioneering)	2	15,600	4,680	20,280
Research Activity Start-up	2	1,800	540	2,340
JSPS Research Fellows	4	4,000	1,200	5,200
JSPS International Research Fellows	1	800	0	800
Publication of Scientific Research Results	1	700	0	700
Total	39	319,200	95,310	414,510

2. Multi-year Fund for FY 2018

Research Categories	Number of Selected Projects	Budget (Unit: ¥1,000)		
		Direct Funding	Indirect Funding	Total
Scientific Research (C)	23	21,800	6,600	28,400
Challenging Exploratory Research	3	3,200	960	4,160
Young Scientists (B)	10	7,700	2,310	10,010
Grant-in-Aid for Early-Career Scientists	10	10,400	3,120	13,520
Fostering Joint International Research	1	9,000	2,700	11,700
Fostering Joint International Research (B)	1	1,200	360	1,560
Total	48	53,300	16,050	69,350

VI Research Collaboration

1. Open Use

Type	Project/Center	Category	Number of Accepted Proposal	Total Number of Researcher	Notes
Open Use at Project/Center	Subaru Telescope		95	309 (54)	53 Institutes, 8 Countries
	Solar Science Observatory	Ground-based Solar Observatory	*	*	*
		Sun-observing satellite “Hinode”	**	**	**
	Nobeyama Radio Observatory	45-m telescope (Regular Program)	20	159 (55)	42 Institutes, 12 Countries
		45-m telescope (Short Program)	4	29 (11)	14 Institutes, 4 Countries
		45-m telescope (Back-up Program)	2	24 (6)	8 Institutes, 5 Countries
		45-m telescope (Large Program)	2	168 (142)	67 Institutes, 15 Countries
		45-m telescope (GuaranteedTimeObservations)	0	0	
		45-m telescope (Director’s Discretionary Time)	0	0	
	Mizusawa VLBI Observatory	VERA	24	199 (143)	36 Institutes, 18 Countries
	Astronomy Data Center		353	353 (37 at foreign institutes)	80 Institutes, 17 Countries
	Center for Computational Astrophysics		278	278	65 Institutes, 8 Countries
	Advanced Technology Center	Facility Use	23	102 (1)	42 Institutes, 1 Country
		Joint Research and Development	10	47 (2)	15 Institutes
	ALMA Project/ NAOJ Chile Observatory	ALMA (Cycle5)	433	4,700 (4,120)	342 Institutes, 39 Countries
		ASTE	8	51 (12)	20 Institutes, 4 Countries
Joint Development Research			6		6 Institutes
Research Assembly			21		11 Institutes
NAOJ Symposium			0		

The number of foreign researchers shown in brackets ( ) is included in the total.
Notes show the number of institutes and foreign countries represented by the proposal PIs. The country count does not include Japan.
The period of ALMA (Cycle5) is September, 2018 from October, 2017.
* The observation data is open to the public on the web. No application is needed to use the data.
** Since the function of the Hinode Science Center has shifted to the Astronomical data center, there is no procedure of application and adoption as “Hinode”.

2. Commissioned Research Fellows

Visiting Scholars (Domestic)

Name	Position at NAOJ	Affiliated Institute	Period	Host Project/Center/ Division
Shoji, Isao	Visiting Professor	Tokyo University of Science	2018/4/1 ~ 2019/3/31	Astronomy Data Center
Otsubo, Toshimichi	Visiting Professor	Hitotsubashi University	2018/4/1 ~ 2019/3/31	RISE Project
Hayakawa, Takehito	Visiting Professor	National Institutes for Quantum and Radiological Science and Technology	2018/4/1 ~ 2019/3/31	Division of Theoretical Astronomy
Yanagisawa, Toshifumi	Visiting Associate Professor	Japan Aerospace Exploration Agency	2018/4/1 ~ 2019/3/31	Center for Computational Astrophisics

Visiting Scholars (Foreign)

Name	Position at NAOJ	Affiliated Institute	Period	Host Project/Center/ Division
Ziegler, Bodo	Visiting Professor	University Vienna, Dpt. Of Astrophysics	2018/9/2 ~ 2018/10/1	Subaru Telescope
Verley, Simon	Visiting Professor	University of Granada (Spain), Department of Astronomy	2018/4/27 ~ 2018/6/18	NAOJ Chile Observatory

JSPS (Japan Society for the Promotion of Science) Postdoctoral Research Fellows

Name	Research Subject	Acceptance Period	Host Researcher
Oshima, kenta	Elucidations and Applications of Chaotic Transport Mechanisms in the Solar System: Development of Medium-Energy Orbital Mechanics	2018/4/1 ~ 2021/3/31	Fukushima, Toshio
Nakajima, Kimihiko	Observational study of ionising photon escape from galaxies for understanding cosmic reionisation	2018/4/1 ~ 2018/10/31	Tanaka, Masayuki
Moriyama, Kotaro	Direct Measurement of Black Hole Space-Time: Theory of In-falling Gas Cloud and VLBI-Observation Approach	2017/4/1 ~ 2019/3/31	Honma, Mareki
Taniguchi, Kotomi	Studies of the chemical evolution and mechanisms of carbon-chain molecules in the star-forming regions	2017/4/1 ~ 2018/8/31	Saito, Masao
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
Lopez Rodriguez, Enrique	2018/3/19 ~ 2018/4/18	Kashikawa, Nobunari
Capocasa, Eleonora	2018/9/30 ~ 2020/9/29	Flaminio, Raffaele

VII Graduate 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 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- course students since FY 2006 for Department of Astronomical Science, School of Physical Sciences. (School of Mathematical and Physical Sciences was reorganized into School of Physical Sciences in April 2004.)

