II Status Reports of Research Activities

1. Subaru Telescope

1. Subaru Telescope Staff

As of the end of FY 2015, the Subaru Telescope Project staff consisted of 18 dedicated faculty members (five of whom are stationed at Mitaka), five engineers, and three administrative staff members. Additional staff members include two specially appointed research staff, three specially appointed senior specialists, five research experts, and six administration associates, all of whom are stationed at Mitaka. Moreover, 13 research/teaching staff members, 12 of whom are stationed at Mitaka and one of whom is stationed at Pasadena; and three engineers, two of whom are stationed at Mitaka and one of whom is stationed at Nobeyama are posted concurrently. The project also has 79 local staff members dispatched from the Research Corporation of the University of Hawaii (RCUH), including scientific assistants; engineers in charge of software and observational instruments; technicians for facilities, machinery, vehicles, and laboratories; telescope/instrument operators; secretaries; librarians; administrative staff; researchers employed for Grant-in-Aid for Scientific Research; and graduate students. These staff members work together in operating the telescope, observational instruments, and observational facilities; and in conducting open-use observations, R&D, public outreach, and educational activities.

2. Science Highlights

In FY 2015, Subaru Telescope produced many outstanding scientific outcomes which were published in major international journals. Below are some examples:

(1) Deep NIR spectroscopy of 24 quiescent galaxies at around $z = 1.6$ (9.5 billion years ago) with MOIRCS provides us with a precise composite spectrum. By comparing it with a spectral synthesis model, it is found that the average stellar age in these galaxies is very old (1.5 billion years) and the duration of star formation is very short (<1 billion years). We are thus likely to be witnessing the progenitors of present-day elliptical galaxies.

(2) Super wide-field imaging of nearby spiral galaxy M81 and its two interacting companion galaxies with Hyper Suprime-Cam (HSC) has revealed that the young main-sequence stars in these galaxies nicely follow the neutral hydrogen gas distribution which bridges the multiple interacting galaxies. This suggests that the gas is tidally stripped due to interactions and the new stars are formed in the gas during the course of the hierarchical assembly and mergers of galaxies.

(3) High contrast camera HiCIAO, combined with the adaptive optics system which corrects for atmospheric disturbance in astronomical images, has been conducting high resolution imaging of circum-stellar disks around young stars. A circular gap at only 20 AU away from the central star is newly discovered. Together with another known outer gap already found by HST, this disk turns out to have a double ring gap structure. This suggests that multiple (two) planets are being formed simultaneously, and it gives us a new insight into the formation of planets in the proto-planetary disks.

(4) High Dispersion Spectrograph (HDS) targeted 50 solar-type stars with a "super-flare" event, a gigantic explosion at the surface of the star. The spectra have confirmed that (1) those stars are single systems, (2) spin velocities derived from the line widths match the periods of their light curves, and that (3) a shallow absorption line profile is seen as evidence of a strong magnetic field. These results all suggest that the appearance of a giant black spot on the stellar surface leads to the launch of a super-flare.

3. Open Use

The Subaru open use call for proposals is issued every six months. The periods are from February 1 to July 31 (S15A) and from August 1 to January 31 (S15B). The Mitaka office of the Subaru Telescope at the National Astronomical Observatory of Japan (NAOJ) campus accepts submitted proposals. The Subaru Time Allocation Committee, established under the NAOJ advisory committee for optical and infrared astronomy, selects accepted proposals, based on the evaluation and comments of referees. In S15A, 64 programs (102 nights) were accepted out of 162 submitted proposals, requesting 427 nights in total. In S15B, 57 proposals (97 nights) were accepted out of 161 submitted proposals, requesting 372.5 nights in total. Short duration service observations were also conducted. In S15A and S15B, 5 and 2 accepted open-use proposals were by foreign principal investigators, excluding University of Hawai`i observing time. The number of applicants in submitted proposals was 2083 for Japanese researchers (Japanese astronomers at any institute and non-Japanese astronomers belonging to Japanese institutes) and 748 for foreign researchers. The number of researchers in accepted proposals was 899 for Japanese astronomers and 274 for foreign astronomers.

In S15A and S15B, the number of open-use visiting observers was 343, of which 58 were foreign astronomers. 69 astronomers observed remotely from Mitaka. The Mitaka office of the Subaru Telescope takes care of proposal handling and evaluation, and travel procedures for observers and their travel support. The Hilo office makes the observing schedule and supports the accommodation and transportation of visiting observers in Hawai`i. In S15A and S15B, 95.7 % of the open-

use time (including University of Hawai`i time) was used for actual astronomical observations, after excluding weather factor and scheduled maintenance downtime. About 1.5 %, 0.3 %, and 2.5 % of observing time was lost due to instrument trouble, communication trouble, and telescope trouble, respectively.

In S15A and S15B, remote observations from Hilo were not conducted. 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 24 programs with 47 nights. Service observations were made for 12 nights. To make the best use of limited resources at observatories on top of Maunakea, Subaru Telescope has been exchanging telescope time with W. M. Keck Observatory and Gemini Observatory. The number of time exchange nights between Subaru Telescope and Keck was 3 in S15A and 6 in S15B. That between Subaru Telescope and Gemini was 5 in S15A and 3 in S15B.

4. Telescope Maintenance and Performance Improvement

During scheduled maintenance work on the telescope and the enclosure on February 22, the optical-side mirror hatch got stuck. The mirror hatch was restored to its normal position as of February 27, then the open-use observations were resumed on February 29. The mirror hatch is not operational at the time of writing this text. Because normal performance of the mirror hatch is required for the primary mirror recoating work in the next year, we are considering making some repair plans.

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

This year, both the dome angle and the top screen position barcodes and these controllers were renovated. A laser distance meter was installed on the top unit exchanger (TUE) to improve the accuracy and reliability. Some acceleration measurements on the telescope were carried out for better understanding the telescope tracking performance. In addition, while promoting improvements in performance and operational efficiency of the Subaru Telescope, renovation was conducted on the telescope control units, which were installed more than 10 years ago. The local control units that were renovated or modified in this year were: the dome control unit (DCU), the dome rotation processor unit (DRPU), and the telescope control workstations (TWS).

The major causes of the telescope failures is considered to be aging, human error, and adverse weather. This year included a small amount glycol leakage, wind screen malfunction, dropping of the dome lateral guide roller (LGR), breakdown of the lower mirror cover, malfunction of the upper mirror cover, trouble in the Cassegrain-optical secondary mirror unit, top screen malfunction, failure of the 80-ton crane control, uninterruptible power supply (UPS) glitch, and the mirror hatch incident. Bad weather caused a malfunction of the dome shutter and the elevation axis angle sensors, forcing observations to be canceled. A small earthquake occurred, although there was no significant damage observed. Some dips and cracks on the dome rail were found. These dips and cracks should be repaired in the near future.

Additionally, the same as the previous year, we used the telescope status log for the preventive maintenance of the telescope and the enclosure.

5. Instrumentation

The nine open-use facility instruments of Subaru Telescope have been operated stably in FY 2015. Those instruments are Hyper Suprime-Cam (HSC), Subaru Prime Focus Camera (Suprime-Cam), Faint Object Camera And Spectrograph (FOCAS), High Dispersion Spectrograph (HDS), Infrared Camera and Spectrograph (IRCS), Cooled Mid-infrared Camera and Spectrograph (COMICS), Multi-Object Infrared Camera and Spectrograph (MOIRCS), Fiber Multi-Object Spectrograph (FMOS), and 188-elements Adaptive Optics and Laser Guide Star system (AO188/LGS).

