II Status Reports of Research Activities

1. Subaru Telescope

1. Subaru Telescope Staff

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

2. Science Highlights

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

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

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

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

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

3. Open-use

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

4. Telescope Maintenance and Performance Improvement

A windscreen incident happened during night operation on

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

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

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

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

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

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

5. Instrumentation

The eight open-use facility instruments of Subaru Telescope were operated stably in FY 2016. Those instruments are Hyper Suprime-Cam (HSC), Subaru Prime Focus Camera (Suprime-Cam), Faint Object Camera And Spectrograph (FOCAS), High Dispersion Spectrograph (HDS), Infrared Camera and Spectrograph (IRCS), Cooled Mid-infrared Camera and Spectrograph (COMICS), Multi-Object Infrared Camera and Spectrograph (MOIRCS), and the 188-elements Adaptive Optics and Laser Guide Star system (AO188/LGS).

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

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

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

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

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

The Prime-Focus Spectrograph (PFS) is an optical/near-infrared multi-object spectrograph at the prime focus of the Subaru Telescope, which will be the next facility instrument following the successful implementation of HSC. The PFS has about 2400 optical fibers distributed over the 1.3 degree field of view of the prime focus which feed the light of the astronomical objects to four identical spectrographs which will be placed in the telescope dome. The spectrograph modules cover wavelengths ranging from 0.38 μm to 1.26 μm simultaneously. There are slight delays in the schedule: the engineering first-light will be in 2019 and science operation is expected to begin in 2021. Subaru Telescope is responsible for modifying the telescope and enclosure to accept PFS. The design works and reinforcement of the spectrograph floor has been conducted. The data reduction pipeline and the database that combine HSC and PFS data is being developed with US collaborators.

We are conducting a conceptual study of "ULTIMATE-Subaru," the Subaru Telescope's next large facility instrument following HSC and PFS, which will be one of the flagship

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

6. Computer and Network

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

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

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

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

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

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

7. Education (Under-graduate and Graduate Courses)

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

In FY 2017, Subaru Telescope hosted 3 graduate students for long stays in Hilo, of which two were SOKENDAI students. On top of that, intensive education activities were seen also in Mitaka in cooperation with the Division of Optical and IR Astronomy. The numbers of graduate course students in all of Japan who obtained master's degrees and PhD's based on Subaru Telescope data were 17 and eight, respectively, of which two and three belonged to the Division of Optical and IR Astronomy.

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

8. Public Information and Outreach (PIO)

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

Task 1: Provide information about activities and scientific results from Subaru Telescope by effectively using website and social media platforms. Subaru Telescope provides press releases to

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

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

Task 2: Provide escorted tours of the summit and base facilities for the public and special groups. Subaru Telescope started the public tour program in 2004, providing opportunities for guests from 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 2017, 307 people visited the summit facility through the public tour program. This number does not include tours that were suspended due to poor weather conditions. An additional 67 groups visited the summit facility via special tour programs. In total, 677 people visited the summit facility in Fiscal Year 2017. This includes 8 special tours dedicated for the residents of Hawai'i. All tours are escorted by assigned staff and conducted in either Japanese or English.

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

Task 3: Provide on-site and remote lectures for the local community as well as Japanese schools and museums. During Fiscal Year 2017, PIO provided/coordinated a total of 84 lectures at the Subaru Hilo Base Facility or at nearby locations, such as '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 staff also conducted 31 lectures outside Hawai'i and 10 remote lectures for Japanese schools.

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. This year, AstroDay was also held in Kona, on the west side of the island, attracting over 3,000 people.

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

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

2. Okayama Astrophysical Observatory

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

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

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

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

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

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

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

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

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

in the main building. And as of March 31, the C Project Okayama Astrophysical Observatory was dissolved.

1. Open Use

(1) Overview

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

(2) Observation/Research Results

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

(3) Facility and Instrument Maintenance/Management

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

(4) Conferences

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

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

The Observatory held the Okayama Users Meeting (The 28th Optical and Infrared Users Meeting, UM) at the Large Seminar Room of NAOJ Mitaka Campus on September 4 and 5. The present status of the Observatory, including the 188-cm telescope and dome; current condition of the open-use observing instruments and remote observation system; execution summary of the open-use observation programming of semester 2017A and B; future operation of the 188-cm telescope; development status of the fully automated observing system for HIDES Fiber-Feed observation; research results based on openuse of the 188-cm telescope; progress situation of the 3.8-m telescope project and study/preparation of observing instruments; proposals for scientific research using the 3.8-m telescope; status of study and preparation of the promotion system for nation-wide open use at the 3.8-m telescope; current situation of the optical infrared observation facilities such as the Hiroshima University Space Science Center and their research results; etc. were reported. Regarding the nation-wide open use at the 3.8-m telescope,

the content of the discussion through the previous year was reconfirmed and shared among the participants, and the changes due to the change of the newly generated situation was explained by the Observatory, and the specific policies were discussed comprehensively by the participants. As a particularly significant change, it was explained that NAOJ concluded that it would be difficult for three faculty and staff members to be dispatched to Kyoto University and planned to establish the Okayama Branch Office to promote the nation-wide open use at the 3.8-m telescope and post three faculty and staff members.

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

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

2. Developing and Maintaining Open-Use Observing Instruments

(1) HIDES (High-Dispersion Echelle Spectrograph)

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

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

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

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

(3) MuSCAT

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

3. Joint Research with Universities

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

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

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

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

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

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

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

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

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

(5) Other

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

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

4. Unique Research Projects

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

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

were continued.

(2) Development of a far larger scale exoplanet search

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

(3) East Asian Planet Search Network

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

5. PR/Awareness Promotion Activities

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

6. Contract Staff Transfers

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

3. Nobeyama Radio Observatory

1. Nobeyama 45-m Radio Telescope

(1) Open Use Observations

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

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

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

(2) Improvements and Developments

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

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

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

(3) Scientific Results

1) 45-m telescope Legacy Projects

(a) Star Formation Legacy Project

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

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

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

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

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

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

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

2. Radio Polarimeters

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

3. Research Support

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

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

(2) Radio Heliograph (Nagoya University)

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

4. Public Outreach

(1) PR activities at Nobeyama Campus

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

In the area for permanent public access, a controllable radio-telescope antenna miniature and introduction movies are available along with posters and panel displays. In this year, we

officially inaugurated the Nobeyama Exhibition Room of NINS, and open it every day.

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

(2) Cooperation with Local Communities

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

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

(3) NINS Nobeyama exhibition room

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

5. Education

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

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

6. Misc. Activities

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

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

(2) Hiring, Transfer (incoming)

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

(3) Retirement, Transfer (outgoing)

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

(4) NRO Conference Workshops and Users Meeting

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

4. Mizusawa VLBI Observatory

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

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

1. VERA

(1) Observations and Common-Use Observations

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

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

(2) Science Research

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

2. The Japanese VLBI Network (JVN)

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

The University Collaborative Workshop was held at Ibaraki in July 2016, and a white paper entitled "High-Spatial-Resolution/Time-Domain Astronomy in the centimeter band" was approved as the baseline of the university collaboration. Along with this white paper, maser/star formation study is led mainly by Ibaraki University, while active-galactic-nuclei/black-hole science is led by Yamaguchi University. In particular, observations with the Ibaraki-Yamaguchi interferometer are

the key for these studies. Survey observations of 1) Compact radio sources in the galactic center, 2) High-z AGN's, 3) Fermi gamma-ray sources, have been carried out.

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

3. Japan-Korea VLBI

(1) Observations and Common Use Observations

In FY 2017, a total of 131 (1138 hours) VLBI observations, common use observations, large program observations, and test observations, were conducted by KaVA (KVN and VERA Array) at 43 and 22 GHz bands. The data of the seven VLBI stations were correlated at the Korea-Japan Correlation Center at KASI Daejeon campus in Korea.

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

(2) Results of Research

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

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

4. EAVN

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

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

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

5. Future Plans for SKA

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

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

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

Finally, the observatory applied to the SKA organization

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

6. Geodesy and Geophysics

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

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

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

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

7. System Development

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

8. Timekeeping Office Operations

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

9. Ishigakijima Astronomical Observatory

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

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

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

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

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

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

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

10. Public Relations (PR) and Awareness Promotion Activities

(1) Open House Events

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

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

On July 16: The Star Festival at the site of the 6-m antenna at Kinko Bay Park in Kagoshima City co-hosted with Kagoshima City and Kagoshima University, with approximately 350 visitors.

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

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

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

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

(2) Regular Public Visiting

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

The numbers of visitors to each facility are as follows,

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

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

11. Education

(1) Under-graduate and Post-graduate Education

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

(2) Research experience for high school students

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

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

5. Solar Science Observatory (SSO)

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

1. Hinode Space Observatory

The scientific satellite Hinode is an artificial satellite that was launched on September 23, 2006, by the ISAS division of JAXA, as Japan's third solar observational satellite following Hinotori (1981) and Yohkoh (1991). Hinode is equipped with three telescopes: the solar optical telescope (SOT), the X-ray telescope (XRT), and the extreme ultraviolet imaging spectrometer (EIS). In addition to the detailed magnetic field and velocity field of the solar photosphere, it carries out simultaneous observations of the radiance and velocity field from the chromosphere to the corona. The telescopes equipped on the Hinode satellite were developed through international collaboration with the US NASA and the UK STFC under the cooperation of ISAS/JAXA and NAOJ, and the European Space Agency ESA and the Norwegian Space Center NSC join its scientific operations. NAOJ played a central role in the development of the science payload in Japan and has been making a significant contribution to the science operation and the data analysis since the launch. The data acquired with Hinode is released to everyone as soon as the data for analysis are ready.

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

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

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

2. Ground-based Observations in Mitaka Campus

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

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

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

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

these digitized data are opened to the public when ready, high precision digitization has been applied to the Ca II K line data for improving the quality as a part of the PSTEP research activity.

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

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

3. SDAS

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

4. Educational Activity

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

5. Public Outreach (PO) Activity

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

6. Science and Community Meetings

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

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

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

7. Awards

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

Y. Katsukawa: 6th NINS Young Researcher Award

R. Kano: 4th ISAS Award

8. Others

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

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

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

6. NAOJ Chile Observatory

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

1. Progress of ALMA Project

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

2. ALMA Open-Use and Scientific Observations

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

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

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

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

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

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

3. Educational Activities and Internships

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

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

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

4. Public Outreach Activities

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

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

The NAOJ ALMA website was renewed in May 2017. The new site has an increased number of articles including review articles that summarize the ALMA research themes and interviews with ALMA staff members, together with 49 news articles and eight press releases posted this year. Furthermore, the contents of the new website (e.g. images) became more openly available in accordance with the terms of use under the Creative Commons License, which allows easier use of contents. A mailing-list-based newsletter has been issued on a monthly basis with approximately 2,500 subscribers. Updated, detailed information is available on Twitter (@ALMA_Japan), with nearly 38,500 followers as of the end of FY 2017.

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

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

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

5. International Collaboration (committees, etc.)

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

6. Workshops and Town Meetings

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

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

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

Radio Use-Phase II)

8. Research Staff Changes

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

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

9. Main Visitors

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

10. Progress of ASTE Telescope

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

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

The open-use program in FY 2017 provided spectroscopic observations in 345 GHz and 460 GHz bands for a period of four months. To render support for researchers contributing to the observational performance enhancement of ASTE, the Guaranteed Time Observation (GTO) scheme has been offered since FY 2013, which allows them to exclusively make proposals for the GTO slots. A total of 25 proposals for open-use observations were submitted. These proposals were reviewed by the Millimeter/submillimeter Program Subcommittee and 20 proposals were adopted. Open-use observations were carried out from the ASTE Mitaka operation room or from other universities and research institutes from early June to late September, 2017. Also, the ASTE telescope has been tentatively equipped with DESHIMA (Deep Spectroscopic High-redshift Mapper), a superconducting on-chip filterbank spectrometer under joint research and development by Delft University of Technology (Netherlands), SRON (Netherlands), the University of Tokyo, Nagoya University, and the National Astronomical Observatory of Japan since October 2017, and successfully detected astronomical spectra for the first time with this new technology.