(1) Objective of Department of Astronomical Science

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, to be 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 admitted:
 Two (for the five-year doctoral course)
 Three (for the three-year doctoral course)
Degree: Doctor of Philosophy

(2) Admission Policy

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 who have not only basic academic skills, but also the logical and creative aptitude required for advanced research.

(3) Department Details (Course Offerings)

Optical and Near Infrared Astronomy
 [Fields of education and research supervision]
 Ground-based astronomy / Optical and infrared telescope system / Planets / Sun, stars and interstellar matter / Galaxies and cosmology

Radio Astronomy
 [Fields of education and research supervision]
 Ground-based astronomy / Radio telescope system / Sun, stars and interstellar matter / Galaxies

General Astronomy and Astrophysics
 [Fields of education and research supervision]
 High-precision astronomical measurement / Astronomy from space / Data analysis and numerical simulation / Earth, Planets, and the Sun / Galaxies and cosmology

(4) Education and Research Supervision

In observational research with state-of-the-art optical-IR and radio telescopes, and theoretical research, the research and educational efforts are fused together to offer advanced-level education in astronomy and astrophysics. The department the consist of Optical Near-Infrared Astronomy Unit, Radio Astronomy Unit, and General Astronomy and Astrophysics Unit, but all three units cooperate in the education and research supervision of the students. To ensure that students with a wide variety of backgrounds can perform original and creative research in the ever-developing field of astronomy, they are guided to focus on learning basic astronomy in the first year. In order to focus on astronomical research, including the basis of observational astronomy, instrument development, and theoretical astronomy, from the second year onwards students learn subjects ranging from principles to applications of advanced technologies that will be the basis of astronomical observations; how to design, fabricate and test new instruments; and the forefronts of data acquisition and data analysis.

(5) Financial Supports

In order to provide students with an economical basis upon which they can develop into young researchers skilled in conducting research effectively, the department has set up the Associate Researcher program in addition to the Research Assistant system.

In FY 2018 there were 17 Associate Researchers and 3 Research Assistants.

To further improve the research environment for the students, the department provides Oversea Travel Fund, to encourage the students to participate in international conferences to give English talks, observations at various overseas observational facilities, and so on; and the Research Fund to pursuit their own original ideas to plan and carry out research, experiment, etc. In FY 2018, the Overseas Travel Fund sent 13 students abroad for various research activities.

(6) Undergraduate Students

For undergraduate students, and for students abroad, we run the Sokendai Summer Students Program, Spring School and Asian Winter School to offer chances to experience research at the Department of Astronomical Science. Admission Guidance also targets undergraduate students.

(7) Number of Affiliated Staff (2019/3/31)

Chair of the Department of Astronomical Science	1
Optical and Near Infrared Astronomy Course	
Professors	9
Associate Professors	13
Assistant Professors	16
Radio Astronomy Course	
Professors	9
Associate Professors	10
Assistant Professors	18
General Astronomy and Astrophysics Course	
Professors	5
Associate Professors	14
Assistant Professors	13
Total	107

(8) Graduate Students (24 students)

1st year (1 student)

Name	Principal Supervisor	Supervisor	Title of Research Project
Takemura, Hideaki	Nakamura, Fumitaka	Hirota, Tomoya	Observational Study of Nearby Star-Forming Regions

2nd year (5 students)

Name	Principal Supervisor	Supervisor	Title of Research Project
Liang, Yongming	Tanaka, Masayuki	Matsuda, Yuichi	Correlation between galaxies and intergalactic medium in the most massive overdensities
Ito, Kei	Tanaka, Masayuki	Matsuda, Yuichi	The systematical study of protocluster based on the Subaru wide field survey
Tsukui, Takashi	Iguchi, Satoru	Nagai, Hiroshi	Study on the Radio galaxy formation with Supermassive Black Hole
Tsuda, Shuichiro	Honma, Mareki	Shibata, Katsunori	The observational study of Sgr A* with KaVA data
Namiki, Shigeru	Koyama, Yusei	Tanaka, Masayuki	Galaxy evolution in distant galaxy clusters with multi-wavelength observations

3rd year (4 students)

Name	Principal Supervisor	Supervisor	Title of Research Project
Ishikawa, Hiroyuki	Usuda, Tomonori	Hayashi, Saeko	Study of atmospheric compositions and physical parameters of M-dwarfs
Tanioka, Satoshi	Aso, Yoichi	Takahashi, Ryutaro	Direct measurement of coating thermal noise using a folded cryogenic optical cavity
Hatta, Yoshiki	Sekii, Takashi	Hara, Hirohisa Katsukawa, Yukio	Asteroseismic measurements of internal rotation of stars via solving inverse problems
Watanabe, Noriharu	Usuda, Tomonori	Takami, Hideki Aoki, Wako	Research for giant planets around hot stars

4th 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 and spectroscopy
Zhao, Yuhang	Leonardi, Matteo	Flaminio, Raffaele	Frequency dependent squeezing for gravitational wave detector
Fukagawa, Nao	Aoki, Wako	Iono, Daisuke	Mass and environmental dependence of gas inflow and outflow of galaxies around the cosmic noon
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	Systematic study of the interplay between supermassive black holes and their environments
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