Since the last fiscal year, there have been discussions on how we maintain or stop operations of the facility instruments. Following the instrument plan proposed in last January, it was decided to terminate the operation of FMOS by the end of April, 2016 in order to accept a next generation facility instrument PFS.

The operation of HSC has been stable, similar to the last fiscal year. To further stabilize the operation, the replacement of the instrument control computer (OBCP) with new hardware and an improvement of the filter exchange unit (FEU) have been performed while consulting closely with the HSC development team. In addition, the implementation of a new dome-flat lamp system with improved uniformity is ongoing to better calibrate HSC data. However, because of the increased number of observing runs of HSC, there are concerns over the limited amount of time for instrument maintenance works and the strong restrictions on the observing schedule due to the limited number of filters available in an observing run. We are trying to improve the instrument exchange procedures to resolve those concerns.

There are several upgrade projects for the other facility instruments. The installation of new detectors (HAWAII-2RGs) in MOIRCS has been done successfully and it achieved engineering first light in December, 2015. In preparation for the first open-use observation in 2016 after the upgrade, we have been working on the characterization of the instrument with the new detectors and further improvement of the operation. The other ongoing upgrade projects are the fiber MOS unit for HDS; the polarimetric function in thermal infrared for IRCS and in mid-infrared for COMICS; the integral field unit (IFU) for FOCAS and MOIRCS; and the Transponder-Based Aircraft Detector (TBAD) for the LGS system.

In FY 2015, three carry-in (PI-type) instruments HiCIAO (high-contrast coronagraph imager), Kyoto-3DII (optical integral field spectrograph), and SCExAO (Subaru Coronagraphic Extreme Adaptive Optics) have been offered through the Subaru open-use program. SCExAO has been commissioning a high-order wave-front correction mode, which realizes extreme adaptive optics correction. This mode has been offered through

the Subaru open-use program on a trial basis since S15A.

A Multi-Object Adaptive Optics (MOAO) science demonstrator (RAVEN), which has been developed in collaboration with Canadian institutes, has conducted additional test observations and science observations in S15A and demonstrated the performance of the MOAO system. RAVEN finished its operation at the Subaru Telescope and was transported back to Canada to be used as a test bed.

There are new PI-type instruments, IRD (InfraRed Doppler instrument) and CHARIS (Coronagraphic High Angular Resolution Imaging Spectrograph), which are currently being developed toward the first light observations expected in July 2016. Other than these approved new instruments, there are new PI-type instrument carry-in proposals from the University of Tokyo; SWIMS (Simultaneous-color Wide-field Infrared Multi-object Spectrograph) and MIMIZUKU (mid-infrared multi-field Imager and spectrograph). Considering the impacts to the existing observatory resources, the acceptance review process for these two instruments is currently suspended until the installation of the other new PI type instruments at the summit has been completed.

The Prime-Focus Spectrograph (PFS) is an optical/near-infrared multi-object spectrograph at the prime focus of the Subaru Telescope, which will be the next facility instrument following the successful implementation of Hyper Suprime-Cam (HSC). The PFS has about 2400 optical fibers distributed over the 1.3 degree field of view of the prime focus. The fibers feed the light from astronomical objects to four identical spectrographs which will be placed in the telescope dome. The spectrograph modules cover the wavelength range from 0.38 μm to 1.26 μm simultaneously. The subcomponents of PFS are being developed at each partner institute, aiming for engineering first light in 2018. Subaru Telescope is responsible for modifying the telescope and enclosure to accept PFS and the design work progressed. A Chinese consortium has officially joined PFS collaboration and NAOJ will handle their funds for PFS development.

We are conducting a conceptual study of the next large facility instrument following HSC and PFS, which will be one of the flagship instruments at the Subaru telescope in the era of TMT. We have studied the concept of a wide-field near-infrared imager and multi-object spectrograph assisted by a ground-layer adaptive optics (GLAO) system, which uniformly improves image quality over a wide field of view by correcting only for the turbulence at the ground layer of the Earth's atmosphere by using an adaptive secondary mirror. In FY 2015, the concepts for the GLAO, wide-field near-infrared instruments, and their science cases were summarized in the study report and reviewed by the external reviewers.

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 troubles or attacks/intrusions such as illegal access.

Observation data archiving has been ongoing from the previous year. The archive is operational without serious problems. We provide a user interface that is suitable to downloading large amounts of data in a batch process per requests by users who wish to download data taken by Hyper Suprime-Cam (HSC) during its Strategic Science Program (SSP).

The data archive system in Mitaka is also operating reliably.

We officially rolled out remote observations from Mitaka using the remote observation monitor system for a limited amount of time. During observation semesters from February 2015 through January 2016, 24 observation programs utilized the remote observation monitor system for 47 nights. This was a significant increase in the nights where the remote observation monitor system was used since last year, when 25 observation programs used 28 nights. In expectation of the increase in the number of nights when the remote observation monitor system is used, we hired research fellows to provide support to the users of the remote observation monitor system. 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, an interactive processing server, and a database server to the system in 2015.

The current system requires fast transfer of large volumes of data between the storage and processing servers. Data transfer speed of the current system is not fast enough to meet our requirements. We must wait for over 30 minutes before data reduction starts; in cases of observations with very frequent exposures this causes delays in deciding whether or not to continue observation. Therefore, we experimented with replacing NFS with a fast data I/O software; the result was several times faster data I/O. We decided to continue the test in a test environment with more computers to simulate the production system. The additional hardware was delivered by the end of this fiscal year. Configuration and performance tests of the test system are planned in 2016.

The dedicated network link between Hawai`i and Mitaka has been procured with a single year contract since April 2014. Bidding was held to select the network link provider for 2016. The link speed will become 1 Gbps, based on the data rate form HSC and the actual data amount used during 2015. A provider was selected successfully and we prepared our own network system so that it can connect to the network service that the provider will offer starting from April 2016.

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.

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 ten. 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 eight had supervisors who belonged primarily to Subaru Telescope.

In FY 2015, Subaru Telescope hosted 7 graduate students for long stays, of which 2 were SOKENDAI students. On top of that, intensive education activities were seen also in Mitaka in cooperation with the Division of Optical and IR Astronomy. The numbers of graduate course students in all of Japan who obtained master's degrees and PhD's based on Subaru Telescope data were 17 and 6, respectively, of which one each belonged to the Division of Optical and IR Astronomy.

We also regularly hosted a series of educational programs at Subaru Telescope. In September 2015, we hosted a Subaru Autumn School in which 13 under-graduate students from all over Japan participated and learned the reduction and analysis of Subaru Telescope data and heard a series of lectures. Moreover, in October, we hosted two Subaru Telescope observation training courses, one for 8 undergraduate students from all over Japan, and the other for 7 new SOKENDAI students at NAOJ. In the Hilo Office, we had regular Subaru Telescope seminars in English 2-3 times a 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 2015, there were 31 web-postings (14 in Japanese, 17 in English) about the discoveries from the Subaru Telescope. Articles about the instrument development, the work and the activities at the Subaru Telescope, and other announcement totaled 52 (25 in Japanese, 27 in English). Some postings are also distributed through the media as well as posting services such as the American Astronomical Society's mailing exploder. Many articles appeared in the Japanese newspapers, and some in the local newspapers; with more prevailing in the on-line postings.

