II Status Reports of Research Activities

1. Subaru Telescope

1. Subaru Telescope Staff

As of the end of FY 2016, the Subaru Telescope Project staff consisted of 19 dedicated faculty members including five stationed at Mitaka, four engineers, one specially appointed senior specialist and three administrative staff members. Additional staff members include three specially appointed research staff, three specially appointed senior specialist, five research experts, 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 appointed concurrently. The project also has 73 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 through Grants-in-Aid for Scientific Research; and graduate students. These staff members work together in operating the telescope, observational instruments, and observational facilities; and in conducting open-use observations, R&D, public outreach, and educational activities.

2. Science Highlights

In FY 2016, Subaru Telescope produced many outstanding scientific outcomes which were published in major international journals. Below are some examples:

(1) Using the Fiber Multi-Object Spectrograph (FMOS), a 3D map of as many as 3000 galaxies was created at the redshift of 1.2–1.5. The estimated expansion of the Universe is consistent with the general relativity proposed by Einstein. Using Hyper Suprime-Cam (HSC), (a) an extremely rare, double source plane gravitational lensing system, in which two distant galaxies are simultaneously lensed by a foreground galaxy, was discovered, which will help us understand the history of the Universe, and (b) it was found that star-forming galaxies in the distant Universe (about 5 billion years ago) show more similarity in spatial distribution to mysterious invisible “dark matter” than those in the nearby Universe (about 3 billion years ago).

(2) In HSC survey data, an extremely faint dwarf galaxy was discovered at the distance of 280 thousands light-years away, thanks to the very high sensitivity of the Subaru Telescope. This discovery suggests the presence of a large number of yet-undetected dwarf satellites in the halo of the Milky Way and provides important insights into galaxy formation through hierarchical assembly of dark matter.

(3) Observations of Saturn using COMICS revealed that the optically faint Cassini Division and the C ring were sometimes brighter than the other rings in the mid-infrared light. The data give important insights into the nature of Saturn’s rings.

3. Open-use

We continued to solicit proposals for observation topics for each semester: S16A (February 1 - July 31) and S16B (August 1 - January 21). Proposals were collected by the Mitaka office and adopted or rejected by the Subaru Time Allocation Committee (under the Advisory Committee for Optical and Infrared Astronomy) based on reviews by Japanese and international referees. In S16A, 41 programs (86 nights) were accepted out of 184 submitted proposals, requesting 451.7 nights in total. In S16B, 31 proposals (49 nights) were accepted out of 142 submitted proposals, requesting 409.8 nights in total. Service observations were made for 10 nights. In S16A and S16B, 2 and 1 accepted open-use proposals were by foreign principal investigators, excluding University of Hawai`i observing time. The number of applicants in submitted proposals was 2063 for Japanese researchers (Japanese astronomers at any institute and non-Japanese astronomers belonging to Japanese institutes) and 794 for foreign researchers. The number of researchers in accepted proposals was 651 for Japanese astronomers and 232 for foreign astronomers.

In S16A and S16B, the number of open-use visiting observers was 308, of which 43 were foreign astronomers. 104 astronomers observed remotely from Mitaka. Observing proposals were solicited and collected, the procedures for Japanese researchers to travel for observations, and travel expense reimbursement were handled by the Mitaka Office. Subaru Telescope made the observing schedule and provided support for the observers’ lodging, transportation, and observations while in Hawai`i. In S16A and S16B, 91.9 % of the open-use time (including University of Hawai`i time) was used for actual astronomical observations, after excluding the weather factor and scheduled maintenance downtime. About 1.7 %, 0.3 %, and 6.1 % of observing time was lost due to instrument trouble, communication trouble, and telescope trouble, respectively.

In S16A and S16B, remote observations from Hilo were conducted for 2 programs with 2 nights. However, remote observations from Mitaka, where observers in Mitaka can participate in observations remotely in addition to on-site observers at the summit, were conducted for 22 programs with 68 nights. The service observations were conducted for 11.55 nights. The number of time exchange nights between Subaru Telescope

and Keck was 5.5 in S16A and 8.5 in S16B. That between Subaru Telescope and Gemini was 5 in S16A and 2 in S16B.

4. Telescope Maintenance and Performance Improvement

Repair plans for the optical-side mirror hatch, which broke down in February of last year (FY 2015) were considered. Some experiments and preparation were carried out for the repair work during 7 days in August. The mirror hatch repair is scheduled for June and July of next year, requiring 14 days down-time in each month (total 28 days).

Primary mirror recoating work which was planned for this year was postponed to autumn of next year (FY 2017) due to the mirror hatch incident. During the next year it will be required to repair the mirror hatch reliably and recoat the primary mirror. The primary mirror recoating work is scheduled for a total of 73 days down-time, with some other maintenance work.

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

In this year, electrical boards for the Auto Guider and Shack-Hartmann CEU (Central Electric Unit) Board, DPA (Driver and Power Assembly unit) for the tip and tilt secondary mirror, bogie rubber spring for dome AZ rotation, and slip-ring for dome electrical power were replaced. Maintenance work for the primary mirror transporter and primary mirror washing facility were done. TWS (Telescope Work Station) user interfaces and barcode tape for dome AZ angle detection were updated. Long-term maintenance plan were drawn up. The Hitomi satellite (ASTRO-H) which had severe incidents unfortunately was observed at the request of ISAS. Function tests of the primary mirror actuator prototype, welding repair work on the dome bogie rail were also done in the year.

In addition, while promoting the improved performance and operational efficiency of the Subaru Telescope, renovation to the telescope control units, which were installed more than 10 years ago, proceeded. The local control units that were renovated or modified in this year were the balance control unit (BLCU) and tertiary mirror control unit (TMCU). By finishing BLCU and TMCU replacement work this year, all renovation of the telescope control units which has been carried out sequentially over 10 years was completed. It is planned to start the second round updating the aging TSC (Telescope System Computer) server from next year.

The major causes of the telescope trouble this year were, aging, maintenance error (human error), and defective design. Aging on UPS2 (Uninterruptible power supply #2), maintenance error during PIR unit (FMOS) installation, manufacturing failure in FRCU (PF) (Filed Rotation Control Unit for Prime Focus) local unit, POpt (Suprime-cam) Hexa-pod trouble (random failure?), aging of the man-basket PLC (Programmable Logic Controller), operational error in barcode value readings, aging of the TUE (Top Unit Exchanger) gripper 2 motor encoder, shoddy workmanship on cabling of the tip-tilt secondary mirror, shoddy workmanship in assembling work of dome AZ slip-ring, defective design in EL cable wrapper, aging of the AZ cable wrapper, defective design on IR-side Main Shutter, and maintenance error for operating of the safety switch #15 occurred causing observations to be canceled.

Additionally, we developed a mechanism to remotely obtain status logs on the local machine. We would like to continue to utilize the telescope status log and work on preventive maintenance for the telescope and the enclosure.

5. Instrumentation

The eight open-use facility instruments of Subaru Telescope have been 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 188-elements Adaptive Optics and Laser Guide Star system (AO188/LGS).

In these years, there have been discussions on how we will maintain or cease operation of the facility instruments, except for HSC. As reported in last year, FMOS was decommissioned in April, 2016. Also, it was decided to decommission Suprime-Cam after the observations in May, 2017. In addition, possible decommissioning of FOCAS was discussed because assigning dark nights to FOCAS has been almost impossible and the situation will get worse after the commissioning of PFS. The discussions have been held within Subaru, in SAC, and in the Subaru users' meeting. It was basically agreed to stop the operation of FOCAS in early 2019 (in the earliest case), or after the commissioning of PFS (in the latest case).

The operation of HSC has been stable, similar to the last fiscal year. In this fiscal year, HSC observations have been made for approximately two weeks in almost in every month except for May and October. Although these frequent observations did not create problems in HSC operation, there were a few problems with the filter exchange unit (FEU) around the end of this fiscal year which led to cancellations of the observations. Those troubles were all recovered on the next day and further maintenance work was made after the observing runs to remove the cause of the troubles. We are carefully monitoring the operation of the FEU and will work on its stabilization. For HSC, installation of the filter transmission measurement system, installation of the new on-axis dome-flat system, and a test of FEU reinstallation to exchange filters during an observing run have been made 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 units (IFU) for FOCAS and MOIRCS; the Transponder-Based Aircraft Detector (TBAD) for the LGS system; and an upgrade of the real-time control system for AO188. In addition, upgrades of the aging control computers and devices of the first generation instruments are ongoing.

In FY 2016, four carry-in (PI-type) instruments HiCIAO

(high-contrast coronagraph imager), Kyoto-3DII (optical integral field spectrograph), SCExAO (Subaru Coronagraphic Extreme Adaptive Optics) and CHARIS (high-contrast integral-field spectrograph) have been offered to the Subaru open-use program. Operation of Kyoto-3DII at the Subaru telescope ended in S17A. 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) was under construction, aiming to have the first-light observation in June 2017. 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), which are to be used on the 6.5 m University of Tokyo Atacama Observatory (TAO) telescope, were approved but only for engineering observations.

The Prime-Focus Spectrograph (PFS) is an optical/near-infrared multi-object spectrograph at the prime focus of the Subaru Telescope, which will be the next facility instrument following the successful implementation of Hyper Suprime-Cam (HSC). PFS is being developed through international collaboration including seven countries, led by Tokyo IMPU. The PFS has about 2400 optical fibers distributed over the 1.3 degree field of view of the prime focus that feed the light of the astronomical objects to four identical spectrographs which will be placed in the telescope dome. The spectrograph modules simultaneously cover the wavelength range from 0.38 μm to 1.26 μm. The subcomponents of PFS were developing at each partner institute aiming towards engineering first-light in 2018. Science operation is expected to begin in 2020. Subaru Telescope is responsible for modifying the telescope and enclosure to accept PFS; the design work and reinforcement of the spectrograph floor have been conducted. Efforts to develop a database that combines HSC and PFS data, so that users can access both instruments' data seamlessly, has started as a US-Japan collaboration. Peking University (though the Chinese consortium) and Max-Plank Institut für Extraterrestrishe Physik (MPE) officially joined PFS collaboration and NAOJ will handle their funds for PFS development.

We are conducting a conceptual study of "ULTIMATE-Subaru", 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. The 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 2016, we had an ULTIMATE-Subaru science workshop at NAOJ Mitaka Campus by inviting scientists from Japan and potential partner countries. We are also working on the conceptual study of the GLAO system and wide-field near-infrared instruments in collaboration with Australia and Canada. We have now an official (short-term) agreement with Australia to collaborate in the GLAO feasibility studies.

6. Computers and Network

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

The observation data archive was continued from the previous year. The archive is operational without serious problems. The data archive system in Mitaka also showed stable performance.

We officially rolled out remote observations from Mitaka using the Remote Observation Monitor System for limited instruments in 2015. An increasing number of observers are using the Remote Observation Monitor System in Mitaka. During the observation semesters from February 2016 through January 2017, about 40 observation programs utilized the remote observation monitor system for about 100 nights. The Proposal Management System (ProMS) also worked very well.

Computers for HSC data analysis (HSC On-site Data Analysis System) were procured in fiscal years 2010 and 2011. We added storage to the system in FY 2016.

We purchased a test system for the HSC On-site Data Analysis System that comprises a filesystem that surpasses NFS in access speed. We are currently configuring the test system toward real-time data analysis during observations in the next fiscal year.

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

Since the current rental contract for our computer and network infrastructure comes to an end in February 2018, we spent a sizable amount of time for the procurement of computers and network systems for continuous service after March 2018. We created the specification draft for a new rental contract from March 2018 to February 2023 and requested information. We always studied ways to keep the performance and functions as well as to reduce cost and updated the specifications.

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

In FY 2016, Subaru Telescope hosted four graduate students for long stays, of which one was a SOKENDAI student. 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 14 and 8, respectively, of which two and four

belonged to the Division of Optical and IR Astronomy.

We also regularly hosted a series of educational programs at Subaru Telescope. In December 2016, we hosted a Subaru Winter School at National Central University in Taoyuan, Taiwan. There were 23 participants from Japan, Taiwan, China, and South Korea (four were from Japanese institutes). 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 September 2016, and the other was for six new SOKENDAI students at NAOJ held in January 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 Public Information and Outreach (PIO) office is tasked with addressing the accountability for what the Subaru Telescope does and is keenly aware of the importance of citizens understanding our work, for both the short-term and long-term success of the project. The increased importance of positive awareness in the local community has profound meaning for the next generation telescope project on Maunakea. Therefore PIO pays more attention to the interaction with the local community, in its three major areas of tasks.

Task 1: Disseminating information about the results from the Subaru Telescope and the work at the Subaru Telescope. The primary tools are the postings on our own website; providing press releases to the Japanese, local, and international media; and holding press conferences. During Fiscal Year 2016, there were 19 web-postings (9 in Japanese, 10 in English) about discoveries from the Subaru Telescope. Articles about instrument development; the work and the activities at the Subaru Telescope; and other announcement totaled 76 (46 in Japanese, 30 in English). Some postings are also distributed through the media as well as posting services such as the American Astronomical Society's mailing exploder. Many articles appeared in Japanese newspapers, and some in the local newspapers; with more prevailing in the on-line postings.

In addition, newer tools such as Twitter, Facebook, and YouTube are becoming more useful in spreading awareness in a timely manner. The PIO office is making extra effort in providing striking visuals for such social media postings. Filming requests from outside totaled more than 23 from Japanese media (including 1 for an English language production), in addition to the numerous inquiries/questions from the media, educational institutions, and museums.

Task 2: Provide escorted tours for the public and special groups to see the facility. The public tour program that started in 2004 continues to provide opportunities to see the telescope up-close for guests from Japan and from around the world. Dedicated full-time staff leads tours and provided timely communication to those requesting tours. It is possible to register for the general tours program on-line. Except for summer months when the tour program was suspended due to the inclement weather related access issues on Maunakea, a total of 456 people visited through this program. There were 127 additional groups who visited through special tour programs and resulted in a total head count of 1048 people who visited the summit facility. The tours are all escorted by the assigned staff, in either Japanese or English language. The telescope tours include 8 tours (2 per day on 4 days) specifically targeting the residents of the State of Hawaii, in the hope of increasing the positive awareness of what the telescope does.

Facility tours of the Hilo Base Facility are most of the time accompanied by other activities described in the next major task area, namely: special lectures, hands-on sessions, or presentations by the student group. A total of 40 groups, with 398 people, visited the base facility this year.

Task 3: Public outreach includes lectures in the local community, special presentations in the schools, and remote presentations for Japanese schools or museums. PIO provided/coordinated 75 lectures at the Hilo Base Facility or in its vicinity such as at the ʻImiloa Astronomy Center. There were 17 lectures outside of the island, and 11 remote lectures for off-site locations. The local lectures included 37 classroom presentations during the Journey through the Universe program over the course of a week.

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

Another special local event where many astronomy observatories participate is the annual Onizuka Science Day at the University of Hawai`i at Hilo. Six hundred selected students between grades 4 and 12 (upper elementary school to high school) with families and teachers from all over the island gathered for this event. PIO provided 2 hands-on workshops and an exhibit booth.

Events like these where Subaru Telescope staff meet and interact with students and members of the local community are effective for improving the recognition of the Subaru Telescopes activities. Of course material about these events is distributed via the website and social media.

A special effort was made in the following two areas: posting articles summarizing Subaru Telescope's achievement, and faculty development seminars. In the summary series, there are 22 articles published on the Subaru Telescope's website. The seminar speakers included prominent leaders from the local community, so that the staff of the Subaru Telescope has better understandings of the cultural and historical aspects of the place where they work.

2. Okayama Astrophysical Observatory

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

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

Several joint projects with universities have been conducted, including Kyoto University's Okayama 3.8-m New Technology Optical and Infrared Telescope Project, 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 include a project designed to convert the 91-cm telescope into an ultra-wide-field near-infrared camera (OAO-WFC) in order to engage in a comprehensive survey of infrared-variable objects in the Galactic plane. A new project has just begun this FY to make the 188-cm telescope robotic 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). This project aims at establishing a large sample of exoplanets by Doppler technique. Collaborations with foreign researchers are also continued actively.

The personnel breakdown as of March 2017 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; eleven contract employees, including one specially appointed associate professor, two research experts, 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.

1. Open Use

(1) Overview

The numbers of nights allotted to open use in 2016 were 118 for the first semester (2016A, January to June) and 108.5 for the second semester (2016B, July to December). Observing proposals submitted in response to the calls for proposals were reviewed by the Okayama program subcommittee and 1 project observation program, 0 academic degree support program, 15 general observation proposals, and 2 miscellaneous observation proposals were accepted for 2016A, and 1, 0, 13, and 2 were accepted for 2016B. One and one observing proposals were approved for the category "Target of Opportunity (ToO)" observations introduced since 2016A for 2016A and 2016B, respectively. Three proposals, one from each of China, Hawai`i, and Turkey, were accepted in 2016A, and one from Hawai`i was accepted in 2016B. The Observatory supported their observations with human resources. Open-use observation generally proceeded without incident.

(2) Observation/Research Results

The majority of objects observed through the open use in 2016 were stellar sources and exoplanets. Others included Solar System objects, the Milky Way Galaxy, galaxies outside the Milky Way, and quasi-stellar objects. The following primary observation themes were noted: exoplanet search and binary-mass determination via precise radial velocity measurements; exploration of the physical properties and activities of single and binary stars via high-dispersion spectroscopy; and the observation of exoplanet transits by precise differential photometry. Optical low-dispersion spectroscopic observations of stars for classification remained significant. As in previous years, a number of observational studies were conducted by individual groups of researchers within the open-use framework, and their respective research results were reported in meetings and conferences or were published in peer-reviewed journals.

(3) Facility and Instrument Maintenance/Management

The 188-cm telescope and its dome had evolved into a stable and high-functioning observing system by FY 2014 after the major refurbishment in FY 2012. Efforts were made to automate the high dispersion spectroscopic observations with the fiber-feeding system in this FY 2016. The remote observing environment provided to the open use with some limitations last year has been available for open use with no conditions since 2016A. 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. Efforts were continued to simplify the re-aluminization process as were done in the last year. The 1.5-m primary of 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 cleanings of the primary, secondary, and tertiary mirrors of the 188-cm telescope after September.

The dome was checked daily. The replacement of the wire rope for driving the slit door, scheduled once every 4 years, was done successfully in November. The front sheaves for the wire were replaced just before that. Other maintenance work was also performed, including repair of the worn-down guiding

rails for the slit doors, maintenance of the dome rotation driver, and replacement of the old power lines, in order to achieve smooth open-use operation and prolonged life-time of the facility and equipment. 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.

(4) Conferences

The program subcommittee for the 188-cm telescope met on May 30 and November 18 in 2016 and March 23 in 2017 to evaluate proposals for the open use of 2016B, 2017A (first semester of 2017) and 2017B (second semester of 2017), respectively, and formulated an observation program for each semester.

The third one was held ahead of the usual schedule, conventionally at the end of May in the next FY year, in order to devote the activity of the Okayama program subcommittee during FY 2017 to the Kyoto University 3.8-m telescope project. The Okayama Users Meeting, also known as the 27th Optical and Infrared Users Meeting, was held in the Large Seminar Room of NAOJ Mitaka Campus on September 7 and 8. Various reports were made: current status of the Observatory including the telescope and dome, execution summary of the program subcommittee, status of the open-use observing instruments and remote observing environment, development status of the queue observing system for the HIDES Fiber-Feeding mode, etc. Reports on the status of and scientific results from the two new user-led instruments for the 188-cm telescope were also made. Reports were made on the progress of the Kyoto University 3.8-m telescope project including observing instruments. Reports were done on the research results from the open use of the 188-cm telescope and on the operations of other optical and infrared observational facilities such as the Hiroshima Astrophysical Science Center.

A special session was arranged to discuss in more detail than last year the practical policy and plan for the transfer of the open-use observations from the 188-cm telescope to the Kyoto 3.8-m Telescope comprehensively. Detailed discussions were held among interested domestic researchers including Okayama open-use users, Kyoto University staff, NAOJ staff, and others.

The policy agreed upon at the Users Meeting was reported later at the general meeting of the Group of Optical and Infrared Astronomers (GOPIRA), the GOPIRA symposium and the Advisory Committee for Optical and Infrared Astronomy at NAOJ. Last of all, the policy that includes the following items was reported at the Advisory Committee for Research and Management at NAOJ on October 31, 2016. These reports included that the operation of the open use of the 188-cm telescope will be terminated by semester 2017B, that the open-use of the 3.8-m telescope will open in August 2018, that the Okayama program subcommittee is given the role of the scientific committee for the operation of the open use at the 3.8-m telescope, and that NAOJ continues to hold the 188-cm and smaller existing telescopes and facilities for the time being, etc.

The Director General of NAOJ requested the Advisory Committee for Optical and Infrared Astronomy make "Plans for the transfer to and operation of the open use of the Kyoto University 3.8-m telescope." The Okayama program subcommittee made the report draft upon a request from the Advisory Committee and submitted it to the committee at the end of March 2017.

2. Developing and Maintaining Open-Use Observing Instruments

(1) HIDES (High-Dispersion Echelle Spectrograph)

The instrument HIDES is a cross-dispersed high-dispersion echelle spectrograph, provided for open use. Development of the fiber-link system (HIDES-F) since FY 2006 has continued to improve its observing capabilities. Open use of the high-efficiency (HE) fiber link with approximately 50-K wavelength resolution has continued since 2011A. The HE link offers an improvement in throughput of nearly one magnitude over the previous value and radial velocity measurement precision of approximately 2 m/s, which is comparable to the case of the Coudé light path. The high-resolution (HR) link with nearly 120-K wavelength resolution has been offered as a PI-type open-use instrument since 2016A. The HR link provides a 4 times better sensitivity at maximum than the case of the Coudé light path. Control software was adjusted to deal with queue and automated observations. An astro-comb developed by researchers at the National Institute of Advanced Industrial Science and Technology (AIST) and their collaborators as a next generation astronomical wavelength standard was installed into the Coudé room of the 188-cm telescope, and the tuning and tests were carried out. This year the total numbers of accepted proposals to HIDES were 8 and 6 in 2016A and 2016B, including 1 and 1 project observations, respectively.

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

ISLE is a near-infrared imager and low- or mid-dispersion spectrograph. It has been available for open use with no conditions since 2011B. It is the only open-use instrument in East Asia that offers near-infrared spectroscopic capability and is characterized as having the world's best low-noise readout capability (less than 10 electrons). Relative photometry at the one milli-magnitude level is regularly achievable with its imaging mode for bright sources. A carry-in YJH-band filter from a user and the HK-band filter as standard equipment enable it to obtain a well-connected spectrum from Y-band to K-band. The numbers of open-use programs using ISLE conducted in semesters 2016A and 2016B were 5 and 6, respectively; which included 1 and 1 miscellaneous category programs, respectively. Nine of them were spectroscopy and the other two were imaging photometry.