5th year (5 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
Okutomi, Koki	Aso, Yoichi	Flaminio, Raffaele	Development of a successive optimization method for the telescope control for stable observation of gravitational waves
Ryu, Tsuguru	Hayashi, Saeko	Usuda, Tomonori	High-Contrast Imaging for Intermediate-Mass Giants with Long-Term Radial Velocity Trends
Uchiyama, Hisakazu	Kashikawa, Nobunari	Matsuda, Yuichi	Coevolution of protoclusters and AGN

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
Kataoka, Satoru	The University of Tokyo	Gouda, Naoteru	Analysis of the Galaxy using astrometric data
Kawakami, Tomohiro	The University of Tokyo	Ohashi, Nagayoshi	Observational Study of Star Formation
Hoshino, Haruka	The University of Tokyo	Kokubo, Eiichiro	Theoretical study on formation and evolution of planetary systems
Matsuda, Kazuma	The University of Tokyo	Takato, Naruhisa	Observational studies of exoplanets
Yamazaki, Yuta	The University of Tokyo	Nakamura, Fumitaka	Theoretical Astronomy
Luo, Yudong	The University of Tokyo	Nakamura, Fumitaka	Big Bang Nucleosynthesis with Primordial Magnetic field
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	The impact of the Galactic structures on the Solar motion measurement by Gaia
Sato, Kazuki	The University of Tokyo	Sakamoto, Seiichi	Observational Study of Star/Planetary System Formation with Radio Telescopes
Tanimoto, Yuta	The University of Tokyo	Takato, Naruhisa	Observational studies of exoplanets
Chin, Kah Wuy	The University of Tokyo	Kawabe, Ryohei	Developments of Multi Colors Imaging Camera using KIDs
Terasawa, Shoko	The University of Tokyo	Ohashi, Nagayoshi	Formation process of class 0 protostar and protoplanetary disk
Choi, Ins	The University of Tokyo	Ohashi, Nagayoshi	Observational studies of protostellar disks and protoplanetary disks
Tatsuuma, Misako	The University of Tokyo	Kokubo, Eiichiro	
Mori, Kanji	The University of Tokyo	Nakamura, Fumitaka	Quantum Mechanical Constraint on Carbon Fusion Reaction and Its Impact on Type Ia Supernovae
Yamaguchi, Masayuki	The University of Tokyo	Kawabe, Ryohei	Superresolution Imaging of Planet Formation Observed with ALMA – Co-Evolution of Planets and Protoplanetary Disk
Sasaki, Hirokazu	The University of Tokyo	Nakamura, Fumitaka	Neutrino oscillations in core-collupse supernovae
Fujii, Yoshinori	The University of Tokyo	Flaminio, Raffaele	Development of the vibration isolation system for the KAGRA detector
Yamada, Ayato	The University of Tokyo	Gouda, Naoteru	Effects of the orbital resonances on the Milky Way rotation and solar motion
Marchio, Manuel	The University of Tokyo	Flaminio, Raffaele	Development of an optical absorption measurement system to characterize KAGRA sapphire mirrors and new high-reflectivity crystalline coatings

3. Commissioned Graduate Students

Doctoral Course	Affiliated Institute	Period	Supervisor	Title of Research Project
Kuramochi, Kazuki	The University of Tokyo	2018/4/1~ 2019/3/31	Kobayashi, Hideyuki	Direct imaging of Black Hole shadows with sub-mm VLBI
Mukae, Shiro	The University of Tokyo	2018/11/1~ 2019/10/31	Hayano, Yutaka	Verification of the correction accuracy of optical distortion for TMT/IRIS imager. Measurement and analysis on optical surface form under the cryogenic environment.
Aritomi, Naoki	The University of Tokyo	2018/12/1~ 2019/3/31	Flaminio, Raffaele	Frequency dependent squeezing for future upgrade of the KAGRA gravitational wave detector
Murayama,Yosuke	University of Tsukuba	2018/12/1~ 2019/3/31	Shan, Wenlei	Development of large-format focal plane array using microwave kinetic inductance detectors

Master's Course	Affiliated Institute	Period	Supervisor	Title of Research Project
Ishikawa, Ryotaro	Tohoku University	2018/4/1~ 2019/3/31	Katsukawa, Yukio	Development of a new instrument and data analysis technique for high-precision spectro-polarimetry
Miyachi, Yusuke	Yamaguchi University	2018/4/1~ 2018/9/30	Honma, Mareki	Comparing study between high precision astrometry results with VERA and a simulation result based on the density wave theory
Yoshioka, Keisuke	The University of Electro-Communications	2018/4/1~ 2019/3/31	Kawabe, Ryohei	Development of ultra wide-band camera at Millimeter and SubMillimeter Wavelengths
Okino, Hiroki	The University of Tokyo	2018/4/1~ 2019/3/31	Kobayashi, Hideyuki	Study of Black Hole with Submillimeter VLBI observation
Lee, Sujin	The University of Tokyo	2018/4/1~ 2019/3/31	Kobayashi, Hideyuki	Studying pulsars(magnetars) using VLBI.
Mochizuki, Chisato	Japan Women's University	2018/4/1~ 2018/9/30	Tanaka, Masayuki	The Properties of Ultra Diffuse Galaxies explored by Subaru Telescope
Eto,Yuki	Kagoshima University	2018/10/1~ 2019/8/31	Kameno,Seiji	Observational Study on Protostar-Jet Driving Mechanism with ALMA Polarimetry
Tanaka, Kenta	The University of Tokyo	2018/10/1~ 2019/3/31	Aso,Yoichi	Gravitational wave astronomy
Nakamura, Raito	The University of Electro-Communications	2018/10/1~ 2019/3/31	Kawabe, Ryohei	Development of broadband horn array for millimeter/submillimeter multi-color camera