In addition, newer tools such as Twitter, Facebook, and YouTube are becoming more useful in spreading awareness in a timely manner. The PIO office is making extra effort in providing striking visuals for such social media postings. Filming requests from outside totaled more than 22 (13 in Japanese, 9 in English), in addition to the numerous inquiries/questions from the media, educational institutions, and museums.

Task 2: Provide escorted tours for the public and special groups to see the facility. The public tour program that started in 2004 continues to provide opportunities to see the telescope up-close for guests from Japan and from around the world. Except for summer months when the tour program was suspended due to the access issues on Maunakea, a total of 421 people visited through this program. There were 131 additional groups who visited through special tour programs and resulted in a total head count of 923 people who visited the summit facility. The tours are all escorted by the assigned staff, in either Japanese or English language.

Facility tours of the 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 67 groups, with 393 people, visited the base facility this year.

Task3: Public outreach includes lectures in the local community, special presentations in the schools, and remote presentations for Japanese schools or museums. PIO provided/coordinated 93 lectures at the Hilo Base Facility or in its vicinity such as at the 'Imiloa Astronomy Center. There were 10 lectures outside of the island, and 15 remote lectures for off-site locations. The local lectures included 55 classroom presentations during the Journey through the Universe program.

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

Another special local event where many astronomy observatories participate is the annual Onizuka Science Day at the University of Hawai`i at Hilo. 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 4 hands-on workshops and an exhibit booth.

There was a very significant event in August 2015 which was the International Astronomical Union's General Assembly in Honolulu. PIO provided a booth and dispatched staff to answer questions, in addition to providing special tours of the telescope.

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 and the Tokyo Institute of Technology's Gamma-Ray Burst Optical Afterglow Follow-up Project. Meanwhile, the 188-cm telescope, the 50-cm telescope, and the 91-cm telescope of the Observatory are involved in "The Optical & Near-Infrared Astronomy Inter-University Cooperation Program" supported by MEXT, which commenced in 2011.

The Observatory's unique research activities include a project designed to convert the 91-cm telescope into an ultra-wide-field near-infrared camera (OAO-WFC). It also engages in a comprehensive survey of infrared-variable objects in the Galactic plane. Another project is the upgrade of the functionalities of the 188-cm telescope in order to significantly improve its planet searching capability through a Grant-in-Aid for Scientific Research (Basic Research (A), FY 2011–2015). Collaborations with foreign researchers are also continued actively.

The personnel breakdown as of March 2016 was five full-time staff members, including two associate professors, one assistant professor, one engineer, and one chief clerk; ten contracted staff members, including three research experts, one postdoctoral fellow, 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 2015 were 115 for the first semester (2015A, January to June) and 124 for the second semester (2015B, July to December). Observing proposals were called for publicly each semester. The Okayama program subcommittee reviewed the submitted proposals and accepted 1 project observation program, 1 academic degree support program, 13 general observation proposals, and 1 miscellaneous observation proposal (introduced in 2015A) in 2015A, and accepted 1, 1, 13, and 0 in 2015B. One proposal from Hawai`i was accepted in 2015A, and one from Turkey and one from Hawai`i were accepted in 2015B. 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 2015 were stellar sources and exoplanets. Others included supernovae, galaxies outside the Milky Way, AGNs, 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 near-infrared 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 improve the pointing accuracy and to automate the high dispersion spectroscopic observations with the fiber-feeding system in this FY 2015. The remote observing environment has been refined further since FY 2014 and has been made available for open use since 2015B. During the maintenance period in June, the annual re-aluminization of the primary mirror of the 188-cm telescope and the subsequent optical axis alignment of the smaller mirrors against the primary were completed. Efforts were made to simplify the re-aluminization process. The 1.5-m primary of the KANATA Telescope at Hiroshima University was also accepted for re-aluminization in the maintenance period this year. Participants in the aluminization work from that organization were given NAOJ-mandated safety and hygiene training as necessary. Lubrication of the telescope and dome was performed in July. 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 October.

The dome was checked daily. Other maintenance work was also performed, including the repair of the iron part of the hatch opening on the second floor and repainting of the scaffold of the vacuum aluminizing chamber in May; repair of the worn-down guide rails for the lower slit door in October; and repair of the external panels of the dome hemisphere to prevent rain

leakage in November. Much attention was paid to the operation and maintenance of the facility and equipment. The wire rope of the dome slit door driver was inspected and investigations continued in order to determine the causes of the unusually rapid deterioration of the wire rope and possible measures to prevent the deterioration. Work safety was given priority in accomplishing the aforementioned maintenance work and observing instrument exchanges. The Administration Office and Reception Room on the first floor of the Main Building were renovated and the Director's Room was moved from the second floor to in-between these two rooms. The asphalt pavement of the parking spaces west of the main building and the access road from the city road to the parking lot were renewed as well.

(4) Conferences

The program subcommittee for the 188-cm telescope met on June 16 and November 17 to evaluate proposals for the open use of 2015B and 2016A (first semester of 2016), respectively, and formulated an observation program for each semester. The Okayama Users Meeting, also known as the 26th Optical and Infrared Users Meeting, was held in the Large Seminar Room of NAOJ Mitaka Campus on August 17 and 18. Various reports were made: current status of the Observatory, execution summary of the program subcommittee, full operation of the remote observing environment, automation of observing, etc. Reports on three new user-led instruments for the 188-cm telescope were also made. Discussions were held on the future operation of Target-of-Opportunity (ToO) observations and operation of open-use observing instruments. A special session was arranged on the era of the Kyoto 3.8-m telescope and detailed discussions were held among Okayama users, Kyoto University staff, and NAOJ staff (see the printed version of the Proceedings of the FY 2015 Users Meeting for details). Further reports were made on the research results from open-use projects, progress of the Kyoto University 3.8-m telescope project including observing instruments, and operations of other optical and infrared observational facilities such as the Higashi–Hiroshima Observatory.

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 started to be offered as a PI-type open-use instrument in 2016A. The HR link provides a 4 times better sensitivity at maximum than the case of the Coudé light path. This year the total numbers of accepted proposals to HIDES were 7 and 9 in 2015A and 2015B, including 1 and 1 project observations, respectively.

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

The open-use instrument ISLE is a near-infrared imager and low- or mid-dispersion spectrograph, and has been available for project observations and the academic degree support programs 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 YJH-band filter brought in by a user was installed in FY 2015, which extended the shorter wavelength limit for spectroscopy from J-band edge (~1.16 μm) to Y-band edge (~0.96 μm). By using the YJH-band filter and the existing HK-band filter, it became possible to obtain a well-connected spectrum from Y-band to K-band. The numbers of open-use programs using ISLE conducted in semesters 2015A and 2015B were 6 and 3, respectively; which included 1 and 1 academic degree support programs, respectively; and 1 and 0 miscellaneous category programs, respectively. Five of them were spectroscopy and the other four 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. High observing efficiency has been achieved by improving CCD output linearity and auto-guider functionality and by introducing CCD charge shuffling and VPH grisms. 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 was made available to observers as a PI-type open-use instrument starting from semester 2015B. When it is used, its input part is installed into the Cassegrain unit of the HIDES fiber link and so is its output part is installed into KOOLS. Accepted proposals were 4 and 2 for 2015A and 2015B, respectively.