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

This instrument provides imaging and spectroscopic

capability in the optical. It has been available for open use as a PI-type instrument since 2008A. It is equipped with an offset-guider and CCD charge shuffling functionality. Non-sidereal motion objects can be tracked for long integration times. The integral field unit using a fiber-bundle developed by a team at Kyoto University has been made available as a PI-type open-use instrument since 2015B. When it is used, its input part is installed into the Cassegrain unit of the HIDES fiber link and its output part is installed into KOOLS (KOOLS-IFU). Accepted proposals were 4 and 1 for 2016A and 2016B including 1 and 1 ToO programs, respectively. The open use of KOOLS ended in 2016B. After that KOOLS was overhauled by the Observatory together with researchers at Kyoto University to be a first-light instrument for the 3.8-m telescope.

(4) Others

MuSCAT (MUlti-color Simultaneous Camera for studying Atmospheres of Transiting exoplanets), which was previously a carry-in observing instrument, was made available to the open use as a PI-type instrument from 2016B. It can achieve 0.05% accuracy in relative photometry for a star of 10-th magnitude at V-band when it performs a series of one-minute exposures. Four programs, which included one miscellaneous category program, were conducted with MuSCAT in 2016A and four open-use observing programs, which included one miscellaneous one, were accepted in 2016B.

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. Kyoto University has completed the construction of the dome that houses the telescope. The Observatory hired a specially appointed associate professor to be in charge of transferring the open use from the 188-cm telescope to the 3.8-m telescope and strengthened the cooperative implementation framework. The Observatory also hired a Specially Appointed Research Staff Member to prepare open-use observing instruments and advance the conversion and refinement of the KOOLS-IFU system, for which open use at the 188-cm telescope has been terminated, to be an initial open-use observing instrument for the 3.8-m telescope. Kyoto University and the Observatory jointly collected input about the observing instruments planned for the 3.8-m telescope from the domestic astronomical community in order to fix the specifications of the equipment around the focal planes where observing instruments will be attached. A research program has been approved in which one observatory staff member participates as a co-investigator on the grant-in-aid for scientific research from the Japan Society for the Promotion of Sciences (Basic Research A (General), FY 2016-2019) applied for by researchers at Kyoto University. The grant allows us to develop a near-infrared fiber-fed spectrograph for the telescope.

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

The Program has entered its sixth (and final) year since its commencement in 2011. The Observatory has contributed the 188-cm, 91-cm, and 50-cm telescopes to the Program, and has taken a leading role along with the Office of International Relations. Through the cooperative observational and educational network, OISTER, established by the Program, the Observatory performed observations for one campaign as a PI and provided a total of 22 nights worth of observational data on three objects this year. As for the immediate follow-ups of gamma-ray bursts, which are the main targets of the program, there were 12 alerts that were observable from the Observatory, observations were performed four times and afterglow was detected in one of them. Three peer-reviewed papers were published utilizing OISTER. Another 18 peer-reviewed papers that have something to do with the Program were published. The seventh workshop on the Program was held.

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

Optical follow-up observations of GRBs using the 50-cm telescope are in progress in cooperation with the Tokyo Institute of Technology's Kawai Laboratory. During FY 2016, the automatic observation scheduler performed observations on nearly every possible night; 24 GRBs were observed, with optical afterglows successfully detected in two. Observation results were published as 9 GRB Coordinates Network (GCN) circulars. In addition, follow-up observations of candidate gravitational wave sources and monitoring of 9 objects that include dwarf novae, eclipsing binaries, asteroids, and comets were concurrently performed, which resulted in publication of four peer-reviewed papers.

(4) Other

The Observatory welcomed four third-year undergraduate students and their supervisor from the University of Tokyo between August 30 and 31 and provided them with an opportunity to conduct high-dispersion spectroscopic observations using the 188-cm telescope during the early half-night on August 30. Test observations were conducted with the near-infrared observing system with the 30-mm aperture dedicated to bright star photometry (IR-TMT) having been placed at the Observatory during the last FY in collaboration with researchers at Tohoku University. The observations were carried out from the main building of the Observatory or from Tohoku University remotely by way of the internet.

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 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 2016 monitoring in the Ks-band of two regions of 20 square-degrees each centered at L=30 degrees and 80 degrees were nearly completed. In addition, automatic monitoring of other objects, such as the Orion star forming region and bright blazars were carried out.

(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 has begun aiming at establishing an original large scale sample of exoplanets. For that purpose, activities have begun to develop robotic operation of spectroscopic observations with the 188-cm telescope and to improve the sensitivity and stability of the spectrograph.

(3) East Asian Planet Search Network

The Observatory also conducts studies focusing on the search for exoplanetary systems, involving researchers from South Korea, China, Turkey, and Russia. Efforts continued in FY 2016 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.

5. PR/Awareness Promotion Activities

In this FY about 40 astronomy-related questions from the public were posed irregularly to the Observatory and were answered appropriately. The 4D2U screenings, co-hosted with the Okayama Astronomical Museum, attracted 3,847 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 four lecture requests made by local boards of education and community centers. The Observatory posted four research result web releases and 1 press release.

The yearly special open-day was suspended again following the last FY because a serious shortage of parking space was anticipated due to the construction of the Kyoto University 3.8-m Telescope and there was some concern about being able to ensure the safety of the guests.

6. Contract Staff Transfers

The following transfers of contract staff members took place in FY 2016:

Eiji Kambe resigned as a research expert on June 30. Eiji Kambe joined as a specially appointed associate professor on July 1. Akihiko Fukui resigned as Specially Appointed Research Staff due to the expiration of his contract on September 30. Akihiko Fukui jointed as a Specially Appointed Senior Specialist on October 1. Kazuya Matsubayashi joined as Specially Appointed Research Staff on November 1.

3. Nobeyama Radio Observatory

1. Nobeyama 45-m Radio Telescope

(1) Open Use Observations

The 35th open use observations period started on December 1, 2016 as scheduled. The full capabilities of the new four-pixel receiver FOREST and limited capabilities of the Z45 receiver are offered.

The statistics of the proposals are as follows, "General Proposals": 23 accepted including 5 from abroad (29 submitted), "Joint Proposals" with ASTE telescope: 4 accepted with 1 from abroad (6 submitted), "Short Programs": 12 accepted with 1 from abroad (29 submitted), "Backup Programs", which are carried out when weather is not acceptable for the main observations: 1 accepted (1 submitted), "DDT Programs", which are submitted after the deadline: 2 accepted (3 submitted). In addition, the 45-m telescope joined the VERA open use observations for 2 proposals. There were no applications for "Large Programs." The S40 receiver was decommissioned.

Open use observations have been halted since March 17, 2017, when the master collimator driving system went out of order. Most of the observations scheduled after this issue arose will be carried over to the next observing season.

(2) Improvements and Developments

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

- The replacement of the millimeter calibrator driving system was completed. The design work for the mirror exchange systems was done.
- The Spectral Window mode with the FOREST receiver was implemented, and flexible setting of the spectrometer was realized.
- Development of the new data archive system and the data reduction procedure with the CASA pipeline started. These will lead to automation of the observing system in the future.
- Preventive and corrective painting of the antenna mount structure was done.
- NRO supported user instruments including the digital spectrometer ROACH, a 90 GHz continuum camera, and the simultaneous 22/43/86 GHz VLBI observation system.

(3) Scientific Results

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

(a) Star Formation Legacy Project

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

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

We are conducting 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 using FOREST aboard the 45-m telescope. We plan to make maps of the inner Galaxy and the outer Galaxy including the spiral arms and bar structure. In 2016, we covered areas with 22 and 2 square degree for a total of 24 square degree. Now, 130 square degrees have been mapped. As a result, we have revealed a wide range of molecular clouds and their fine structures; we also found the most distant molecular cloud, new cloud-cloud collision systems, and an interacting region with a supernova.

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

We started COMING (CO Multiline Imaging of Nearby Galaxies) in April 2015 to map more than 200 nearby galaxies in ^{12}CO(1–0), ^{13}CO(1–0), and C^{18}O(1–0) emission lines using FOREST. Up to now, mapping observations of 129 galaxies have been completed (54 % of the original plan). A paper on the relation between molecular gas density and star formation efficiency was published (Muraoka et al. 2016, PASJ, 68, 89) and one on a dwarf spiral galaxy, NGC 2976, is in press. In addition, two master theses and five undergraduate theses were published. We also developed a data reduction pipe-line system.

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.
- The polar axis gears of the 1, 2, 9.4, and 17 GHz antennas were replaced, and their pointing accuracies were improved.

3. Research Support

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

To better understand the influence of the activities of host stars on the atmospheric environment of habitable planets, we have been carrying out monitoring observations at 100 and 200 GHz bands with a 10-m telescope, the Solar Planetary Atmosphere Research Telescope (SPART). This year we continued the observations with SPART. To investigate short-

term changes of the CO abundance in the Venusian middle atmosphere revealed by SPART, we started simultaneous and synergetic observations with the Atacama Large Millimeter/Submillimeter Array, Japanese Venus Climate Orbiter AKATSUKI (JAXA/ISAS), and the 1.6-m Pirka Telescope employing the Near Infrared Echelle Spectrograph (Nayoro Observatory, Faculty of science, Hokkaido University). Through this approach we address the links between the photochemical reaction networks and the circulation of materials induced by the dynamics between the Venusian upper and lower atmosphere. In addition, the purpose-built console and display room of SPART was completed. This room is opened to the public where visitors can study the terrestrial planets of the Solar System, the aim of SPART, and the history of the Nobeyama Millimeter Array.

(2) Radio Heliograph (Nagoya Univ.)

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 the internet has functioned very well. About 30 researchers from seven countries (China, Germany, Japan, South 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/or Nagoya Univ. and are stored, maintained, and made public there. In September 2016, an international workshop, 'Physics with Radio Observations - Continued Operation of Nobeyama Radioheliograph - ', was held and 36 researchers (including 20 from overseas) attended it. In addition to science results from NoRH, we discussed research topics during this continued operation by ICCON, and how to collaborate with a new solar radio telescope in China.

4. Public Outreach

(1) PR activities at Nobeyama Campus

Nobeyama Campus received a cumulative total of 46,636 visitors throughout the year, including participants in special open house events. Staff members conducted 40 guided tours, including ones for Super Science High School (SSH) students and the Campus Tour Week, while 4 requests for lectures and 20 requests for on-site filming and interviews were granted. These requests, especially those by some local broadcast stations in Nagano prefecture but also from national broadcasting media such as NHK, increased due to efforts to strengthen cooperation with local communities. The Campus Tour Week for educational institutions was scheduled during the summer. Eight groups took advantage of this opportunity, and many students in the groups enjoyed the visit. For the workplace visits, 4 students from 3 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, an antenna experience facility and some introduction movies are available along with posters and panel displays. In this year, we tentatively opened the Nobeyama NINS exhibition room. Also, in order to familiarize the public with NRO, we renovated the website to accommodate smartphones as well as personal computers.

A photography event for the Nobeyama starry sky was carried out at NRO because many requests to take pictures in Nobeyama Campus at night have been received. We held the event during the period when it does not affect radio observations, with 31 participants who were selected from about 100 applicants. We used some pictures taken at the event, which were offered by the participants, for an original calendar, displays during the Special Open House, and so on.

(2) Cooperation with Local Communities

The annual Nobeyama Special Open House was held with contributions by Nagano Prefecture as well as Minamimaki Village, the Minamimaki Chamber of Commerce, and its youth division. Moreover, Jimoto Kansha Day (Thanks Day for the Locals) was held as the Special Open House for locals (Minamimaki and Kawakami Village) at the Vegetaball With by Shinshu University 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. Also, a training course and examinations were carried out through a special partnership with Shinshu-Saku Hoshizora Annai-nin, which was managed by Saku Koiki Rengo (the union of local governments in the Saku area).

Moreover, the conference of "Nagano-ken ha Uchuu-ken (Nagano prefecture is Astro-Prefecture)" was founded with Kiso Observatory, IoA, The Universoty of Tokyo, etc. The first meeting was held at Matsumoto Campus of Shinshu University on November 23 with about 100 participants. The webpage and mailing list were set up and some activities started.

(3) The Nobeyama NINS exhibition room

After the improvement work of the building of the Nobeyama Millimeter Array and installation of the 4D2U theater in last year, the Nobeyama NINS exhibition room was tentatively operated in the summer season from July to September. From questionnaire results, about 8,000 guests visited the room and their degree of recognition of other institutes as well as NAOJ was improved.

(4) NRO Conference Workshops

- July 20-21, 2016
  NRO-ALMA Joint Science/Development Workshop 2016 (representatives: Masao Saito (NRO), Daisuke Iono (Chile Observatory))
- October 20-22, 2016
  ALMA/45m/ASTE Users Meeting 2016 (representatives: Eiji Akiyama, Daisuke Iono, Ken'ichi Tatematsu (Chile Observatory), Masao Saito (NRO))
- March 28-29, 2017
  NRO Galactic Plane Survey Workshop 2016 (representative: Tetsuhiro Minamidani)

5. Education

NRO accepted three postgraduate students. The one is a second-year Ph.D. student in SOKENDAI studying carbon chain molecule chemical reactions. The others are visiting students from Kagoshima University and the University of Tsukuba, and they received Ph.D. degrees from their respective universities based on the studies using the Nobeyama 45-m Radio Telescope.

SOKENDAI held the workshop on Radio Astronomical Observation using the Nobeyama 45-m Radio Telescope form June 6 to 10, with 12 undergraduate students in attendance. One third of the participants were 4th year students, just about to decide their course after graduation. While guiding the students, from observations to presentation of the results requires significant effort, the event offers an invaluable opportunity for undergraduates to experience observations using a radio telescope and think of their future career.

6. Misc. Activities

(1) Hiring

Kazufumi Torii: Specially Appointed Assistant Professor

(2) Resignation, Transfer

Masao Saito: Associate Professor to TMT-J Project
Hitoshi Arai: Research Supporter
Yoshio Tatamitani: Research Expert

4. Mizusawa VLBI Observatory

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

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

1. VERA

(1) Observations and Common Use Observations

The four stations of VERA were operated by remote control from AOC (Array Operation Center) at NAOJ Mizusawa Campus. In FY 2016, a total of 536 VLBI observations (4410 hours) 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 calls-for-proposals with the 43, 22, and 6.7 GHz bands for semesters 2016B and 2017A were released in May and October, respectively. A total of 9 proposals, which requested a total time of 224 hours, were submitted, including 4 proposals for 82 hours from overseas. Based on the evaluations by referees elected from scientists in related fields, the VLBI program committee decided to accept a total of 5 proposals (138 hours) in 2016B and 2017A.

(2) Science Research

In FY 2016, Mizusawa VLBI Observatory published a total of 40 refereed journal papers for scientific achievements. Among them, four papers were published by the Observatory staff as PIs. Nine papers were scientific results directly related to VERA astrometry observations, one was the results from KaVA, and two were from the Japanese VLBI Network (JVN). In addition, various scientific results from other VLBI arrays, ALMA, and multi-wavelength time-domain studies on active galactic nuclei (AGN) were published, which were developed based on previous VERA sciences. It should be noted that there were 31 papers published through international collaboration.

For the VERA project results, a new research method for distance measurements was reported. It utilized the accurate proper motion and radial velocity measurements for the H_2O masers associated with a high-mass star-forming region G7.47+0.06. The high accuracy (10 % error) distance, 20 ± 2 kpc, was successfully determined demonstrating that the method can be applied to sources farther than 10 kpc whose annual parallax is barely measurable with VLBI. For star-formation studies, a research group lead by Kagoshima University detected the jet-driven bow-shock structure in the outflow associated with the high-mass young stellar object S255. In the research field of late-type stars, the first simultaneous VLBI observations of SiO masers in four frequency bands were reported using the newly developed wide-band VLBI backend system developed by the Mizusawa VLBI Observatory. It is expected that the system will be employed for combined VLBI observations with the NRO 45-m Telescope and KVN. There was a paper that reported the first KaVA imaging result for the SiO masers around a late-type star. The AGN research group reported the new synthesis imaging method for interferometers utilizing the sparse modelling.

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, GSI) to make the Japanese VLBI Network (JVN), which is operated at 3 bands of 6.7 GHz, 8 GHz, and 22 GHz. VLBI observations were carried out for about 300 hours in total in 2016. In addition, single-dish observations of up to 4,000 hours were carried out as research related to JVN. The main research subjects are active galactic nuclei and maser / star formation.

In October 2016, the Astronomical Society of Japan released a special issue of PASJ on university collaboration. This volume includes 8 papers based on JVN operations such as the results of VLBI survey observations with small-number high-sensitivity baselines (Fujinaga et al.), results of 6.7 GHz methanol-maser monitoring by the East Asian VLBI network (EAVN) (Sugiyama et al.), and a report on the Ibaraki telescopes (Yonekura et al.).

More than 10 papers including other related papers have been published in 2016. Since the activities of university VLBI collaboration have been appreciated, an Assistant Professor position was established at Yamaguchi University, and filled by Dr. Motoki, who obtained a Ph.D. by doing research using JVN at Hokkaido University and worked as a postdoc at Mizusawa VLBI.

In July 2016, the university collaborative workshop was held at Ibaraki. Many participants attended, and white papers for the future direction were created based on this discussion. A project, entitled "high spatial resolution / time-domain astronomy in the centimeter band," was approved as a baseline of the university collaboration. It is planned that maser / star formation study will be mainly carried out at Ibaraki University, while active galactic nuclei / black hole science will be mainly done at Yamaguchi University. In particular, observations with a small number of baselines; time variation observations; and research with the Ibaraki and Yamaguchi interferometers will play an important role in the future of the project.

3. Japan-Korea VLBI

(1) Observations and Common Use Observations

In 2016, a total of 158 VLBI observations (1234 hours), common use observations, large program observations, and test observations, were conducted by KaVA (KVN and VERA Array) with the 43 and 22 GHz bands. The data of the seven VLBI stations were correlated at the Korea-Japan Correlation Center at KASI Daejeon Campus in Korea.

KaVA common-use calls-for-proposals for semesters 2016B and 2017A were made in May and October of 2016, respectively. In total, 17 proposals requesting a total time of 582 hours were submitted. Through the evaluations by referees elected from scientists in related fields and subsequent decisions made by the VERA and KVN combined Time Allocation Committee, a total of 12 proposals (377 hours) were accepted in 2016B and 2017A.

(2) Results of Research

The number of science outcomes based on KaVA data is steadily increasing since the opening of the KaVA common use in FY 2014. In FY 2016, three research papers that made use of KaVA common-use data were published in peer-reviewed journals. These are all related to AGN, where a variety of AGN topics were explored: a follow-up monitoring of an optically-violent quasar (CGRsBS J0809+5341); radio imaging of high-redshift ($z > 5$) quasars (e.g., J0131-0321); and a high-cadence monitoring of a jet acceleration region (M87). In particular, the former two are the first papers that were led by research groups external to Korea/Japan, indicating that users of KaVA are spreading into the world.

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). For the AGN LP, the acceleration profile of the M87 jet is beginning to be determined in higher detail. For the SFR LP, surveys of 87 water masers (22 GHz) and methanol masers (43 GHz) are actively going on. For the LTS LP, roughly 90 % of the survey of approximately 80 circum-nuclear masers was completed; work to narrow down the observational targets is ongoing. Some of these LP preliminary results were presented at international conferences.

4. EAVN

To expand the capability of international VLBI throughout East Asia, the commissioning of the East-Asian VLBI Network (EAVN) is actively ongoing through collaboration between Japan, Korea, and China. In FY 2016, a total of 8 test observations were conducted with EAVN, and the first EAVN image was successfully obtained (with KaVA plus Tianma at Shanghai). The 9th EAVN Workshop was held at Guiyang, China. Direct discussions were held with Chinese researchers, particularly ones from Shanghai and Urumqi; and we reached a consensus on the further acceleration of EAVN activities and collaboration. As a result, the KaVA Science Working Groups were expanded into the "EAVN Science Working Groups" by inviting Chinese researchers.

While the technical commissioning of the EAVN array is progressing, some science-oriented observations were also launched, such as an EAVN monitoring of nearby supermassive black holes near in time to the Event Horizon Telescope observations. The program was performed with KaVA+CVN+JVN at a high cadence of 1-2 weeks, and the array operation went well without any major troubles. The common use of EAVN is planned to open by 2018.

5. Geodesy and Geophysics

The regular geodetic sessions of VERA are allocated two or three times every month to maintain the orientation and shape of the array. VERA internal geodetic observations are performed once or twice per month using K-band, and Mizusawa participate in IVS sessions using S- and X-bands on a once-per-month basis. The 1-Gbps recording system of S/X bands was newly developed to widen the recording bandwidth in IVS sessions.

In FY 2016, we participated in 9 IVS sessions and performed 19 VERA internal geodetic sessions. The final estimation of geodetic parameters is derived by using the software developed by the VERA team.

After "The 2011 Earthquake off the Tohoku Pacific coast" ($Mw = 9.0$), VERA Mizusawa was displaced by co-seismic crustal movement, and continuous post-seismic creeping was detected in FY 2016. According to the newest analysis, the co-seismic steps are $X = -2.020$ m, $Y = -1.389$ m, and $Z = -1.060$ m, and displacement by creeping during FY 2016 is $X = -0.075$ m, $Y = -0.059$ m, and $Z = -0.014$ m.

Continuous GPS observations at VERA stations are carried out in order to detect short term coordinate variations and to estimate atmospheric propagation delays. The results of GPS positioning also show a post-seismic motion to the East-

Southeast of Mizusawa even though 6 years have passed since the occurrence of the 2011 Earthquake off the Tohoku Pacific coast. Continuous gravity observations with super-conducting gravimeters were carried out at Mizusawa and Kamioka. The observation at Kamioka was terminated in 2016. Gravity change observation is also carried out at Ishigakijima as a joint project with other institutes and university groups. The features of the annual change are observed and studied by several techniques including VLBI, GPS, and gravimeters. The strain and tilt observation data obtained at 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.

6. System Development

In 2016, we have developed two down-converters for dual polarization receiving of the Q-band. We have performed a VLBI experiment between KVN and VERA using OCTAD and OCTADISK2 installed in KVN. The fringes of the experiments are detected successfully in cooperation with VERA, KVN, and the manufacturer. Fringes of an experiment between Italy and VERA are also detected in all channels after data conversion between domestic and international data formats. Upgrades to OCTAD made AOV observations possible. We started discussion of the SKA project and high frequency VLBI as future plans of the observatory. We performed various basic design and development, including a low power consumption optical transmitter/correlator and balloon-borne radio interferometry.