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

7. Center for Computational Astrophysics (CfCA)

1. Overview

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

2. Open Use

(1) Computer Systems

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

While XC30 is leased for five years from Cray Japan Inc., the center has built the following equipment to aid the open-use computer operations: a series of dedicated computers for gravitational N-body problems, known as GRAPE's; PC clusters for small to medium-scale computation; large-scale file servers; a group of servers for processing computational output data; and networking instruments to encompass the overall computer system. These components are central to numerical simulations by researchers in Japan and overseas. In particular, the GRAPE system is promoted for its effective open use. The center undertook development, improvement, and maintenance for both hardware and software for the system this year.

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

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

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

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

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

(2) Tutorials and Users Meeting

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

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

3. PR Activity

In FY 2017, the following press releases were issued from

the center:

• “First Global Simulation Yields New Insights into Ring System”
April 28, 2017, Shugo Michikoshi and Eiichiro Kokubo

• “Electron surfing and drift accelerations in a Weibel-dominated high-Mach-number shock”
September 25, 2017, Yosuke Matsumoto, Tsunehiko Kato, et al.

• “Supersonic gas streams left over from the Big Bang drive massive black hole formation”
September 29, 2017, Shingo Hirano, et al.

• “Surface Helium Detonation Spells End for White Dwarf”
October 5, 2017, Ji-an Jiang, Masaomi Tanaka, et al.

• “Astronomers Follow Gravitational Waves to Treasure”
October 16, 2017, Masaomi Tanaka, et al.

• “Rare First Moment of Stellar Explosion Captured by Amateur Astronomer”
February 22, 2018, Masaomi Tanaka, et al.

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

4. 4D2U Project

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

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

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

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

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

5. External Activities

(1) Joint Institute for Computational Fundamental Science

The Joint Institute for Computational Fundamental Science (JICFuS) is an inter-organizational institute established in February 2009 as a collaboration base between three organizations including the Center for Computational Sciences (CCS) of the University of Tsukuba; the High Energy Accelerator Research Organization, known as KEK; and NAOJ to provide active support for computational scientific research (it has now expanded to include eight institutes). CfCA forms the core of NAOJ’s contribution to JICFuS. In particular, the institute engages primarily in computer-aided theoretical research into the fundamental physics in elementary particle physics, nuclear physics, and astrophysics. The scientific goal of the institute is to promote fundamental research based on computational science by encouraging interdisciplinary research between elementary particle physics and astrophysics. In addition to its ability as a single organization, a major feature of the institute is the cooperation of each community to provide considerate and rigorous support to present and future researchers. Another important mission of the institute is to provide researchers around Japan with advice regarding efficient supercomputer use and the development of novel algorithms for high-performance computing to meet research goals from the perspective of computer specialists. In addition, JICFuS was chosen as the organization responsible for “Research and Development, Application Development of scientific/social issues that require particular attention by the use of the Post K-computer” in FY 2014.

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

variations of ULXs is thus revealed by the simulations.

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

(2) HPCI Consortium

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

6. Staff Transfers

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

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

8. Gravitational Wave Project Office

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

1. Development of KAGRA

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

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

(1) Vibration Isolation Systems

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

(2) Auxiliary Optics

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

(3) Mirror Characterization

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

2. R&D

(1) R&D for upgrades of KAGRA

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

developed at MIT, and obtained promising results. Thermal noise investigation is also the objective of another experiment being conducted at ATC to directly measure coating thermal noise at cryogenic temperatures.

(2) DECIGO

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

3. Education

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

4. Outreach

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

5. International Collaboration and Visitors

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

6. Publications, Presentations, and Workshop Organization

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

7. Acquisition of External Funds

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

8. Staff

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

9. TMT-J Project Office

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

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

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

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

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

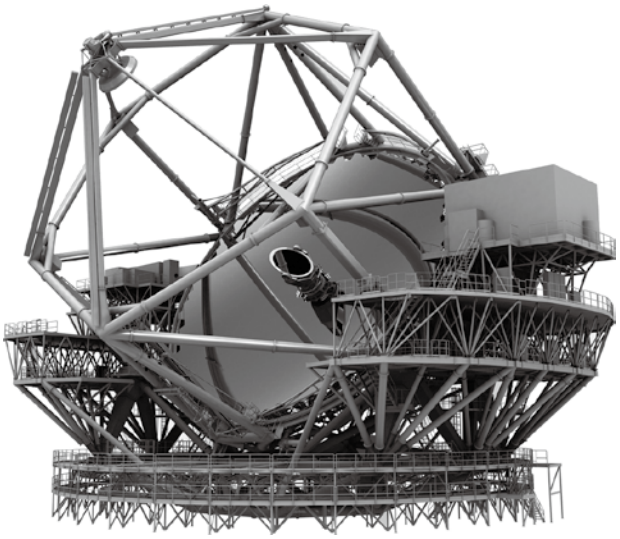

Figure 1: Conceptual image of the completed TMT.

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

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

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

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

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

(1) Fabrication of the primary mirror segments

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

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

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

Figure 2: Mirror segment blanks shipped overseas.

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

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

(3) Science instruments

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

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

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

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

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

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

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

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

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

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

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

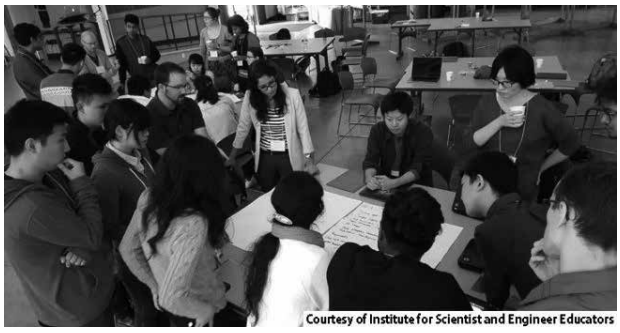

Figure 3: International workshop "Preparing TMT Future Science and Technology Leaders" held at the University of California, Santa Cruz in August 2017 for the young researchers and engineers.

10. JASMINE Project Office

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

(1) Overview

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

Prior to commencement of the JASMINE mid-sized scientific satellite project, an ultra-small size project and a small size project were implemented to progressively build up scientific results and to accumulate the necessary technical knowledge and expertise. The Nano-JASMINE micro-satellite project, with a primary mirror aperture of 5 cm is currently underway. It aims to test part of the technologies to be used in JASMINE and to produce scientific results based on the astrometric information for bright objects in the vicinity of the Solar System. Despite its small aperture, the satellite is capable of observational precision comparable to the Hipparcos satellite. The combination of observational data from Nano-JASMINE and the Hipparcos Catalogue is expected to produce more precise data on proper motions and annual parallaxes. The satellite is scheduled for launch in the near future. An additional plan is underway to launch a small-scale JASMINE satellite (Small-JASMINE), with a primary mirror aperture of about 30 cm, in FY 2024. This satellite will engage in observations of a limited area around the nuclear bulge and certain specific astronomical objects. This small-sized version has the goal of obtaining advanced scientific results at an early stage. The mid-sized JASMINE satellite, with a main aperture of approximately 80 cm, is designed for surveying the entire bulge and is targeted for launch in the 2030's. Internationally, Japan shares responsibilities with ESA. With the Gaia Project, ESA performs visible-light observation of the entire sky at a precision of 10 μas, while Japan engages in infrared observation of the bulge, which is a method suitable for observations in the direction of the Galactic Center.

(2) Major Progress in FY 2017

1) Organization of the office

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

2) Progress of the Nano-JASMINE Project

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

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

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

The objective of the small-sized JASMINE project is to use a three-mirror optical system telescope with a primary mirror aperture of 30 cm to perform infrared astrometric observations (Hw band: 1.1–1.7 μm). A goal is to measure annual parallaxes at a precision of less than or equal to 20 μas and proper motions, or transverse angular velocities across the celestial sphere, at a precision of less than or equal to 20 μas/year in the direction of an area of a few degrees within the Galactic nuclear bulge and in the directions of a number of specific astronomical objects of interest in order to create a catalogue of the positions and movements of stars within these regions. The project is unique

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

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

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

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

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

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

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

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

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

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

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

(2) IRD (Infrared Doppler Instrument)

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

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

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

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

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

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

(2) SEIT (Second Earth Imager for TMT)

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

3. Science Research, Education, and Outreach

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

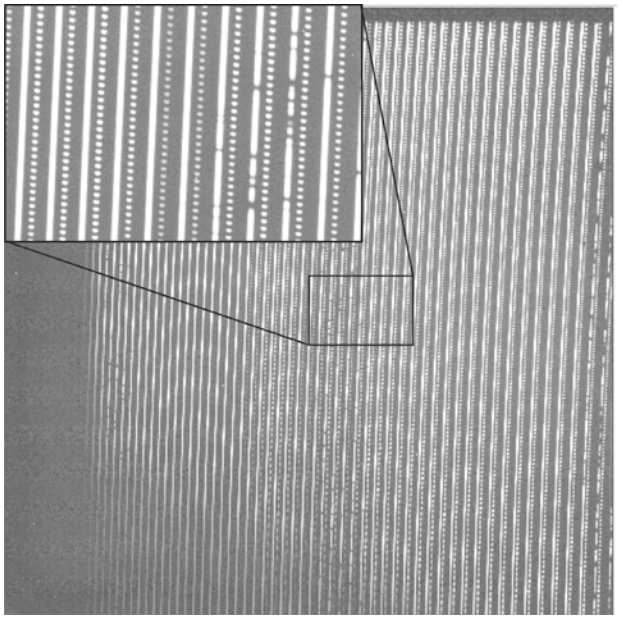

Figure 1: First light image of IRD obtained on the Subaru Telescope. Both stellar spectra and laser frequency comb spectra are imaged on the detector through optical fbers.

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

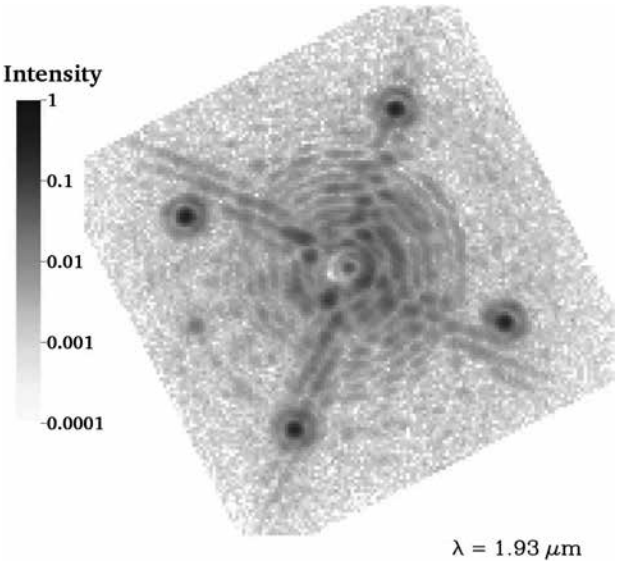

Figure 2: Point source image at 1.93 micron from an extreme adaptive optics system SCExAO and infrared integral field spectrometer. The four point-like structures are artificial point sources made by a deformable mirror for accurate astrometry. From Brandt et al. 2017.