(4) Others

MuSCAT (MUlti-color Simultaneous Camera for studying Atmospheres of Transiting exoplanets) was accepted as a carry-in observing instrument for open use on the 188-cm telescope. Its use in the open-use time began in 2015B. It can achieve 0.05 % accuracy in relative photometry for a star of 10th magnitude at V-band when it performs a series of one-minute exposures.

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 the

Nano-Optonics Institute (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. The project proceeded significantly with the telescope construction having been included in the supplementary budget of FY 2013 and the dome construction in the main budget of FY 2015.

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

The Program has entered its fifth year since its commencement in 2011. The Observatory has contributed the 188-cm, 91-cm, and 50-cm telescopes to the Program, and has taken a leading role along with the Office of International Relations. Through the cooperative observational and educational network, OISTER, established by the Program, the Observatory provided a total of 49 nights worth of observational data on five objects this year. Two of the objects were targets of collaborative observations with the X-ray astronomical satellite "Suzaku" or of simultaneous VLBI observations with VERA. As for the immediate follow-ups of gamma-ray bursts, which are the main targets of the program, there were 19 alerts that were observable from the Observatory, observations were performed six times and afterglows were detected in two of them. Three peer-reviewed papers were published utilizing OISTER. Another 20 peer-reviewed papers that have something to do with the Program were published. The sixth workshop on the Program was held.

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

Optical follow-up observations of GRBs are in progress in cooperation with the Tokyo Institute of Technology's Kawai Laboratory. During FY 2015, the automatic observation scheduler performed observations on nearly every possible night; 15 GRBs were observed, with optical afterglows successfully detected in two. Observation results were published as 12 GRB Coordinates Network (GCN) circulars. In addition, follow-up observations of candidate gravitational wave sources and monitoring of eclipsing binaries and comets were concurrently performed, which resulted in publication of two peer-reviewed papers. The telescope operation was suspended for a month due to a malfunction in the dome rotation mechanism. A worn-out roller in the machinery was replaced and measures were taken against abrasion.

(4) Other

The Observatory welcomed five third-year undergraduate students and their supervisor from the University of Tokyo between August 12 and 14 and provided them with an opportunity to conduct high-dispersion spectroscopic observations using the 188-cm telescope during the early half-night on August 12.

Development of a near-infrared observing system dedicated to bright star photometry (IR-TMT) continued in collaboration with researchers at Tohoku University. The system consists of a wide-field infrared camera with 30-mm aperture developed by researchers at Tohoku University being mounted on the equatorial mounting of a 30-cm class telescope housed in a 4-m dome at the Observatory. It aims to produce a high precision photometric catalog of bright stars in the near-infrared. The control system of the equatorial mounting was developed by the Observatory and the near-infrared camera by the Tohoku University researchers. The camera was placed on the mounting in December and various adjustments were carried out for test observations of astronomical objects.

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 of currently 0.25 square degrees, 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 2015 a region of 6 square-degrees in the constellation Scutum was observed at the Ks-band about 70 times, and a region of 16 square-degrees in the constellation Cygnus was observed about 12 times. Many variable star candidates were identified.

(2) Automation of Exoplanetary System Searches

Through a Grant-in-Aid for Scientific Research (Basic Research (A), "Automation of exoplanetary system searches," representative: Hideyuki Izumiura, FY 2011–2015), a project is underway to improve the functionalities of the 188-cm telescope and its dome, to enhance the precision and stability of the telescope, to facilitate automation of observation, and to further expand the search for exoplanetary systems. The 188-cm telescope and its dome were refurbished in FY 2012 for this purpose. A new control system including the observing instruments was achieved in FY 2013. An automatic focus correction system was developed in FY 2014. Functionality was developed to improve the overall pointing accuracy by sensing small movements of the 188-cm reflector primary mirror in its cell. Also, development advanced for a system capable of performing automatic observations based on observing instruction.

(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 2015 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. It should be noted that a system consisting of a G-type giant with possibly two mutually-retrograde planets was discovered from

the collaboration with Chinese colleagues and was published in a peer-reviewed journal.

5. PR/Awareness Promotion Activities

An Observatory representative delivered a lecture to nearly 20 people in Okayama City on Tuesday, July 7 as part of the Nation-Wide Tanabata Participatory Lectures. 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 4,740 visitors. Nineteen Observatory tours were conducted, including those for pupils from local elementary schools in Asakuchi City and Yakage Town. The Observatory also responded to three lecture requests made by local boards of education and community centers. It should be noted that the Observatory received special publicity during the NameExoWorlds campaign led by the IAU from 2014 to 2015. Of the first 20 stars with planets for naming, six had planets discovered by the 188-cm telescope and the high dispersion echelle spectrograph HIDES(-F) with fiber-link at the Observatory. The names of the stars and their planets were determined by public votes from all over the world and the names were announced by the IAU on December 15, 2015.

6. Contract Staff Transfers

The following transfers of contract staff members took place in FY 2015: Akihiko Fukui joined as a Project Research Fellow in April and Kouki Kamiya resigned as a Research Support Staff Member at the end of September.

3. Nobeyama Radio Observatory

1. Nobeyama 45-m Radio Telescope

(1) Open Use Observations

The 34th open use observations period started on December 1, 2015. In addition a new four pixel receiver FOREST with limited capabilities has been offered since Jan 6, 2016 as scheduled. The "Education Program" was not offered.

The statistics of the proposals are as follows, "General Proposals 1st period": 13 accepted including 2 from abroad (25 submitted), "General Proposals 2nd period": 8 accepted with none from abroad (21 submitted), "Short Programs": 5 accepted (9 submitted), "Backup Programs," which are carried out when weather is not acceptable for the main observations: 2 accepted (3 submitted). One proposal for "General Proposals 2nd period" was accepted as a "Backup Program" as recommended by the Time Allocation Committee. In addition, 2 proposals for the 45-m telescope's participation in VERA open use observations were conducted. The S80 and S100 receivers and the AOS were decommissioned.

(2) Improvements and Developments

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

- The replacement of the subreflector servo system was completed. A plan was developed for the millimeter wave calibration drive system repairs to be conducted next year.
- Surface measurements with the holography system and surface adjustment were performed. Consequently the surface accuracy of the 45-m telescope was improved.
- Gold foil was put on the 2nd and 3rd mirrors to reduce the loss of the beam transmission system and decreasing the antenna noise temperature by about 10 K at 3 mm.
- Some parts of the new multi-pixel receiver FOREST were replaced and the gain stability and linearity were improved.
- New AD converters were installed in all the intermediate frequency lines and were used in open use observations.
- NRO supported user instruments including the Z45 receiver in the 45 GHz band, the digital spectrometer ROACH, and a 90/150 GHz continuum camera.

(3) Scientific Results

We are carrying out the (a) Star Formation Project, (b) Galactic Plane Survey, and (c) Nearby Galaxy Project as legacy projects with the 45-m telescope. The star formation project and the Galactic plane survey project obtained scientific data and their results are described below. 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. We succeeded in finding a protostellar molecular outflow in the Orion Molecular Cloud data by using existing data taken by BEARS.

(b) Galactic Plane Survey Project (FUGIN: FOREST Ultra-wide Galactic plane survey In Nobeyama)

We are conducting the highest resolution simultaneous survey to date 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 2015, we covered areas with 46 and 28 square degrees for a total of 74 square degrees. In the last two years, 115 square degrees have been mapped. As a result, we have revealed a wide range of molecular clouds and their fine structures and also found a new cloud-cloud collision system and an interacting region with a supernova.