4. Degrees Achieved with NAOJ Facilities

Name	Degree	Title of Research Project
Ryu, Tsuguru	Doctor of Philosophy, SOKENDAI	Direct Imaging of Intermediate Mass Giants with RV Trends
Uchiyama, Hisakazu	Doctor of Philosophy, SOKENDAI	The Environment of Quasars in the High Redshift Universe
Okutomi, Koki	Doctor of Philosophy, SOKENDAI	Development of 13.5-meter-tall Vibration Isolation System for the Main Mirrors in KAGRA
Michiyama, Tomonari	Doctor of Philosophy, SOKENDAI	Revealing Star Formation Activity and Feedback Mechanisms in Nearby Merging Galaxies
Ando, Misaki	Master of Science, SOKENDAI	The Physical Condition of Gas in the Nucleus of the Merging Starburst Galaxy NGC 1614 Revealed by CO Observations

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: 25,648 (Including 4,182 in group tours.)
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: 5,470 (22 events)
Open Facility: 50-cm Telescope for Public Outreach

[4D2U Theater Showings]
Dates: Friday before second Saturday; first, second, and third Saturdays
Visitors: 9,706 (47 events)
Open Facility: 4D2U Dome Theater

[Special Open-House Event] Mitaka Open House Day
Dates: October 26 (Fri), 2017, 14:00–19:00
October 27 (Sat), 2017, 10:00–19:00
Topic: The Universe, Hot and Cold
Visitors: 3,737

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 were hosted by the Institute of Astronomy, University of Tokyo ("The First Instruments for TAO? The First Light Achieved at the Subaru Telescope!" Takafumi Kamizuka, Project Research Staff at the University of Tokyo and Hidenori Takahashi, Project Assistant Professor at the University of Tokyo) and NAOJ ("Our Small Neighbors in the Solar System Explored with Ground-based Telescopes" Ryou Ohsawa, NAOJ Project Assistant Professor; and "Hirayama Family and Kozai Oscillation — Japanese Strength that Changed Research on Asteroids" Takashi Ito, NAOJ Assistant Professor; and "The Appearance of Asteroid Ryugu as First Seen by Hayabusa-2" Noriyuki Namiki, Professor at NAOJ / SOKENDAI)

* 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: 19,666
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 2018
Date: August 18 (Sat.), 2018, 10:00–20:30
Visitors: 4452

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; plastic bottle rocket launch; a quiz game; tours of the supercomputer "Aterui II"; and a special guided tour for the Array Operations Center (AOC) and the VLBI correlator.

Special lectures about black holes were given by Professor Mareki Honma, and Professor Hideyuki Kobayashi of Mizusawa VLBI Observatory and Assistant Professor Tetsuhiro Minamidani of Nobeyama Radio Observatory, and were enormously well received.

OSAM (Yugakukan) offered various experiments in the science stalls, workshops, etc., which were run by the student interns. The Open Day was a great success, strengthening ties with the local people.

Iriki: VERA Iriki Station
[Open year-round]
Dates: April to March (except for the New Year's season)
Visitors: 1,388

[Special Open Day]
Date: August 11 (Sat.), 2018, 12:00–21:00
Visitors: 3,800

This special open event was held in conjunction with "Yaeyama Highland Star Festival 2018" hosted by the executive committee primarily formed by members of Satsuma-Sendai city hall and Kagoshima University.

At the NAOJ VERA 20-m radio telescope and the Kagoshima University 1-m optical/infrared telescope facilities, guided tours of telescopes and observation building were held. NAOJ offered such attractions as parent-child science experiments, the making of bamboo cicada, live relay of daytime Venus observations by the 1-m optical/infrared telescope. This time offered a chance to try-on a JAXA space suit, which was well received.

This year special lectures were given by Associate Professor Shinichiro Tokudome from JAXA, and Specially Appointed Research Staff Member Koichiro Sugiyama of Mizusawa VLBI Observatory. All visitors had fun and were satisfied with the 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: 9,580

[Special Open Day]

Date: February 10 (Sun.), 2019, 10:00–16:00

Visitors: 248

A special open house event was held this year again under the name "Star Island 18." Same as last year, the free shuttle buses were appreciated by the visitors. The number of visitors was 248. Because the population of the island is about 2,000, approximately 10 % of the residents 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 Astronomy Data Center Associate Professor Masatoshi Oishi at the Ogasawara Visitor Center with 38 guests in attendance.

Ishigaki-jima: VERA Ishigaki-jima Station

[Open year-round]

Dates: April to March (except for the New Year's season); premises are open to the public 24 hours/day, and the observation rooms are open during the hours of 10:00–16:30

Visitors: 2,844

[Special Open day] The Special Open Day was held as a part the Southern Island Star Festival.

Date: August 12 (Sun.), 2018, 10:00-17:00

Visitors: 306

Same as previous years, attractions like antenna tours, a commemorative photo booth, commemorative lectures, and exhibits were offered.

Ishigaki-jima: Ishigaki-jima Astronomical Observatory

[Open year-round]

Dates: April to March

Open Hours: Wednesdays through Sundays (except for the New Year's season; when Monday 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: 13,564 (475 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 4,503 guests.