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

1. Project Overview

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

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

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

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

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

2. Educational Activities/Internship

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

3. Outreach/PR

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

4. Joint Research/International Collaborations

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

5. Career Development

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

13. Solar-C Project Office

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

1. SOLAR-C Project

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

2. Small-sized Projects

(1) CLASP Project

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

(2) Sunrise-3 Project

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

(3) FOXSI-3 Project

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

3. Major Activity in FY 2017

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

Since publishing the first science results from the flight experiment in September 2015, the CLASP project has been preparing for the second flight experiment, which is scheduled for 2019. The Japanese CLASP team fabricated new flight components, which are needed to observe a different spectral window from the first flight, and started the assembly of the telescope and the spectrograph. The proposal for the gondola for Sunrise-3 has also been approved by NASA in this fiscal year, and Sunrise-3 is scheduled to be flown in FY 2021. We made the optical, mechanical, and thermal designs of the Sunrise Chromospheric Infrared spectroPolarimeter (SCIP), and developed mechanisms for the polarization modulator and image

scanner. The interfaces with various European components were clarified. About half of total budget for CLASP-2 and Sunrise-3 was funded by JAXA through the Small-size Solar Observing Program. The development of a high-speed CMOS camera for FOXSI-3 was completed successfully and the combination test with the X-ray mirror provided by the US team was performed. The FOXSI-3 project is now in the final prepartations for flight in summer of 2018.

4. Others

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

14. Astronomy Data Center

1. Introduction

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

2. DB/DA Project

The DB/DA-project conducts research and development on astronomical Data Bases and Data Analysis. It also opens various astronomical data to researchers and educators (http://dbc.nao.ac.jp/). SMOKA (http://smoka.nao.ac.jp/) is the core of the DB/DA-project and opens archival data of the Subaru Telescope, OAO 188-cm Telescope, Kiso 105-cm Schmidt Telescope (the University of Tokyo), MITSuME 50-cm telescopes (Tokyo Institute of Technology), and 150-cm KANATA Telescope (Hiroshima University). The total amount of opened data is about 20 million frames (154 TB) as of May 2018. SMOKA contributes to many astronomical products. The total number of refereed papers using SMOKA data is 220 as of May 2018.

3. Network Project

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

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

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

4. JVO Project

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

5. HSC Data Analysis/Archiving Software Development

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

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

object spectrograph PFS at Subaru Telescope will start its commissioning with early-delivered hardware components this year. We have been involved in discussions of data formats, and development of science data archives which are tied to the HSC products.

6. Open-use Computer System and Service

The rental open-use computer system, "National Astronomical Observatory of Japan: Data analysis, archive, and service system", was replaced and the new system has been in operation since March 2018. The system plays a leading role as part of the Inter-University Research Institute.

The system consists of "Multi-Wavelength data analysis subsystem", "Large data archive and service subsystem (MASTARS; SMOKA; HSC science archive; ALMA data archive; VERA data archive; NRO data archive and shared servers; Okayama data archive; and Solar archive)", "JVO subsystem", "Data analysis subsystem in Mizusawa Campus", "Development subsystem", and "Open-use terminals and printers in Mitaka Campus."

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

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

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

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

7. Others

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

15. Advanced Technology Center (ATC)

1. Organization and Summary of Activities in ATC

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

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

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

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

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

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

2. Workshops and Development Support Facilities

(1) Mechanical Engineering Shop (ME shop)

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

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

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

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

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

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

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

The fabrication team has been working on the auxiliary optical system of KAGRA, and has fabricated five-axis lens

positioners for the Beam Reducing Telescopes. In addition, blade springs that are made from beryllium copper and Maraging steel for the vibration isolation system and various parts of the auxiliary optical system were delivered.

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

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

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

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

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

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

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

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

Table 1: The requests in FY 2017.

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

(2) Thin Film Processing Unit

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

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

(3) Space Chamber Shop and Space Optics

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

(4) Optical Shop

Activity of optical shop in 2017

1) Management

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

2) Repairing and upgrading measurement systems

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

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

(5) Optical and Infrared Detector Group

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

(6) Facility Management Unit

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

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

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

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

3. Prioritized Area Developments

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

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

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

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

Table 2: Total number of defective receivers.

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

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

(2) TMT

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

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

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

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

(3) KAGRA

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

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

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

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

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

4. Advanced Technology Developments

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

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

(2) Telescope Receiver Developments

1) Telescope Receiver Developments

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

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

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

2) Development of advanced future receivers

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

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

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

2. Ultra-Wideband receiver

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

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

3. Terahertz receiver

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

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

4. Multibeam receiver

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

(3) SIS junction development

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

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

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

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

(4) HSC

During the fiscal year of 2017, HSC has been intensively used for 130 nights. Half of the observing times were allocated to the Subaru Strategic Program (HSC-SSP) and the other half were for general observer programs including UH time, and Gemini/Keck exchange time. Over the year, we had two mechanical problems in the Filter Exchange Units (FEU's) and each time we had to ask Uraguchi-san, who designed the FEU's,

to do the trouble shooting. Minimum impacts on the actual observations were recorded. However, because HSC has been operated for more than four years since its first light, we started to encounter troubles occasionally which had not been expected originally. Therefore, new maintenance schemes should be worked out in collaboration with the Subaru Telescope staff. In the meantime, as for the concerned CCD trouble, we observed no new problems and we keep following the progress. At the detector lab, we successfully worked out a new clock pattern to reduce the readout time of a CCD and cut 5 seconds by accepting a gain loss of 2/3. We applied the clock pattern on the actual HSC camera and will make a test observing run to see if we have other side effects.

5. Basic Technology Development

(1) MKID camera /CMB Instruments

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

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

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

In this year, the following research results were obtained.

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

(2) Near-IR Imaging Sensor Developments

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

(3) Multicolor Millimeter/Submillimeter Continuum Camera

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

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

(4) Development of Terahertz Intensity Interferometry

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

6. Open Use Programs, Joint Research and Development

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

16. Public Relations Center

1. Overview

The Public Relations Center engages in the publication, promulgation, and promotion of scientific achievements made not only by NAOJ but also by others in the field of astronomy in general to raise public awareness; responds to reports of discoveries of new astronomical objects; and provides the ephemeris and other astronomical information directly related to people's everyday activities, such as sunrise and sunset times. In FY 2017, the Center has been comprised of 6 offices and 1 unit: the Public Relations Office, the Outreach and Education Office, the Ephemeris Computation Office, the Library Unit, the Publications Office, the IAU Office for Astronomy Outreach (OAO), and the General Affairs Office.

2. Personnel

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

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

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

3. Public Relations Office

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

(1) Online-Based Information Sharing

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

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

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

NAOJ e-mail newsletters No.172–188 were issued, introducing research results and NAOJ hosted events.

We continued to produce videos explaining research results, videos explaining astronomical phenomena, and videos introducing outreach activities. Including English versions, 22 original videos were produced. The videos are uploaded mainly on YouTube. As of the end of March 2018, these videos have accumulated a total of 1,383,083 minutes of play time and 385,982 views. Continued from last year, our office performed live stream broadcasting five times of heavenly bodies with the 50-cm Telescope for Public Outreach. There were about 7,590 viewers in total. We were also invited to do an official live broadcast for niconico and there were more than 30,000 viewers. In addition, we conducted live internet broadcasts of lectures on the Special Open House Day for Nobeyama Radio Observatory and Mitaka Open House Day.

Month	Access counts	Month	Access counts	Month	Access counts
April 2017	360,945	August 2017	806,200	December 2017	1,094,577
May 2017	429,503	September 2017	490,786	January 2018	1,674,509
June 2017	390,178	October 2017	630,664	February 2018	653,580
July 2017	417,534	November 2017	418,373	March 2018	413,780
Total: 7,780,629					

Table 1: Monthly website access statistics for the Public Relations Office website, NAOJ Public Relations Center (April 2017–March 2018).

Project PR movie “Public Relations Center”	English Version
Project PR movie “Okayama Astrophysical Observatory”	English Version
Project PR movie “Subaru Telescope”	English Version
Project PR movie “NAOJ Chile Observatory”	English Version
Mitaka Campus Public Visits Reach 200,000 Guests!*	Japanese Version
Project PR movie “Solar Science Observatory”	Japanese/English Versions
Eclipse - Crossroads in the Sky	Japanese/English Versions
National Astronomical Observatory of Japan: Striving to Solve the Mysteries of the Universe	Japanese caption Version
Time-lapse photography of Phoenicid meteor shower (marked)	
Project PR movie “Gravitational Wave Project Office”	Japanese/English Versions
Project PR movie “Subaru Telescope” 2nd version	Japanese/English Versions
Total Lunar Eclipse on January 31	Japanese Version
Exploring the Universe with “Subaru”*	Japanese/English Versions
Operation Guide for the HSC Viewer*	Japanese/English Versions
Message from New Director General of NAOJ, Dr. Saku Tsuneta	Japanese/English Versions
“Mitaka” Now Delivers More Realistic Universe in More Languages*	Japanese/English Versions

Table 2: Summary of Produced Videos.

April 12, 2017	Collisions generate gas in debris disks
April 28, 2017	First Global Simulation Yields New Insights into Ring System
May 18, 2017	First Direct Exploration of Magnetic Fields in the Upper Solar Atmosphere - Ultraviolet spectropolarimetry opens a new window for solar physics research -
June 13, 2017	ALMA Hears Birth Cry of a Massive Baby Star
June 14, 2017	Nobeyama 45-m Radio Telescope Developed by the National Astronomical Observatory of Japan and Mitsubishi Electric Recognized as “IEEE Milestone”
August 2, 2017	Running Out of Gas: Gas Loss Puts Brakes on Stellar Baby Boom
August 25, 2017	Phoenicid Meteor Shower from Dead Comet Arises again after 58 Years*
September 28, 2017 (EN) September 5, 2017 (JP)	First Detection of an Intermediate-Mass Black Hole Candidate in the Milky Way
September 11, 2017 (EN) August 8, 2017 (JP)	Photosynthesis under the light conditions different from the Earth: New prediction of a detection wavelength for searching phototrophs on exoplanets
September 29, 2017	Supersonic gas streams left over from the Big Bang drive massive black hole formation
October 5, 2017	Surface Helium Detonation Spells End for White Dwarf
October 31, 2017	Minor Merger Kicks Supermassive Black Hole into High Gear
November 6, 2017	Forest of Molecular Signals in Star Forming Galaxy
November 10, 2017	Winds blowing off a dying star
November 17, 2017	Solar Minimum Surprisingly Constant - More than Half a Century of Observation yields New Discovery
November 21, 2017 (EN) August 3, 2017 (JP)	Uncovering the Origins of Galaxies' Halos
January 12, 2018	Black Hole Spin Cranks-up Radio Volume
January 25, 2018	FUGIN Project: Large-scale Exploration of the Invisible Milky Way - Making the Most Detailed Radio Map of the Milky Way
February 6, 2018	HINODE Captures Record Breaking Solar Magnetic Field
February 14, 2018	Rotating Dusty Gaseous Donut around an Active Supermassive Black Hole
February 20, 2018	No relation between a supermassive black hole and its host galaxy!? - The co-evolution mystery deepened by a new ALMA observation
February 22, 2018	Rare first moment of stellar explosion captured by amateur astronomer
March 13, 2018 (EN) March 5, 2018 (JP)	Double or Nothing: Astronomers Rethink Quasar Environment

Table 3: Web Releases.

October 17, 2017	Astronomers Follow Gravitational Waves to Treasure
February 27, 2018	Early science results from the Hyper Suprime-Cam Survey

Table 4: Press Conferences.

(2) Research Result PR

There were 25 research result announcements (compared to 20 in FY 2016 and 27 in FY 2015). For press releases aimed towards overseas audiences, the Office has continued to use the delivery services of the American Astronomical Society, AlphaGalileo, and EurekAlert! from AAAS. We released all the research releases in both English and Japanese. We made videos introducing the content indicated with a * mark.

In the perennially popular Astronomy Lectures for Science Journalists program, the 24th lecture entitled "Approaching the Mysteries of the Solar Corona from Magnetic Field Observation - Present and Prospects for Solar Research - " was held on July 25, 2017. Nineteen people (8 companies) participated in the lecture.