(c) Nearby Galaxy Project (COMING: CO Multi-line Imaging of Nearby Galaxies)

We started COMING (CO Multi-line Imaging of Nearby Galaxies) in April 2015 to map more than 200 nearby galaxies in ^{12}CO, ^{13}CO, and C^{18}O J=1–0 emission lines using FOREST. As of now, mapping observations of more than 40 galaxies are complete. Among our samples, the precise ^{13}CO/^{12}CO line ratio has been obtained for a barred galaxy NGC 2903. Excitation analysis revealed that star formation efficiency is determined by molecular gas density. In addition, through comparison with archived data of CO (J=3–2), it became clear that gas content depends on the surface gas density in dwarf galaxy NGC 2976.

2. Radio Polarimeters

Nobeyama Radio Observatory took over operation of the Radio Polarimeters at the beginning of the H27 (2015) fiscal year. On a monthly basis, the data are examined by solar research groups in Kyoto University, in 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.

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 environments of habitable planets, we have been carrying out monitoring observations in the 100 and 200 GHz bands with a 10-m telescope, the Solar Planetary Atmosphere Research Telescope (SPART). In conjunction with the refurbishment of the Interferometer Building (IB), all the NMA systems were removed and the new control room

for SPART was installed. Hereafter, the SPART system and its observations will be exposed to visitors. For corrective maintenance in 2015, carbon dust in the Az/El motors was removed and the 4K-GM/JT compressor leakage was repaired.

Observations started in March 2015, and we successfully demonstrated that CO mixing ratios in Venus's middle atmosphere were gradually decreasing. Comparative studies with the Radio Polarimeter data in Nobeyama are now on-going. In the coming year, atmospheric conditions on Venus and Mars are predicted to vary as the solar activity moves toward its minimum. Monitoring observations enable us to study chemical networks, dynamics, and the effects of high energy particles. We initiated a joint study with the Japanese Venus Climate Orbiter AKATSUKI.

(2) Nobeyama Radioheliograph (Nagoya Univ.)

In FY 2015, an international consortium (ICCON) assumed operation of the Nobeyama Radioheliograph (NoRH, see http://hinode.stelab.nagoya-u.ac.jp/ICCON/). The remote operating system via internet has functioned very well. About 30 researchers from six countries (China, Japan, Korea, Russia, the UK, and the USA) participated in operation, including the system health check and data verification. Observational data are automatically transferred to NAOJ and Nagoya Univ. and are stored/maintained there. NoRH data are used by researchers all over the world to study short-time scale phenomena, such as solar flares, and to study long-term activity as well. Recently, a methodology to determine the magnetic field intensity in the solar corona has been established. Then a press release was issued in February 2016 and an article was inserted in a science newspaper. On March 9 in 2016, a partial solar eclipse was successfully observed and the microwave images during the eclipse are released on the homepage of the Institute for Space-Earth Environmental Research (ISEE), Nagoya Univ.

4. Public Outreach

(1) PR activities at Nobeyama Campus

The Nobeyama Campus received a cumulative total of 52,614 visitors throughout the year, including participants in special open house events. Staff members conducted 42 guided tours, including ones for Super Science High School (SSH) students and the Campus Tour Week, while 3 requests for lectures and 22 requests for on-site filming and interviews were granted. These requests, especially those by some local broadcast stations in Nagano prefecture, increased due to efforts to strengthen cooperation with local communities. The Campus Tour Week for educational institutions was scheduled during the summer. Though only 1 group took advantage of this opportunity, students in the group enjoyed the visit. For the workplace visit, 7 students from 4 schools, primarily local junior-high schools, visited the observatory. Also, we conducted a career educational program for local high-school students and experience training for local teachers. For SSH initiatives, two 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 renovated all the panel displays and a brochure for children in order for visitors to become more familiar with NRO. The website of NRO presents introductory descriptions of radio astronomy and some events as well as observational results.

(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 forests of the University of Tsukuba. 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. NRO has also participated in the "Three Major Scenic Locations for Star Gazing in Japan • Night Sky Summit" conducted with the sponsorship of the Minamimaki Tourism Association since the planning stage. 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).

The "Artist in Residence" Program was carried out at NRO, organized by Siga-Kogen Romance Art Museum. Participating artists were inspired to make some artworks, which were exhibited in the special exhibition "Viewing the Universe", held in the Museum from July to October. Also, one of the old receivers from the 45-m radio telescope was displayed in the exhibition.

(3) Improvement Plan for the Nobeyama Millimeter Array Building

The building of the Nobeyama Millimeter Array will be improved to install an exhibition area highlighting NINS as well as NAOJ, in order to establish a PR center not only for astronomy but also for the natural science. The improvement work on the building and installation of the 4D2U theater were carried out in this year.

(4) NRO Conference Workshops

- Nov 2, 2015
  NRO Galactic Plane Survey Workshop 2015 (representative: Atsushi Nishimura)
- July 28-30, 2015
  NRO-ALMA Science/Development Workshop 2015 (representatives: Masao Saito (NRO), Daisuke Iono (Chile Observatory)
- Oct 20-22, 2015
  ALMA/45m/ASTE/Mopra Users Meeting 2015 (representative: Daisuke Iono (Chile Observatory), Masao Saito (NRO))

5. Education

NRO accepted two postgraduate students. One is a first-year Ph.D. student in SOKENDAI studying chemical reactions of carbon chain molecules. The other one is a visiting student from Kagoshima University whose research is a molecular cloud survey in the outer Galaxy and development of a new digital spectrometer using ROACH technology.

SOKENDAI held the workshop on Radio Astronomical Observation using the Nobeyama 45-m Radio Telescope from June 1 to 5, with 12 undergraduate students in attendance. The majority 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 to think of their future career.

6. Misc. Activities

(1) Hiring

Hiroyuki Kaneko: Specially appointed research staff
Yusuke Miyamoto: Specially appointed research staff

(2)Transfer

Jun Nishimura: Specially appointed research staff (to Nagoya University)

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 2015, a total of 427 (3670 hours) VLBI observations were conducted with VERA, such as common-use observations, VERA project observations, fringe detection observations for maser and reference sources, geodesy observations, JVN (Japanese VLBI Network) observations, KaVA (KVN and VERA Array) observations, and others. These VLBI data, except for KaVA, were processed at the Mitaka VLBI Correlation center in NAOJ Mitaka Campus until 2014; in 2015 these processing functions were moved to the Mizusawa correlation center. The correlated data were sent to each researcher for the case of common-use and JVN observations and to persons in charge of data analysess in the case of project data and geodesy data. Iriki station was damaged by a typhoon at the end of August. Due to this damage, Iriki station was unavailable for VERA observations for about two months.

VERA common-use calls-for-proposals with the 43, 22, and 6.7 GHz bands for semesters 2015B and 2016A were released in May and November, respectively. A total of 11 proposals, which requested a total time of 462 hours, were submitted, including 3 proposals for 130 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 7 proposals (227 hours) in 2015B and 2016A.

(2) Science Research

In FY 2015, the second part of the PASJ VERA special issue has been published as a continuation from the one in FY 2014. The FY 2015 part included 6 papers, and in total there have been 13 papers in the VERA special issues in 2014—2015. This has been the third PASJ VERA special issue after the ones in FY 2008 and FY 2011.