7. Timekeeping Office Operations

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

8. Ishigakijima Astronomical Observatory

FY 2016 was the 10th year of the Ishigakijima Astronomical Observatory (IAO). In FY 2013, the "Starry Sky Study Room" was established as an annex to screen the 4D2U (Four-Dimensional Digital Universe) theater by Ishigaki City, and the number of visitors has increased to more than 15,000 people per year. The total number of visitors since FY 2006 has exceeded 100,000. The observatory missions such as conducting observational study, public outreach, and regional promotion have been accomplished well. The 10th anniversary ceremony was held in November. Special events including a science cafe, photograph exhibition, and stargazing party were also given.

In terms of the research, observations of transient objects such as gamma-ray bursts, supernovae, and Solar System objects were performed in collaboration with Japanese universities. Three refereed papers using the observational data of IAO were published, including studies of supernova SN 2016coi and comet 15P/Finlay. The total number of the papers has reached 19.

In FY 2016, the 15th "Southern Island Star Festival" was held. The number of participants has also been increasing, and about 11,000 people attended the light-down stargazing party. Special events to mark the 15th anniversary were held, including a movie screening of "Welcome Home, HAYABUSA" and the starry sky photo contest. The Japanese Tanka contest on "Beautiful Stars" for which the judge was a famous Tanka poet Machi Tawara was also held. In total, about 13,000 people participated in the festival.

In terms of the education, 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 the workshop, three new minor planets candidates were found by the observations of the high school students. One of these three objects was assigned the provisional designation 2016 PH14 and was recognized as a discovery of IAO by the IAU Minor Planet Center.

On the other hand, active interaction and collaboration with Japanese public astronomical observatories was performed. The Nayoro Observatory in Hokkaido, with which IAO concluded an agreement for cooperation, held a star festival in July; IAO assisted with the star festival by providing a live relay of the landscape and the starry sky from IAO.

9. Public Relations (PR) and Awareness Promotion Activities

(1) Open House Events

On April 17, 2016: the Seventh Open Observatory Event held at the Ibaraki University Center for Astronomy, and NAOJ Mizusawa VLBI Observatory, Ibaraki Station, with approximately 348 visitors in attendance.

On July 17: 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 200 visitors.

On August 6–14: The Southern Island Star Festival 2016 held together with a special open house event at the VERA Ishigakijima Station and Ishigakijima Astronomical Observatory with approximately 11,000 visitors to the whole Star Festival. Events included an astronomical observation party at Ishigakijima Astronomical Observatory, attended by 338 visitors; and a special public opening of the VERA Station attended by 252 visitors.

On August 7: Special open house of VERA Iriki station held jointly with the Yaeyama Highland Star Festival 2016, with approximately 4,500 visitors in attendance.

On August 20: Iwate Galaxy Festival 2016, open house of NAOJ Mizusawa Campus, held with 2500 visitors in attendance.

On February 12, 2017: "Star Island 16", open house event of VERA Ogasawara Station held, with 227 visitors in attendance.

(2) Regular Public Visiting

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

The numbers of visitors to each facility is as follows,

a) VERA Mizusawa Observatory 18,100
The campus is regularly open to the general public with the cooperation of the Oshu Space and Astronomy Museum (OSAM: Yugakukan) located in the campus.
b) VERA Iriki Station 5,949
c) VERA Ogasawara Station 9,930
d) VERA Ishigakijima Station 2,442
e) Ishigakijima Astronomical Observatory 15,061
Stargazing sessions: Evenings on Saturdays, Sundays.
The "Starry Sky Study Room" (featuring the 4D2U "Four-Dimensional Digital Universe"), constructed adjacent to the observatory in 2013 by Ishigaki City, was very popular, welcoming 4,317 guests.

10. Education

(1) University and Post-Graduate Education

Regarding postgraduate education, Mizusawa VLBI Observatory assisted two graduate students from the University of Tokyo and two from SOKENDAI for their Ph.D. research. In addition, one Ph.D. student from oversees started Ph.D. courses in SOKENDAI from autumn. One of the students from SOKENDAI completed his Ph.D. thesis, and another Ph.D. student found a job as a science communicator before graduation. An undergraduate student from Nihon University was accepted as a summer student 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 22–25 at the Nishihara main campus and were opened to the public at the satellite campuses. Observational workshops were held in Ishigakijima from August 29 to September 1, with about 30 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.

(2) Research Experience for High School Students

During August 3–5, the VERA Ishigakijima station and the Ishigakijima Astronomical Observatory held "The Chuaraboshi Research Team Workshop" for 17 high school students from Ishigakijima, Okinawa main island, and Hyogo prefecture. It was organized under support from JSPS. It is noteworthy that observations carried out at Ishigakijima Astronomical Observatory produced results including the discovery of a new minor planet candidate which was assigned a provisional designation. (Please refer to 8: Ishigakijima Astronomical Observatory for more details.) "The 10th Z Star Research Team Event" was held August 8–10 to use the VERA Mizusawa antenna for observation. A total of 15 high school students from the Tohoku region were accepted for research experience. Continued from previous years, Mizusawa VLBI Observatory supported the SSH (Super-Science High-school) research activities for Yokote Seiryo High School in Akita Prefecture to use the Mizusawa 20-m antenna.

5. Solar Observatory

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

1. Observational Facilities in Mitaka

(1) Magnetic Field Observation

The SFT, which has been the main instrument of the Observatory at Mitaka Campus, has kept observing photospheric vector magnetic fields at active regions and H-alpha flares since its completion of 1992. The main instrument on the SFT was updated to an infrared Stokes polarimeter in 2010. Whereas previous magnetic field observations covered part of the solar surface, this new instrument was designed to obtain high accuracy vector magnetic field information over the full solar disk in order to elucidate the origins of the solar activity cycle. This polarimeter is equipped with a 15-cm infrared lens and performs slit scanning observations using infrared spectral lines (photosphere: iron, 1.565 μm line; chromosphere: helium, 1.083 μm line), which are sensitive to the magnetic field on the Sun. This allows for constant acquisition of unprecedented infrared polarization data for the photosphere and chromosphere of the entire solar disk. It had taken about two hours to cover the full-disk Sun with a slit scan for each wavelength range, but a two-camera system renewed in 2014 enables us to observe both wavelength ranges simultaneously. The data acquisition is now conducted more efficiently. However the system had a problem in light path design; a camera could not sit in an optimal position as designed and it was renovated this year by suspending the regular observations for several months. To further improve the polarimetric data quality, the installation of an advanced infrared camera with a large format and low read-out noise is being conducted, and this year, the infrared detector H2RG EG-C and its control electric circuit SIDECAR+MACIE were procured using a grant from the Project for Solar-Terrestrial Environment Prediction (PSTEP), Grants-in-Aid for Scientific Research on Innovative Areas.

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

Sunspot observations have been performed continuously since 1929. These observations are currently conducted via automatic detection of sunspots in digital images captured with a 10-cm refractor and a 2 k × 2 k pixel charge coupled device (CCD) camera mounted on the new (full-disk) sunspot telescope. Observations were conducted for 241 days in FY 2016, from April 2016 to March 2017.

Because full-disk solar image data are a widely demanded resource in the astrophysics/geophysics researcher community, some out-of-date synoptic instruments need to be upgraded. Efforts are underway to update the photospheric and chromospheric imaging instruments and to further flesh out the data. For instance, the SFT has started advanced observations in the H-alpha line to acquire full-disk, high-resolution images. It can obtain Doppler velocity information based on imaging at multiple wavelengths around the H-alpha line center. High temporal resolution enables the more complete capture of active phenomena, and a combination of multiple exposure times allows for a wide dynamic range. Further improvement in dynamic range and read-out noise was accomplished using sCMOS cameras installed in FY 2015. This advancement has enabled us to observe many phenomena, such as flares and prominence eruptions, even during the recent downturn in solar activity. The Observatory also uses the SFT to conduct regular full-disk imaging observations in the G-band (430 nm) and continuum wavelengths. In addition, CaII K (393 nm) filter observation started in FY 2015.

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

2. Opening of Data Archives to the Public

The Solar Observatory has made nearly 16.2 TB of data available to the public online, including data from the current observations of white light, H-alpha, and magnetic fields as well as those from nearly 100 years of various types of solar observations. The various phenomena occurring in the solar-terrestrial environment must be studied in terms of both sudden, short-term events (space weather) and in terms of gradual changes occurring over years or decades (space climate). The Observatory will continue providing fundamental data for these studies. The Observatory possesses nearly 100 years of accumulated records, including continuum images, Ca II K-line images, and H-alpha images recorded on film, photographic plates, and hand-drawn sketches, all of which have an importance of their own. The Observatory will make these available to the public as well as soon as they are digitized and organized. It is noted that there exist some of the world's oldest records of solar activities, which are expected to add particular

insight into future research. Higher bit digitization of old Ca II K line images improving the data quality was conducted this year as a part of research activity for the PSTEP, Grants-in-Aid for Scientific Research on Innovative Areas.

Data publicized via the website were previously stored on a server owned by the Observatory. The data have since been transferred to the Astronomy Data Center, where all relevant data servers have been managed in an integrated fashion. The same data are stored at multiple locations in the data center, serving as a backup in case of disaster.

The Observatory is also contributing to scientific verification of data from the Nobeyama Solar Radio Polarimeters which have been maintained by Nobeyama Radio Observatory since Nobeyama Solar Radio Observatory was shut down at the end of FY 2014. To ensure the same data quality as before, a monthly meeting is held for members from inter-university users, Nobeyama Radio Observatory, and the Solar Observatory to check the obtained data.

3. Other Activities/Personnel Transfers

International cooperation includes support for the Japan–Peru collaborative solar observations, with which the Solar Observatory has been involved since 2004. In addition to the collaboration in solar spectrograph installation and operation in Peru, relocation of the 10-cm coronagraph which had been used in Norikura Solar Observatory is envisioned. For this purpose, reassembling the coronagraph in the Observatory and site selection in Peru are undergoing. The Solar Observatory also supports the operation of another 10-cm coronagraph with a NOGIS filter system in a Chinese observatory (3200 m elevation) in the Yunnan province. This coronagraph was relocated from Norikura in 2013 to observe two dimensional intensity and velocity fields of the solar corona in the coronal green line of Fe XIV (530.3 nm). The Observatory supported repair of a broken electric circuit board of the coronagraph this year. A new coronagraph reusing a 25 cm diameter lens from the coronagraph of Norikura Solar Observatory is planned in China. The lens which has been displayed in a visitor facility of Mitaka Campus was cleaned and stored in a container in case of transportation to China in the near future. The Observatory is participating the JSPS bilateral cooperative program between Japan and Russia for FY 2016–2017 (Japanese representative: Dr. Y. Yokoi, University of Tokyo) and is carrying out bilateral joint research project in solar physics, by exchanging scientists between the two countries.

The solar optical observations carried out at Hiraiso Solar Observatory of the National Institute of Information and Communications Technology are considered to be terminated. To examine the possibility of utilizing the instruments in the future at other institutes, the relevant equipment (H-alpha Lyot filter and the telescope/coelostat for solar magnetic field measurements) were placed in storage at Mitaka until it has been decided where to send them.

The solar research symposium for the entire solar community was held at ISAS between February 20 and 22, 2017. It included a session which served as the users meeting for the Observatory where topics related to open use and future plans were discussed.

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

Regarding personnel transfers, Dr. Satoshi Morita was selected as a specially appointed research specialist after the end of his term as a research expert at the end of FY 2016. It was decided to start a new project “Solar Science Observatory” by unifying the Solar Observatory with Hinode Science Center from FY 2017 to promote more efficient research activity in the field of solar physics.

6. NAOJ Chile Observatory

The ALMA Project is a global partnership of East Asia (led by Japan), Europe, and North America (led by the United States) in cooperation with other nations to 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 or the Hubble Space Telescope. Early scientific observations with ALMA began in FY 2011 with a partial number of antennas and full operation commenced in FY 2012. This report describes the progress of the project, which includes results of the open-use scientific observations and public outreach activities. The ASTE telescope is a single-dish 10-m submillimeter telescope located in the Atacama highlands and has been operated to make headway into southern-hemisphere 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 fifth round of ALMA open-use observations commenced in October 2016 as Cycle 4. The main capabilities of Cycle 4 include: interferometric observations using forty 12-m antennas; Atacama Compact Array (ACA) observations (interferometric observation with ten 7-m antennas and single-dish observations with three 12-m antennas); seven frequency bands (Bands 3, 4, 6, 7, 8, 9 and 10); and maximum baselines extended to 12.6 km (for Bands 3 to 6), 6.8 km (for Band 7), and 3.7 km (for Bands 8 to 10). In addition to these, Cycle 4 also provides new opportunities for large programs that require long observations over 50 hours, millimeter-wavelength VLBI, ACA stand-alone mode, solar observations, and polarization for spectral line observations. In response to the Cycle 4 call for proposals, 1,571 proposals were submitted from all over the world.

The call for the sixth round of open-use observations was issued as Cycle 5. The Cycle 5 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, 6, 7, 8, 9, 10 and newly-added Band 5), and maximum baselines of 16.2 km (for Bands 3 to 6), 8.5 km (for Band 7), and 3.6 km (for Bands 8 to 10). It should also be noted as a remarkable development that the ALMA maximum baseline will be made available for open-use observation with Bands 3 to 6. The call for proposals for Cycle 5 is set to be closed at 00:00 JST on April 21, 2017. Cycle 5 is scheduled to start in October 2017.

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. An international team led by Akio Inoue at Osaka Sangyo University detected emission lines from ionized oxygen in a distant galaxy 13.1 billion light-years away. The galaxy was first discovered with the Subaru Telescope and observed with ALMA this time. This is the most distant galaxy in which oxygen has ever been detected and thought to be one type of source that triggered "cosmic reionization" in the early history of the Universe just several hundred millions of years to one billion years after the birth of the Universe. This observation result is a very important step towards understanding the cosmic reionization which has yet to be explored. A team of Japanese astronomers led by Takashi Shimonishi at Tohoku University revealed a hot core containing various molecular gases around a newborn massive star in the Large Magellanic Cloud using ALMA. This is the first hot molecular core that has ever been detected outside the Milky Way Galaxy and has a very different composition than similar objects found in the Milky Way. Studying complex organic molecules contained in hot cores will be a key to unveiling the chemical diversity of the Universe. Since the Large Magellanic Cloud is known to have lower metallicity compared with the Milky Way, this result provides an important clue to revealing the distribution of organic molecules in the early Universe with low metallicity. A research team led by Takashi Tsukagoshi at Ibaraki University observed the young star TW Hydrae using ALMA and revealed the detailed distribution of dust in its protoplanetary disk. They made comparative analysis of observation results in two frequencies and found that larger dust particles are absent in the most prominent gap with a radius of 22 astronomical units. Based on a theoretical model, the result indicates that a possible Neptune-like planet is forming in the gap. These findings will help scientist identify what type of planet is forming in a specific location of a protoplanetary disk.

3. Educational Activities and Internship

During the summer vacation of universities, the NAOJ Chile Observatory accepted five undergraduate students, three of which conducted research activities in Mitaka and other two in Chile, as well as four visiting researchers in total which include: one Japanese graduate student each from Osaka Prefecture University and the University of Tokyo and internationally one post-doctoral fellow each from the University of Chile and

Leiden University of Netherlands for a period of one month.

4. Public Outreach Activities

Achievements of ALMA scientific observations and test observations were covered by nearly 40 newspaper/journal articles and 11 television/radio programs, reporting ALMA observation results in various fields of astronomy. In particular, a news program called "Good Morning Japan" on NHK G channel featured ALMA's detection of the most distant oxygen in the Universe in June 2016, and another NHK program called "News Watch 9" introduced ALMA observation results of a protostar in March 2017. The detection of the most distant oxygen was covered by more than 400 news websites worldwide and the BBC website featured the observation results of TW Hydrae achieved by Takashi Tsukagoshi (Ibaraki University) et al. As seen in these examples, the scientific results by Japanese researchers have been increasingly broadcast worldwide.

The NAOJ ALMA website posted 51 news articles and eight press releases. A mailing-list-based newsletter has been issued on a monthly basis with approximately 2,500 subscribers. Updated, detailed information is available on Twitter (@ALMA_Japan), with nearly 33,250 followers as of the end of FY 2016.

In May 2016, the NAOJ Chile Observatory hosted a week-long ALMA booth at the Japanese Geoscience Union Meeting held in Makuhari Messe. The NAOJ Chile Observatory organized public lectures and Science Cafe events on 17 occasions in FY 2016 and gave talks on the progress of ALMA to a large number of visitors. In particular, the 22nd ALMA Public Lecture "Star and Planet Formation Explored by ALMA" held in Nagoya City Science Museum on November 26, 2016 attracted a big audience of over 200, which was a great opportunity to introduce the latest scientific results of ALMA to the public.

The NAOJ Newsletter featured ALMA's semiannual achievements in the April and November 2016 issues.

From the mid-March 2015, ALMA started to accept public visitors at 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 tour of the OSF including the control room and watch 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 live experience at the workplace of ALMA researchers.

5. International Collaboration (committees, etc.)

On November 17, 2016, the Management Agreement Concerning Operations of ALMA was signed in Santiago by the representatives of NAOJ, the European Organization for Astronomical Research in the Southern Hemisphere (ESO), and Associated Universities Inc. (AUI) of the United States.

In the international ALMA project, meetings are held frequently by various committees. In FY 2016, the ALMA Board met face-to-face once, and the ALMA Scientific Advisory Committee (ASAC) twice. In addition to these, teleconferences have been held on a near-monthly basis among the members of the ALMA Board and ASAC. 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

- July 20 to 21, 2016 NAOJ Nobeyama Radio Observatory (NRO)
  NRO-ALMA Science/Development Workshop 2016
- September 20 to 23, 2016 Renaissance Indian Wells Resort & Spa, Indian Wells, CA, USA
  Half a Decade of ALMA: Cosmic Dawns Transformed
- December 19 to 20, 2016 NAOJ Mitaka
  ALMA/45 m/ASTE Users Meeting 2016
- March 24, 2017 Okayama University of Science
  ALMA Cycle 4 Town Meeting

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

- Satoru Iguchi: Grant for Basic Science Research Projects by the Sumitomo Foundation
- Seiji Kameno: International Research Support Program by Foundation for Promotion of Astronomy
- 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 1)

8. Research Staff Changes

(1) Hired
- Xing Walker Lu: Specially Appointed Research Staff
- Naslim Neelamkodan: Specially Appointed Research Staff
- Natsuko Izumi: Specially Appointed Research Staff
- Kazuki Tokuda: Specially Appointed Research Staff (assigned to Osaka Prefecture University)
- Sarolta Zahorecz: Specially Appointed Research Staff (assigned to Osaka Prefecture University)
- Takuya Hashimoto: Specially Appointed Research Staff (assigned to Osaka Sangyo University)
- Sanemichi Takahashi: Specially Appointed Research Staff (assigned to Kogakuin University)

(2) Departed or Transferred
- Kana Morokuma: Specially Appointed Research Staff
- Tatsuya Takekoshi: Specially Appointed Research Staff

9. Main Visitors

- September 15, 2016
  Mr. Toshiei Mizuochi, Vice Minister of Education, Culture, Sports Science and Technology, visited the Santiago Office of the Joint ALMA Observatory (JAO).
- October 13, 2016
  Mr. Shigeharu Orihara, Counselor of the Japanese Embassy in Chile, visited the OSF and AOS.
- October 18, 2016
  Mr. Hiroshi Nagano (National Graduate Institute for Policy Studies; former Chair of the OECD Global Science Forum) visited the OSF and AOS.
- November 23, 2016
  Director General of the National Astronomical Observatories of the Chinese Academy of Sciences (NAOC) and his party visited the NAOJ Santiago Office.

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 the submillimeter astronomy. Since ALMA entered its operation phase in FY 2012, ASTE is 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 in the world with a 10-meter-class antenna that can observe the southern sky: one is ASTE and the other is APEX operated by Europe. Therefore, having ASTE operated by Japan will be a big advantage for strengthening ALMA proposals and for implementing our strategies for further extended capabilities with new observing instruments. For the future, ASTE is also important since it provides opportunities for nurturing young researchers who will play key roles in the equipment development for the next generation. In the near future, ASTE will be incorporated into the open-use program to have organic collaboration with the Nobeyama 45-m Telescope.

The open-use program in FY 2016 provided spectroscopic observations in 345 GHz and 460 GHz bands for a period of three 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. In addition to this, Joint slots have been newly established to allow researchers to jointly request observation time with ASTE and the Nobeyama 45-m Telescope at the same time. A total of 14 proposals for open-use observations and GTO slots were submitted (including 9 for open-use, 4 for Joint slots, and one for GTO). These proposals were reviewed by the Millimeter/submillimeter Program Subcommittee and 11 proposals were adopted including 6 for open use, 4 for Joint slots, and one for GTO in the first call. Open-use observations were carried out from the ASTE Mitaka operations room or from other universities and research institutes from September 26 to December 8, 2016.

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 computers for gravitational many-body problems, carrying out research and development of computational astrophysics, and performing astronomical research with simulations. The main supercomputer of the present system, ATERUI (Cray XC30), has 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 (PC clusters) for small-scale calculations.. Efforts in visualizing astronomical data also continue.

2. Open Use

(1) Computer Systems

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

While XC30 is leased for five years from Cray Japan Inc., the center has built the following equipment to aid the open-use computer operations: a series of dedicated computers for gravitational N-body problems, known as GRAPEs; PC 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, GRAPEs, and smaller computational 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 FY 2015 on studies that involved the project's open-use computers. It turned out that 112 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. Two papers were accepted in FY 2015 for payout in FY 2016, while two papers were accepted in FY 2016 for payout in the same year at approximately 90,000 JPY.

□ Statistics on the Cray XC30
Operating hours
- Annual operating hours: 8550.7
- Annual core operating ratio: 89.84 %

Users
- Category S: 0 adopted in the first term, 0 in the second term; total 0
- Category A: 12 adopted at the beginning of the year, 1 in the second term; total 13
- Category B+: 8 adopted at the beginning of the year, 1 in the second term; total 9
- Category B: 91 adopted at the beginning of the year, 10 in the second term; total 101
- Category MD: 13 adopted at the beginning of the year, 4 in the second term; total 17
- Category Trial: 34, year total

□ Statistics on the GRAPE system
Users
- Category A: 2 adopted at the beginning of the year, 1 in the second term; total 3
- Category B: 6 adopted at the beginning of the year, 0 in the second term; total 6
- Category Trial: 1, year total

□ Statistics on PC cluster
Operating hours
- Annual operating hours: 8597.4
- Annual job operating ratio: 72.9 %

Total users: 41, year total

(2) Tutorials and Users Meeting

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

□ Cray XC30 workshop for beginning users: August 29, 2016, 5 attendees

□ IDL visualization workshop: August 30, 2016, 6 attendees

□ Cray XC30 workshop for intermediate users: August 31, 2016, 7 attendees

□ Hydrodynamics simulation school: February 18–21, 2017, 40 attendees

□ N-body simulation Spring School: February 8–12, 2017, 12 attendees

□ Users meeting: November 29–30, 2016, 67 attendees

3. PR Activities

In FY 2016, two press releases were issued from CfCA; "Avoiding 'Traffic Jam' Creates Impossibly Bright 'Lighthouse'" (September 8, 2016, Tomohisa Kawashima and Ken Ohsuga, CfCA/NAOJ), and "Mystery Solved Behind Birth of Saturn's Rings" (October 31, 2016, Ryuki Hyodo, Kobe University). A Twitter account @CfCA_NAOJ and YouTube channel have been operated to provide the information on CfCA.