(3) Activities as NAOJ's Public Relations Center

The following activities were pursued in addition to the Center's regular task of aiding research result releases. The Public Relations Office organized lectures with research projects. On February 4, 2018, the NAOJ lecture meeting/23rd ALMA public lecture "ALMA Explores the Cold Universe - Revealing the Mysteries of Planets' Birth - " was held with 265 guests in attendance.

We ordered an outside filmmaker to make a 2nd episode of "NAOJ Topics," a video introducing NAOJ's research activities for the public (Japanese and English versions).

For the purpose of promoting the use of the contents on the website and improving the work efficiency, we updated the "Terms of Use of the Website of NAOJ."

We opened the special site "NAOJ VR." Visitors can experience a virtual tour of Mitaka Campus.

To publicize NAOJ abroad, we hosted/co-hosted booths at overseas meetings where the press and museum personnel gather (World Conference of Science Journalists in San Francisco October 2017, Science Centre World Summit 2017 in Tokyo November 2017, and AAAS meeting in Austin February 2018).

Upon request from the Graduate University for Advanced Studies (SOKENDAI), we translated the website of the Department of Astronomical Science, School of Physical Sciences, SOKENDAI, into English.

(4) New Astronomical Objects

Four staff members, including one full-time and three part-time, handled reports of new astronomical objects and other communications submitted to NAOJ. In this fiscal year, there was a total of 18 reports including confirmation requests for new celestial object candidates and other reports. The contents were: 4 novae/supernovae, 5 variable stars/transient objects, 4 comets, 4 luminous objects, 1 other. Among the many examples of reporting a known asteroid or ghosts as a new object, the report of an object in March 2018, was communicated via NAOJ to the IAU Central Bureau for Astronomical Telegrams and was recognized as an independent discovery of Nova Canis Majoris 2018.

(5) Citizen Astronomy

From FY 2016, the Public Relations Office has promoted "Citizen Astronomy," in which the public plays a part in astronomical research activities using observational data released by NAOJ. Citizen astronomy is one example of "Citizen Science" projects in which researchers / research institutes and the public collaborate on scientific activities. In FY 2017, we considered a concrete citizen astronomy program using the first dataset published in February 2017 from the Hyper Suprime-Cam Subaru Strategic Plan (HSC-SSP) done by the Subaru Telescope and Hyper Suprime-Cam. We developed the user-friendly website to display the HSC images and opened it to the public. We developed a program to determine the shapes of colliding galaxies by using the website. In order to verify the functions and browsing capabilities of this program, a workshop was held on January 8, 2018 for educational officials and astronomy enthusiasts with 26 participants. Under the initiative of the Public Relations Center, this program is being promoted through cooperation with the Subaru Telescope and Astronomy Data Center.

4. Outreach and Education Office

(1) Public Visits

A total of 21,310 people participated in Mitaka Campus Public Visits (former name was Visitors' Area) in FY 2017. In addition, the group tours in 2017 consisted of 111 general tours (4,171 guests), and 30 workplace visits by schools (361 guests), and 5 others such as inspections (108 guests), for a total of 153 tours accommodating 4,640 guests. Therefore, 25,950 guests visited Mitaka Campus in total. Note that for the integrated studies, lectures by researchers, question-and-answer sessions, and visits to research facilities also took place. The office developed an audio guide for most of the Visitors' Area, including making the scripts for the audio guide and recording them in Japanese and English.

Regular stargazing parties were held twice a month (the day before the 2nd Saturday and the 4th Saturday) with the 50-cm Telescope for Public Outreach. These were held regardless of cloudy or rainy weather. Advance booking (300 people for each session; a lottery system from April to September and advanced reservations until filled system from October to March) was introduced in FY 2012 for these events. A total of 23 sessions were held with 4,772 participants this year. In addition to this, the telescope was used by 15 groups (794 people) for group tours, inspections, etc.; so a total of 5,566 people observed with the 50-cm Telescope for Public Outreach.

The Outreach and Education Office held the regular public screenings at the 4D2U Dome Theater four times per month (1st, 2nd, 3rd Saturday, the day before the 2nd Saturday). Advanced reservations were required for these. A total of 45 screenings were held this year, with 5,097 guests participating. For five of the regular public screenings, the office held "Astronomers' Talks" where researchers talked about the latest research and these were popular. Group screenings were performed on Wednesdays and Fridays for 69 groups (2,007 people). In

addition, 93 group tours (1,384 people) were organized and a total of 8,488 guests watched the 4D2U stereoscopic movies.

Guided tours corresponding to cultural property events (November 3 and March 21, advanced reservations needed) and the NAOJ Solar Tower Telescope Special Open Days (November 4, November 5, March 24, and March 25, no reservations needed) were held with 1,058 attendees.

(2) Telephone Inquiries

The office received inquiries from the media, government offices, and the general public. The Outreach and Education Office responded to 5,320 telephone inquiries (Table 5) and 111 letters, 48 of which were official documents.

(3) Educational and Outreach Activities

The "FUREAI (Friendly) Astronomy" project, now in its 8th year, provided lectures to 85 schools which is the highest number of schools ever. In this fiscal year, a total of 57 lecturers provided events for 7,801 students. In eight years, 47,149 students in total have attended the lectures in 481 schools from Hokkaido in the north to Okinawa in the south.

"Summer Nights: Let's Count Shooting Stars 2017 (August 2017)", "Let's Gaze at the Geminid Meteor Shower 2017 (December 2017)", and "Let's Observe the Total Lunar Eclipse 2018 (January 2018)" were held and we received 1,411 reports, 2,569 reports, and 2,042 reports, respectively.

For three days from July 31 (Mon) to August 2 (Wed), "Astronomy Classes for Kids in Summer" events were held for elementary and junior high school students around the Mitaka area. Each day had different themes (assembly of telescopes, three-dimensional star handcrafts, and radio telescope observation) with 138 participants in total. Participants experienced things unique to the observatory, such as being taught by astronomers and using the teaching material produced in collaboration with projects.

The Public Relations Center participated as the secretariat for the "Mitaka Open House Day", a special public event held at Mitaka Campus and organized by the steering committee. This two-day event was held on October 13 (Friday) and October 14 (Saturday) with the theme "The Universe, Hot and Cold." It was co-hosted by the Astrobiology Center, National Institutes of Natural Sciences; the Institute of Astronomy, the School of Science, the University of Tokyo; and the Department of Astronomical Science at the School of Physical Sciences of the Graduate University of Advanced Studies. The event flourished: 303 guests attended on pre-open day, and 2,966 guests attended on open day, so 3,269 guests attended in total. Activities included the viewing of facilities not normally open to the public, interactive panel displays, mini lectures, quizzes and games that are popular among children, and a virtual reality experience. Each Project offered a selection of activities based on their own expertise which were suitable for a wide range of age groups.

(4) Community Activities

The "Mitaka Picture Book House in the Astronomical Observatory Forest" welcomed 38,457 visitors in FY 2017. The Outreach and Education Office supervised the exhibition "Elements of Things - How We are Made - (July 2017 - June 2018)." We also cooperated with an opening ceremony, modern and traditional Tanabata events, moon viewing event, and other events. In addition, through the "Mitaka Picture Book House in the Astronomical Observatory Forest, Picture Book Original Drawings Hallway Exhibit Contest" which started from FY 2013, the Outreach and Education Office cooperated in the selection of 6 winning books.

The Outreach and Education Office conducted the 9th "Mitaka Solar System Walk" from September 22 (Fri) to Sunday, October 22 (Sun) in cooperation with Mitaka City and the non-profit organization (NPO) Mitaka Network University. Stamps were placed at 246 shops and facilities around Mitaka City. Adding 18 limited event stamps, 264 stamps were placed and this is a record number. Approximately 20,000 guide-maps/stamp sheets were distributed, of which 3,256 people turned theirs in for a prize. The number of participants who collected all the stamps was 380. It was a good chance to tour the Solar System while promoting commerce, industry, sightseeing and providing people a way to enjoy Mitaka and rediscover the city's charm.

The Office also provided the venue for "Astronomy Course for Apprentice Starry Sky Guides, Star Sommelier Mitaka - Let's Become Apprentice Starry Sky Guides! - " hosted by Mitaka Network University and also assisted by providing teachers and workshops.

The "Information Space of Astronomy and Science" for which Mitaka City, Mitaka Network University, and Mitaka City Planning Board co-operate celebrated the third year since its opening and 7 exhibitions were held in FY 2017. The Public Relations Center had proposed 2 of these exhibitions and helped with 3 lectures. Also, the office offered outreach and monthly astronomical information images through large-scale information displays and "Cosmic Reading Bookstore Corner," a display of sample books available to read which changes themes (once every 2 months), and cooperated on the

	Solar Ephemeris	Lunar Ephemeris	Ephemeris	Time	Solar System	Universe	Astronomy	Other	Total
April–June	134	101	35	7	158	120	97	577	1229
July–September	127	90	49	5	176	108	103	677	1335
October–December	163	137	44	8	198	103	89	581	1323
January–March	157	258	38	5	126	110	97	642	1433

Table 5: Telephone inquiries made to the Outreach and Education Office of the NAOJ Public Relations Center (April 2017–March 2018).

"M Marche Project" conducted on the 4th Sunday of every month. We welcomed 11,062 guests in the 2017 fiscal year and celebrated 40,000 visitors since the opening. It has been acknowledged as a location in town where science can be easily accessed.

(5) Merchandizing Business

Continued from the last fiscal year, the Office cooperated with merchants who organized the NAOJ original goods and aided in making them. Especially this year, there was a new effort that made use of NAOJ's intellectual property such as packaged products of teaching materials developed for Astronomy Classes for Kids in Summer. In addition to vending machines dispensing capsule toys which are already in place, the office invited the merchants to place a "Jumbo Carddass Machine," so that they can sell photo cards. The office contributed to placing the sales location at the Mitaka Open House Day and Special Open House Day for Nobeyama Radio Observatory. A total of 1,424 items of these goods were sold in the fiscal year. In order to share information on merchandizing know-how, we invited the public relations specialists of each project to a meeting and exchanged opinions about NAOJ original goods, which are spreading to all projects.

(6) International Activities

NAOJ and Leiden University (the Netherlands) co-organized "Astronomy Museums, Visitor Centres & Public Observatories Workshop" at Leiden University from September 27 to September 29, 2017. This workshop is about the activities of astronomical museums, visitor centers, etc., and was conducted at NAOJ Mitaka Campus for the first time in September 2015. We plan to hold it every two years and this is the second time that it had been held. About 30 people participated and there were 25 lectures, workshops, etc.

In cooperation with IAU/OAD (South Africa), Leiden University and others, we are proposing and discussing about making the international guidelines on astronomy education with the IAU executive department and commission C1.

From March 24 to March 28, 2018, NAOJ and Fukuoka City co-hosted CAP2018 (Communicating Astronomy with the Public 2018) at the Fukuoka City Science Museum with 446 participants from 53 countries. The CAP2018 main theme was "Communicating Astronomy in Today's World: Purpose & Methods." This edition was the largest CAP Conference ever. The conference hosted 5 plenary sessions with 24 plenary talks, 141 parallel sessions, including a planetarium session; 24 workshop sessions with 20 unique workshops, 111 posters, and a special session dedicated to the 100 Year Anniversary of the IAU.

5. Ephemeris Computation Office

The Ephemeris Computation Office (ECO) estimates calendrical phenomena such as the apparent positions of the Sun, Moon, and planets on the basis of international standards and publishes the "Calendar and Ephemeris" as part of the compilation of almanacs, which is one of NAOJ's raisons d'être.

(1) ECO published the 2018 edition of the Calendar and Ephemeris, the 2018 version of the calendrical section of the Rika Nenpyo (Chronological Scientific Tables), and the 2019 edition of the Reki Yoko (posted in the official gazette on February 1, 2018). The Calendar and Ephemeris webpage was updated to match what was published in the Reki Yoko.