[Special Open day] [Southern Island Star Festival 2018]

Dates: August 11 (Sat.) to August 19 (Sun.), 2018

Visitors: 3,098

This year is the 17th anniversary of both the completion of VERA Ishigaki-jima Station and the Southern Island Star Festival. Due to unfortunate weather, the light down starlit sky observation meeting had to be moved to an indoor sports field, but there were still 1,800 participants. This year, for the first time a nighttime visit to Ishigaki-jima Local Meteorological Observatory, was conducted and 53 guests participated. The annual planetarium screening was attended by 404 guests.

The activities at Ishigaki-jima Astronomical Observatory boost regional efforts 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), especially, open until 18:00 during the summer (Jul. 20 to Aug. 31))

Visitors: 42,453

Open Facilities: 45-m Radio Telescope, Nobeyama Millimeter Array, Nobeyama Radioheliograph, etc. (just viewing) and NINS Nobeyama Exhibition Room

[Open House Day]

Date: August 25 (Sat.), 2018, 9:30–16:00

Visitors: 2,028

The theme of the 2018 Open House Day was "The Door to the Universe is Here ~Nagano Prefecture is the Astro-Prefecture." We had two lectures on the theme, which attract large audiences every year. One was "Radio photo album made by the parabolic antenna – to pursue the birth of stars in galaxies" by Associate Prof. Sorai, Kazuo (Hokkaido Univ./Univ. of Tsukuba). The other was "Tomo-e Gozen – to search for flashes in the sky of Nagano Prefecture" by Dr. Sako, Shigeyuki (IoA, the University of Tokyo).

After the preceding rainy days, it was fine weather from the early morning, though it was uncharacteristically hot and humid for Nobeyama. We had 2,028 visitors, which was about the same as last year. We had some established hands-on events, such as touch the main reflector panel of the 45-m Radio Telescope, antenna handicrafts, and antenna origami. At the NINS exhibition room, 4D theater presentations, exhibitions of other institutes, and operation demonstrations of a 10-m antenna were offered. 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 a "Nagano Prefecture is the Astro-Prefecture" stamp-rally event. All participants had a good time at the Open House Day because we were supported by many people from the local community and Shinshu University, Faculty of Agriculture as well as NAOJ and other institutes of NINS.

[Jimoto Kansha Day (Thanks Day for the locals) and Open Symposium]

Date: February 9 (Sat), 2019, 10:00–15:30

Visitors: 66

The local people have difficulty joining 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 response to these comments, we established this event in cooperation with Shinshu University, Faculty of Agriculture, Education and Research Center of Alpine Field Science and University of Tsukuba, Mountain Science Center, Yatsugatake Forest. This year, the event was hosted by the University of Tsukuba at Vegetaball With, Minamimaki Village Rural Exchange Center. In the morning, we had two lectures, "To resolve the enigmas of the Universe in radio" from NRO and "My studies are made in Nobeyama!" from Shinshu University. We had an open symposium on the theme of "To preserve endangered species around the Yatsugatake Area" in the afternoon. A few lectures introduced the current status of some plants seen in Minamimaki Village, such as primrose and Betula dahurica. It was impressive that the participants seemed to listen with attention because it was related to the local area.

4. Subaru Telescope

[Summit Facility Tour]

Dates open for public tours: 56 (these dates are listed in the public tour program page at the Subaru Telescope's web site. Among the 56 dates, 11 were cancelled due to the earthquake that occurred in May, some hurricanes in August, and the UPS repair in November. No tours scheduled during the winter months of October to March.)

Public Tour Visitors: 554

Special Tour Visitors: 109 groups, 545 visitors

[Base Facility Tour]

Special Tour Visitors: 21 groups, 195 visitors

[Public information]

○ Primary means of public information is posting at the official website https://subarutelescope.org

- Science results from the Subaru Telescope – 7 Japanese and 7 English article
- Special activities reports, announcements on Call for Proposals, and recruitment – 26 Japanese and 22 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: 16 cases, reached 472 people

2. Remote presentations, mainly to Japan: 10 cases, reached 917 people

3. Lectures, demonstrations, workshops, etc. in the vicinity: 49 cases, reached 1,446 people

4. Lectures in Japan: 22 cases, reached 1,481 people

5. Others - Exhibits etc.: 12 cases, reached approximately 3,570 people

6. Media coverage: 18 Japanese media. 9 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	34	0	34
China	41	0	41
Thailand	9	0	9
Taiwan	23	0	23
Hong Kong	0	0	0
Singapore	1	0	1
Indonesia	0	0	0
Philippines	0	0	0
Other areas in Asia	10	0	10
Hawai`i	46	0	46
U.S.A.	136	0	136
Australia	6	0	6
Italy	14	0	14
U.K.	25	0	25
France	12	0	12
Canada	5	1	6
Guam, Saipan	0	0	0
Germany	24	0	24
Other areas in Europe and Oceania	72	0	72
Mexico	6	0	6
Brazil	0	0	0
Africa	1	0	1
Other areas in South and Central America *	39	0	39
Total	504	1	505

* Most travelers to South and Central America went to Chile.