CfCA took part in the special open house of Mizusawa Campus, Iwate Galaxy Festival 2015, held on August 20, 2016. About 150 visitors attended the ATERUI guided tours and experienced a close-up observation of the facility. In addition CfCA assistant professor Ken Osuga gave one of the special lectures, presenting the latest results of black hole research using ATERUI. At the Mitaka open house held on October 22, 2016, CfCA made the computer room accessible to the public and introduced simulation astronomy with GRAPE and the PC cluster. At this open house, the image panels which cover the ATERUI body were displayed to introduce ATERUI to those visiting Mitaka. In addition to the open house, CfCA accepted a group of high school students to tour the computer room in the Mitaka Campus. Moreover, in the NINS exhibition room in Nobeyama Campus, CfCA displayed GRAPE boards and posters to introduce research results from simulation astronomy calculated by the CfCA system.

4. 4D2U Project

In FY 2016, the 4D2U project continued to develop and provide the movie contents and software. Simulation movies titled "Dynamics of Saturn's Ring (II. Propeller Structure)," "Giant Impact of Protoplanets," and "Formation of Planetesimals" were released on the 4D2U website in July 2016. Two of these movies, "Giant Impact of Protoplanets" and "Formation of Planetesimals", as well as "Formation and Evolution of Dark Matter Halos (II. Formation of the Large-Scale Structure of the Universe) ver. 2" were published on the 4D2U YouTube channel with a format for VR on smartphones.

The updated version of the four-dimensional digital universe viewer, "Mitaka," was released in July 2016 (ver.1.3.2). This version of Mitaka included new functions, e.g. displaying probes like Juno and Kepler; and the topographic and toponomastic data of Mercury. Moreover, four languages (Italian, Indonesian, Portuguese, and Thai) were added. In February, 2017, the 4D2U project put out a news release "Mitaka for VR" designed to operate with VR headsets, like Oculus Rift CV1 and HTC Vive. Mitaka for VR enabled us to enjoy the all-around view of the virtual universe while walking through the virtual universe freely and looking around celestial objects and space probes.

In FY 2016, demonstrations of Mitaka VR were given during the open campus days of Mizusawa, Nobeyama, and Mitaka; and the Inter-University Research Institute Corporation Symposium. 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. In FY 2016, all of the 4D2U contents were provided to the 3D planetarium of Kurobe Yoshida Science Museum in Toyama prefecture, which was upgraded to stereoscopic projection in April 2016. In addition, the 4D2U Theater of the NINS exhibition room in Nobeyama Campus installed all of the 4D2U contents.

A Twitter account @4d2u and YouTube Channel have been operated to provide the 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 their 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. The program started last year.

In order to implement research plans, Hiroyuki Takahashi was engaged as a project assistant professor. Takahashi performed general relativistic radiation magnetohydrodynamics

(MHD) simulations of accretion disks and jets around black holes/neutron stars. The simulation revealed that supercritical accretion is possible onto not just black holes, but neutron stars as well. In the case of a strongly magnetized neutron star, a magnetosphere forms around the neutrons star. Then, the gas of the disk finally falls onto the magnetic poles and strong jets appear around the rotation axis.

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 WGs 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 fully exploit the resources of the post-K system have begun in relevant communities and organizations. The post-K generation equipment is scheduled to commence operation in FY 2019 or later. In principle, therefore, it is possible for the NAOJ to play a central role in the post-K generation HPCI through participation in this discourse.

6. Contract Staff Transfers

The following staff members were hired on a contract basis in this FY:
(Research experts) n/a
(Postdoctoral fellows) Yukari Ohtani
(Research associates) Tomohisa Kawashima, Tetsuo Taki, Yuki Tanaka, Satoki Hasegawa

The following contract staff members departed in this FY:
(Research experts) Shoichi Oshino
(Postdoctoral fellows) n/a
(Research associates) Tomohisa Kawashima

8. Hinode Science Center

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

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

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

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

FY 2016 marks the tenth year since the satellite's launch. The mission extension has been approved in JAXA for four more years until FY 2021. The NASA Senior Review is expected to be held in July 2017 to approve the request of the NASA mission extension for three more years. The ESA Science Program Committee also approved support at the current level of funding until the end of FY 2018, possibly to be extended to the end of FY 2020. The funding from STFC will be requested in FY 2017 for an extension of two more years.

1. The Hinode Satellite: Onboard Telescopes and Scientific Operation

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

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

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

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

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

through collaboration with ESA, allowing for data acquisition for every orbit. Scientific operation was again performed in FY 2016 via S-band data reception. The S-band reception frequency was increased with help from ESA and NASA, allowing for continuation of regular, stable scientific operation.

Obtained data is collected at ISAS/JAXA, converted into the FITS format, and provided to researchers around the world in the form of Level-0 data, which is close to raw data. HSC staff members and students took part in satellite operation for a total of 218 days in FY 2016, 76 days of which were for contracted work. Moreover, the contribution rates to the scientific operation of the HSC were 27.1% (domestic) and 17.1% (overall). Instantaneous publication of all data acquired by Hinode began on May 27, 2007, with stable continuation, implemented by HSC.

Calls for Hinode Operation Plans (HOP), which encourage proposals for open-use observations together with other satellites and terrestrial observational equipment, promote joint observations among solar researchers worldwide. As of March 2017, a total of 337 applications have been accepted. In particular, core HOP proposals made by members of the scientific instrument team became refined over multiple implementations. Through systematic observations they have produced results which increase in significance as the solar cycle progresses. And new HOPs were added aiming for collaborative observations with the ALMA cycle-4 solar campaign.

2. Hinode Satellite Data Analysis

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

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

In FY 2015, HSC staff members and students published 10 peer-reviewed papers related to Hinode, bringing the total to 260 papers by the end of March 2017. Cumulatively, a total of 942 peer-reviewed papers have been published on Hinode-related topics in the six major journals (ApJ, AAP, SP, PASJ, Nature, and Science). Intensified collaborative research with newly launched missions (SDO and IRIS) and advanced ground-based facilities (ALMA) will further enhance the number of research papers for pursuing the essence of solar activity.

3. Other Activities

In FY 2016, one postdoctoral fellow was engaged as a member of HSC.

The Hinode Science meetings for Japanese and international researchers have been held regularly to advance research in fields related to solar physics thorough use of the Hinode satellite. We have taken turns at organizing the meetings, and the tenth Hinode Science meeting took place during September 5 – 9, 2016, at Nagoya University, Nagoya (Japan). The number of participants amounted to 153 from 14 overseas countries, and a total of 161 papers were presented at the meeting.

To celebrate the tenth anniversary of the launch of the Hinode mission, we have:

1. produced a movie (https://www.youtube.com/embed/dqoIqXiz1Dk).
2. renewed the web pages of the project (http://hinode.nao.ac.jp/).
3. held a public lecture on September 10, 2016 at Nagoya University.
4. published a special issue of the Astronomical Herald (vol 109, August-October edition).
5. published a special issue of NAOJ News (No. 282, 2017 January issue).
6. produced a poster as an insert in the above NAOJ News.

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

Name	Organization (Country)
Rutten, Robert J.	Universiteit Utrecht (The Netherlands)

Table 1. Long-term Visitors.

9. Gravitational Wave Project Office

2016 has been marked by the announcement of the first two detections of gravitational waves from the coalescence and merger of black holes binaries and by the operation iKAGRA, the first 3-km long laser interferometer located underground at Kamioka. These first detections demonstrate that KAGRA will be able to detect the coalescence of binary black holes as soon as its sensitivity reaches the order of 1 Gpc distance for stellar mass binary black holes. The Gravitational Wave Project Office (GWPO) of NAOJ has pursued the construction of KAGRA at Kamioka. In particular the office was one of the leading groups in the operation of iKAGRA. The group has now entered an intense phase of work on site to install the vibration isolation system, one of the largest detector subsystems. To this end more than ten NAOJ staff members are working at Kamioka on a regular basis.

1. Development of KAGRA

KAGRA is an interferometric gravitational wave detector being constructed at an underground site in Kamioka, Gifu prefecture. In addition to the quiet underground environment, the use of cryogenic mirrors to reduce the thermal noise makes KAGRA a unique instrument among other large gravitational wave detectors.

KAGRA's construction is planned to proceed in several stages. Initial KAGRA (iKAGRA) was the first step of the phased development of the KAGRA detector, in which a room-temperature Michelson interferometer was constructed. In March 2016, iKAGRA detector installation was completed and we successfully operated the first km-scale underground interferometer ever built on the Earth. The test operation of the iKAGRA interferometer started on March 25, 2016 and continued until April 25 with a short commissioning break in the middle. This operation gave us an opportunity to check the validity of the KAGRA facility as well as accumulate a lot of experience in installing and commissioning a large-scale precision instrument underground. The next step of the KAGRA development is called bKAGRA phase 1, in which we will build a cryogenic Michelson interferometer. The efforts of the NAOJ GWPO are now focused on the realization of bKAGRA phase 1.

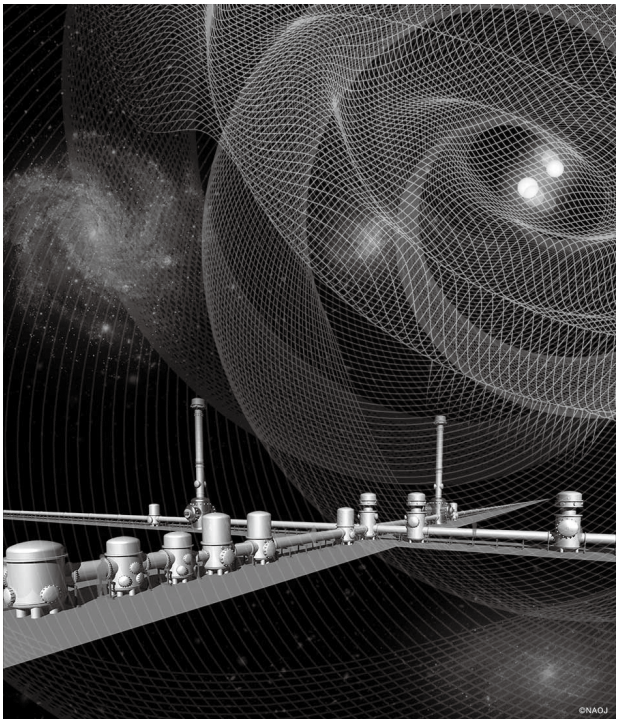

Figure 1: Sketch of gravitational wave space-time ripples impinging upon the KAGRA detector.

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

(1) Vibration Isolation Systems

The vibration isolation system (VIS) is composed of the suspensions required to isolate all the interferometer mirrors and some other optical components from ground vibrations. Four different types of suspensions, having different complexities to meet the varied isolation requirements of different components, have been developed at NAOJ for this purpose. We are now installing mirror suspensions necessary for bKAGRA phase 1, including two 14-meter-long suspensions for cryogenic mirrors, five large room-temperature suspensions, and two small suspensions. Preparation of those suspensions progressed well in FY 2016. In the latter half of the fiscal year, we started the installation of some of the suspensions. Currently more than 10 members of the GWPO are regularly working in Kamioka for the installation works of the VIS.

(2) Auxiliary Optics

The Auxiliary Optics (AOS) subsystem is responsible for providing optical components for stray light control, optical angular sensors, beam reducing telescopes (BRTs), beam monitoring cameras and optical windows. Highlights of the activities in FY 2016 are relevant to the BRT and some of the large optical baffles. Prototyping of the BRT as well as the design of the vibration isolation stage for the BRT were mostly finished by ATC. Two optical baffles with diameters of 1 m were installed into KAGRA. Design of the wide-angle baffles was mostly completed in collaboration with ATC and KEK. Two

papers were published on the optical baffles, and one of them was nominated as a monthly highlighted paper by the Optical Society of America (OSA).

(3) Mirror Characterization

We are also developing a system to accurately measure the optical absorption of mirrors, which is a critical characteristic for the cryogenic mirrors of KAGRA. The system was originally capable of measuring samples of up to 2-inch diameter. We are now upgrading the system to be able to produce scanned absorption maps of KAGRA sized (22 cm diameter) mirrors. 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

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

(2) DECIGO

In this fiscal year, the DECIGO working group compiled the Pre-DECIGO project; its scientific objectives and targets along with the conceptual design of the satellite were published in a summary paper. After that, Pre-DECIGO was renamed "B-DECIGO" for some reasons including an attempt to show it will have sufficient sensitivity to detect gravitational waves with a meaningful event rate (and so not just a simple precursor of DECIGO). Taking advantage of outcomes from LISA Pathfinder, the working group started to define several subprojects (or experiments) to show/enhance technical feasibility of a B-DECIGO satellite; in the near future, the working group will propose B-DECIGO to JAXA by summarizing those efforts.

3. Education

In FY 2016 the office included two PhD students and two master students among its members. In addition we received two undergraduate students under the SOKENDAI summer students program and we hosted three graduate students from the University of Tokyo/ICRR. We also received a master student from Beijing Normal University for six months and we had three visits by a Ph.D. student from CNRS/APC for a total duration of three months. Finally, two of the GWPO members taught at the Department of Astronomy of the University of Tokyo, at Hosei University, and at the Osaka City University.

4. Outreach

Since the first detection of the gravitational waves, the public interest in GW has increased significantly. In order to better share and promote our activities to the public, we have opened a completely renewed website for our group with a modern design. We also updated the leaflet of GWPO with professional graphics and design.

We organized a Workshop for Popularizing Cutting-Edge Astronomy in Toyama and Kamioka to provide the latest developments in astronomy with emphasis on the GW to high school teachers, curators of scientific museums, and so on. In addition to this workshop, the members of the GWPO gave more than 10 public lectures and talks about the GW astronomy and wrote 3 articles for popular magazines as well as 1 web article about the first detection of the GW in the FY 2016.

The TAMA and KAGRA sites continued to get attention from various people. We accepted more than 200 visitors for TAMA (excluding the open-day visitors) and the GWPO members took care of more than 150 visitors to KAGRA. Among them are journalists from National Geographic Magazine, NHK, and so on.

5. International Collaboration and Visitors

The GWPO is a member of the KAGRA collaboration, a scientific collaboration which includes also members from abroad. Apart from KAGRA, the GWPO has a collaboration with CNRS, Beijing Normal University (BNU), the University of Hamburg, and University of Trento in the context of R&D for future upgrades to KAGRA. In this framework we received the visits of Prof. Zhu from BNU, Dr. Leonardi from Trento, and Dr. Tacca from CNRS. We also had several exchanges with the Virgo collaboration with which one of the office members is affiliated. We received short visits from Dr. Vocca and Dr. Travasso (University of Perugia) and from Dr. Arai (Caltech). As usual we received several visitors at TAMA including the MEXT financial Director, a delegation from the ministry of Economy and the ministry of Education, the association of students in Mathematics and/or Physics and Astronomy at the University of Amsterdam, and the Japan Scientific Instruments Association.

6. Publications, Presentations, and Workshop Organization

The members of the office have authored 32 peer reviewed publications including the paper reporting about "GW151226: Observation of Gravitational Waves from a 22-Solar-Mass Binary Black Hole Coalescence" which received a lot of interest

in the scientific community and a paper about "Vacuum and cryogenic compatible black surface for large optical baffles in advanced gravitational-wave telescopes" which was highlighted by OSA. Moreover 16 presentations were given by the office members at international conferences.

7. Acquisition of external funds

GWPO did not receive external funds apart from those related to 6 grants allocated by JSPS.

8. Staff

One assistant professor moved to another group of NAOJ and a new position was opened in the GWPO. One JSPS postdoc moved to a specially appointed assistant professor position and a specially appointed specialist was hired. Overall in FY 2016 the project included 1 professor, 1 associate professor, 8 research staff, 5 engineers, 3 administrative staff, and 4 graduate students.

10. TMT-J Project Office

The TMT Project is a project to build an extremely large 30-meter telescope under the collaboration of five partner countries including Japan, the United States of America, Canada, China, and India. Heading the project for NAOJ is the TMT-J Project Office. In 2014, an agreement was executed between the participating organizations, TMT International Observatory was founded to assume the construction and operation of the observatory, and construction was commenced. 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.

Maunakea on Hawai`i is the planned construction site for TMT. The approval process for the use of the land in the Maunakea Conservation District for TMT has proceeded. In Fiscal Year 2016, with onsite construction scheduled to commence in April 2018, Japan proceeded with the mass production of the telescope primary mirror segments, detailed design of the telescope structure, and the design and development of the science instruments.

By the end of the fiscal year, 3 Professors, 4 Associate Professors, 1 Chief Research Engineer, 1 Specially Appointed Associate Professor, 1 Assistant Professor, 3 Specially Appointed Senior Specialists, 1 Research Administrator Staff, 1 Special Senior Specialist, 1 Research Expert, 1 Research Supporter, 3 Specially Appointed Research Staff, 2 Administrative Supporters, and 1 RCUH Staff held full-time positions. In addition, 1 Professor, 5 Associate Professors, 2 Assistant Professors, and 1 Research Engineer primarily assigned to the Advanced Technology Center, Subaru Telescope, 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), National Astronomical Observatories of Chinese Academy of Sciences, University of California, California Institute of Technology, Department of Science and Technology of India, and National Research Council of Canada. The Association of Universities for Research in Astronomy (AURA, USA), participating as an Associate Member, is currently taking steps for the U.S. to eventually become an official participant. TMT International Observatory, operated according to deliberations and decisions made in quarterly Board meetings of the TMT Board of Governors, is overseeing the construction work performed in each country as well as developing the onsite infrastructure. The board meetings

Figure 1: Conceptual image of a constructed TMT.

are attended by 3 representatives from Japan.

In December 2015, as the protest movement at Maunakea continued to gain momentum, the supreme court 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. As a result of the judgment, a review process for permit approval was reopened by the State of Hawai`i in February 2016. After a period of preparation that included the appointment of a hearing officer and approval of interested parties, hearings, which are a particularly important step in the review process, were held a total of 44 times between October 2016 and March 2017. At the conclusion of the hearings, a judgment regarding permit approval is submitted by the hearing officer to the Hawai`i Board of Land and Natural Resources where the final judgment is expected to be made. The TMT-J Project Office, with efforts that included actual attendance at the hearing, collected detailed information about the approval process and the hearing in order to prepare for conferences concerning the TMT International Observatory. The year 2016 also brought a surge in support for TMT construction in Hawai`i. The TMT-J Project Office put in its own effort as well to garner more understanding by holding dialogues with local stakeholders.

In parallel with this process, the TMT International Observatory initiated a selection process for a backup construction site in case construction at Maunakea becomes impossible. Candidate sites included Spain, Mexico, China, India, and 2 locations in Chile for a total of 6 locations. The criteria for consideration included favorable conditions for science observation, as well as the availability of the site for construction to commence by April 2018. Based on these criteria, TMT International Observatory selected La Palma in the Canary Islands as the backup construction site. Japan, as part of this process, held meetings in 5 locations (Sendai, Tokyo, Kyoto, Hiroshima, and Hilo) to explain the current situation in Hawai`i and to evaluate the alternate candidate construction sites. At the GOPIRA (Group of Optical and Infrared Astronomers) Symposium, the issue was deliberated and votes were cast by

affiliated researchers for the selection of a backup site. Based on the result of this process, Japan came to agree with the selection of La Palma as the backup construction site.

2. Japan's Progress on Its Work Share – the Telescope Structure, the Primary Mirror, and Science Instruments

For the construction of TMT, Japan is leading the design/fabrication of the telescope structure and a portion of the fabrication of the primary mirror and science instruments. In Fiscal Year 2016, the following progress was made.

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

The TMT primary mirror is comprised of 492 mirror segments. With replacements included, a total of 574 mirror segments must be fabricated. The processes required in the fabrication of mirror segments are: fabrication of the mirror blanks, spherical grinding of the front and back surfaces, aspherical grinding and polishing of the front surface, machining, and mounting of the mirror segments onto a support assembly. 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 Fiscal Year 2016, 49 mirror blanks were fabricated and spherical grinding was completed on 60 mirror blanks. With the share of work for the processes beginning from aspherical grinding/polishing and ending with mounting the mirror segment on a support assembly distributed among 4 countries, the plan calls for Japan to be leading this work for 175 of the mirror segments. In Fiscal Year 2016, ashperical grinding was performed on 8 mirror segments and 5 were ashperically polished. In addition, with the U.S. scheduled to begin their share of work to make the mirror segments aspherical, shipment of spherical mirror blanks to the U.S. was commenced.

Figure 2: Mirror segment blanks which have started to be shipped overseas (Courtesy of Canon Inc.)

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

Japan is leading the design and production of the telescope structure which functions as the mount for the science instruments and optics systems, including the primary mirror, and points them in the direction of a target astronomical object. Work on the detailed design of the telescope structure was initiated in Fiscal Year 2014 using the baseline design received in Fiscal Year 2013. In continuation of the 3 international reviews conducted by Fiscal Year 2015, an international review was conducted for the Segment Handling System, Aerial Service Platform, and Elevator in Fiscal Year 2016. With the completion of these reviews, the detailed design of the telescope structure was completed.

(3) Science instruments

As part of the international collaboration, Japan is leading the fabricating for a portion of 2 out of the 3 first-light science instruments.

The Infrared Imaging Spectrometer (IRIS), for which Japan is assigned the task of creating its imaging components, is currently in the preliminary design phase. In Fiscal Year 2016, the first preliminary design review was conducted for IRIS with the focus primarily on its optics and mechanics. Preparation work was performed to be ready for the final review of the preliminary design, scheduled for the next fiscal year, which will cover electronics, software, schedule, budget requirement, and issues indicated in the first review that require further study.

For the Wide Field Optical Spectrometer (WFOS), its conceptual study is underway with Japan expected to take the lead on its camera system. In Fiscal Year 2016, design work for the optics of the camera system was performed, and material quality and polishing were studied for the optical elements considered for selection.