(2) As for the website (http://eco.mtk.nao.ac.jp/koyomi/index.html.en), ECO continuously updated the contents of the Ephemeris Wiki and worked on checking the accessibility sequentially. ECO cooperated with the astronomical phenomena awareness campaigns again this year. The radiant points of the Perseid and Geminid meteor showers were published in the Astronomical Information section of the website. There were about 25 million page views for this fiscal year.

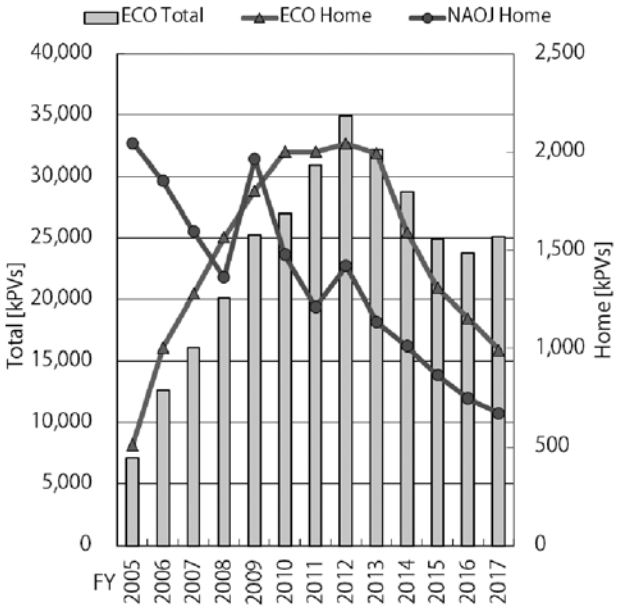

Figure 1: Pageview Statistics of ECO Website.

(3) The Japan Association for Calendars and Culture Promotion hosted Calendar Culture Mini Forum, its 7th General Meeting, and the Calendar Presentation Ceremony.

(4) ECO hosted regular exhibitions in collaboration with the Library, selecting from NAOJ's invaluable collection of historical archives for Japanese and Chinese books. The theme of the 56th permanent exhibition was "Achievements of Sekisui Nagakubo." This exhibit can also be viewed at the Rare Materials Exhibition of the Library's website, in Japanese only (http://library.nao.ac.jp/kichou/open/index.html).

6. Library Unit

The Library Unit collects and sorts scientific journals and books in order to make them available for the research and

study of NAOJ researchers and students. In recent years, with the continuing digitalization of scientific materials, the portion of the materials in electronic format has increased.

For non-NAOJ personnel who wish to use the Mitaka Library materials, the Library is open to the public on weekdays. In FY 2017, 232 non-NAOJ personnel came to use the Library. Also for researchers and students belonging to other organizations, we loan books or provide photocopies via the institute's library. In FY 2017, photocopies or loans were provided in a total of 93 cases.

Important documents, especially those originating from the Edo Era Tenmonkata (Shogunate Astronomer), are preserved while taking into account the environment of a specialized library. Images of some of the important documents are available to the public on the Library Unit homepage.

On June 1, 2017, the Unit updated the library information system. This improved the convenience of the Online Public Access Catalog (OPAC).

During the Mitaka Open House Day festivities in October, we opened part of the Mitaka Library to the public as in the past. We extended the subject themes again as we did in Fiscal Year 2016. In addition to materials for general and young readers, we actually allowed visitors to take a look at many specialized books related to astronomy.

The number of books and journals owned by Mitaka Library and each observatory and the condition of continuing NAOJ publications are published in Section XI Library, Publications.

7. Publications Office

The Publications Office continued its activities in planning, editing, and printing NAOJ's original materials for PR and promotions. The following periodicals were also published this year:

- Annual Report of the National Astronomical Observatory of JAPAN Volume 29 Fiscal 2016 (Japanese)
- Annual Report of the National Astronomical Observatory of JAPAN Volume 19 Fiscal 2016 (English)
- Report of the National Astronomical Observatory of JAPAN Volume 19 (Japanese)
- Publication of the National Astronomical Observatory of JAPAN Volume 14
- NAOJ Pamphlet (Japanese)
- NAOJ Pamphlet (English)
- NAOJ News, No. 285 – No. 293 (April 2017 – March 2018)
- NAOJ Calendar (The 13th in the series)
- Radio Astronomy Public Relations Comic "ALMAr's Adventure" (#7)
- NAOJ Publicity Poster Series (#7 and #8)

Continuing from the previous year, the Publications Office strove to strengthen its international publication ability and digital publication ability. Regarding the production of an international edition of the Rika Nenpyo (Chronological Scientific Tables), we finished proofreading and we are in the final editing process. In digitalization efforts, we expanded the Publications Office's digital publication website for e-books and prepared for publication of contents by categorizing them into "public relations," "science writing," "academic," and "general." In normal business, the Office produced and distributed the Annual Report of the NAOJ, Publication of NAOJ, and the NAOJ pamphlets. In particular, the Office promoted multilingualization of the pamphlet, produced a Spanish version in addition to Japanese and English, prepared data for Chinese and Korean versions, and prepared to publish five language versions in total.

In the systematic production of special editions with the goal of developing project outreach support in NAOJ News, extra copies of each of the special editions ("People Advancing the TMT Project Vol. 02 Special Edition" April; "People Advancing the TMT Project Vol. 03 Special Edition" November; "CfCA Special Edition" October; and "Okayama Astrophysical Observatory Special Edition" March 2018) were printed and these aided the outreach efforts of each project. From now on, to develop and share NAOJ News articles as a resource to be used as outreach content for each project, we plan to promote the production of overall, basic articles through close cooperation with researchers and promote international magazine compiling. Other than periodicals, the 2018 calendar "Okayama Astrophysical Observatory" (the 13th since 2005) was created. The Office provided native check services to the Public Relations Office; CfCA; the Graduate University for Advanced Studies; the NAOJ Directorate, and CAP2018 for English language publications, contributing to the expansion and enhancement of NAOJ's international information dissemination. In addition, like in other years editing support was also given to the publication of the "Rika Nenpyo 2018 (Chronological Scientific Tables, Astronomy section)."

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

International Astronomical Union (IAU) Office for Astronomy Outreach (OAO) is tasked to communicate with and manage National Outreach Contacts (NOC's, windows for outreach in each country) as a priority issue. The Office also started to discuss new selection methods and guidelines for NOC's in order to smoothly and continuously develop the NOC activities in each country.

In FY 2017, the editing and publishing of the CAP journal returned from the European Southern Observatory (ESO) to NAOJ for the first time in four years. Journal #23 was issued in February 2017 and 2,700 copies of the printed edition were distributed, mainly overseas. The online edition can be freely browsed at the IAU web page.

For international information provision, the office posted a total of 460 postings from OAO on IAU social media during FY 2017. The Facebook community grew by 23 % and the Twitter community by 22 %. Meanwhile, the IAU Astronomy Outreach Newsletter (e-mail news) was delivered 24 times and 300 items of information were provided to 4,600 subscribers all over the

world. The newsletter has been translated and redistributed into four different languages by collaborators in the respective countries. The Office is also responsible for making the website contents (Themes) of the IAU website for the Public.

We are promoting the Astronomy Translation Network (translation work by volunteer network) as an NAOJ proposal project for OAO activities. There are 144 registered volunteers and five working groups (Indonesian, Portuguese, Chinese, Spanish, and French) have started work for each language.

For the international conference CAP2018 in Fukuoka, the OAO Coordinator participated in the operation as one of the Co-Chairs of the Science Organizing Committee, and the OAO Sub-Coordinator was in charge of public relations and making the proceedings as the Vice-Chair of the Local Organizing Committee. For the details of the conference, please refer to the section of the Outreach and Education Office, which hosted the conference.

In addition, OAO participated in the "Strategic Plan 2020–2030," IAU's plan for the next ten years, during FY 2017. In cooperation with the IAU 100 Secretariat established at the IAU secretariat and Leiden University, OAO is preparing the IAU 100 project as one of the implementing organizations of the IAU 100 anniversary project in 2019.

In cooperation with the Outreach and Education Office, NARIT (Thailand), and IAU/OAD, we held the "You are Galileo!" workshop at the University of Mandalay (Myanmar) on November 29–30, 2017.

17. Division of Optical and Infrared Astronomy

1. Overview

The primary objectives of divisions in NAOJ are facilitating and invigorating projects and individual research through personnel exchanges to place researchers in environments more suitable for their individual projects. While pursuing challenging exploratory research on observation and development, the Division furthers these goals by launching new projects as necessary. The Division also actively engages in graduate education efforts to foster next-generation talent. These activities are based on the concept that the Division of Optical and Infrared Astronomy is a center for personnel exchange between Subaru Telescope, which engages in open use, and universities and research institutes in Japan, which focus on developmental research into new instruments and observational research. This fundamental principle has been developed since the Subaru Telescope was constructed.

The Division of Optical and Infrared Astronomy oversees OAO (Okayama Astrophysical Observatory) and Subaru Telescope (C Projects); the TMT-Japan (TMT-J) Project Office and the Gravitational Wave Project Office (B Projects); and the JASMINE Project Office and the Extrasolar Planet Detection Project Office (A Projects). The Extrasolar Planet Detection Project Office migrated to the Astrobiology Center of the National Institutes of Natural Sciences on December 31, 2017. This transition extends its vision to explore "life in the Universe" and uncover its mysteries. Most of its members concurrently held positions of the Division. The Division and the Projects carry equal weight in organizational terms. Almost all NAOJ members in optical- and infrared-related fields have positions in the Division with either the Division or one of the A, B, or C Projects as the primary appointment. At times, they may also have concurrent positions in other projects. The primary staff of the Division of Optical and Infrared Astronomy in FY 2017 consisted of one professor, five assistant professors, four research affiliates, and three JSPS postdoctoral fellows.

The Division coordinates educational, research, and administrative activities for Subaru Telescope Mitaka Office and the Extrasolar Planet Detection Project Office. Since personnel transfer often occurs within the Division of Optical and Infrared Astronomy, the Division plays an increasingly important role in coordinating between Subaru Telescope and the TMT-J Project Office. The Division as a whole maintains and operates facilities which are auxiliary to research, such as mailing lists and web servers for Division of Optical and Infrared Astronomy-related projects such as Subaru Telescope, TMT-J, the Extrasolar Planet Detection Project Office, Gravitational Wave Project Office, and JASMINE Project Office. The remainder of this report will focus on the research projects conducted by the primary staff of the Division of Optical and Infrared Astronomy and the activities of projects that support open use.

2. Observational Research

(1) Observational Research Using Various Types of Telescopes

Observational research utilizing the Subaru Telescope focuses on a wide variety of fields such as cosmology; galaxy formation and evolution; the formation of stars and planets; the structure and evolution of the Milky Way; stellar spectroscopy; Solar System bodies; and the search for exo-planets.

Optical and Infrared Synergetic Telescopes for Education and Research (OISTER) is a NAOJ-lead initiative to form a network of small aperture size, 0.5 meter to 2.0 meter, telescopes owned by universities around Japan and overseas to promote Time Domain Astronomy research and graduate level astronomy education. FY 2017 marked the achievement of one of the most important objectives, successful observations of a gravitational wave source (GW170817). A result of Time Domain Astronomy research by OISTER was presented in a “You are Galileo!” workshop.

With great help from both Subaru Infrared Camera and Spectrograph (IRCS) and the second-generation adaptive optics (AO188) high angular resolution observations for star-forming galaxies at z~2.5 were realized in order to investigate their internal structures. By combining adaptive optics (AO188) and narrow-band filters, spatially resolved maps of star-forming regions within galaxies were obtained. Observation of extended ionized gas in a cluster of galaxies with the Subaru Telescope was also conducted.