As the results of the project observations of VERA, the parallaxes and proper motions have been reported for five galactic star-forming regions, namely, G48.99−0.30, G49.19−0.34, IRAS 20126+4104, IRAS 21379+5106, and IRAS 07427−2400. The last source is located in the Perseus spiral-arm, and together with the previously published sources associated with the arm, non-circular motion associated with the Perseus spiral-arm was successfully detected, showing systematic inward motion toward the Galactic center and lagging behind the Galactic rotation. It has been shown that the motions can be described well by a density-wave-type spiral model. This is the first result on the Galactic non-circular motion based on VERA astrometry, and thus it is one of the milestones of the Galactic structure study with VERA. Simulation studies have been performed to evaluate the expected accuracy with which future VLBI astrometry will be able to constrain the Galactic parameters. It is demonstrated that astrometric measurements for ~300 sources will provide accuracies of a few % for the Galactic fundamental parameters and accuracies of about 10 % for the parameters associated with the non-circular motion and asymmetric structure, such as spiral arms and/or bar.

Astrometric results are also published for a late-type star U Lyn, and the data are used to calibrate the Period-Luminosity relation of Mira-type variables based on U Lyn and 8 other sources for which accurate distances have been measured so far.

Other than the Galactic astrometry, astrometric observations of the core position of TeV blazar Mrk 501 have been used to constrain the Lorentz factor of the jet, demonstrating that accurate VLBI astrometry has a wide range of possible applications other than Galactic structure studies.

2. JVN (Japanese VLBI Network)

The Japanese VLBI Network (JVN) is operated as a joint research project of NAOJ and seven universities. JVN consists of VERA and radio telescopes operated by universities and research institutes such as ISAS/JAXA, NICT, and GSI. VLBI observations by JVN were done for 250 hours at 3 bands of 6.7, 8, and 22 GHz in FY 2015. Single Dish Observations related to JVN were also done about 2000 hours at each telescope. The major research topics are AGNs, masers, and star forming regions.

The main subjects of research are active galactic nuclei and masers in star-forming regions. Scientific results obtained

with JVN were published as four papers, while ten more papers reported JVN related scientific studies. Fujinaga et al. (2016) reported the results of a gamma-ray-emitting-AGN survey through high-sensitivity VLBI observations. Sugiyama et al. (2016) reported the first results of internal motion in a 6.7 GHz methanol maser source obtained by EAVN (East-Asian VLBI Network) including JVN. Yonekura et al. (2016) reported on the telescope and observing system of Ibaraki station. Nine papers including the above four will be published as a special issue of PASJ in FY 2016.

Education is also one of the main aims of university collaboration in VLBI. Twenty-nine students conducted undergraduate studies using JVN and related research activities. Sixteen master-course students completed their master's theses using JVN, and two Ph.D. students finished their theses using JVN. Many university students made presentations and talks in research meetings related to JVN.

3. Japan-Korea Joint VLBI (KaVA)

(1) Observations and Common-Use Observations

In 2015, a total of 121 (1023 hours) VLBI observations, common-use observations and test observations, were conducted by KaVA (KVN and VERA Array) with the 43 and 22 GHz bands. The data of the seven VLBI stations were correlated at the Korea-Japan Joint Correlation Center at KASI Daejeon Campus in South Korea.

KaVA common-use call-for-proposals for semesters 2015B and 2016A were made in May and November of 2015, respectively. In total, 20 proposals requesting a total time of 736 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 15 proposals (507 hours) were accepted in 2015B and 2016A.

(2) Results of Research

Following the successful opening of KaVA common-use observations and the first publications of KaVA papers in FY 2014, the science productivity of KaVA is growing satisfactorily with the stable array operation throughout FY 2015. As for AGN science, the detailed motions of relativistic jets are now regularly monitored for a number of sources; three refereed papers were published on several bright blazars including 3C345 during FY 2015. Moreover, our KaVA monitoring of the M87 jet made the first discovery of a superluminal motion near the black hole. The talk on this result was selected for a press release at the ASJ meeting in March 2016 and was picked up by many media outlets, returning scientific results from KaVA to the broad general public. Another refereed paper reporting a detailed imaging of SiO masers around the late-type star WX Psc was also accepted.

The KaVA Large Program has finally started from late FY 2015, which aims at performing ambitious, high-scientific-impact studies with KaVA by spending a large amount (typically more than 100 hours per year) of the machine time. Currently three large programs are ongoing, each of which is led by one of the three KaVA science working groups (AGN, star-forming regions, and late-type stars). Not only researchers in NAOJ/KASI but also many external researchers (universities in Japan/Korea, Australia, Italy, etc.) are joining these projects. Scientific outcomes based on these programs will be expected to emerge from the next year.

4. EAVN

Aiming at expanding the capability of international VLBI over East Asia, the development of the East-Asian VLBI Network (EAVN) is currently underway as a collaboration between Japan, South Korea, and China. Technical assessment of the array and test observations are promoted by the Japan-Korea-China joint task force (the so-called Tiger Team), and in FY 2015 a report summarizing the successful detections of fringes over the last few years was published in the proceedings of an international conference (Wajima et al. 2015). Following this success, in FY 2015 further test observations were conducted to evaluate the imaging performance of the EAVN array at 8, 22, and 43 GHz. Detailed reports of these data will appear next year.

Meanwhile, recently there is a growing discussion toward the future construction of a new VLBI facility in Thailand (Thailand VLBI Network; TVN). In these circumstances, in FY 2015 a KaVA science workshop was held in Thailand in collaboration with local astronomers, and discussed the possibility and potential impact of the future extension of TVN by joining the EAVN.

In FY 2015 the annual EAVN workshop was held at Hokkaido University, and the next meeting in FY 2016 will take place in China.

5. Geodesy and Geophysics

The regular geodetic sessions of VERA are allocated two or three times per month to maintain baseline accuracy of the array. VERA internal geodetic observations are performed once or twice per month using K-band, and the VERA Mizusawa station participates in IVS sessions using S- and X-bands on a once-per-month basis. In order to improve stability among the geodetic results, experimental geodetic VLBI observations which use newly developed high speed samplers and recorders were started and geodetic results were obtained from 8-Gbps recording data.

In FY 2015, 11 IVS sessions and 17 sessions of VERA internal geodetic observations were conducted. The final estimation of geodetic parameters is derived by using the software developed by the VERA team.

After "The 2011 off the Pacific coast of Tohoku Earthquake" (Mw=9.0), VERA Mizusawa was displaced by co-seismic crustal movement, and post-seismic creeping continued to be detected in FY 2015. According to the newest analysis, the co-seismic steps are $X = -2.066$ m, $Y = -1.420$ m, and $Z = -1.064$ m; and the displacement by creeping during FY 2015 is $X = -0.101$ m, $Y = -0.056$ m, and $Z = -0.015$ 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-south-east of Mizusawa even though 5 years have passed since the occurrence of the 2011 off the Pacific coast of Tohoku Earthquake. Continuous gravity observations with superconducting gravimeters are carried out at Mizusawa and Kamioka. Similar observation is 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 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 2015, the magnetic tape recorders were replaced with new hard disk drive recorders, and the Mitaka FX correlator was also replaced with a newly developed software correlator. The software correlator is located at Mizusawa Campus and is now in regular operation. The modifications to the KJCC (Korea Japan Correlation Center) system were done based on the feed-back from scientific evaluation of the KaVA observations. Discussions on future development have been done in particular toward high frequency VLBI and SKA as future extensions of VLBI activities. Basic design and development were done including a low power consumption optical transmitter, ultra-wideband A/D convertors, high accuracy surface reflectors, 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 VERA Mizusawa station. The facilities have been operating stably, contributing to the determination of UTC (Coordinated Universal Time) through continuous management and operation of the time system. The NTP (Network Time Protocol) server at the Timekeeping Office provides “Japan Central Standard Time” on a network. This service has been in great demand with more than 1,500,000 daily visits recorded last year.