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

In 2016, the TMT Science Forum, held once a year since 2013, was convened in Japan. This forum is a gathering to discuss topics such as scientific research, science instrument development, and the operation plan for the TMT. For the last 3 years, the forum was held in the U.S. with an important goal of developing a cooperative relationship with U.S. scientists for the TMT Project with funding from the U.S. National Science Foundation. This was the first time the TMT Forum was held outside of the U.S. It was held in Kyoto from May 24 to 26 and was attended by 140 participants who actively deliberated on topics including 2nd generation science instruments.

The study of scientific research for TMT was facilitated with the Science Advisory Committee of TMT International Observatory leading the way. Japan also made important contributions through its continued participation in the International Science Development Teams (ISDTs) established in 2013.

In Japan, continued effort has been made for the project to better reflect the opinions of the science community

communicated through forums such as the TMT-J Science Advisory Committee. In Fiscal Year 2016, the effect of moving the construction site elsewhere, particularly on scientific research and observatory operation, was evaluated through the aforementioned backup construction site candidate selection process. Also, with the continuation of the strategic fundamental research fund for the purpose of fundamental technology research for the development and design of 2nd generation science instruments, support funding for development was made available and provided to 6 universities and other 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, including updates particularly regarding the situation at the Maunakea construction site and the work share progress made by Japan. Additionally, TMT Newsletters No.46 through 50 were delivered. Efforts were made in public relation through lectures held in various areas throughout Japan and exhibits at the National Institutes of Natural Sciences Symposium and Inter-University Research Institute Symposium. Approximately 50 lectures and requested classes were held for the public.

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

TMT also assembled an international team that includes Japan to study topics such as education and personnel training, and as part of this project. In December, an international workshop was held in Hilo, Hawai`i catering to the young researchers and engineers that will lead the next generation. 40 graduate students and young researchers, that include 6 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 management and operation of large scale projects.

Donations to the TMT Project have been raised continually; 2 corporations and 302 individuals provided donations in 2016 (from January to December).

Figure 3: TMT Science Forum in Kyoto.

11. JASMINE Project Office

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

(1) Overview

The JASMINE mission seeks to survey virtually the entire 20° × 10° Galactic Bulge around the center of the Galaxy and to perform infrared (Kw-band: 1.5–2.5 μm) measurements of the annual parallaxes, proper motions, and celestial coordinates of the stars at a high 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 nearby space. Despite its small aperture, the satellite is capable of observational precision comparable to the Hipparcos satellite. The combination of observational data from Nano-JASMINE and the Hipparcos Catalogue is expected to produce more precise data on proper 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 2022. This satellite will engage in observations of a limited area around the nuclear bulge and certain specific astronomical objects. This small-sized version has the goal of obtaining advanced scientific results at an early stage. The mid-sized JASMINE satellite, with a main aperture of approximately 80 cm, is designed for surveying the entire bulge and is targeted for launch in the 2030's. Internationally, Japan shares responsibilities with ESA. With the Gaia Project, ESA performs visible-light observation of the entire sky at a precision of 10 μas, while Japan engages in infrared observation of the bulge, which is a method suitable for observations in the direction of the Galactic Center.

(2) Major Progress in FY 2016

1) Organization of the Office

The JASMINE Project Office is composed of five full-time staff members, six staff members with concurrent posts, one research associate, 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. On the other hand, we now have the possibility that the Europena Space Agency (ESA) can launch the Nano-JASMINE satellite, as well as another possibility for the launch. We are now negotiating for the launch. Assembly of the flight model that will actually be launched into space was completed in FY 2010. The extra time yielded by the launch delay has been used for additional testing to further ensure project success. Maintenance of the satellite has also been performed. Steady progress was also made in the development of the algorithms and software required to determine astrometric information from raw observational data at the required level of precision. International cooperation with the data analysis team for the Gaia Project has been conducted smoothly. A Japanese WG led by Ryoichi Nishi of Niigata University continued to actively engage in investigating the scientific results to be obtained in the future by Nano-JASMINE.

3) Overview of Planning and Developing the Small-JASMINE Project

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

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

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

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

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

This project office is progressively dissolving and moving to the Astrobiology Center. There have been 42 refereed papers in English, 10 non-refereed papers in English, 13 presentations in English, 5 non-refereed papers in Japanese, 3 books in Japanese, and 39 presentations in Japanese.

1. Development of the Subaru next generation exoplanet instruments and exoplanet observational research

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

HiCIAO is a coronagraph camera for direct imaging of exoplanets and circumstellar disks for the 8.2-m Subaru Telescope, which can simultaneously utilize various imaging modes to differentiate by polarizations, multi-bands, and angle. It is a high-contrast, modular instrument. 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. Currently, we are continuing with the development, maintenance and use of the extreme adaptive optics instrument SCExAO and the CHARIS integral field unit (IFU) as post-SEEDS activities.

(2) IRD (Infrared Doppler Instrument)

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

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

SCExAO is a 2000 element extreme adaptive optics system. CHARIS IFU is an exoplanet observation instrument for spectroscopy of giant exoplanets. EPO has been involved in the development of these next-generation high-contrast instrumentations.

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 (now the 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. The components have been considered and conceptual design is proceeding.

3. Science research, education, and outreach

The SEEDS project successfully finished in January 2015 without any major troubles. Now we are expanding observations using SCExAO and CHARIS. This fiscal year, 14 papers were published on SEEDS alone. Highlights are given below.

SEEDS has discovered spiral arms in the disk of LkHα330 and revealed the distribution of large/small dust in them. High-contrast direct imaging of intermediate-mass giants has discovered 3 companions that cause long-term radial velocity trends and set upper limits on any companions around 2 stars. A comprehensive direct imaging survey of young (< 1 Myrs) stars using the SEEDS data has indicated the frequency of wide-orbit giant planets. A new companion brown dwarf has been discovered in the Pleiades cluster.

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

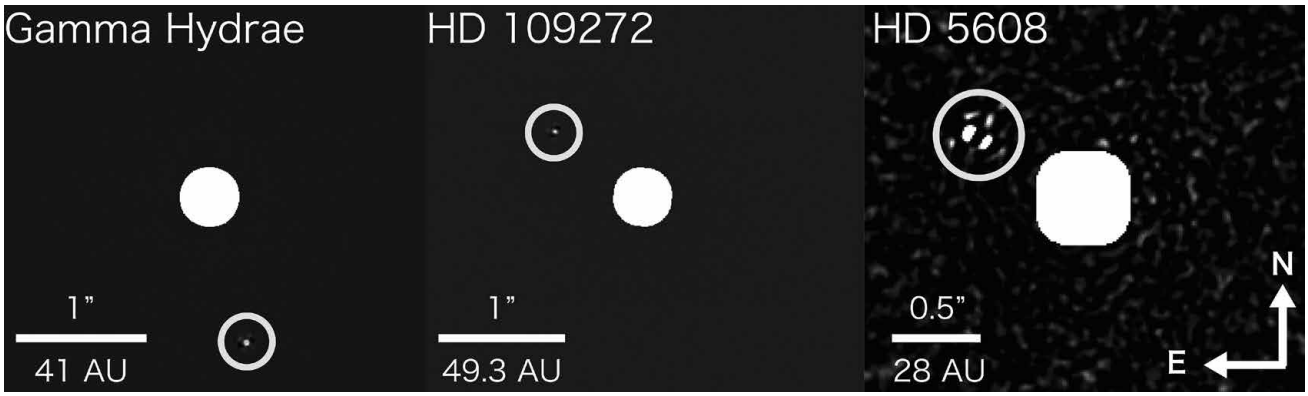

Figure 1: HiCIAO high contrast imaging of intermediate-mass giants with long-term radial velocity trends. Central stars are within the white regions, while the dots in circles are the newly discovered companions. Observing wavelength is near-infrared.

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

1. Project Overview

In FY 2016, operation preparation for the Laser Altimeter (LIDAR) of Hayabusa2 was carried out. And, a thermal test of the APD detector of the Ganymede Laser Altimeter (GALA) for the Jupiter Icy Moon Explorer (JUICE) mission was made. Also the RISE Project Office proposed four option plans as future directions for planetary sciences within NAOJ. The Hayabusa2 asteroid explorer was launched on December 3, 2014; initial test operations finished in January; and Hayabusa2 is underway to C-type asteroid Ryugu. Before rendezvous with the target asteroid start in the summer of 2018, the RISE Project Office developed a scientific data production/analysis tool as a preparation necessary for operation of the laser altimeter. The tool has been implemented, however a test using simulated data has not been completed due to a delay in the Hayabusa2 project supplying the simulated data. For GALA, the RISE Project Office members intensively tested an APD to confirm its suitable temperature range, and acquired basic data for GALA development. As for future directions for planetary science, the RISE Project Office held discussions and proposed 4 options to the Planetary Science Subcommittee: (1) Lunar deep interior exploration, (2) Small body studies, (3) Oscillation of planetary atmospheres, and (4) Cosmo-hydrology. For lunar deep interior exploration, we investigated the merits of 3 observational methods to measure the lunar Q value and the size of the solid/liquid core with high accuracy using lunar surface observation instruments by making the most of the heritage of Kaguya and the Geodetic research of RISE. For small body studies, we considered research into the evolution of primitive Solar System bodies and the delivery of water to the inner planets by investigating main belt comets (MBC) with ground-based observations and space probes by using the ongoing Martian Moon Explorer mission as a springboard. In the oscillation of planetary atmospheres, we are fostering the possibility of collaborative observations between France, Tokyo Institute of Technology, and NAOJ to measure Jupituer's free oscillation. For cosmo-hydrology we promoted Solar System bodies research within NAOJ based on a long-term vision of planetary science activity in NAOJ.

2. Educational Activities/Internship

Seven RISE members delivered 18 lectures on a part-time basis to graduate students at the University of Aizu. Also the Office accepted four third-year undergraduate students of Iwate University and Iwate Prefectual University for a week.

3. Outreach/PR

In FY 2016, one of the Office members volunteered for the Kirari Oshu Astronomy class of Oshu City. Three members participated in the 4D2U Astronomer's Talks; lectures were given 3 times. And 4 members participated in Fureai (Friendly) Astronomy classes 6 times. One member was sent to the open campus of VERA Ogasawara station to provide an introduction to the research and 2 mini-lectures. Members also gave public presentations at Anan City Science Center and Mitaka Astronomy Pub.

4. Joint Research/International Collaborations

From Russia, Professor Alexander Gusev and Ms. Ekaterina Kronrod visited the Office for three months and two months, respectively, for joint research on thermo-mineralogical modeling of the lunar interior and future lunar and planetary explorations. Jointly with The People's Republic of China and the Republic of Korea, the Offi ce member held a summer school for planetary science and exploration in East Asia in June in Wuhan City, China. Five Japanese graduate students participated in the summer school to promote international exchange of young scientists.

5. Career Development

One research staff member left the RISE Project Office in September as his term ended. To fill this vacancy, the Office opened an announcement of a job opportunity. The retired research staff member is now employed as a specially appointed associate professor at Aizu University.

14. 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 experiment CLASP (the Chromospheric Lyman-Alpha SpectroPolarimeter), and also preparing for participation in the large balloon-borne experiment Sunrise3. In addition, the activity for participation in the U.S. sounding rocket experiment FOXSI3 has started since Fiscal Year (FY) 2016.

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 latter half of 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 measurement of magnetic fields in the chromosphere and high-resolution imaging/spectroscopic observations that have 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 Project

(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 at the far 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 Sep 2015. The second flight experiment is scheduled for 2019 and will change the observed spectral line from H Lyα to the chromospheric Mg II line at 280 nm.

(2) Sunrise3 Project

The Sunrise3 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 2020. Under the international collaboration, the Japanese team will jointly develop a high-resolution spectropolarimeter that is equivalent to the science instrument planned in SOLAR-C. 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) FOXSI3 Project

The FOXSI3 project is the approved third observational sounding rocket experiment in the US FOXSI program with focusing hard X-ray telescopes. 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 2016

The SOLAR-C proposal, which was submitted to JAXA in Feb 2015, was not selected in the mission definition review as the candidate for the 1st JAXA Strategic Middle-class Satellite Mission. The SOLAR-C WG is refining the science objectives, investigating the possibility of reducing the diameter of the large optical telescope, and rebuilding the international collaboration framework. In terms of the international collaboration, the science objectives team for the next generation solar physics mission, which has been formed at the request of the space agencies JAXA, NASA, and ESA, has started to prioritize the potential JAXA-led solar physics missions for launch in the mid-2020's.

While publishing the first science results from the flight experiment in September 2015, the CLASP project has been preparing for the second flight experiment. The proposal for the second flight has been approved by NASA during FY 2016, and the next flight is scheduled for 2019. We are now preparing for the flight. The Sunrise3 proposal to a German funding agency has also been approved in this fiscal year, and the Japanese team has submitted funding proposals to obtain the development funds. The team has defined the Sunrise3 science cases, and the basic optical design has been carried out to satisfy the requirements. The FOXSI3 project has conducted the development of a high-speed CMOS camera and carried out the test production of a 3D printed alloyed titanium optical baffle for the stray light reduction.

4. Others

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

Dr. D. Song has been appointed as a Project Research Fellow since January 2017.

15. 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 provides archival data of Subaru Telescope, OAO 188-cm Telescope, Kiso 105-cm Schmidt Telescope (the University of Tokyo), MITSuME 50-cm Telescopes (Tokyo Institute of Technology), and KANATA 150-cm Telescope (Hiroshima University). The total amount of opened data is about 17 million frames (119 TB) as of May 2017. SMOKA contributes to many astronomical products. The total number of refereed papers using SMOKA data is 203 as of May 2017.

Continuing from the previous year, in FY 2016, we improved the system for improved operational efficiency and for the development of SMOKA's advanced retrieval functions (i.e. supernova retrieval). In addition, the first Subaru Telescope HSC SSP data release (observations up through November 19, 2015, a total of 850,000 frames) was opened to the public in March 2017.

As of May 2017, we are preparing the design of a new computer system scheduled to begin operation in March 2018 and examining the options for program and data transfer.

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) Upgrading the Wide Area Network service: We have operated the circuit service between Mizusawa and Sendai since 2015. In 2016, the service bandwidth has been upgraded from 40 Gbps to 80 Gbps. Also, we made a 100 Gbps interconnection between NAOJ and SINET operated by NII: National Institute of Informatics.
2) Use of the 100 Gbps Transpac line to the U.S.A.: NAOJ and the WIDE project are jointly operating the Transpac, the US-JAPAN Academic research and education network. The Transpac has 100 Gbps bandwidth of circuits between Tokyo and Seattle. In 2016, SINET, JGN, and Univ. of HAWAII submitted applications to use this circuit. Also through cooperation with the Univ. of HAWAII it became possible to extended the circuit from Seattle to the UH Hilo campus.
3) The Traffic analyzer system was installed: This system can mirror the inbound and outbound internet traffic based on the filter rule conditions. We can make the information and network security enforcement more cost efficient.

4. JVO Project

A new version of the JVO portal (v2), for which the usability of the user interface was greatly improved, was released. ALMA WebQL, a quick-look application for ALMA data, was updated. The feature to query to the atomic/molecular line database was implemented, which enables a user to see the line information just below the spectrum data. The features to display the spectrum data in the rest frame of the target source and to select the color map to be used for drawing an image were also implemented.

A Gaia data search service was released. In comparison to the data search service operated by the Gaia project, our system provides a more user-friendly GUI and also enables a user to search large amounts of data without a limit on the number of search result.

A test version of Subaru WebQL was developed and released. This web application enables a user to adjust the contrast of images so that they can examine the data for not only bright sources but also for dim diffuse sources.

Total number of access counts to the JVO services was 3.6 million and a total of 1 TB was downloaded in the 2016 fiscal year.

5. Project for HSC Data Analysis/Archiving Software Development

This project started in January 2009, primarily to develop the data analysis pipeline and data archiving software for Hyper Suprime-Cam (HSC). Our main effort is concentrated 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.

Since March 2014, the Subaru Strategic Program (SSP) with HSC has been undertaken, producing stable large data output (about 300–400 GB per night). We preformed data analysis of the SSP data, produced a database storing the processed results, and made an internal data releases in August 2016 to the SSP team collaborators. The image products involve 2.6 million files and their total size reached about 200 TB. The catalog database stores about 300 million objects in a 15 TB database volume. We have developed various user interface software for

getting image or catalog products using the database through web browsers, and many of these functions have been offered to collaborators. The hardware and software for the data releases are in stable operation. In February 2017, we made the first world-wide Public Data Release (PDR) based on the data set that was distributed among the SSP collaborators in late January 2016. We have approximately 300 registered users, including individuals from various institutes in about 25 countries. No apparent major problems in the PDR have been reported to date. The PDR is expected to greatly promote scientific outcomes. Major problems in the pipeline software have been significantly reduced, although further improvements to functions are still necessary to achieve the planned accuracies for calibrations/measurements of celestial objects in the images. The on-site data analysis system being developed since 2011 has been supporting SSP and general observations by providing observing tools such as an observation log viewer, which is used to monitor the data analysis results through a web browser. This system has been contributing much to the smooth operation of the Subaru Telescope.

6. Open-use computer system and service

The new rental open-use computer system, "National Astronomical Observatory of Japan: Data analysis, archive, and service system," has been in operation since March 2013. The system plays a leading role as part of the Inter-University Research Institute. The system consists of "Multi-Wavelength data analysis subsystem", "Large data archive and service subsystem" (MASTARS, SMOKA, HSC science, ALMA, VERA, NRO, Okayama and Catalog archive service), "JVO subsystem", "Solar data archive, analysis and service subsystem", "Data analysis subsystem in Mizusawa Campus", and "Development subsystem". The total storage, memory and number of CPU cores within the system are about 6 PB, 13 TB and 2000 cores, respectively. In FY 2016, the total number of valid users was 364 (including 55 users from overseas institutes). We are working to replace the rental computer system in the current year.

In the course of the Inter-University Research we also held and supported some workshops on using software and systems. The dates and numbers of participants in FY 2016 were as follows.

1. HSC-SSP Database school, Apr 11, 2016, 21 users
2. HSC imaging analysis school, Jul 20–21, 2016, 15 users
3. IDL School for FITS data analysis, Aug 2–3, 2016, 12 users
4. SOKENDAI summer student program (Support), Aug 7–31, 2016, 4 users
5. Autumn school "Approach from theory and observation: the character and distribution of the dark matter" (Support), Nov 10–11, 2016, 10 users (analysis workshop)
6. SQL school in FY 2016, Dec 13–14, 2016, 5 users
7. N-body simulation school, Feb 8–10, 2017, 12 users
8. IDL School for the beginner, Feb 28–Mar 1, 2017, 4 users

The total number of participants of the schools in FY 2016 was 83 users.

7. Others

As part of outreach and promotions activities, 97 issues of "ADC News" were published from No. 483 to No. 579 in FY 2016. The news was distributed by E-mail to users and appeared on the ADC web pages.

16. Advanced Technology Center (ATC)

1. Organization and Summary of Activities in ATC

At the Advanced Technology Center (ATC), we are working on the development of astronomical observation equipment that is requested 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, from this fiscal year, we have set up a new R&D framework called "Basic Technology Development," which does not belong to either of the categories "priority area development" or "advanced technology development." These research and development themes shall have a time limit of two years. At the same time, the Advisory Committee for ATC discusses the approach to research and development issues to be tackled at the ATC; in particular, clarifying the directives for selecting the themes for "advanced technology development" as well as how to approach them and making guidelines for organizational building and restructuring "basic technology development" projects.

For ALMA receivers (Bands 4, 8, 10), whose development we have been supporting with the highest priority, shipping was completed in FY 2013 (by March 2014), and then we reformed our organizational structure. From October 2014 we moved to the new organizational structure and carried out not only maintaining the ALMA receivers but also promoting the research, development, and future upgrades to the receivers as well as receivers to be installed on the 45-m reflector and ASTE telescope. Under this organization structure in FY 2016, we have performed ALMA receiver troubleshooting and upgraded the FOREST receiver mounted on the Nobeyama 45-m telescope. In addition, we conducted a commissioning observation with the radio camera on the ASTE telescope led by the radio camera development group that joined ATC last year.

As high priority areas of development, the observation instruments IRIS and WFOS were developed for TMT and the vibration damping, vibration isolator, mirror holders, etc. were successfully developed for the gravitational wave telescope KAGRA.

In the development of IRIS in FY 2016, we have moved forward with the basic design phase (Preliminary design phase). We specified the interface conditions of the IRIS imaging system to be handled by NAOJ/ATC, completed the basic optical and opto-mechanical design and passed through the intermediate review (Preliminary Design Review 1, PDR - 1) in November 2016. Starting in December 2016, we have been making basic designs for electrical systems and software, cost estimates, and the schedule for the final design and manufacturing phases.

We have been studying the concept of a camera system for WFOS, a wide field-of-view multi-object spectroscope, which is another TMT first generation observational instrument. We have continued the concept review of the camera system in FY 2016.

In particular, mainly led by optical engineers at ATC, we redesigned the optical system, analyzed stray light due to specification changes, pointed out the problem of vignetting in the lens system when polycrystalline fluorite was adopted, and then showed the effect on imaging performance and the necessity of measures against stray light within WFOS.

For the KAGRA auxiliary optics, we designed the optical transmission monitoring system (TMS) and made some prototypes last year. In April 2016, the test operation of the initial phase of KAGRA (iKAGRA) was completed. Since manufacturing and testing of almost all of the vibration isolators used in the room temperature part of KAGRA involved in the final design were mostly made by the ME shop at ATC, we are proud that ATC is making a big contribution to the success of KAGRA's trial operation. This fiscal year, continuing from the last fiscal year, we carried out assembly of anti-vibration filters and pre-shipment tests in collaboration with the project office. In addition, we proceeded with the design of the vibration isolation system of the wide-angle scattering baffles to be installed in the immediate vicinity of the cooling mirror.

For advanced technology development, the main themes of research and development are "CLASP, Solar-C", "Telescope Receiver Development", and "HSC".

The CLASP observation rocket experiment is a pioneering project of the solar magnetic field observation of the Sun in the far ultraviolet region. After succeeding in the first experiment carried out in September 2015, we have been preparing for the second flight experiment (planned to launch in 2019) in which the observation wavelength is to be changed. In addition, among the projects the SOLAR-C Preparation Project Office supports, there is a balloon observation project, Sunrise-3, scheduled to be implemented around 2020 after CLASP's second flight. This fiscal year we successfully completed the real optical design of the focal plane observation instrument, SCIP, for Sunrise-3 to be provided by Japan.

In "Development of Telescope Receivers," based on the technology cultivated in the development of the ALMA receivers, we have supported not only evaluation and installation of the Nobeyama FOREST receiver but also development and installation of receivers for 3 cartridge dewars to be used in the ASTE telescope.