Utilizing the Sloan Digital Sky Survey (SDSS) catalogue, four scientific reports were published. Two of them focused on low-ionization broad absorption line quasars. The third shows evidence for higher black hole spin in radio-loud quasars. This result was made into an NAOJ press release with the help of NAOJ’s Public Relations Office. The fourth report focused on the quenching of super massive black hole (SMBH) growth. This shows the first observational evidence that the number fraction of radio-loud quasars increases with the mass of the SMBH’s above a critical BH mass of $2 \times 10^9\,M_\odot$.

The dust torus cooling timescale once the active galactic nucleus (AGN) is quenched was estimated. The dust torus emission completely disappears within 100 years for most of the AGN luminosity range.

Combining data from the Gemini optical and NuSTAR X-ray observatories, a study on the relevance of the nuclear geometrical structure of the AGN to the extension of ionized gas on host galaxy scales was conducted. Based on ALMA submillimeter/millimeter and Chandra X-ray data, observational study on an active galactic nucleus (AGN) was conducted, particularly focusing on the effects of its X-ray radiation on the surrounding interstellar media.

A study on protoplanetary disks by using both Subaru and ALMA observations is on-going. An observational proposal to ALMA was approved. Now the obtained ALMA data are being

analyzed.

(2) International Cooperative Observational Research

The Division also engages in international collaborative studies with overseas researchers.

Site survey for a future large infrared telescope in the western Tibet area was continued in cooperation with the National Astronomical Observatories and Chinese Academy of Sciences (NAOC). Based on past meteorological data in China, clear-sky probabilities in the area were evaluated. This result was presented in the NAOJ Symposium on Engineering in Astronomy 2017.

A study on extended ultraviolet regions around galaxies continues with researchers in the USA.

(3) Research Using Archives

The image data of all Kiso Ultraviolet-Excess Galaxies were released on the website of Kiso Observatory, University of Tokyo. A paper on this work was published. Digitization of Kiso Schmidt plates continued. As of the end of FY 2017, we have scanned 2393 plates out of about 7000 plates, together with some special project plates. These data are archived in the Astronomical Data Archive Center (ADAC), NAOJ, and will be opened for public access.

Research on the verification of astronomical phenomena described in the New Testament is being done jointly with the National Institutes for the Humanities. Studies of astronomical phenomena based on other old ephemerides and documents are continuing.

A study on the relics of past interaction in the outskirts of nearby galaxies was conducted.

3. Observational Instrument Development

Studies of coronagraph masks for the Subaru Telescope and WFIRST were conducted.

The Infrared Doppler Instrument (IRD) at Subaru Telescope was developed and engineering runs were conducted with a laser frequency comb system as a spectrograph drift calibrator.

One of the topics of interest is the search for the undiscovered "axion," a dark matter candidate. An axion will interact with a magnetic field and create a photon. To investigate this phenomenon both laser interferometric techniques and long superconducting magnets are powerful tools. A joint NAOJ and KEK group has started to discuss this experiment.

The analysis of ghosts in Hyper Suprime-Cam continued.

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

4. Operational Support for Subaru Telescope

The Division of Optical and Infrared Astronomy offers support for the open use of the Subaru Telescope. This includes organizing open calls for open-use programs, program selection, administration, management of open-use-related travel expenses, and promoting PR activities for Subaru Telescope. The Division also provides support for various research conferences held at Mitaka Campus.

5. Research Environment Maintenance

A web server has been maintained for research activity PR. In this year both the web server and the mailing-list server were replaced with new hardware. And also the web contents were restructured to improve robustness.

The Division manages the printers and rented multi-function photocopiers; sub-networks; and data backup servers for Subaru Telescope Mitaka Office as part of its efforts to maintain the research environment, and also gives assistance for setting-up computers for new administrative supporters.

6. PR, Outreach, and Discoveries of New Astronomical Objects

The Division cooperates with the Public Relations Center in supporting matters related to discoveries of new astronomical objects and PR/outreach activities such as web releases and press conferences related to Subaru Telescope research results.

The Division actively participates in a special public event held at Mitaka Campus (Mitaka Open House Day).

To introduce the activities of the Division of Optical and Infrared Astronomy, we contributed to the Symposium of the Inter-University Research Institute Corporations in 2017.

7. Contributions to International Committees and Events

As a cooperative program between EACOA (East Asian Core Observatory Association) and SEAAN (South-East Asian Astronomy Network), the "You are Galileo!" workshop was held at Mandalay University, Myanmar on November 29 & 30, 2017.

NAOJ, with Hyogo University, conducts a joint program with the National Astronomical Observatory of Vietnam, Nha Trang to strengthen our research and education capabilities.

8. Hosting Scientific Conferences and Meetings

Department members contributed as SOC and LOC co-chairs to the East Asian Young Astronomers Meeting (EAYAM) 2017 in Ishigaki Island.

The 8th OISTER workshop was held at NAOJ Mitaka Campus on December 14 & 15, 2018.

9. Visitors

The OISTER program conducted short-term visiting observation training courses for 14 graduate students. In March 2018, researchers from Hyogo University and NAOJ visited Nha

Trang and one researcher from Vietnam came to Japan for the observation programs. Prof. Xue-bing Wu in the Kavli Institute for Astronomy and Astrophysics at Peking University visited NAOJ. Prof. Jin Koda of Stony Brook University also visited.

10. Educational Activities

The Division of Optical and Infrared Astronomy provides postgraduate education to 20 graduate students from the Graduate University of Advanced Studies, the University of Tokyo, Tokyo University of Agriculture, and Japan Women's University.

Division staff members made active contributions to seminars and self-directed studies. Since April 2015 we have held a 30-minute seminar in the afternoon every day throughout the year. In December, we held the annual workshop of the Division of Optical and Infrared Astronomy so that staff members and graduate students can understand the current studies and interests of each other.

18. Division of Radio Astronomy

The Division of Radio Astronomy oversees Nobeyama Radio Observatory, Mizusawa VLBI Observatory, the RISE Lunar Exploration Project, and NAOJ Chile Observatory operating the Atacama Large Millimeter/submillimeter Array (ALMA) and Atacama Submillimeter Telescope Experiment (ASTE). The scientists and engineers of these projects are attached to the Division of Radio Astronomy to conduct radio astronomy research under mutual cooperation among these radio astronomy projects. The research themes of the Division of Radio Astronomy are represented by keywords such as Big Bang, early Universe, galaxy formation, black holes, galactic dynamics, star formation, planetary system formation, planets and satellites, the Moon, the evolution of interstellar matter, and the origin of life in the context of the evolution of the Universe. Radio astronomy unravels mysteries and phenomena in the Universe through radio waves, which are invisible to human eyes. The detailed research results are reported in each project's section and in the research highlights. The Radio Astronomy Frequency Subcommittee has been established within the division, engaging in discussions on protection against artificial interference generated by electrical equipment, which causes major obstacles in radio astronomical observations.

1. Radio Astronomy Frequency Subcommittee

The mission of the Radio Astronomy Frequency Subcommittee is to protect the environment for radio astronomy observations. In 1932, Karl Jansky of the U.S.A. first discovered radio waves emitted by astronomical objects, albeit accidentally. Since then, dramatic advances have been made in radio observation methods, showing us new perspectives of the Universe invisible at the optical spectrum. Four Novel Prizes have been awarded to achievements made in the field of radio astronomy so far.

Just as light pollution from artificial light sources is an obstacle in optical observation, artificial radio interference generated by the electronic devices surrounding us is a major obstacle in radio observations. As breathtaking advancement has been achieved in wireless communication technologies in recent years, wireless commercial products such as mobile phones, wireless LAN's, and automotive radars are widely used. The areas of radio applications will continue to expand in the future owing to their ubiquitous nature. But because of its unique capabilities, compatibility among various radio services, including both active and passive ones, will become a serious issue. Frequency is a finite resource and its sharing is an unavoidable issue. Therefore, further efforts will be necessary for maintaining the sky free from artificial interference for better radio astronomy observations.

(1) Role and Organization

The purpose of the Radio Astronomy Frequency Subcommittee is to ensure that radio astronomical observations are free from artificial interference and to raise public awareness of the importance of protection activities. Radio astronomical observation does not emit radio waves; thus, it does not interfere with other wireless communications. A proactive approach is needed to widely raise awareness of the efforts to protect the environment for radio observations. Regular explanatory sessions are provided at the Ministry of Internal Affairs and Communications (MIC) and regional Bureaus of Telecommunications to solicit appreciation of the importance of protecting the field.

The coordination between the community of radio astronomy and commercial wireless operators is led by the MIC in Japan and internationally by the International Telecommunication Union (ITU) Radiocommunication Sector (ITU-R) of the United Nations. As part of the activities for FY 2017 the Subcommittee took an active role in formulating the opinion of the Japanese radio astronomical community (on behalf of the Japanese radio astronomers) in these coordination efforts.

The Subcommittee is composed of members from NAOJ and representatives of universities and research institutes in Japan.

(2) Current Challenges

A sharing study between active radio services and radio astronomy is crucial for compatibility under the condition of limited availability of frequency resources. Some rules and regulations have been established to address the issue of interference cooperatively. The Radio Astronomy Frequency Subcommittee remains responsible for taking measures for new developments in wireless services including the following challenges.

• Significant increase in wireless activities in response to natural disasters:

After the Great East Japan Earthquake in 2011, risk of radio interference has been increased by new wireless communication services prepared for natural disasters.

• Development of new radio applications:

There has been a rapid increase in demand for higher frequencies. 76 GHz automobile radars become common. Wide band radars up to 81 GHz may become more popular as they may reduce car accidents resulting in injury or death. It is anticipated that industrial structures will dramatically change with the advent of the fifth generation mobile phone technology allowing high-speed, multiple concurrent connections, and ultra-low latency, which will be installed into various mobile phones. Some satellite operators launched new plans for improving broad-band communication to ships and planes globally.

• Reassigning of vacant frequency bands resulting from enhanced efficiency in radio use:

The digitization of television broadcasting has created vacant frequency bands, which have been reassigned for mobile phones and other applications.

The effect of interference arising from such radio applications (e.g. wireless business) varies widely depending on the frequency band used. Radio astronomy observations have been given priority in a number of frequency bands within the range between 13.36 MHz and 275 GHz under the ITU Radio Regulations (RR). However, negotiations will be necessary between some radio services and radio astronomy if the same priority level is to be shared within a certain band or under adjacent/proximity conditions. Even faint signals of negligible significance to general radio services, can have a chance of substantial adverse effects on radio astronomy observations.

Sources of interference that need to be addressed continue to increase and include the following devices and systems: the 23 GHz CATV wireless transmission system used in emergencies, where ammonia observations are affected; 21 GHz next-generation satellite broadcasting, where water maser observations are affected; 1.6 GHz mobile satellite phones for emergencies, where the observation of pulsars and the like are affected; the fifth generation mobile phones, where silicon monoxide (SiO) maser observations are affected by the 43.5 GHz band (one of the candidate frequency bands); and Ka-band broad-band communication from airliners to satellites, where water maser observations are affected. 79 GHz automotive radars around Nobeyama Radio Observatory have considerable impact on the observing conditions. Although radio astronomy observations in the 60 GHz band are not common because of the high rate of absorption in the atmosphere, the 60 GHz system must be watched closely because its second harmonic can have adverse effects on CO observations in the 115 GHz band.

(3) International Activities

The ITU Radio Regulations (RR), which allocate radio frequencies to wireless applications, are revised once every three to four years in the World Radiocommunication Conference (WRC). The RR includes frequency bands in which radio astronomy observation is prioritized. Among these meetings, the Radio Astronomy Frequency Subcommittee is regularly involved in the WP7D (radio astronomy) and WP1A (frequency management) meetings. The Subcommittee also takes part in various international conferences, representing the Japanese community of radio astronomy researchers.