X Award Winners

Award Recipients	Affiliated Division	Job Title	Award	Date
Ishikawa, Ryoko	SOLAR-C Project Office	Assistant Professor	FY2018 The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology, The Young Scientists' Prize	2018/4/17
Hada, Kazuhiro	Mizusawa VLBI Observatory	Assistant Professor	FY2018 The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology, The Young Scientists' Prize	2018/4/17
Takiwaki, Tomoya	Division of Theoretical Astronomy	Assistant Professor	The 7th NINS Young Researcher's Prize	2018/6/3
Hirota, Tomoya	Mizusawa VLBI Observatory	Assistant Professor	JSPS hirameki☆tokimeki Science Award	2018/7/2
Asayama, Shinichiro	NAOJ Chile Observatory	Associate Professor	The 1st NAOJ Young Researcher's Prize	2018/7/5
Tsuzuki, Toshihiro	Advanced Technology Center	Engineer (Gijyutsuin)	The 21st Optical Design Award, Optical Society of Japan	2018/10/31
Kojima, Takafumi	Advanced Technology Center	Assistant Professor	2018 IEEE Microwave Theory and Techniques Society Japan Young Engineer Award	2018/11/29
Agata, Hidehiko	Public Relations Center	Associate Professor	Contribution to Hosting of International Conferences Awarded	2018/12/5
Iye, Masanori	—	Professor emeritus (NAOJ)	FY2018 JNTO Award for Contribution to Invitation and Hosting of International Conferences Awarded	2019/2/28
Communicating Astronomy with the Public Conference 2018 -CAP2018 Fukuoka Japan	—	—	FY2018 JNTO Award for Contribution to Invitation and Hosting of International Conferences Awarded	2019/2/28

XI Library, Publications

1. Library

Number of books in each library (2019/3/31)

	Japanese Books	Foreign Books	Total
Mitaka	17,740	47,089	64,829
Nobeyama	1,274	6,261	7,535
Mizusawa	4,986	18,113	23,099
Hawai`i	1,671	4,655	6,326
Total	25,671	76,118	101,789

Number of journal titles in each library (2019/3/31)

	Japanese Journals	Foreign Journals	Total
Mitaka	367	1,670	2,037
Nobeyama	16	82	98
Mizusawa	659	828	1,487
Hawai`i	15	12	27
Total	1,057	2,592	3,649

2. Publication

Here we list continuing publications produced by NAOJ in FY2018.

(Mitaka)

01) Annual Report of the National Astronomical Observatory of Japan (in Japanese), No. 30, Fiscal Year 2017: 1 issue
02) Annual Report of the National Astronomical Observatory of Japan (in English), Vol. 20 Fiscal Year 2017: 1 issue
03) Calendar and Ephemeris, 2019; 1 issue
04) NAOJ News, No. 297–308; 12 issues
05) Guide to the National Astronomical Observatory of Japan pamphlet (Japanese); 1 issue
06) Guide to the National Astronomical Observatory of Japan pamphlet (English); 1 issue
07) Rikanenpyo (Chronological Scientific Tables), 2019; 1 issue
08) NAOJ Calendar (The 14th in the series); 1 issue
09) Radio Astronomy Public Relations Comic “ALMAr’s Adventure” (#8); 1 issue

XII Important Dates

April 1, 2018 – March 31, 2019

2018	
April 2	Minister Hayashi of MEXT visted NAOJ Mitaka for inspection.
April 4	ALMA Cycle 6 Town Meeting and Proposal Workshop was held at NAOJ Mitaka.
April 15	Ninth Open Observatory event held at the Ibaraki University Center for Astronomy and the NAOJ Mizusawa VLBI Observatory Ibaraki Station, with 473 visitors in attendance.
April 17	Assistant Professor Kazuhiro Hada won MEXT Commendation for Science and Technology for Young Scientists.
April 21	Exhibited a booth about Subaru Telescope and its achievements in astronomy at the round-the-world voyage commemorative event of the Hawaiian traditional voyage ship "Hokulea" and deepened exchanges with local citizens.
April 25~27	An exhibition and lecture were held at the Optics & Photonics International Exhibition 2018 (OPIE'18) at PACIFICO Yokohama.
May5	21 staff members, about a quarter of all staff members, participated in the Astro Day event held at the Hawai`i Island Hilo shopping mall and carried out hands-on activities about the Subaru Telescope and astronomy for the local citizens and deepened exchanges with them.
May 13	A memorial ceremony for Former Director General Kozai Yoshihide who passed away on February 5 was held.
May 16	A press conference "ALMA Finds Oxygen 13.28 Billion Light-Years Away - Most Distant Oxygen Indicates Mature Nature of a Young Galaxy" was held jointly with Osaka Sangyo University at the Umeda Satellite Campus of Osaka Sangyo University with 8 media companies in attendance.
May 18	At the "Maunakea Skies Talk" event in the 'Imiloa Astronomy Center, four local staff members gave a general lecture to the local citizens about our work at Subaru Telescope, and deepened exchanges with local people.
May 30	Participated in a local career fair "National Guard Youth Challenge Academy Career Placement Fair" and provided job information for Subaru Telescope to local high school students.
June 1	Held a lecture for the general public at the 'Imiloa Astronomy Center and our Director Michitoshi Yoshida shared the latest astronomical achievements made by Subaru Telescope with local people.
June 1	A press conference "Supercomputer Astronomy: The Next Generation" co-hosted with Cray Japan Inc. was held at Mizusawa Campus with 14 media companies in attendance.
June 4~8	Observation training of Radio Astronomy at Nobeyama Radio Observatory for Undergraduate Students was performed; there were 8 participants.
June 13	"The 25th NAOJ Lecture for the Science Media" titled "The Universe Described by Computers — the Five Years of the Supercomputer ATERUI and the Next Generation System —" was held at Hitotsubashi Hall with 19 participants (16 media companies) in attendance.
July 4	Assistant Professor Tomoya Hirota won the JSPS Hirameki Tokimeki Award for providing benefits to society through the products of work supported by the Grants-in-aid for Scientific Research and for instilling intellectual curiosity in the hearts of the children who will carry the future of Japan.
July 5	NAOJ held a ceremony to celebrate its 30th annversary at Hitotsubashi Hall.
July 5	Yoshiharu Asaki, an associate professor at the NAOJ Chile Observatory gave a lecture as a Tanabata event at the Santiago Japanese School.
July 7	Seiichi Sakamoto, Director of the NAOJ Chile Observatory gave an astronomy lecture for the women's club of the Japan-Chile Chamber of Commerce and Industry at the NAOJ Santiago Office.
July 7	Held the annual Tanabata Star Festival together with the Japanese Chamber of Commerce and Industry of Hawaii to deepen cultural exchanges and promote astronomy.
July 8	The NAOJ Public Talk titled "The Unknown Universe Explored with ATERUI — the Universe Revealed by a Supercomputer" was held at Oshu City Cultural Hall (Z Hall) with 156 participants in attendance.