In addition, we cooperated with Osaka Prefecture University in GLT receiver development, continued technical cooperation with Nagoya University for the NANTEN 2 telescope, and produced and shipped a three cartridge dewar for the LLAMA Project based on a consignment business contract.

We think that it is one of ATC's important missions to spread the technology and know-how accumulated in ATC to

other projects and universities/research institutions to raise the overall community technologically.

Hyper Suprime-Cam (HSC) started scientific observation from March 2014, and is being used for the observations in a Subaru strategic program (SSP) and open-use observations. Although it has basically worked well up to now, we had a problem occur in the filter replacement mechanism. But we have a prospect that it can be resolved by performing preventive maintenance in a cycle shorter than assumed, because it is partly due to the loosening of the fixation of the machine parts. In order to reduce the time overhead by shortening the CCD readout time, a verification experiment in the laboratory is under consideration with the aim of increasing the CCD readout speed.

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

At the Advisory Committee for ATC (including external committee members), discussions on not only the project promotion system at the Advanced Technology Center, but also the method of research and development contributing to future astronomy were started according to the request from the Director General. In FY 2016 discussions were held primarily about how to carry out advanced technology development contributing to the future of radio camera and infrared detector development.

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 measuring/ultra-precision fabrication teams cooperate to advance projects by leveraging their expertise.

The design team has mainly been working on mechanical design for the KAGRA and TMT/IRIS projects. Major contributions to the projects are as follows,

[KAGRA project]
- Mechanical design of the vibration isolation table for the Beam Reducing Telescope.
- Mechanical design of the Beam Reducing Telescope.
- Assembly of Bottom Filters for the vibration isolation system.
- Mechanical design of the suspension system for wide angle baffles.

[TMT/IRIS project]
- Design and thermal structural analysis of an optical element holder in cryogenic conditions.
- Thermal contraction analysis of the Imager structure.
- Seismic response analysis of overall IRIS structure.
- Cryogenic endurance test of mechanical components (ball bearing and ball screw) for the Imager.
- Attend preliminary design review.

The fabrication team has been working on the auxiliary optical system of KAGRA since last year, and has fabricated a five-axis lens positioner (prototype) for the Beam Reducing Telescopes. In addition, various parts of the vibration isolation system, auxiliary optical system, and transmission monitor system were delivered.

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

In addition, we completed the fabrication of the pupil mirror array holder and the slit mirror array holder final model, which are parts for the IFU (Integral Field Unit) of the Subaru Telescope.

In collaborative development programs, we made the base plate and other prototype parts for an ultra-wide-field high-speed CMOS camera (tomo-e) under development by the University of Tokyo, Institute of Astronomy. Continuing on, we are making the final one-quarter scale model. And, we are supporting the development of a secondary mirror center cone for the TAO project.

The ultra-precision section of the fabrication team has responded to fabrication requests. Development of the wideband 37-pixel corrugated horn array has continued from the previous year. In the same way, trail fabrications for the corrugated horn for the ALMA Band 10 receiver continued and more data required for machining was obtained. Both topics will be continued. A 37-pixel Si lens array with AR coating was successfully finished as a prototype for the 109-pixel Si lens array. This was successfully installed and took data on the Nobeyama 45-m Radio Telescope. But new challenges have

Table 1: The requests in FY 2016.

From FY 2015	6	
ATC	28	
TMT/IRIS	7	
KAGRA	32	
ASTE	3	
CLASP2,SOLAR-C	5	
HSC	1	
TMT	1	
JASMINE	4	
Division of Optical and Infrared Astronomy	1	
Exoplanet Project office	7	
Public Relations Center	2	
Solar Observatory	1	
Subaru Telescope	3	
Okayama Astrophysical Observatory	3	
External Organizations		
IoA, Univ. of Tokyo	2	
Saitama University	2	
Total	102	
To FY 2016		5

arisen in the AR coating, and development will be on going.

The measurement team has responded to not just measurement requests but also supported fabrication in order to assure the high specifications. The main topic among measurement only requests was the measurement of dummy mirrors and connected parts for the KAGRA project. The main topic in fabrication support was the pupil mirror array holder.

(2) Thin Film Processing Unit

Fundamental experiments continued to design and develop the concrete processes of coating using inhomogeneous multilayers. Data were obtained with a simple in-situ monitor for thickness and refractive index during the deposition process. These data were used to try to improve the performance of an AR-multilayer, and it worked.

(3) Space Optics

Acquisition and accumulation of fundamental technologies for space observations using platforms such as balloons, sounding-rockets, and satellites are progressing through planned or ongoing project activities. In FY 2016, Space Optics primarily supported the development activities of solar observation projects that are situated as Advanced Technology Developments in ATC.

Space Optics has supported the development of the polarization calibration system of the second CLASP sounding-rocket experiment in which the target lines for the solar chromosphreric magnetic field observations at FUV wavelengths have changed. A new activity for developing the focal plane instrument of the Sunrise-3 balloon project, which aims for vector magnetic field observations of the solar photosphere and chromosphere from the altitude of the Earth's stratosphere, has started in this fiscal year.

(4) Optical Shop

Activity of the Optical Shop in 2016

1) Management

- Measuring instrument maintenance. (such as daily inspections)
- Technical consulting for users (29 cases)
- Repair and upgrade.
  - Exchange of the clean booth cover for the ZYGO
  - Installation of Keyence VH-B18
  - Upgrade of PC for FT-IR

And others

2) Common use of measurement instruments (April 2016 - March 2017)

- The number of annual user: 267
  NAOJ: 223 (including 99 form ATC)
  External organizations: 44 (including 9 from Institute of Astronomy, University of Tokyo)
- Use of LEGEX910 (large-scale 3-D measurement machine): 23
  Number of operating days: 27

(5) Optical and Infrared Detector Group

We have conducted the second round of the joint purchasing program for MESSIA6, a general purpose focal plane array controller for astronomical instruments, as part of shared use of the Advanced Technology Center. MESSIA6 was build based on the electronics developed for Hyper Suprime-Cam in cooperation with the University of Tokyo, and the High Energy Accelerator Research Organization (KEK). In this year, a total of 6 sets were purchased for 4 organizations including NAOJ divisions. We also supported the installation work of a fully-depleted CCD manufactured by Hamamatsu Photonics K.K. and MESSIA6 for the KOOLS observational instrument of Kyoto University and Okayama Astrophysical Observatory at our laboratory. We continue to provide the documentation of MESSIA6, and support the users for installing MESSIA6 and CCDs onto their instruments.

(6) Facility Management Unit

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

We carried out renovation work on one draft chamber used in washing work etc. in the laboratory to obtain a control wind speed satisfying the regulation value. Regarding the four draft chambers used for cleaning work etc. in the clean room, we have re-renovated three units that did not meet the regulation values.

Also, we replaced the stainless steel discharge piping with PVC in the acid-treated draft chamber with the scrubber decontamination device, as a countermeasure against corrosion of the piping. 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.

With regard to the newly built No. 3 building (TMT building), construction of circulating cooling water facilities was considered in order to be able to use refrigerators in each laboratory, and Cold Evaporator (CE) piping connections are being considered.

There are many projects that use laboratory equipment, including ATC, GWPO/KAGRA, TMT, Division of Radio Astronomy/Chile Observatory, HSC, JASMINE, Division of Optical and Infrared Astronomy, Extrasolar Planet Detection Project Office, Subaru Telescope, Hinode Science Center, and SOLAR-C/CLASP. Projects that require high cleanliness in equipment development use clean rooms. In the 110 clean room of the No.1 building and the 101 large clean room 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 clean room 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 maintaining the defective receivers, and repaired four Band10 receivers during FY 2016.

Table 2: Total number of defective receivers.

Receiver	Total	Breakdown		Repaired in FY 2016	Remaining for repair
		Initial failure	Aging failure		
Band 4	6	3	3	0	0
Band 8	17	14	3	0	0
Band 10	21	6	15	4	5

Table 2 shows the total number of defective receivers broken down into “initial failure” and “aging failure.” And also shown are the number of receivers repaired in FY 2016, and the number of receivers remaining to be repaired. These remaining receivers are still inside of the antennas and will be replaced during receiver system maintenance.

All of the initial failures of Band 10 receiver were fixed in FY 2016. Thus, aging failure of electrical devices will dominate future maintenance. We have continued good collaboration with local engineers in Chile for careful maintenance such as “periodic health checks”, “preventative maintenance” and so on.

(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 FY2016. 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 optical and opto-mechanical design of the IRIS imager. All these designs and documents were reviewed and accepted at the intermediate review (Preliminary Design Review 1) in November, 2016. After the PDR-1, we started working on the preliminary design of electronics, software, etc. and producing a management plan, cost, and schedule for the coming final design phase and fabrication phase.

In parallel, we have been continuing the prototype experiment and trial fabrication looking ahead to the coming final design phase and fabrication phase. The major issues are the durability of the ball screw under the cryogenic conditions, the cooling characteristics of the surface shape of the optical coating, and trail fabrication of the high-precision aspheric mirror.

We have been working on a conceptual study for the WFOS camera system. WFOS is another first generation instrument of TMT. In FY 2016, we figured out new optical designs that meet new requirements. It was found that the vignetting fraction was no less than 30 % as long as we employ a refractive system.

We also assessed an impact of polycrystal calcium fluoride lenses on its image quality, and found that no more than one polycrystal lens should be used in the camera. Thirdly, we conducted a stray light analysis for WFOS, and confirmed that during a full moon scattered light at the dome floor was a significant stray light source. This suggests the importance of internal baffling. An optical designer in ATC contributed to part of the optical designing work and the stray light analysis.

(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 and manufacture of some parts of the transmission monitor system (TMS). This optical system will be located at the end of each 3-km arm optical cavity of KAGRA to monitor the tilt and shift of the beam line, and make feedback signals to the control system. A prototype test of the beam reducing telescope (BRT), which is a part of the TMS, has been done, and the test results have been reflected in the design of the actual setup. The BRTs need to be isolated from vibrations as is done for the other mirrors in the KAGRA interferometer, and the design of the vibration isolation stages for BRTs has been ongoing. In addition, the design of the vibration isolation system for the wide-angle baffles, which will be installed next to the main mirrors, has been ongoing.

KAGRA-VIS is a subsystem to suspend mirrors required for the KAGRA interferometer to isolate them from seismic motions. 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. With these contributions, the initial phase of KAGRA (iKAGRA) finished its test run in April 2016. In this fiscal year we have continued to assemble and test several mechanical filters cooperating with the GWPO. For “standard filters,” 13 out of the required 19 pieces have been assembled, and for “bottom filters,” 2 out of 4 pieces have been assembled. Moreover, for work to upgrade KAGRA (to bKAGRA) in this fiscal year, the GWPO asked us to design a part called "bottom filter recoil mass" and propose the installation procedure. The ME shop did the work, and the designed parts have been installed in KAGRA.

As shared use of the ATC facilities, “pre-isolators” were tested by the GWPO in the large clean room. In addition, researchers from KEK and ICRR tested hydrocatalysis bonding (HCB) of sapphire parts to a sapphire dummy mirror in the ISO1 clean booth. The three-dimensional measurement system was used several times to evaluate the test results.

4. Advanced Technology Developments

(1) CLASP2/Sunrise/SOLAR-C

The CLASP sounding-rocket experiment is a pioneering project of observing the solar magnetic fields at far ultraviolet wavelengths. After succeeding in the first experiment conducted in September 2015, the development team has been preparing the new instrument to observe different chromospheric lines than those observed in the first flight. This will be used for the second flight experiment scheduled in 2019. The major activities in this fiscal year were the modified optical design and the development of the optical components in response to the change of target lines.

The Solar-C Project Office is participating in a balloon project, Sunrise-3, to be launched around 2020 after the CLASP 2nd flight. The detailed optical design of the focal plane instrument, SCIP, that the Japanese team is primarily responsible for has been carried out in this fiscal year.

(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 responsibility for the development and support for installation of the Nobeyama FOREST receiver and the development, tests, and installation of receivers for a 3-cartridge receiver cryostat for the ASTE telescope. And also, we maintain good collaboration with other radio telescopes operated by universities, such as technical collaboration on NANTEN2 with Nagoya University, cooperative production of a receiver for the Greenland Telescope with Osaka Prefecture University, and fabrication of a 3-cartridge receiver cryostat for the LLAMA telescope through a manufacturing cooperation contract with the Universidade de São Paulo.

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, Band 2+, and Band 2+3. 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

We supported ALMA band 1 development and preparation towards production through several technical studies. We also supported studies led by NRAO and ESO for the development of Band 2+ (67–95 GHz) and 2+3 (67–116 GHz) prototype receivers, respectively. In the case of Band 2+, a corrugated horn and dielectric lens have been designed and fabricated. Preliminary tests after integration in the Band 2+ prototype receiver show good performance.

2. Ultra-Wideband receiver

In terms of RF bandwidth, we are developing SIS mixers based on high-critical-current-density junctions with the goal of covering the full ALMA Band 7+8 (275-500 GHz). So far, we have demonstrated a DSB mixer which satisfies ALMA requirements in the full 300-500 GHz band. In addition, we have designed and fabricated corrugated horns and waveguide components for Band 7+8, and are currently evaluating the performance of prototypes. In terms of IF bandwidth, we have successfully achieved the direct connection of an SIS mixer and an IF amplifier, and extended IF bandwidth to 3-18 GHz (currently, 4-8 GHz in ALMA).

3. Terahertz receiver

We have continued the development of optical components and superconducting mixers for the 1.2–1.6 THz band. In FY 2015, we demonstrated the possibility to fabricate good quality corrugated horns for these frequencies. Last year, based on them, we completed the design of ALMA compliant optics. With respect to superconducting mixers, we have worked on the design of a quasi-optical mixer in collaboration with Paris Observatory.

4. Multibeam receiver

We have worked on the concept of a multibeam receiver based on superconducting integrated circuits, and started fabrication of the first prototypes. In addition, we are collaborating with KASI in Korea towards a wideband multibeam receiver.

(3) SIS junction development

We have made steady progress in fabricating high current density (Jc) SIS junctions with the goal of providing a steady supply of high quality mixing devices to be used in receivers installed in telescopes, first and foremost ALMA, as well as future receiver development research. The devices are implemented with a Jc as high as 25–45 kA/cm^2, which is 2–4 times as high as that conventionally achievable. This breakthrough happened one year ago when found an effective way to protect the tunnel barrier from damage during counter electrode deposition by applying a 5 nm thick cap Al layer above the oxide barrier. The mixer devices fabricated in this way have enabled a single receiver to operate across an octave frequency range. With these devices, we demonstrated a receiver operating across two ALMA bands (Band 7 and Band 8) with a sensitivity meeting ALMA specification. This achievement proves the feasibility of improving ALMA observation capability by merging ALMA receivers.

In parallel with the development of high-Jc junctions, we

have initialized an investigation into fabricating SIS mixers on free-standing membranes. This technique is essential for next-generation multi-pixel SIS receivers, which enable a large field of view in a radio telescope. In order to carry out this study, we have setup two sophisticated pieces of equipment in the cleanroom: a deep-reactive-ion etching system (MUC-21, Sumitomo Precision Co.) and a SUSS MA6 mask aligner that enables backside alignment. We have established a fabrication process of Si membranes from silicon-on-insulator wafers and demonstrated 6-micrometer thick free-standing Silicon membranes with a diameter of 3 mm and flat surface (the maximum bending is less than 5 micrometers). This achievement brings us a bright outlook, especially for the development of multibeam receivers with a wider field of view for ALMA.

(4) HSC

Hyper Suprime-Cam (HSC) started its science operation in March, 2014 and has been offered to the Subaru Strategic Program (SSP) and general observer's programs. During the two years so far, 137 nights were allocated for SSP and a similar number of nights were allocated for general observers. The operation has been stable over this time, but during FY 2016, we encountered mechanical problems several times in the actuators of the central unit (CU) of the filter exchanger system. An ATC engineer found several loose bolts in the CU. This suggests the importance and necessity of preventive maintenance more frequently than we had originally planned. We found the first CCD failure on April 2012 and the number of failed CCDs grew to three by May 2015. No new trouble in the CCDs was, however, reported in FY 2016. If we see more detector failure, we will have to decrease the back bias voltage to reduce the risk but this causes degradation of image resolution. Careful trade-off studies should be made based on the on-going lab experiments. After two years of SSP observations were completed, it became evident that the survey speed is about 80 % of the original plan. This is mainly because the weather was worse than our estimate of the number of clear nights. One possible solution is to reduce the CCD readout time by paying a penalty of increased readout noise. In FY 2017, we should work out optimization of the CCD clocking. This is worth spending time because even a moderate squeeze amounts to big savings of observing times over the decades of HSC operation. In fact, Suprime-Cam has been used over 19 years. We planned to install the detection efficiency monitor in FY 2016 but it was postponed due to the delay of M1 re-coating. We will set it up in October, 2017.

5. Basic Technology Development

(1) MKID camera /CMB Instruments

We are developing a wide field of view, broadband, and high sensitivity millimeter / submillimeter wave instruments. 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 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) Development of broadband corrugated horn array (S. Sekiguchi et al. 2017 IEEE TST)
2) Broadband antireflection structure on Si (T. Nitta et al. 2017 IEEE TST)
3) Design of Octave-band OMT-MKID (S. Shibo et al. 2016 SPIE)
4) Confirmation of the interface between the data acquisition system of the MKID camera and the Nobeyama 45-m Radio Telescope by a test installation

(2) Near-IR Imaging Sensor Developments

In this year, we have made a trial chip of small-pixel and large-format Indium Gallium Arsenide (InGaAs) image sensors in cooperation with KEK, Hiroshima University, and Kagoshima University. The cost is expected to be lower than existing near-infrared sensors. We have successfully made fully-functional chips with a small number of bad pixels, however the readout noise slightly increased. Near infrared test observations were conducted with the manufactured chips attached to Hiroshima University's Kanata Telescope. We continue to investigate making a low noise InGaAs image sensor compatible with both small-pixels and large-format, which is suitable for a near-infrared wide field camera.

(3) Multicolor Millimeter/Submillimeter Continuum Camera

Exploring a large patch of the sky in the millimeter/submillimeter bands with a continuum camera will provide the opportunities to effectively measure the redshifts of submillimeter galaxies, the structure of the hot plasma in clusters of galaxies, and the physical properties of the dust in star-forming regions. Thus, we are developing a Transition Edge Sensor (TES) bolometer camera in collaboration with the University of Tokyo, Hokkaido University, the University of California Berkeley, and McGill University.

In FY 2016, science commissioning of the bolometer camera, capable of simultaneous observation at 1.1 mm and 0.87 mm wavelengths, on board the ASTE telescope was conducted. As a result, we have achieved the target mapping speed at the 0.87 mm wavelength, and demonstrated the effectiveness of the novel intensity calibration instrument. Our experiences are shared with the development projects such as DESHIMA and A-Pol to enhance the continuum observation capability in East Asia.

(4) Development of Terahertz Intensity Interferometry

New interferometer technology making use of intensity fluctuations in astronomical sources has been developed in the terahertz frequency region. In collaboration with the National

Institute of Advanced Industrial Science and Technology (AIST), low leakage superconducting tunnel junction detectors are being developed, and their leakage current is evaluated and fedback to the fabrication process. Compact sorption coolers were developed to cool the wide bandwidth SIS photon detectors, showing a cooling capacity of 400 uW at 0.8 K. Our proposal for imaging intensity interferometry is based on delay time measurement using photon bunches, which was demonstrated by simulation and presented in workshops. The development of SIS photon detectors is made possible by the grant-in-aid for challenging exploratory research programs from JSPS.

6. Open Use Programs, Joint Research, and Development

In FY 2016, we accepted open use programs of ATC facilities twice a year including 10 collaboration programs and 23 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.

17. Public Relations Center

1. Overview

The Public Relations Center engages in the publication, promulgation, and promotion of scientific achievements made not only by NAOJ but also by others in the field of astronomy in general to raise public awareness; responds to reports of discoveries of new astronomical objects; and provides the ephemeris and other astronomical information directly related to people's everyday activities, such as sunrise and sunset times. In FY 2016, 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 2016, 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 of the Library, 5 specially appointed senior specialists, 3 research experts, 21 public outreach officials, 1 research supporter, and 2 administrative supporters.

On April 1, 2016, Associate Professor Hitoshi Yamaoka arrived and specially appointed senior specialist Hiroko Tsuzuki arrived in the Public Relations Office on September 12.

On November 30, 2016, public outreach official Diaz Rosas Elian Abril in the IAU Office of Astronomy Outreach finished her term. On March 31,2017, public outreach official Takao Ibaraki, public outreach official Kuninori Iwashiro, and public outreach official Hiroshi Futami finished their terms.

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. Our office organized and held independent workshops with public relation officials to improve the skills of outreach personnel.

(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.

Last fiscal year, a special website "Multiwavelength Universe"English version was opened. This website won the WebAward 2016 Best Science Site.

For the NAOJ Chile Observatory, the Public Relations Office reviewed and offered advice on the proposal for the website renewal.

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 2017, the number of followers exceeds 80,000. From this fiscal year, we have strengthened our English version of Twitter. In the second half of the fiscal year, we started to post daily. Also, NAOJ quizzes on Twitter were started and they made the Twitter more interactive. Also, from this fiscal year, our office started to disseminate visual images on Instagram.

NAOJ e-mail newsletters No.159–171 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, 19 original videos were produced. The videos are uploaded mainly on YouTube. As of the end of March 2017, these videos have accumulated a total of 459,139 minutes of play time and 86,005 views. This fiscal year, as a new effort, our office twice performed live stream broadcasting of heavenly bodies with the 50-cm Telescope for Public Outreach. There were about 2,000 viewers in total. In addition, we conducted live internet broadcasts including the lectures mentioned below and on Mitaka Open House Day.

Month	Access counts	Month	Access counts	Month	Access counts
April 2016	358,635	August 2016	1,237,959	December 2016	522,840
May 2016	579,476	September 2016	444,328	January 2017	620,472
June 2016	555,124	October 2016	430,131	February 2017	481,406
July 2016	463,076	November 2016	532,127	March 2017	386,173
Total: 6,611,747					

Table 1: Monthly website access statistics for the Public Relations Office website, NAOJ Public Relations Center (April 2016–March 2017).

“Keiichi Kodaira Video Clip”for the digital book	English Version
Hunting Black Holes	Japanese/English Versions
“FUREAI (Friendly) Astronomy” PR movie	Japanese Version
HSC/M31 Video Clip	
HSC/Virgo1 Video Clip	
Dr. Flaminio interview about Breakthrough Prize in Fundamental Physics	Japanese/English/Italian Versions
Dr. Barton interview about Breakthrough Prize in Fundamental Physics	Japanese/English Versions
Project PR movie “Public Relations Center”	Japanese Version
Perseid Meteor Shower (Aug.12, 2016)	Japanese Version
CfCA “Pulsar Video Clip”	
Project PR movie “Okayama Astrophysical Observatory”	Japanese Version
Project PR movie “Subaru Telescope”	Japanese Version
Project PR movie “NAOJ Chile Observatory”	Japanese Version
Cultural Properties Protection Week Movie “NAOJ Solar Tower Telescope”	Japanese/English Versions

Table 2: Summary of Produced Videos.