In FY 2017, the Subcommittee participated in the ITU-R WP7D meetings held in April and October in Geneva. In these meetings, the following items were discussed as major agenda items related to radio astronomy: modernization of Global Maritime Distress Safety Systems (GMDSS) utilizing 1.6 GHz satellite communication; upgrades of the maritime radio communication system utilizing the 160 MHz maritime mobile-satellites, establishment of a correspondence group for compatibility studies to ensure compatibility between vehicle radars and radio astronomy, identification of frequency band candidates for the new International Mobile Telecommunications (IMT2020), and so on. The WRC-19, which is scheduled for 2019, aims to identify frequency bands for IMT2020 from 11 candidate frequency bands ranging from 24 GHz to 86 GHz and to allocate active services to frequencies above 275 GHz.

(4) Activities in Japan

The three major domestic activities of the Radio Astronomy Frequency Subcommittee include: participation in various committees and working groups hosted by the MIC, direct negotiations with wireless operators regulated by the MIC, and informative activities to raise public awareness about radio interference to radio astronomical observations. Negotiations with wireless operators to reduce interference sources represent a major part of the Subcommittee's activities in Japan.

The committees and working groups hosted by the MIC are to formulate Japan's strategies on various wireless issues for international conferences. Other MIC-related meetings provide opportunities for discussing the radio application technologies related to MIC's wireless policy, and for negotiating on interference issues with wireless operators authorized by MIC. Negotiations directly affecting the protection of radio astronomy observations have been conducted concurrently to dealing with the interference problems related to societal and technological trends.

Several examples of the interference problems discussed in section (2) above are given below.

In November 2015, WRC-15 resolved to allocate 77.5–78 GHz to the radiolocation service, allowing automotive vehicles to utilize the whole 76–81 GHz band for their radar, which may invite large scale commercial use of high-resolution automobile radars in the 76 GHz and 79 GHz bands. Of particular concern are the possible effects of interference from these radars on the 45-m radio telescope at Nobeyama Radio Observatory, which engages in observations of spectral-lines of deuterated compounds and other molecules in interstellar matter. The observations with the Nobeyama 45-m Radio Telescope located in Japan will continue to carry significance in relation to the international project ALMA, which deploys 66 high-performance radio telescopes at an altitude of 5,000 m in Chile. Since automotive radars are highly relevant to human life safety, negotiations have been conducted with careful analysis in order to reach a mutually acceptable agreement.

A new radio wave application is being planned for 21 GHz next-generation satellite broadcasting with a picture resolution 16-fold higher than that of the current HDTV. This band is near the 22 GHz radio astronomy band, which is important for water maser observation. The radio signals from the satellite come from outer space. Their detrimental effects need to be alleviated with a filter at the output stage of the satellite. The NHK Science & Technology Research Laboratories developed a bandpass filter to suppress spurious signals to an acceptable level. The measurement results of radio emissions from the satellite launched in December 2017 verified that the filter has a proper protective effect against radio interference.

Radio observations in the 60 GHz band are not common because of the high atmospheric absorption rate in that frequency range. Albeit in fact, the 60 GHz system must be watched closely in terms of its proliferation in the market, since interference from it may affect CO observations in the 115 GHz band, which is within the band of the second harmonics of the 60 GHz radio system.

In response to the update plan of the satellite systems announced by Iridium LLC (U.S.A.), the committee started discussions aiming to reduce radio interference risks caused by unwanted emissions from the 1.6 GHz signal to the astronomy band (OH maser observations). Discussions are being held on what interference risks are involved and what measures should be taken to alleviate radio interference.

The World Radiocommunication Conference (WRC) will determine the frequency band for the next-generation mobile phones in 2019. The MIC organized a joint working group with some radio services and organizations including the Radio Astronomy Frequency Subcommittee. The Subcommittee played an active role in preparing a joint study report regarding the 11 candidate frequency bands given in the WRC-19 Agenda Items.

Additionally, radio astronomy observations could be adversely affected by some of the new wireless technologies: wireless power transmission (WPT) for electric vehicle energy charging (non-beam), next generation railway radio communication systems between bullet trains and trackside, and so on. The Subcommittee continues to monitor their progress and shares the information with related radio astronomers.

Moreover, the Subcommittee has been engaged in making applications to the MIC to request frequency protection for the NAOJ telescopes as well as other telescopes owned by the Japanese community of radio astronomers on their behalf.

Collecting actual interference cases at various observatories is also important. To raise public awareness about "Interference to Radio Astronomy," these collected cases are effectively used in presentations by our community members. We are also preparing tutorial materials for the general public. As optical astronomers are actively working to protect their observation environment against artificial light, we, radio astronomers, are making the same efforts for the sake of continuing observations in radio astronomy in coming ages.

19. Division of Solar and Plasma Astrophysics

The Division of Solar and Plasma Astrophysics is mainly made of staff members from the Solar Science Observatory and the Solar-C Project Office. It conducts research on the Sun in close coordination with these projects. An NAOJ fellow and graduate students supervised by the staff of the above-mentioned projects also belong to the Division.

The Division conducts both theoretical and observational research into the inner structure of the Sun and outer solar atmosphere including the photosphere, chromosphere, corona, and solar wind; and various phenomena in the magnetized plasma such as flares, sunspots, solar faculae, and prominences. The Division's theoretical research includes helioseismology studies of the internal structure of the Sun, and applications of plasma physics and magnetohydrodynamics to various phenomena on the Sun as well as on Sun-like stars. The solar group at NAOJ started observations from space in the very early stages of Japan's space program. The Division has participated in the development of the Hinode satellite, which is currently in orbit, and is playing a major role in its scientific operation. Research is also being carried out using the Solar Flare Telescope and other telescopes in Mitaka Campus. In ground based observations, the Division conducted research to introduce and utilize new technologies in the Solar Flare Telescope and has been conducting long-term monitoring observations of solar activity, and the obtained data are open to the community.

1. Research in Solar Physics

NAOJ fellow S. Toriumi published one paper in a refereed journal as lead author. This work is about the numerical MHD modeling of flare-productive active regions, and he revealed the evolution processes by which subsurface magnetic fields create magnetically energetic active regions above the surface. He also published three refereed papers as a co-author, including for example, theoretical investigations of the relationship between flare durations and magnetic structures, and research related to 18th Century Japanese sunspot sketches. Toriumi has been promoting collaborative research with international partners; he invited Dr. V. Pipin of the Institute of Solar-Terrestrial Physics, Russian Academy of Sciences, and conducted collaborative research on solar-stellar dynamos and starspots.

The Division has a seminar (on Friday afternoon, roughly twice a month) whose speakers are from both inside and outside of the Division. The organizer for this year was S. Toriumi.

2. Educational Activities

The teaching staff of the Division supervised three graduate students from SOKENDAI (the Graduate University for Advanced Studies) and one from the University of Tokyo. Among them, Y. Hatta passed the examination for the Master's thesis. The Division, in cooperation with Kyoto University and Nagoya University, supported the annual "Leading-edge Solar Research-Experience Tour" in March for undergraduate students; nine students visited solar-related research organizations and experienced the latest research in the field.

3. International Cooperation

Y. Katsukawa has been a member of the Science Working Group of the Daniel K. Inouye Solar Telescope, a 4-m telescope under construction at Haleakala, Hawai`i. In Europe, another 4-m solar telescope is now in the planning stage. NAOJ sent a Letter of Intent and is watching the progress. Several plans are also under consideration for future ground-based telescopes that would involve collaborations with East Asian countries and Peru.

20. Division of Theoretical Astronomy

1. Overview

The Division of Theoretical Astronomy (DTA) aimed at achieving internationally outstanding research results both in quality and quantity toward the accomplishment of the following four goals that were set by the NAOJ Board, and is engaged in research activities for FY 2017 accordingly:

- Advance the world class cutting-edge theoretical research.
- Pursue theoretical astronomy research, particularly in areas that utilize the NAOJ supercomputer or large-scale observational instruments to give further insight into their new development.
- Encourage collaborations among researchers in Japan and strengthen the domestic theoretical astronomy research.
- Invigorate postgraduate education.

The division handles a wide variety of themes in theoretical astronomy research, addressing a diversity of hierarchical structure of the Universe in terms of formation and evolution processes, dynamics, and physical state of matter, covering a span from the early Universe to galaxies, stars, planetary formation, activities of compact objects, and plasma phenomena in astronomy and astrophysics; joint research with observational astronomy using observational facilities of various frequency bands such as the Subaru, ALMA, and Nobeyama radio telescopes; and interdisciplinary research with physics of elementary particles and atomic nuclei.

The Division of Theoretical Astronomy aims to facilitate Japan's high competitiveness on the international plane through continuous production of world leading research results and offers a superb research environment as a base for theoretical research accessible to researchers in Japan and overseas. It has accepted a wide range of both Japanese and international researchers as visiting professors, visiting project research fellows, and long-term research fellows who actively engage in various research projects in the division. In particular, the division has fostered research developments to create an influential research center for young researchers and is actively engaged in personnel exchanges with many universities and research institutes. In addition, the division actively organizes numerous cross-disciplinary international conferences, domestic meetings, and seminars for the fields of theoretical astronomy and astrophysics, observational astronomy, and experimental physics, and it leads research activities in various related fields of astronomical science. The division's full-time professors, associates, assistants, and project assistant professors, together with NAOJ postdoctoral fellows and JSPS fellows, conduct a variety of unique research projects involving postgraduate students from the Graduate University of Advanced Studies, the University of Tokyo, and the Graduate School of Japan Women's University.

2. Current Members and Transfers

In FY 2017, the dedicated faculties of the Division of Theoretical Astronomy included two professors, two associate professors, and four assistant professors in addition to one adjunct professor and one adjunct assistant professor who concurrently held primary positions at the Center for Computation Astrophysics. In addition to these research and educational members, the division was served by four project assistant professors, including one research associate, two JSPS fellow, one EACOA fellow, and in addition one administration associate who gave full support to all activities of the division. Among them Akimasa Kataoka, an assistant professor, joined our division from December in 2017, Ken Ohsuga, an assistant professor, moved to Tsukuba University as a professor, and Masaomi Tanaka, an assistant professor, moved to Tohoku University as an associate professor at the end of March in 2018.

3. Research Results

The research papers and presentations in the international conferences carried out by the division member(s) as author(s) or presenter(s) are listed below. Categories with fewer than 5 publications have been omitted.

- Peer-reviewed journal papers in English: 117
- Journal papers in English (proceedings of the meetings): 10
- Reports in English (talks at international conferences): 50 (invited talks: 21)
- Reports in Japanese (talks at national meetings, etc.): 34

Some of the research results are presented as the research highlights listed at the beginning of this report. The following highlights include research in which the division members took leading roles:

- General Relativistic Radiation MHD Simulations of Supercritical Accretion onto a Magnetized Neutron Star: Modeling of Ultraluminous X-Ray Pulsars (Takahashi, H. & Ohsuga, K.)
- Superluminous transients at AGN centers from interaction between black hole disk winds and broad-line region clouds (Moriya, T., Tanaka, M., Ohsuga, K. et al.)
- Big Bang Nucleosynthesis and Modern Cosmology (Kajino, T. et al.)
- Big-Bang Lithium Problem, and Effects of Long-Lived Negatively Charged Massive Particles on Primordial Nucleosynthesis (Kajino, T. et al.)
- The new hybrid BBN model with the photon cooling, X particle, and the primordial magnetic field (Kajino, T. et al.)
- Production of Left-handed Amino Acids in Space in the Supernova Neutrino Amino Acid Processing (SNAAP) Model

(Kajino, T. et al.)
- Selection of Amino Acid Homochirality in Stellar Environments (Kajino, T. et al.)
- Short-baseline electron antineutrino disappearance study by using neutrino sources from $^{13}C + {}^{9}Be$ reaction (Kajino, T. et al.)