July 15	As part of Kilauea lava relief efforts, Subaru Telescope supported a field trip for kids in the lava affected area. Subaru Telescope staff gave a lecture and hands-on activities at the ‘Imiloa Astronomy Center. Each student got a goody-bag of astronomical postcards, stickers, coloring papers and spectrum cards. Subaru Telescope and NAOJ staff also donated a lava relief fund from NAOJ to ‘Imiloa to help support school trips for kids in the lava affected area.
July 23~27	Facility Guide Week for Educational Organization was carried out at Nobeyama Radio Observatory.
August 1~2	A citizen astronomy program “What Kinds of Galaxies are There in the Universe? Classifying the “Shapes” of Galaxies” was held at the National Museum of Emerging Science and Innovation, with 245 guests in attendance.
August 2~3	Mars, Jupiter, Saturn observation party was held at Ishigaki-jima Astronomical Observatory. Possibly because the event was held during summer vacation, the number of 2-day participants (68) was very good.
August 9 ~September 4	As a part of the summer student program held by NAOJ and the Department of Astronomical Science of SOKENDAI, two undergraduate students stayed at Chile Observatory and conducted research with ALMA data.
August 11~19	The Southern Island Star Festival (corresponding with the open house events for Ishigakijima Astronomical Observatory and VERA Ishigakijima Station) was held. There were 3,098 guest during the entire festival, even though heavy rains forced the events to be canceled for 3 days. This includes 475 guests welcomed at Ishigakijima Astronomical Observatory and 306 guests welcomed at VERA Ishigakijima Station. In addition the commemorative lecture by Director Hideki Takami had the participation of 60 people.
August 11	Special open house of VERA Iriki station held jointly with the Yaeyama Highland Star Festival 2018, with approximately 3,800 visitors in attendance.
August 13~15	Twelfth Z-star Research Team event held for high school students in the six Tohoku Prefectures, with 12 participants attending. There were 12 participants, divided into two groups of A and B, to analyze astronomical observations and the data using the VERA 20-m radio telescope. Unfortunately neither group was able to detect a new water maser, but it seems they were able to learn various techniques to perform astronomical observation research while thinking.
August 13~15	Chura-boshi Research Team workshop for high school students held at VERA Ishigakijima Station and Ishigakijima Astronomical Observatory, with 5 participants from Ishigakijima, 5 participants from main island of Okinawa, and 1 participant from a high school in Tochigi 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 able to detect a new maser candidate, but it was later found that the object had already been reported in a report published a few years earlier. Unfortunately the optical wavelength group using the Murikabushi Telescope was unable to detect anything.
August 17~18	NAOJ Chile Observatory held a traditional Tanabata event in San Pedro de Atacama.
August 18	Iwate Galaxy Festival 2018, a special open house day of Mizusawa campus, held with 4,452 visitors in attendance.
August 20~31	Held a information booth at the General Assembly of the International Astronomical Union in a collaboration with the Office of International Relations. Introduced research highlights of the Subaru Telescope, particularity with HSC. Reached about 1200 attendees mostly consisting of astronomers.
August 25	Open House day of Nobeyama Radio Observatory. There were 2,028 visitors for this event.
August 27	First Light of Two New Instruments for TAO.
August 27~30	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 of Japan was carried out at the VERA Ishigakijima observation station, Ishigakijima Astronomical Observatory, and there were 26 participants.
August 28	A press conference “Unstoppable Monster in the Early Universe” was held in Tokyo with 12 media companies in attendance.
September 3~7	The East Asia VLBI Workshop (EAVW) held in Pyeong Chang in the Republic of Korea. Because it became a pivotal meeting including noteworthy events such as the signing of an agreement between the concerned organizations, it experienced an unprecedented groundswell to continue enhancing the network along with aiming to further elucidate star forming regions and the structures surrounding black holes, with over 100 participants, first and foremost from Korea but also including Europe and the United States.
September 7	Norikazu Mizuno, a professor at NAOJ Chile Observatory gave an astronomy lecture at Buenos Aires Japanese School.
September 24	A public lecture titled “OYATTOSA! 6-m Radio Telescope” was held jointly with Kagoshima University at Kurimoto Campus of Kagoshima University.