May 11, 2016	New Test by Deepest Galaxy Map Finds Einstein's Theory Stands True
May 25, 2016	Footprints of Baby Planets Imprinted in a Gas Disk
June 7, 2016	Japan OISTER collaboration uncovers the origin of extraordinary supernovae
July 26, 2016	Ancient Eye in the Sky
August 12, 2016	Dense molecular gas disks drive the growth of supermassive black holes—Are supernova explosions the key?
September 5, 2016	Discovery of an Extragalactic Hot Molecular Core
October 31, 2016	A joint observation by solar observing satellites Hinode and IRIS quantitatively explores the formation of the solar chromosphere
November 21, 2016	Discovery of Unexpected Supersonic Events Everywhere on the Sun - Results from 5-minute Flight of the Sounding Rocket Experiment “CLASP” -
November 22, 2016	Record-breaking Faint Satellite Galaxy of the Milky Way Discovered*
November 28, 2016	Timing the Shadow of a Potentially Habitable Extrasolar Planet Paves the Way to Search for Alien Life
December 5, 2016	ALMA measures size of seeds of planets
January 16, 2017	Tail of Stray Black Hole hiding in the Milky Way
January 24, 2017	Micro spacecraft investigates cometary water mystery
January 31, 2017	Tracing the Cosmic Web with Star-forming Galaxies in the Distant Universe
February 24, 2017	Saturn’s Rings Viewed in the Mid-infrared
February 28, 2017	First Public Data Release by the Hyper Suprime-Cam Subaru Strategic Program
March 8, 2017	Ancient Stardust Sheds Light on the First Stars — Most distant object ever observed by ALMA
March 29, 2017	Subaru Telescope Detects the Shadow of a Gas Cloud in an Ancient Proto-supercluster
January 15, 2016	Signs of Second Largest Black Hole in the Milky Way - Possible Missing Link in Black Hole Evolution
February 4, 2016	A Violent Wind Blown from the Heart of a Galaxy Tells the Tale of a Merger
February 25, 2016	Subaru-HiCIAO Spots Young Stars Surreptitiously Gluttonizing Their Birth Clouds
February 25, 2016	New Fast Radio Burst Discovery Finds ‘Missing Matter’ in the Universe
March 3, 2016	ALMA Spots Baby Star’s Growing Blanket
March 10, 2016	Deciphering Compact Galaxies in the Young Universe
March 10, 2016	Mysterious Infrared Light from Space Resolved Perfectly

Table 3: Web Releases.

June 16, 2016	ALMA Detected the Most Distant Oxygen
September 6, 2016	Avoiding “Traffic Jam” Creates Impossibly Bright “Lighthouse”*

Table 4: Press Conferences.

(2) Research Result PR

There were 20 research result announcements (compared to 27 in FY 2015 and 16 in FY 2014). For press releases aimed towards overseas audiences, we have continued to use the delivery services of American Astronomical Society, AlphaGalileo, and EurekAlert! from AAAS. We released almost 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 23rd lecture entitled "ALMA Opens a New Astronomy" was held on December 2, 2016. Thirty people (23 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 June 11, 2016, NAOJ and Riken Lecture "Origin of Materials told by the Universe;" on September 10, Hinode 10th anniversary lecture "Exploring the Universe and the Earth through Solar Observations;" and on November 26, the NAOJ lecture meeting/22nd ALMA public lecture "Exploring birth of stars and planets with ALMA" were held respectively. In addition, the office persevered in helping to organize and publicize the Subaru Telescope/ Shinshu University public lecture "From Shinshu via Hawai'i, a Galactic Research Journey" on November 23 and "The Subaru Telescope/Hiroshima University public lecture" on November 27.

Furthermore, since the 23rd NINS Symposium "Frontiers of Modern Astronomy: a Second Earth and the Dark Universe" was held on March 5, 2017 with NAOJ responsible for the planning and operating, the Public Relations Center was at the center of holding the event, in cooperation with the General Affairs Section, General Affairs Division.

To expand our public relation materials, our office took photographs at Mizusawa VLBI Observatory, Okayama Astrophysical Observatory, and KAGRA. For KAGRA, movies were also taken simultaneously.

Our office organized workshops with public relation officials inviting lectures from outside to improve the skills of outreach personnel. Training in photography was offered on July 25, 2016, and training in science writing was offered on January 18, 2017.

To publicize NAOJ abroad, we exhibited booths at oversea meetings for the public and events where the press gathers (New Scientist Live in London: September 2016 and AAAS meeting in Boston, February 2017). In addition, we ordered an outside film maker to make a 6 minute video for release at the American Physical Society Annual Meeting and screened it in March 2017.

(4) New Astronomical Objects

From this fiscal year, the responsibility for New Astronomical Objects moved from the Ephemeris Computation Office to the Public Relations Office. 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 15 reports including confirmation requests for new celestial object candidates and other reports. The contents were: 4 novae/ supernovae, 6 variable stars/transient objects, 1 comet, 1 minor planet, and 3 luminous objects. Among the many examples of reporting a variable star or known asteroid as a new object, the report of a transient object in September, was communicated via NAOJ to the IAU Central Bureau for Astronomical Telegrams and was recognized as an independent discovery of Nova Scorpii 2016 No. 2 (V1656 Sco.)

4. Outreach and Education Office

(1) Public Visits

A total of 20,522 people visited the Mitaka Campus Visitors' Area in FY 2016. In addition, the group tours in 2016, consisted of 110 general tours (4,408 guests), and 36 workplace visits by schools (362 guests), for a total of 146 tours accommodating 4,770 guests. Note that in the workplace visits, lectures by researchers, question-and-answer sessions, and visits to research facilities also took place. The office started developing the audio guide in the Visitors' Area. From October, our office began experimental operation at the 20-cm Telescope Dome, Repsold Transit Instrument Building, Gautier Meridian Circle Building, and Astronomical Instrument Museum.

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 4,671 participants this year. The Regular Stargazing Parties celebrated their 20th anniversary in April 2016. More than 60,000 guests have visited in these 20 years.

	Solar info	Lunar info	Ephemeris info	Time	Solar System	Universe	Astronomy	Other	Total
April–June	167	70	43	28	330	92	147	554	1431
July–September	126	110	63	15	209	149	134	803	1609
October–December	192	233	44	4	276	121	137	649	1656
January–March	136	63	29	6	225	112	107	400	1078

Table 5: Telephone inquiries made to the Outreach and Education Office of the NAOJ Public Relations Center (April 2016–March 2017).

The Outreach and Education Office changed the regular public screenings at the 4D2U Dome Theater from three times a month to four times (1st, 2nd, 3rd Saturday, the day before the 2nd Saturday). Advanced reservations were required for these. A total of 47 screenings were held this year, with 5,432 guests participating. For five of the regular public screenings, the office held "Astronomer's Talks" where NAOJ researchers talked about the latest research and these were popular. Group screening used to only be performed on Fridays, but we changed to Wednesdays and Fridays. Therefore, the number of group tours became larger and 81 group screenings were held with 2,655 guests attending. Especially at Wednesday group screenings, teacher training sessions were held. 96 tours were organized with 1,189 attendees. In total, 224 screenings were held and a total of 9,276 guests enjoyed 4D2U's stereoscopic images.

The regular "Tangible Cultural Property Tours" ceased operation at the end of March 2016. In 2016, the NAOJ Solar Tower Telescope Special Open Days (November 3, November 5, and November 6, no reservations needed) and Tangible Cultural Heritage Tours (November 3 and March 20, advance reservations needed) were held with 624 attendees.

(2) Telephone Inquiries

The office received inquiries from the media, government offices, and the general public. The Outreach and Education Office responded to 5,774 telephone inquiries (Table 5) and 134 letters, 52 of which were official documents.

(3) Educational and Outreach Activities

For the "Fureai (Friendly) Astronomy" project, now in its 7th year, a total of 49 lecturers provided events to 80 schools out of the 86 which applied, reaching 8,017 students.

We presented the results of the questionnaire performed in Fiscal Year 2015, at the Japanese Society for Education and Popularization of Astronomy Meeting and The Astronomical Society of Japan Fall Meeting. Particularly noteworthy is that for the Astronomical Society of Japan meeting, we presented at the press conference.

"Summer Nights: Let's Count Shooing Stars, 2016" was conducted in August 2016 and we received 2,311 reports. A paper showing the possibility of obtaining observation results close to skilled observers by collecting a large number of reports from the general public was published in "Planetary and Space Science."

On August 16 (Tuesday) and August 17 (Wednesday), "Astronomy classes for kids in Summer" events were held for elementary and junior high school students. On the first day, there were lectures about the assembly and use of telescopes. In cooperation with the JASMINE Project Office, the second day was lectures about the distances of celestial bodies, three-dimensional star handcrafts of the big dipper, and an interpretation using the four-dimensional digital universe viewer, "Mitaka." Also, star gazing parties were scheduled for both days (Cancelled on the first day due to the typhoon.) The total number of attendees was 77.

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 21 (Friday) and October 22 (Saturday) with the theme "Gravitational Waves, a new Frontier of Astronomy." 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: 542 guests attended on pre-open day, 3,992 guests attended on open day, 4,534 guests attended in total. Each Project offered a selection of activities based on their own expertise which were suitable for a wide range of age groups. Activities included the viewing of facilities not normally open to the public, interactive panel displays, minilectures, quizzes and games that are popular among children, and a virtual reality experience.

From October 2 (Sunday) to October 4 (Tuesday), the "Workshop for Popularizing Cutting-Edge Astronomy" was held with the theme of "Gravitational Wave Astronomy" for staff members of science museums/museums, teachers, and science communicators, who are doing astronomy outreach work. Lectures were held at the University of Toyama and attendees also visited the Large-scale Cryogenic Gravitational Wave Telescope KAGRA of the Institute for Cosmic Ray Research, University of Tokyo; the Underground Neutrino Detector Super-Kamiokande; and the Kamioka Liquid Scintillator Antineutrino Detector (KamLAND, Tohoku University). 64 guests attended.

On March 2 (Thursday) and March 3 (Friday), NAOJ, the International Planetarium Society, and others, co-hosted the "Data to Dome Workshop" at the Large Seminar Room and 4D2U Dome Theater. The aims of this international hands-on workshop were to enable easy visualization and extend the possibility of science communication in planetariums. 52 guests attended including 9 invited speakers and 15 attendees from overseas (U.S.A., Canada, Taiwan, Germany, South Africa, Hong Kong, the Netherlands, and Sri Lanka.)

(4) Community Activities

The "Mitaka Picture Book House in the Astronomical Observatory Forest" welcomed 41,068 visitors in FY 2016. The Outreach and Education Office supervised the exhibition "Ephemeris Counting Life (July 2016 – June 2017)." We also cooperated with 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 3 winning books.

The Outreach and Education Office conducted the 8th"Mitaka Solar System Walk" from Friday, September 23 to Sunday, October 23 in cooperation with Mitaka City and the non-profit organization (NPO) Mitaka Network University

Promotion Organization. Stamps were placed at 170 shops and 67 facilities, including NAOJ Mitaka Campus and the Mitaka City Municipal Office, for a total of 237 locations around Mitaka. Adding 19 limited stamps, 256 stamps were placed and this is a record number. Approximately 18,000 guide-maps/ stamp sheets were distributed, of which 3,379 people turned theirs in for a prize. The number of participants who collected all the stamps was 387. It was a good chance to tour the Solar System while promoting commerce, industry, sightseeing and providing families with a way to enjoy Mitaka and rediscover the city's charm.

The Outreach and Education Office also provided the venue for "Astronomy Course for Apprentice Starry Sky Guides, Star Sommelier Mitaka - Let's Become Apprentice Starry Sky Guides! - " hosted by Mitaka Network University and also assisted 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 second year since its opening and 11 exhibitions were held in FY 2016. 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 "M Marche Project" conducted on the 4th Sunday of every month. We welcomed 21,674 guests in the 2016 fiscal year and celebrated 20,000 visitors and 30,000 visitors since the opening. It has been acknowledged as a location in town where science can be easily accessed.

(5) Merchandizing Business

The office cooperated with merchants who organized the NAOJ original goods and aided in making 5 types of goods and 132 individual products, such as pin badges, cultural property facility post cards, and T-shirts. In addition, the office invited merchants to place vending machines dispensing capsule toys starting from August 2016. These were placed so that visitors can buy goods when the Co-op store is closed on Saturdays and Sundays. Also, the office invited booths selling goods at the Mitaka Open House Day. A total of 1,230 items of these goods were sold in the year.

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 2017 edition of the Calendar and Ephemeris, the 2017 version of the calendrical section of the Rika Nenpyo (Chronological Scientific Tables), and the 2018 edition of the Reki Yoko (posted in the official gazette on February 1, 2017). 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, Geminid, and Quadrantid meteor showers were published in the Astronomical Information section of the website. There were about 24 million page views for this fiscal year.

(3) The Japan Association for Calendars and Culture Promotion hosted its 6th 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 written in Japanese/Chinese. The themes of the 54th and 55th permanent exhibitions were "24 Sekki and Calendar" and "Shigetomi Hazama" respectively. These exhibits can also be viewed at the Rare Materials Exhibition of the Library's website, in Japanese only (http://library.nao.ac.jp/kichou/open/index.html).

(5) New Astronomical Objects work was transferred to the Public Relations Office this fiscal year.

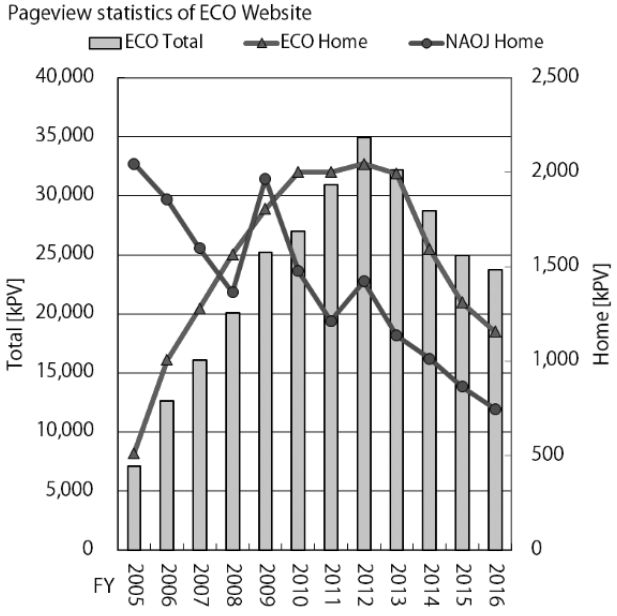

Figure 1: Pageview Statistics of ECO Website.

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 2016, 249 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 2016, photocopies or loans were provided in a total of 96 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.

During the Mitaka Open House Day festivities in October, we used to open part of the Mitaka Library to the public, but in Fiscal Year 2016, we extended the subject themes. 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 28 Fiscal 2015 (Japanese)
- Annual Report of the National Astronomical Observatory of JAPAN Volume 18 Fiscal 2015 (English)
- Report of the National Astronomical Observatory of JAPAN Volume 18 (Japanese)
- NAOJ Pamphlet (Japanese)
- NAOJ Pamphlet (English)
- NAOJ News, No. 273 – No. 284 (April 2016–March 2017)
- Radio Astronomy Public Relations comic "Almar's Adventure" (#6)
- NAOJ Publicity Poster Series (#4, #5, #6)

Continuing from the previous year, in FY 2015 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), the authors performed the first check of the English translation and it is in layout. In digitalization efforts, the Office brushed up the "NAOJ-Universal Multi-Publication System (NAO-JUMPS)," which includes research highlight of the Annual Report of the NAOJ and fixed layout articles from NAOJ News. Together with this, the first book Makali'i in Hawai'i "(ISBN978-4-908895-01-2) was published using the generalized electronic book platform "NAOJ-Delivering next-generation e-books (NAOJ-Deneb)." In normal business, the Office produced and distributed the NAOJ pamphlets and the Annual Report of the National Astronomical Observatory of JAPAN. In the systematic production of special editions with the goal of developing project outreach support in NAOJ News, extra copies of each of the special editions ("The Subaru Telescope Special Edition 2016" July; "Mizusawa VLBI Observatory Special Edition" December; "Hinode Solar Observatory 10th Anniversary Special Edition" January; and "People Involved in the TMT Project Vol.01 Special Edition" March) were printed and these aided the outreach efforts of each project. The TMT Special Edition is especially noteworthy because the office conducted international interviews in California and Hawai'i. The March issue was the California issue, including 12 articles published in both Japanese and English, making a concerted effort towards content internationalization. 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 2017 calendar "SUBARU Telescope" (the 12th since 2005) was created. The Office provided native check services to the Public Relations Office; General Affairs Division, Administration Department; and Hinode Science Center for English language publications, contributing to the expansion and enhancement of NAOJ's international information dissemination. In addition, like in other years support was also given to the publication of the "Rika Nenpyo, (Chronological Scientific Tables)."

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

The Office for Astronomy Outreach (OAO) of the International Astronomical Union (IAU), which is established as an office in the Public Relations Center, communicated with National Outreach Contacts (NOC's) (windows for outreach in each country) in an effort to strengthen cooperative relationships, communication, and coordination with 69 NOC's as of the end of the 2016 fiscal year. Significant progress was made between 17 NOC's this fiscal year. In relation to this, IAU OAO announced that from the next fiscal year we would begin discussing outreach systems for each country that would be more effective in achieving the objectives in the near future.

For international information provision, the office posted a total of 550 postings from OAO on IAU social media during FY 2016. The Facebook community grew by 33 % and the Twitter community by 40 %. Meanwhile, the IAU Astronomy Outreach Newsletter (e-mail news) was delivered 24 times and 300 items of information were provided to 4,500 subscribers all over the world. The newsletter has been translated and redistributed into four different languages by collaborators in the respective countries.

On May 16–20, 2016, the International Conference

CAP2016 of the IAU C2 committee was held in Medellín City, Colombia with 140 participants from 30 countries. OAO contributed to the management of the conference as one of the Executive Chairs, and many staff members participated and deepened international relations through presentations, workshops, etc. In cooperation with the Outreach and Education Office and others, the Office successfully invited the international conference CAP 2018 to Fukuoka and is proceeding on preparatory work in cooperation with the convention organizing committee members, Fukuoka City, and others.

From September 24 to September 26, NAOJ and the Japanese Society for Education and Popularization of Astronomy co-hosted "The 3rd Symposium on Universal Design for Astronomy Education" at NAOJ Mitaka Campus with 131 attendees from 15 countries.

Our office also conducted a survey on the translation network and summarized the key issues for OAO stakeholders and the astronomy outreach community in establishing translation services and language translation requests as part of OAO's activities. We held several evaluation meetings during FY 2016 and begin experimental translation network projects from FY 2017.

IAU OAO received international evaluation by IAU and NAOJ from August 31 to September 2. This is because the agreement on OAO between the IAU and NAOJ was set to expire at the end of the current fiscal year. A thorough and fruitful evaluation process was carried out. The main recommendation from the evaluators was that the scope of astronomy outreach is very wide, so OAO should focus on narrowing down its priorities, and performing projects in a systematic way. In response to the evaluation, OAO reviewed its organization and division of labor, and after having attended the Intercultural Communication Seminar, OAO is pursuing its activities under a new organization structure. In February 2017, IAU and NAOJ exchanged new agreements for 2017-2021 based on the evaluation results.

18. Division of Optical and Infrared Astronomy

1. Overview

The primary objectives of divisions in NAOJ are facilitating and invigorating projects and individual research through personnel exchanges to place researchers in environments more suitable for their individual projects. While pursuing challenging exploratory research on observation and development, the division furthers these goals 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 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 2016 consisted of two professors, and four assistant professors (including one specially appointed assistant professor).

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, Extrasolar Planet Detection Project Office, Gravitational Wave Project Office, and JASMINE Project Office. The remainder of this report will focus on the research projects conducted by the primary staff of the Division of Optical and Infrared Astronomy and the activities of projects that support open use.

2. Observational Research

(1) Observational Research Using Various Types of Telescopes

Observational research utilizing the Subaru Telescope focuses on a wide variety of fields such as cosmology; galaxy formation and evolution; the formation of stars and planets; the structure and evolution of the Milky Way; stellar spectroscopy; Solar System bodies; and the search for exo-planets. A survey of high-z quasars was conducted in the survey data of Hyper Suprime-Cam (HSC) on the Subaru Telescope. A comet which was accidentally captured in a queue observation was analyzed and utilized as data about the dust trail. Comets were observed at the Kiso Observatory of the University of Tokyo. The data reduction in the search for extrasolar planets using direct imaging methods continued. Based on the infrared observations of protoplanetary disks by the Subaru Telescope, observations were proposed to ALMA, and some data were obtained successfully.

(2) International Cooperative Observational Research

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

Planning of the observations and the collaboration with the Fessenkov Astrophysical Institute at Kazakhstan was promoted for a cooperative observations with the East Asian Core Observatories Association (EACOA) medium-size telescope and the Optical and Infrared Synergetic Telescopes for Education and Research (OISTER). In the OISTER workshop held on November 21–22, 2016 at Kyoto University, a talk was given by an attendee from the Fessenkov Astrophysical Institute. A Kazakhstan-Japan Mini Workshop was held at the Fessenkov Astrophysical Institute at Almaty, Kazakhstan during March 28–April 1.

The site survey in western Tibet continued in cooperation with the National Astronomical Observatories, Chinese Academy of Sciences (NAOC). Discussions for the site assessment and construction of a telescope were held with researchers of NAOC, the Purple Mountain Observatory, and Hiroshima University.

A study on extended ionized gas in the Leo cluster was conducted with researchers in Italy. A study on extended ultraviolet regions around galaxies continued with researchers in the USA.

(3) Research Using Archives

Researches on the verification of astronomical phenomena described in the New Testament started jointly with the National Institutes for the Humanities. Studies of astronomical phenomena based on other old ephemerides and documents continued. A statistical study on Ultra Diffuse Galaxies in the Coma Cluster was conducted using archive data from the Subaru Telescope.

The image data of the Kiso Ultraviolet-excess Galaxies (KUG) catalog and the corrections of the positions based on the images were made available on the web page of the Kiso Observatory. A paper on the update was submitted. Digitization of Kiso Schmidt plates continued.