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

- Rare first moment of stellar explosion captured by amateur astronomer (Tanaka, M., Moriya, T. et al.)
- Discovery of a supernova beyond the standard explosion paradigm (Moriya, T. et al.)
- Astronomers Follow Gravitational Waves to Treasure (Tanaka, M. et al.)
- Surface Helium Detonation Spells End for White Dwarf (Tanaka, M. et al.)
- The effect of collective neutrino oscillations on vp process nucleosynthesis (Sasaki, H., Kajino, T. et al.)
- Efficiency of Metal Mixing in Dwarf Galaxies (Hirai, Y., Kajino, T. et al.)
- ALMA polarization observation of the protoplanetary disk around HL Tau (Kataoka, A. et al.)
- First Global Simulation Yields New Insights into Ring System (Kokubo, E. et al.)

4. Domestic Collaborations

The Division of Theoretical Astronomy played leading roles in organizing the following domestic conferences:

- Symposium on "Stellar formation and the role of magnetic field in Galactic structure formation," Kagoshima University, December 20–22 in 2017. (Participants; 45)
- 7th TDA Symposium on "Neutron Stars: Theory and Observation," NAOJ Mitaka, November 22–24 in 2017. (Participants; 67)
-30th RIRONKON Symposium on "Beyond the Horizon of Stellar Astrophysics," University of Tokyo Hongo, December 25–27 in 2017. (Participants; 182)

Toshitaka Kajino performed duties as a chairman of Japan Forum of Nuclear Astrophysics for planning and managing international and domestic conferences related to cosmo-nuclear physics and promoting research collaboration in related fields such as astronomy, astrophysics and nuclear physics in Japan.

5. International Collaborations

Eiichiro Kokubo served on the organizing committee of Commission A4 (Celestial Mechanics and Dynamical Astronomy) of IAU.

Toshitaka Kajino performed duties of the following posts: international referee for the Science, Technology and Innovation Council of Canada; international referee for Partnership for Advanced Computing in Europe (PRACE); international associate for the European Centre for Theoretical Studies in Nuclear Physics and Related Areas (ECT*); and international referee for the Swiss National Science Foundation (SNSF).

The Division of Theoretical Astronomy played leading roles in organizing the following international conferences:

- 14th International Symposium on "Origin of Matter and Evolution of Galaxies," Institute of Basic Science in Daejeon, Korea, June 26–29 in 2017. (Participants; 110)
- International Symposium on "Cosmic Dust X," NAOJ Mitaka, August 14–18 in 2017. (Participants; 55)
- International Symposium on "Stellar Evolution, Supernova and Nucleosynthesis Across Cosmic Time," University of Tokyo, Kavli Institute, September 19–29 in 2017. (Participants; 56)
- East-Asian AGN Workshop 2017, University of Tokyo, Kagoshima University, December 4–6 in 2017. (Participants; 107)
- International Workshop on "Impact of Exotic Nuclear Structure on Explosive Nucleosynthesis," Beihang University, China, November 22–24 in 2017. (Participants; 59)
- International Workshop on "WFIRST-Subaru Synergistic Observations," NAOJ Mitaka, December 18–20 in 2017. (Participants; 88)
- International Symposium "GWASNe2018," NAOJ Mitaka, January 29–31 in 2018. (Participants; 44)
- The 8th DTA Symposium on "Challenge to super-Earths and their atmospheres," NAOJ Mitaka, March 6–8 in 2018. (Participants; 41)

6. Educational Activities

The lecture subjects are listed below to supplement Section III on activities of research and educational adjunct lecturer-ship at the high schools, universities, and graduate schools:

- Eiichiro Kokubo: Earth and Planetary Science I at the University of Tokyo; SSH lecture on The Earth in the Universe at Hibiya high school.
- Haruo Yoshida: UEC passport program seminar entitled Integrable and non-integrable problems in classical mechanics for the first year students of the University of Electro-Communications.
- Tomoya Takiwaki: Special lectures III on Numerical Physics, at the Graduate Course of Chiba University.
- Toshitaka Kajino: Lectures on fundamentals of theoretical astronomy at the Graduate University for Advanced Studies; science of time, space, and matter, and fundamentals of physics at Gakushuin University; astrophysics and modern physics at Japan Women's University; astrophysics at Jissen Women's University; nuclear physics at Meiji University; astronomy investigation I & II, reading papers in turn I & II, and special astronomy investigation II at the Graduate School of the University of Tokyo.

7. Outreach Activities

The Division of Theoretical Astronomy actively engaged in public promotions and outreach activities by offering lectures to the general public. The following lectures were delivered this year:

- Eiichiro Kokubo: "Saturn from Cassini: A Beautiful Ring World" at Aasahi Culture Center at Yokohama and Nakanoshima, "New Solar System 2017" at Ikebukuro Community College, "From Stardust to the Earth" at Space Expo.
- Takiwaki Tomoya: "Supernova Explosion simulated by Supercomputer, A Telescope for Theory" (Mitaka Network University), "Supercomputer reveals the Explosion Mechanism of Supernovae" (Asahi Culture Center Shonan).
- Takashi Moriya: "Origin of the elements" (Asahi Culture Center Yokohama).
- Toshitaka Kajino: "Nobel Prize on Modern Cosmology: Beginning of the Universe and the Discovery of Cosmic Microwave Background Radiation" (Asahi Culture Center Yokohama).

8. Awards

Masaomo Tanaka received the NCU-DELTA Young Astronomer Lectureship Award (October 18 in 2017) in Taiwan. Toshitaka Kajino received the honors of One Thousand Talents Plan Foreign Expert (April 15 in 2017) and State Special Recruited Expert (1 January 2018) in the People's Republic of China.

9. Main Visitors from Overseas

The Division of Theoretical Astronomy strives to fulfill its roles as a center of excellence in Japan for theoretical studies in astronomy and astrophysics and also as an international research institution by providing an excellent research environment. It engages in various joint research projects with visiting researchers from overseas, with the help of Grants-in-Aid for Scientific Research, government subsidies for operating expenses, the NAOJ budget for guest visitors, and others. The main international visitors of FY 2017 to the division are listed below:

BALANTEKIN, Akif B. (University of Wisconsin–Madison, USA)
BAUER, Franz (Pontificia Universidad Catolica de Chile, Chili)
CAI, Maxwell (Leiden University, Netherland)
CASELLI, Paola (Max-Planck-Institute, Germany)
CHAU, Ching Chong (Academia Scinica, Taiwan)
CHEOUN, Myung-Ki (Soongsil University, South Korea)
DELIDUMAN, Cemsinan (Mimar Sinan University of Fine Art, Turkey)
FAMIANO, Michael A. (Western Michigan University, USA)
GAO, Weijia (Beijing Normal University, P. R. China)
HASAGAWA Yasuhiro (NASA Jet Propulsion Laboratory)
LAMBRECHTS, Michiel (Lund University, Sweden)
LIM, Wanggi (University of Florida, USA)
MATTHEW, Kenworthy (Leiden University, Netherland)
MATHEWS, Grant J. (University of Notre Dame, USA)
MAZZALI, Paolo (Liberpool John Moores University)
NORMAN, Colin Arthur (Johns Hopkins University)
PEHLIVAN, Yamac (Mimar Sinan University of Fine Art, Turkey)
PENZLIN, Anna (Heidelberg University, Germany)
PIAN, Elena (Italian National Institute of Astrophysics/ Institute of Space Astrophysics and Cosmic Physics, Italy)
RICHMOND, Michael (Rochester Institute of Technology)
TAN, Jonathan (University of Florida)
VOROBIEV, Eduard (Technical University of Vienna)

21. Office of International Relations

The Office of International Relations strives to promote and facilitate further internationalization at NAOJ by maintaining an environment where multi-cultural researchers and students can engage cooperatively in research and educational activities. Specifically, the Office's main activities include supporting international collaborative projects; managing Security Export Control; offering support for hosting international conferences, workshops, and seminars; hosting booths at international events, and providing support for visiting international researchers and students. In FY 2017 the Office continued to work closely with the Executive Advisor to the Director General in charge of international research coordination.

1. International Collaborative Project Support

The Office of International Relations handled administrative coordination in approval processes to sign agreements and memoranda for international collaborations, conducting preliminary reviews for legal documentation, and managing export security control for export of goods or transfer of technology. In FY 2017, nineteen international agreements, new and renewed, were signed including ones under the name of NINS. In the area of security export control, activities included review and processing of 150 cases (293 items). Out of them, an individual export license as well as a re-export license under EAR was required in one case, which we processed accordingly and obtained the licenses. A security export control briefing was held three times at Mitaka (June: 39 attendants, July: 48 attendants, and March: 6 attendants (in English)) and once in Hawai`i (July: 6 attendants) for improving the knowledge and awareness of NAOJ staff. In addition to these briefings, an explanation hosted by NINS was held in January 2018. The total number of attendants reached 150.

2. Liaison Work for Overseas Astronomical Research Organizations

The Office of International Relations joined the EAO (East Asian Observatory) financial committee meeting held in parallel with the JCMT mid-term review on July 24–29, 2017 in Hawai`i. The office participated in the exchange of opinions for financially healthy management of EAO/JCMT. Also, the office supported the East Asian Young Astronomers Meeting (EAYAM) held at Ishigaki Island on November 13–17, 2017.

The Office also assisted the Executive Advisor to the Director General in charge of international research coordination upon coordinating with the other 3 institutions forming the East Asian Core Observatories Association (EACOA) including NAOC (China), KASI (Republic of Korea), and ASIAA (Taiwan) for selection of the 2018 EACOA/EAO postdoctoral fellowship program recipients.

We hosted an NAOJ booth at the ASIA-Pacific Regional IAU Meeting held at Taipei during July 3–7, 2017 and AAS (The American Astronomical Society) meeting at Washington D.C. during January 7–14, 2018 to promote research results and to explain the current status of each project. Though it was our first time attending AAS, the reaction from the participants was much greater than we expected. We would like to keep attending AAS for the time being.

Furthermore, the Office supported the activities of the Office for Astronomical Outreach of the IAU (IAU OAO) and the IAU Office for Astronomy Development (OAD, located in South Africa). We supported CAP2018 held at Fukuoka during March 23–29, 2018 as an LOC member.

Same as last year, the Public Relations Office was responsible for overseas activities in relation to the general public, while the Office of International Relations was in charge of activities related to overseas researchers.

3. Support for Hosting International Researchers and Students

The Office enhanced its framework for offering organizational support for research, education, and living arrangements for foreign researchers and exchange students. The Support Desk offers support services to ease difficulties for foreigners living in Japan. It supports, on-site if required, covering various matters such as administrative procedures at municipal and other governmental offices, finding and moving into an apartment, and other various procedures and applications for starting up a new life, consultation on shopping, children's education, health and others, and gathering/providing useful information relating to everyday life. The Support Desk has been highly appreciated by users. To provide better services, Support Desk has been changed to be 2 staff × 3 days each shift. Thus, on Thursday when both of the SD staff members are at the office, we hold regular meetings between the SD staff and the other office members. As a result, the smooth transfer of on-going issues, as well as information sharing, became possible.

The Office continued the Japanese language lessons, helping foreign members of NAOJ acquire beginner level capability, and for FY 2017, a combination of E-learning features and classroom lessons were provided, as was in the previous year.

The Office continued its activities to support non-Japanese speaking staff, by translating various forms for applications and notices, including e-mail text and explanations of procedures (112 documents).

4. Assistance in International Partnerships Involving Japanese Research Organizations

The Office oversaw the Optical and Infrared Synergetic Telescopes for Education and Research (OISTER) project conducted by Okayama Astrophysical Observatory, Ishigakijima Astronomical Observatory, and nine Japanese universities.

Although the budget for the OISTER project was transferred

to the Research Promotion Division from FY 2017 onward, the Office continued to provide administrative support.

Also the Office provided support for the Asian Core Observatories Initiative led by the Executive Advisor to the Director General in charge of international research coordination under NINS's research enhancement program with the Research University Network of Japan.