September 25~26	"The 16th Mizusawa VLBI Observatory Users Meeting" was held with 50 participants. This time, people from industry also participated. There was spirited discussion of Japanese, East Asian, and world VLBI programs.
October 1 ~October 1 2019	NAOJ Chile Observatory accepted a visiting graduate student from Kagoshima University through the Tobitate! (Leap for Tomorrow) Study Abroad Initiative.
October 4	Seiichi Sakamoto, Director of NAOJ Chile Observatory gave a lecture for the Chilean "Inspiring Girls" initiative at the Joint ALMA Observatory.
October 6	Subaru Telescope staff joined an astronomy outreach event "Astro Day" on the west side of Hawai`i Island and shared astronomical discoveries with local public.
October 20~24	A total of 10 undergraduate students from Japan participated in the observation experience program at the Subaru Telescope.
October 22	The 27th Inter-University Research Institute Corporations Symposium was held at the Nagoya City Science Museum. NAOJ had a booth exhibition to introduce ALMA and Masaaki Hiramatsu, an assistant professor at the NAOJ Chile Observatory, gave a lecture on ALMA.
October 26~27	"Mitaka Open House Day" held with 3,737 visitors in attendance.
November 3	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 at Vegetaball With, Minamimaki Village Rural Exchange Center.
November 15	A press tour for domestic media "Subaru Telescope: 20 Years Wishing Upon a Star" was held at Mitaka Campus with 32 participants (14 media companies) in attendance.
November 19	"NAOJ International Media Tour - Subaru Telescope: 20 Years Wishing Upon a Star - " for overseas media and embassy officials was held at Mitaka Campus with 3 participants in attendance.
November 23	Teachers and students of Santiago Japanese School visited the NAOJ Santiago Office.
November 26~30	Cone Searches face-to-face Meeting organized by the Joint ALMA Observatory was held at the NAOJ Santiago Office.
November 27~30	The Republic of Korea Ambassador to Chile visited ALMA and Seiichi Sakamoto, the Director of NAOJ Chile Observatory, guided him.
December 14~15	East Asian ALMA Development Workshop 2018 was held at Osaka Prefectual University.
December 17~19	East Asian ALMA Science Workshop 2018 was held at I-site Namba.
December 26~27	2018 ALMA/45m/ASTE Users Meeting was held at NAOJ Mitaka.

2019

January 6~10	Held an information booth at the American Astronomical Society's annual meeting in collaboration with the Office of International Relations at NAOJ. Introduced Subaru Telescope's recent discoveries and jobs to about 600 people. Subaru Telescope staff also held presentations for local high school students.
January 20~25	Six graduate students from the Department of Astronomical Science, SOKENDAI (Graduate University for Advanced Studies) worked together to conduct an observation program at the Subaru Telescope.
January 26	Held an interactive booth at the annual Onizuka Science Day at the University of Hawai`i at Hilo.
January 27	A press conference "Missing-Link in Planet Evolution Found" was held jointly in Tokyo with Kyoto University, Tohoku University, Kobe University, and Kyoto Sangyo University with 6 media companies in attendance.
February 9	"Jimoto Kansha Day (Thanks Day for the Locals) & Open Symposium" was held as the Special Open House for locals (Minamimaki and Kawakami Village) at Vegetaball With , Minamimaki Village Rural Exchange Center by Yatsugatake Forest, Mountain Science Center, University of Tsukuba as the main host. It was carried out by 3 Nobeyama Institutes (Tsukuba and Shinshu Universities and Nobeyama Radio Observatory). There were 66 participants.
February 9~11	Star Island 18 open house event of VERA Ogasawara Station held, with 248 visitors in attendance.
February 14~17	NAOJ (in collaboration with 8 domestic universities and institutes) hosted an exhibit booth at the 2019 AAAS Annual Meeting in Washington, DC.

February 20	Held “Subaru Telescope First Light 20th Anniversary” event at base facility in Hilo inviting local people including members of the Japanese Chambers of Commerce and members of other observatories which have telescopes on the summit of Maunakea. More than 100 people participated. Conducted special tours for media from Japan and local Hawai`i media visiting the Subaru Telescope at the summit and news stories about Subaru Telescope and its 20th Anniversary were widely reported in Japan and Hawai`i.
February 23~24	The Third “Nagano is a Astro-Prefecture” meeting and Open Lectures were held at Kiso-town culture center by “Nagano Prefecture is Astro-Prefecture” liaison council, which consists of Nobeyama Radio Observatory, Kiso Observatory of the University of Tokyo, and so on. There were about 60 participants in the meeting and about 120 in the open lectures.
March 4~8	Staff Members of the Subaru Telescope visited classes in the public schools in Hilo and vicinity during the Journey through the Universe program. Over 1,000 students were reached by Subaru Telescope and TMT staff members.
March 27	NAOJ and Minamimaki Village entered an agreement to utilize the facility of NRO to promote PR activities for the scientific results of NAOJ and the tourism and education activities of Minamimaki Village. The activities based on the agreement will be determined by an operation council to be founded following the agreement.
Throughout the year	Together with other Maunakea Observatories, Subaru Telescope started a special tour program “Kamaʻāina Observatory Experience (KOE)” dedicated for Hawai`i residents. In 2017, Subaru Telescope conducted 10 KOE tours for a total of 120 visitors. KOE is separate from Subaru Telescope’s public tour program that started in 2004.

XIII Publications, Presentations

1. Refereed Publications

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Abdellaoui, G., et al. including **Mizumoto, Y.**, **Saprykin, O.**, **Watanabe, J.**: 2018, EUSO-TA - First results from a ground-based EUSO telescope, *Astropart. Phys.*, **102**, 98–111.

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