8. Ishigakijima Astronomical Observatory

FY 2015 is the 10th year since Ishigakijima Astronomical Observatory (IAO) was opened in FY 2006. Since “Room for Learning the Starlit Sky” was established as an annex to the observatory by Ishigaki City in FY 2013 to screen 4D2U (Four-Dimensional Digital Universe), the number of visitors per year has increased to more than 14,000 people in FY 2015.

In terms of the research at IAO, observations of transient objects such as gamma-ray bursts and Solar System objects were performed in collaboration with Japanese universities. There were six published refereed papers for which the observations at IAO played an important role, including the study of the comet 17P/Holmes.

The number of participants in the “Southern Island Star Festival,” which has been held for 14 times, has also been increasing, and 9000 people attended the light-down stargazing party. Since FY 2015 is the 70th anniversary of the end of World War II, the movie “Vega shining over the battlefield,” produced by the Yamanashi Prefectural Science Center, was screened in the astronomy lecture room, and a Japanese Tanka contest on “Stars and Peace” was held by inviting famous Tanka poet Machi Tawara to be a selector. Eventually about 11,000 people participated in the festival.

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. The asteroid (372024) that was discovered by the high school students who participated in the workshop in 2008 was named “Ayapani” by public subscription.

On the other hand, interaction and personnel exchange with Japanese public astronomical observatories were promoted. The star summit was held in Minamimaki, Nagano, where Nobeyama Radio Observatory is located. The special rice-fish called "Space Medaka" were donated from by Saji Observatory in Saji, Tottori, and they are being bred in Ishigaki City, Nagura elementary and junior-high school.

9. Public Relations (PR) and Awareness

In order to promote public outreach, special open house events were done as follows, and regular campus visits are also offered throughout all the seasons as summarized below.

(1) Open House Events

April 19, 2015

The Sixth Open Observatory Event held at the Ibaraki University Center for Astronomy, and NAOJ Mizusawa VLBI Observatory, Ibaraki station, with approximately 230 visitors.

July 4

The 23rd Tanabata 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 100 visitors.

August 8

The special open house of VERA Iriki station held jointly with “The Yaeyama Highland Star Festival 2015,” with approximately 4000 visitors in attendance.

August 15–23

The “Southern Island Star Festival 2015” held together with a special open house event at the VERA Ishigakijima station and Ishigakijima Astronomical Observatory with 10,930 visitors

to the whole "Star Festival." Events included an astronomical observation party at Ishigakijima Astronomical Observatory, attended by 877 visitors; and a special public opening of the VERA station attended by 238 visitors.

August 22

"Iwate Galaxy Festival 2015", open house of NAOJ Mizusawa Campus, held with 660 visitors in attendance.

February 14, 2016

"Star Island 15," open house event of VERA Ogasawara Station held with 222 visitors in attendance.

(2) Regular Public Visiting

Throughout the year, the following stations are open to public on a regular basis.

The numbers of visitors to each facility is as follows,

a) VERA Mizusawa Observatory 17,415
The open house event is held at the campus with the cooperation of the Oshu Space and Astronomy Museum (OSAM: Yugakukan) located in the campus.
b) VERA Iriki Station 1551
c) VERA Ogasawara Station 8540
d) VERA Ishigakijima Station 2713
e) Ishigakijima Astronomical Observatory 13,906

Stargazing sessions: Evenings on Saturdays, Sundays.

The "Room for Learning the Starlit Sky" (featuring the 4D2U "Four-Dimensional Digital Universe"), constructed adjacent to the observatory in FY 2013 by Ishigaki City, was very popular, welcoming 3925 guests.

(3) Access Statistics of the Website Contents

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

Contents List	Sessions	Internet Users	Page Views
Mizusawa VLBI Observatory	24,201	17,337	72,608
VERA	11,678	6,778	39,952
Kimura Hisashi Memorial Museum	5,726	5,057	8,646
Ishigakijima Astronomical Observatory	80,769	50,319	161,242

10. Education

(1) University and Post-Graduate Education

Regarding postgraduate education, the Mizusawa VLBI Observatory assisted two graduate students from the University of Tokyo and two from SOKENDAI for their PhD/master's research. One of the students from the University of Tokyo completed his master's thesis. One master's student from Tokai University was accepted as a visiting graduate student. Undergraduate students from Tohoku University and Tokai University were accepted as summer students of SOKENDAI. The Observatory staff organized "The Radio Astronomy Winter School 2016" in collaboration with NARIT (National Astronomical Research Institute in Thailand) and UST (University of Science and Technology, South Korea). The school was held February 15-19, 2016 at Chiang Mai in Thailand. About 30 students from Asian countries attended the School. The University of the Ryukyu and NAOJ have offered a joint course on astronomy from FY 2009. Classroom lectures at the university took place August 24-27, and observational workshops were held in Ishigakijima from September 1 to 4, with a total of 25 participants. In addition, staff members of Mizusawa VLBI Observatory give lectures at the University of Tokyo and Tohoku University as visiting professors.

(2) Research Experience for High School Students

"The 9th Z Star Research Team Event" was held August 1-3 to use the VERA Mizusawa antenna for observation. Eleven high school students from Iwate Prefecture attended. During August 12-14, the VERA Ishigakijima station and The Ishigakijima Astronomical Observatory held "The Chura-boshi Research Team Workshop" for 18 high school students from Ishigakijima. It was organized under support from JSPS. One of the groups detected a new maser source using the VERA Ishigakijima station, and presented the results in the open-house of VERA Ishigakijima station. 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. The observational results were presented in "The Junior Session" in the annual meeting of "The Astronomical Society of Japan".

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 outer solar atmosphere, including the photosphere, chromosphere, corona, and solar wind; and active phenomena such as sunspots, faculae, prominences, and flares. This observatory performs regular observations using instruments such as the Solar Flare Telescope (SFT) and also conducts expeditions to observe total solar eclipses. It is also engaged in the planning of future ground-based solar observations. Regular observations of sunspots and flares have been carried out for extended periods, and the resulting data are provided to researchers.

1. Observational Facilities in Mitaka

(1) Magnetic Field Observation

The SFT, which has been the main instrument of the Observatory at Mitaka Campus, has continued observations of active region photospheric vector magnetic fields and H-alpha flares since its full completion in 1992. The main instrument on the SFT since 2010 is an infrared Stokes polarimeter. Whereas previous magnetic field observations covered part of the solar surface, this instrument is designed to perform full-disk polarimetric observation to obtain high accuracy vector magnetic field information in order to shed light upon the origins of the solar activity cycle. This polarimeter is equipped with a 15-cm infrared-transmitting lens and performs slit scanning observations using infrared spectral lines (photosphere: iron, 1.56 μm line; chromosphere: helium, 1.08 μm line), which are sensitive to the magnetic field. This allows for constant acquisition of unprecedented infrared polarization data for the photosphere and chromosphere of the entire solar disk. It had taken about two hours to cover the full Sun with a slit scan for each wavelength range, but a new system enables us to observe two wavelength ranges simultaneously using two cameras installed in 2014. The data acquisition is now conducted more efficiently. To further improve the data quality, the installation of an advanced infrared camera with a large format and low read-out noise is being conducted, 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 2015, from April to March.