3. Observational Instrument Development

The effect of the environment inside the dome on seeing size at the Subaru Telescope has been studied through collaboration with Chofu Aerospace Center of JAXA (Japan Aerospace Exploration Agency), Tokyo Denki University, and RIKEN. The procedure to compare the results of a fluid calculation and a water-flow experiment with the data from the Subaru Telescope environment sensors in the dome was investigated. Analysis of the ghost images of bright stars in the data of Hyper Suprime-Cam at the Subaru Telescope was conducted and a presentation was made about correction methods. Commissioning and tests of the Hosei Twin Astronomical Telescopes (HOTATE) and observations using it were supported.

4. Operational Support for Subaru Telescope

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

5. Research Environment Maintenance

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. The Division maintains the web servers and their contents, and also gives assistance for setting-up computers for new administrative supporters.

6. Planning of Next-generation Large-Scale Projects

The Division is engaged in planning post-Subaru large projects in optical and infrared astronomy, such as TMT and the JASMINE series. The preparation for the assessment of new infrared detectors by the maintenance of old instruments continued.

7. PR, Outreach, and Discovery of New Astronomical Objects

The Division cooperates with the Public Relations Center in supporting matters related to the discovery of new astronomical objects and PR/outreach activities such as publications and press conferences related to Subaru Telescope research results. A Tanabata talk event at Koganei was supported. The Division actively participates in a special public event held at Mitaka Campus (Mitaka Open House Day).

8. Educational Activities

The Division of Optical and Infrared Astronomy provides postgraduate education to 23 graduate students from the Graduate University of Advanced Studies, the University of Tokyo, Tokyo Institute of Technology, Nihon University, Hosei University, and the University of Electro-Communications. Division staff members made active contributions to seminars and self-directed studies. Since April 2015 we have held a 30-minute seminar in the afternoon every day throughout the year. In December, we held the annual workshop of the Division of Optical and Infrared Astronomy so that staff members and graduate students can understand the current studies and interests of each other. The Division participated in the "Fureai (Friendly) Astronomy" project, dispatching lecturers to various schools around the country, providing pupils at elementary and junior high schools with opportunities to learn about and appreciate astronomy.

In collaboration with M-JEED, which is a project by Mongolia and Japan for a higher engineering education development promoted by the Japan International Cooperation Agency (JICA), research abilities and human training were improved through collaborations between teachers and researchers in the National University of Mongolia and NAOJ. In FY 2016, three NAOJ academic staffs visited the National University of Mongolia during September 5-10 and lectured on astronomy.

19. Division of Radio Astronomy

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

1. Radio Astronomy Frequency Subcommittee

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

Just as light pollution from artificial light sources is an obstacle in optical observation, artificial radio interference generated by the electronic devices which surround us is a major obstacle in radio observations. Breathtaking advancement has been achieved in wireless communication technologies in recent years, and wireless commercial products such as mobile phones, wireless LANs, and automotive radars are widely used. The areas of radio applications will further expand in the future owing to 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 the protection activities. Radio astronomical observation does not emit radio waves; thus, it does not interfere with other wireless communications. A proactive approach is needed to widely raise awareness of the efforts to protect the environment for radio observations. Regular explanatory sessions are provided at the Ministry of Internal Affairs and Communications (MIC) and regional Bureaus of Telecommunications to solicit appreciation of the importance of protecting the field.

The coordination between the community of radio astronomy and commercial wireless operators is led by MIC within Japan and internationally by the International Telecommunication Union (ITU) Radiocommunication Sector (ITU-R) of the United Nations. As part of the activities for FY 2016 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 increased due to 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 have become common. Wide band radars up to 81 GHz may become more popular as they may reduce car accidents resulting in injury or death. And, transportation of high speed and high volume data, such as HDTV quality video, is becoming possible through 60 GHz radio transmission systems. 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; a number of new UWB wireless applications used by logistics and manufacturing industries, where geodetic observations are affected; 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 2016, the Subcommittee participated in the ITU-R WP7D meetings in April and October and the WP1A meetings in May and November held in Geneva; and APG19-1 meeting in July in Chengdu, China. 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; upgrading 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 the radio astronomy activities, 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 eleven 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 MIC, direct negotiations for MIC's authorization with wireless operators who generate radio interference, and promotion to raise public awareness about radio interference to radio astronomical observations. Negotiations with wireless operators to reduce interference sources represent a major part of the Subcommittee's activities in Japan.

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

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

For 24 GHz automotive radars, new regulations have been prepared to make an automatic turn-off function a mandatory standard feature so that the device is disabled upon reaching certain areas around radio observatories.

In November 2015 WRC-15 resolved to allocate 77.5–78 GHz to the radiolocation service, allowing automotive vehicles to utilize the whole 76–81 GHz band for their radar, while there is a predicted increase in the use of 76 GHz and 79 GHz high resolution automobile radars. Of particular concern are the possible effects of interference from these radars on the 45-m radio telescope at Nobeyama Radio Observatory, which engages in observations of the 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 prototype bandpass filter to suppress spurious signals to an acceptable level. NHK plans to verify its performance further on a future satellite set to launch in December, 2017.

Radio observations in the 60 GHz band are not common because of the high atmospheric absorption rate in that frequency range. Albeit in fact, the 60 GHz system must be watched closely in terms of its proliferation in the market, since

interference from it may affect CO observations in the 115 GHz band, which is within the band of the second harmonics of the 60 GHz radio system.

Following the MIC discussion for improving disaster measures, the committee discussed with Globalstar Inc. (USA) and signed the revision to the operating condition agreement to establish guard channels and radio quiet zones considering the risk of interference to the radio astronomy (OH maser observation) band from spurious emissions from the 1.6 GHz satellite uplink signal.

In a MIC working group, the Subcommittee was originally concerned that Ka-band broad-band satellite communication services may cause interference to radio astronomy observatories in Japan. However, the evaluation of both the 22 GHz downlink and airliners' 30 GHz uplink signal resulted in developing appropriate operating conditions with no risk of interference to the observatories including Nobeyama Radio Observatory. The working group plans to make a similar evaluation of operating conditions for other satellite operator systems in FY 2017.

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 this 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.

20. Division of Solar and Plasma Astrophysics

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

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

1. Research in Solar Physics

NAOJ fellow S. Toriumi published two papers in refereed journals as lead author. One is about the statistical analysis of the flare-productive active regions, while the other is on the coordinated observation of small-scale energy releasing events in a developing active region by Hinode and IRIS. He also published one refereed paper on flare statistics as a co-author. Toriumi has been promoting collaborative research with international partners; he invited Prof. R. Rutten of Lingezicht Astrophysics/University of Oslo/Utrecht University and organized a scientific meeting on the formation of the solar spectrum.

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 the Graduate University for Advanced Studies (SOKENDAI). Among them, N. Kambara and M. Yoshida passed the examination for the Master's degree. The Division, in cooperation with Kyoto University and Nagoya University, supported the annual "Leading-edge Solar Research-Experience Tour" in March for undergraduate students; eight 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. Some members of the Instituto de Astrofísica de Canarias of Spain came to Japan to promote the construction of another 4-m solar telescope, which is now in the planning stage in Europe, and a meeting to discuss the collaboration was held. Several plans are also under consideration for future ground-based telescopes that would involve collaborations with East Asian countries and Peru.

21. Division of Theoretical Astronomy

1. Overview

The Division of Theoretical Astronomy (DTA) engaged in research activities for FY 2016 with the aim of achieving internationally outstanding research results both in quality and quantity to accomplish of the following four goals that were set by NAOJ:

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

The division handles a wide variety of themes in theoretical astronomy research, addressing a diversity of hierarchical structures of the Universe in terms of formation and evolution processes, dynamics, and physical state of matter, covering a span from the early Universe to galaxies, stars, planetary formation, activities of compact objects, the origins of space-time, and plasma phenomena in astronomy and astrophysics; joint research with observational astronomy using observational instruments of various frequency bands such as the Subaru Telescope, ALMA, and Nobeyama radio telescopes; and interdisciplinary research with neutrino cosmology, gravitational wave astronomy, 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 EACOA fellows, research experts, specially appointed research staff, JSPS fellows, and research supporters conduct theoretical astronomy research and education 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 2016, 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 five project assistant professors, including one research associate, two JSPS fellow, two EACOA fellows, and in addition one administration associate who gave full support to all activities of the division. Among them Takeshi Inoue, an assistant professor, moved to Nagoya University as an associate professor from November in 2016.

3. Research Results

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

- Peer-reviewed papers in English: 91
- Reports in English (talks at international conferences): 71 (invited talks: 16)
- Reports in Japanese (talks at national meetings, etc.): 42

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:

- Impact of New Gamow-Teller Strengths on Explosive Type Ia Supernova Nucleosynthesis (Mori, K., Kajino, T. et al.)
- New Electron Orbits in Collisionless Magnetic Reconnection (Zenitani, S. et al.)
- Kilonova Emission from Compact Binary Mergers (Tanaka, M. et al.)
- Chemodynamical Evolution of Dwarf Galaxies Deduced from r-process Elements (Hirai, Y., Kajino, T. et al.)
- H0LiCOW - Lens Mass Model of HE 0435-1223 and Blind Measurement of Its Time-delay Distance for Cosmology (Wong, K. C. et al.)
- Properties of Interstellar Dust Responsible for Steep Extinction Curves toward Type Ia Supernovae (Nozawa, T. et al.)
- Circumstellar and Explosion Properties of Type Ibn Supernovae (Moriya, T. et al.)
- Radio Transients Associated with Accretion-induced Collapse of White Dwarfs (Moriya, T.)
- Supernovae Powered by Magnetars that Transform into Black Holes (Moriya, T. et al.)
- Properties of Magnetars Mimicking 56Ni (Moriya, T. et al.)

- Formation of Spiral Arm in Galaxies by Swing Amplification (Kokubo, E. et al.)
- Planetesimal Formation by Gravitational Instability of Porous-Dust Aggregates (Kokubo, E. et al.)
- N-Body Simulation of Chariklo's Ring (Kokubo, E. et al.)
- Heavy Element Production in Type II Supernovae: Sensitivity to Nuclear Equation of States (Kajino, T. et al.)
- Relativistic Screening Effects on Big Bang Nucleosynthesis and Low-lying Resonances (Kajino, T. et al.)
- Detectability of Cosmic Dark Flow in the Type Ia Supernova Redshift-Distance Relation (Kajino, T. et al.)
- Impact of Sterile Neutrino Dark Matter on Core-collapse Supernovae (Kajino, T. et al.)
- Neutrino Antineutrino Pair Emissions in Strongly Magnetized Neutron-Star-Matter in Relativistic Quantum Approach (Kajino, T. et al.)
- Possible Measurements of Reaction Cross Sections for Explosive Nucleosynthesis using Laser -Driven γ-ray Pulses (Kajino, T. et al.)
- Isomer Production Ratio of 113Cd following Neutron-Capture Reactions to Investigate the Origin of 115Sn (Kajino, T. et al.)
- Solving the Red Supergiant and Supernova Rate Problems via Relic Supernova Neutrino Spectrum (Kajino, T. et al.)
- Non-Extensive Statistics Solution to the Cosmological Lithium Problem (Kajino, T. et al.)

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

- Japan OISTER collaboration uncovers the origin of extraordinary supernovae (Tanaka, M. et al.)
- Avoiding "Traffic Jam" Creates Impossibly Bright "Lighthouse" (Kawashima, T., Ohsuga, K. et al.)
- New classes of electron orbits in magnetic reconnection (Zenitani, S. et al.)
- Cosmic lenses Bring the Universe's Expansion into Sharper Focus (Wong, K. C. et al.)
- Metallic Iron Grains Hardly Exist in the Universe (Nozawa, T. et al.)
- Mystery of Nucleosynthesis in Type Ia Supernova: Challenge from Precise Nuclear Physics (Mori, K., Kajino, T. et al.)
- Early evolutionary histories of galaxies deduced from r-process elements (Hirai, Y., Kajjino, T. et al.)
- An Elegant Solution of the Big-Bang Lithium Problem? (Kajino, T. et al.)

4. Domestic Collaborations

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

- 5th TDA Symposium on "Pre-solar Grains, Evolution of Interstellar Dust, and the Origin of the Solar System", NAOJ Mitaka Campus, September 26 - 27 in 2016. (Participants; 38)
- Japan SKA Joint Science Forum on "Cosmic Magnetic Field: from Intra-Galactic Phenomena to Large Scale Structure", Yamagata Zao, October 27 - 29 in 2016. (Participants; 35)
- 6th TDA Symposium on "Role of the Magnetic Field in Stellar Formation and its Observational Evidence", NAOJ Mitaka Campus, November 24 - 25 in 2016. (Participants; 37)
- 29th RIRONKON Symposium on "Cosmic Hierarchical Structure driven by Gravity", NAOJ Mitaka Campus, December 20 – 22 in 2016. (Participants; 153)

5. International Collaborations

Toshitaka Kajino performed duties of the following posts: international referee for the National Sciences and Engineering Research Council of Canada (NSERC); 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). Eiichiro Kokubo served on the organizing committee of Commission A4 (Celestial Mechanics and Dynamical Astronomy) of IAU.

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

- The 4th DTA Symposium on Compact Stars and Gravitational Wave Astronomy, NAOJ Mitaka Campus, May 13 – 14 in 2016. (Participants; approx. 20)
- NIC XIV School on Nuclear Astrophysics, Niigata University, June 13 – 17 in 2016. (Participants; approx. 70)
- 14th International Symposium on Nuclei in the Cosmos (NIC XIV), Toki Messa in Niigata, June 19 – 24 in 2016. (Participants; approx. 300)
- 2nd NAOJ-ECT* International Workshop on Many Riddles About Core-Collapse Supernovae: 1 Bethe and Beyond, NAOJ Mitaka Campus, June 27 – July 1 in 2016. (Participants; 52)
- 9th Meeting on Cosmic Dust, Aobayama Campus in Tohoku University, August 15 – 19 in 2016. (Participants; 51)
- Japan-Germany Planet and Disk Workshop, Ishigaki in Okinawa, September 25 – 30 in 2016. (Participants; approx. 50)
- Quarks and Compact Stars 2017 (QCS2017), Yukawa Institute in Kyoto University, February 19 – 22 in 2017. (Participants; approx. 70)

6. Educational Activities

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

· 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.
· Eiichiro Kokubo: Earth and Planetary Sciences I at the University of Tokyo, Solar System and Exoplanetary Systems at the University of the Ryukyu.
· Masashi Tanaka: Introduction to observational astronomy I at the Graduate University for Advanced Studies; advanced astrophysics at Chiba University; advanced stellar physics II at Tohoku University.
· Takashi Hamana: Geology at the Tokyo University of Agriculture and Technology.

Tomoya Takiwaki and Eiichiro Kokubo also delivered SSH lectures on "Supernovae, culminating their Stellar Evolution" at Aichi prefectural high school and "Solar System and Exoplanetary Systems" at Kanazawa Izumigaoka high school, respectively, and contributed much to high school education.

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:

· Toshitaka Kajino: "Cosmology towards the Origin of Matter and Time and Space" (International Conference NIC2017 Commemorative Lecture, Hitotsubashi Auditorium, Tokyo); "Origin of Heavy Elements" (Cosmo-Nuclear Physics Forum, RIKEN, Wako)
· Eiichiro Kokubo: "Solar System" and "Exoplanetary Systems" at Niigata Citizen University; "From Stardust to the Earth" at Osaka Prefectual University; "The Blue Planet" at Yokohama Aasahi Culture Center; "Form Stardust to the Earth and Moon" at Discovery Park Yaizu; "Exoplanet Zoo" at Ikebukuro Community College; "Introduction to Planet Formation Theory" and "Solar System and Exoplanetary Systems" at Waseda University Extension Center; "The Origin of the Earth" at Konan University
· Takiwaki Tomoya: "Science Frontier of Core-Collapse Supernovae" (Asahi Culture Center Tokyo); "Supernovae, culminating their Stellar Evolution" (Asahi Culture Center Yokohama); "Universe" (Shimadoromu General Lecture, Science and Technology Museum, Tokyo)
· Masaomi Tanaka: "The Life of a Star and Supernova Explosions" (Asahi Culture Center Shinjuku); "Following the Moment of a Supernova Explosion" (Mitaka Network University); "Science Frontier of Core-Collapse Supernova Observation" (Asahi Culture Center Shinjuku); "What is the Death of Massive Stars like – Approaching the Mysteries of Supernova Explosions" (Sundai Gakuen Sundai Astronomy Seminar); "What is the Death of Massive Stars like – Exploring the Moment of a Supernova Explosion" (Science Cafe Orion)

8. Awards

Tomoya Takiwaki was awarded the ASJ Young Astronomer Award 2016. Seiji Zenitani and Masaomi Tanaka were given the MEXT Young Scientists' Awards. Masato Shirasaki and Masaomi Tanaka received awards from the Inoue Foundation for Science.

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 2016 to the division are listed below:

Akif B. Balantekin (University of Wisconsin–Madison, US)
Carmen Adriana Martinez Barbosa (Leinden University, Netherlands)
Melina Bersten (National University of La Plata, Argentina)
Myung-Ki Cheoun, (Soongsil University, South Korea)
Emmanouil Chatzopoulos (Lousiana State University, USA)
Vivien Chen (National Taiwan University, Taiwan)
Chau Ching Chon (Academia Sinica, Taiwan)
Silvio Cherubini (Catania University, Italy)
Roland Diehl (Max Planck Institute/Technical University of Munich, Germany)
Kevin Ebinger (University of Basel, Switzerland)
Marius Eichler (University of Basel, Switzerland)
Michael A. Famiano (Western Michigan University, USA)
Morgan Fraser (University College Dublin, Ireland)
Gaston Folatelli (National University of La Plata, Argentina)
Carla Frohlich (University of North Carolina, USA)
Federico Garcia (Argentine Institute of Radio Astronomy, Argentina)
Tristan Guillot (Nice Observatory, France)
Ji-an Jiang (University of Cambridge, UK)
Oliver Just (Max Planck Institute, Germany)
Kostas Kokkotas (University of Tübingen, Germany)
Takami Kuroda (University of Basel, Switzerland)
Kyunjin Kwak, (Ulsan National Institute of Science & Technology, Korea)
Shih-Ping Lai (National Taiwan University, Taiwan)
Sheng-Jun Lin (National Taiwan University, Taiwan)
Doug Lin (University of California Santa Cruz, USA)
Andreas Lohs (University of Darmstadt, Germany)
Grant J. Mathews, (University of Notre Dame, USA)
Gail Mclaughlin (University of North Carolina, USA)
Annabella Mondino Llermanos (National University of Cordoba, Argentina)
Bernhard Mueller (The Queen's University Belfast, UK)

Quang Nygen-Luong (Korea Astronomy and Space Science Institute, Korea)
Valerio Pirronello (Catania University, Italy)
Yoshito Shimajiri (Saclay Nuclear Research Centre, France)
Benjiamin Wehmeyer (University of Basel, Switzerland)

22. 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; liaising with overseas astronomical research organizations; gathering and providing information on international activities; offering support for hosting international conferences, workshops, and seminars; providing support for visiting international researchers and students; and assisting Japanese universities and research organizations for international partnerships. In FY 2016 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 serves as a liaison point for international activities, engages in international agreements or provides support for doing so, and accumulates procedural and administrative knowledge, through consultations or investigations on individual cases to enter into and implement collaboration with overseas universities or research institutions. Other matters handled by the Office include administrative coordination in approval processes to sign agreements and memoranda for international collaborations, conducting preliminary reviews for legal documentation, supporting signing ceremonies, and managing Security Export Control for export of goods or transfer of technology. In FY 2016, nine 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 70 cases (121 items), and an Security Export Control briefing was held in October at Mitaka (15 attendees including 1 from Nobeyama through TV conference connection) for improving the knowledge and awareness of NAOJ staff.

2. Liaison Work for Overseas Astronomical Research Organizations

The Office of International Relations supported the organization of the East Asian Observatory (EAO) Board meeting and the JCMT Board and users' meeting, both held at Mitaka during April 13–14, 2016, and April 15–18, respectively. At the same time, the Office organized the annual directorate meeting of the East Asian Core Observatories Association (EACOA). The four institutions forming the EACOA include NAOC (China), NAOJ (Japan), KASI (South Korea), and ASIAA (Taiwan). The Office also assisted the Executive Advisor to the Director General in charge of international research coordination in coordinating with the other 3 institutions for selection of the 2017 EACOA postdoctoral fellowship program. 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).

The Office cooperated with the IAU OAO during the review of OAO activity from the end of August to early September. The Office also supported the NAOJ Public Relations Office with its exhibit at New Scientist Live held in London during September 28–October 1. Additionally, the Office displayed an exhibit to present NAOJ's projects and research results together with recruitment information at the EAMA10 (10th East Asian Meeting on Astronomy) held September 26–30 at Seoul, South Korea.

The Office supported the organization of the JCMT TAC held in Mitaka during November 21–23, and the East Asian Astro Statistics Workshop held in Mitaka during February 27–March 2.

Pursuant to the reorganization of the Public Relations Office, it has been decided that the Public Relations Office will be responsible for overseas activities in relation to the general public, while the Office of International Relations will be in charge of activities related to overseas researchers.

3. Support for Hosting International Research Conferences, Workshops, and Seminars

The Office of International Relations offers support for the planning and implementation of international research conferences, workshops, and seminars hosted or supported by NAOJ. The work involves consultation and responses to inquiries regarding administrative issues. The Office also offers advice about which organizations or individuals to contact as appropriate, coordinates between organizations, and gathers relevant information. In FY 2016 the Office supported international research conferences and other events by preparing documentation for Japanese visa applications for 36 foreign participants in total.

4. Support for Hosting International Researchers and Students

The Office enhanced its framework for offering organizational support for research, education, and living arrangements for foreign researchers and exchange students. The Support Desk offers support services to ease difficulties for foreigners living in Japan. It 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. The Office continued the Japanese language lessons,

helping foreign members of NAOJ acquire beginner level capability, and for FY 2016, a combination of E-learning features and classroom lessons were provided, as was introduced in the previous year. The Office also provided support for visa applications, and including renewals; support was given to 48 applications: 12 for staff and family members, 18 for invited researchers, and 18 for visitor/long stay researchers.

• 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 (67 documents).

5. Assistance in International Partnerships Involving Japanese Research Organizations

The Office of International Relations assists universities and other educational and research organizations in Japan to engage in international partnerships. It also liaises with the International Strategy Headquarters and the International Cooperation Office at NINS to coordinate international collaborations. The Office oversaw the Optical and Infrared Synergetic Telescopes for Education and Research (OISTER) project conducted by Okayama Astrophysical Observatory, Ishigakijima Astronomical Observatory, and nine Japanese universities.

Although the budget for the OISTER project will be transferred to the Research Promotion Division from FY 2017 onward, the Office will continue to provide administrative support.