Although full-disk solar image data are a widely needed resource in the astrophysics/geophysics community, some of these synoptic instruments are becoming out of date. Efforts are underway to update the photospheric and chromospheric imaging instruments and to further flesh out the data. For instance, the SFT has started advanced observations in the H-alpha line to acquire full-disk, high-resolution images. It can obtain Doppler velocity information based on imaging at multiple wavelengths around H-alpha. High temporal resolution allows it to more completely capture active phenomena, and a combination of multiple exposure times allows for a broad dynamic range. Further improvement in dynamic range and read-out noise was accomplished using sCMOS cameras installed in this year. 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 imaging observations in the G-band (430 nm) and continuum wavelengths. In addition, CaII K (393 nm) filter observation has started this year.

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

2. Opening of Data Archives to 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 when they are digitized and organized. As some of the world's oldest records of solar activities, these materials are expected to add particular insight into future research. 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 information has

since been transferred to the Astronomy Data Center, where all relevant data servers have been managed in an integrated fashion. The same data are stored at multiple locations in the data center, serving as a backup in case of disaster.

3. Other Activities/Personnel Transfers

International cooperation includes support for the Japan–Peru collaborative solar observations, with which the Solar Observatory has been involved since 2004. 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, the coronagraph was reassembled and used to run test observations at Norikura Corona Observatory, this year. 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 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 solar optical observations 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, their removed H-alpha Lyot filter and telescope/coelostat for solar magnetic field measurements were placed in storage at Mitaka this year.

A research plus business conference, dubbed as the annual users meeting, has been held every year jointly with other organizations. The meeting is combined with the solar research symposium for the entire solar community, where topics related to open use and future plans are also discussed. The conference was held at NAOJ between February 15 and 17, 2016.

Observation of the total solar eclipse of March 9, 2016 in Indonesia was conducted by Drs. Hanaoka and Morita. The observation was not so successful because of a cloudy sky, but some data of prominence and corona through the clouds were obtained.

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. Masaoki Hagino replaced a previous research expert, Dr. Naomasa Kitagawa. Dr. Anand Joshi will take a position as specially appointed research staff at the start of the new fiscal year, after the departure of Dr. Ken'ichi Otsuji. Prof. Takashi Sakurai was honorably discharged in the end of FY 2015, March 2016.

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 construct and operate a gigantic millimeter/submillimeter radio telescope deploying 66 high-precision parabolic antennas in the 5000-m altitude Atacama highlands in northern Chile. ALMA aims to achieve a spatial resolution nearly ten times higher than that of the Subaru Telescope or the Hubble Space Telescope. Early scientific observations with ALMA began in FY 2011 with a limited number of antennas and full operation commenced in FY 2012. This report describes the progress of the ALMA project, which includes the results of the open-use scientific observations and public outreach activities. The ASTE telescope is a single-dish 10-m submillimeter telescope located in the Atacama highlands. It has been operated to make headway into submillimeter observations toward the ALMA Era. This report also describes the progress of the ASTE telescope.

1. ALMA Project Progress

Along with scientific observations, ALMA commissioning observations have been underway, including polarization tests and solar observation tests.

NAOJ staff members played leading roles in the polarization tests and solar observation tests. As demonstrated by Koichiro Nakanishi and Hiroshi Nagai for polarization, and Masumi Shimojo for solar observation tests, East Asian researchers have been taking the initiative in the international teams. Also Band 10 receivers, the highest observing frequency band, became available for scientific operations starting from the fourth round of open-use observations of ALMA (Cycle 3) which started in FY 2015. The sub-components developed by Japan, such as the antennas, correlators, and receivers (Bands 4, 8, and 10), are working properly for the operations.

2. ALMA Open-Use and Scientific Observations

The fourth round of open-use observations of ALMA commenced in October 2015 as Cycle 3. The Cycle 3 main capabilities include: interferometric observations using thirty-six 12-m parabolic antennas; Atacama Compact Array (ACA) observations (interferometric observation with ten 7-m antennas and single-dish observations with two 12-m antennas); seven frequency bands (Bands 3, 4, 6, 7, 8, 9, and newly-added Band 10); maximum baselines greatly extended from 1.5 km to 10 km (for Bands 3 to 6), 5 km (for Band 7) and 2 km (for Band 8 to 10); and polarization for continuum observations. In response to the Cycle 3 call for proposals, 1578 observation proposals were submitted from all over the world. This figure exceeded the world's highest number of proposals ever recorded, which was submitted to the Hubble Space Telescope. Such a high submission rate to ALMA shows high expectations for "the global telescope ALMA" with the potential to contribute to a wide-range of fields such as galaxy formation, star and planet formation, the Solar System, astrobiology, and interstellar chemistry.

An open call for the fifth round of open-use observations was issued as Cycle 4. The anticipated capabilities of Cycle 4 include: interferometric observations using forty 12-m antennas; 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), maximum baselines of 12.6 km (for Bands 3 to 6), 6.8 km (for Band 7), and 3.7 km (for Bands 8 to 10). Cycle 4 also provides new opportunities for large programs that require long observations exceeding 50 hours; millimeter-wavelength VLBI observations; ACA stand-alone mode; solar observations; and polarization for spectral line and continuum observations. The public call for Cycle 4 proposals is set to close at 00:00 JST on April 22, 2016. Cycle 4 is scheduled to start in October 2016.

Open use of ALMA has already produced a number of scientific achievements. This section describes some of them, focusing mainly on East Asian projects. A research group led by Yoichi Tamura at the University of Tokyo found several dust clouds with a size of 500 light-years distributed inside SDP.81 through detailed analyses of the image of the gravitationally lensed galaxy SDP.81 captured by high-resolution observations with ALMA and comparison of this image to its gravitational lens model. The results of their study also indicate the existence of a supermassive black hole over 300 million times more massive than the Sun at the center of the foreground galaxy. A research group led by Kyoko Onishi at SOKENDAI (The Graduate University for Advanced Studies) observed the barred spiral galaxy NGC 1097 with ALMA and through a detailed study on the kinematics of molecular gas at the center of the galaxy found that this galaxy harbors a supermassive black hole 140 million times more massive than the Sun. This research result is based on the ALMA observation data obtained within a two-hour observation, which demonstrates the outstanding capability of ALMA in the mass measurement of supermassive black holes. A research team led by Hideki Umehata successfully captured a cluster of nine starburst galaxies in a cluster of young galaxies 11.5 billion light years away from the Earth (at the center of a "proto-Great Wall" known as the largest structure in the Universe). This result supports the idea that the proto-Great Wall is the matrix that supports the formation of galaxies. This could lead to unveiling the formation process of starburst galaxies and their subsequent evolutionary process. A research team led by Yusuke Aso at the University of Tokyo and Nagayoshi Ohashi at NAOJ observed a proto-star called TMC-1A and revealed the movements of the inner rotating gas disk around the proto-star and the outer gas envelope with the highest accuracy ever achieved. The high-sensitivity observations with ALMA made it possible to directly observe the boundary between the disk surrounding the proto-star and the outer infalling gas envelope. These results are very important in

finding out when the proto-planetary disk appears in the process of star formation and how it evolves.

3. Educational Activities and Internship

Two undergraduate students joined research activities on an internship at the NAOJ Chile Observatory office in Mitaka: one came from the University of Science and Technology of Hanoi in Vietnam from June through September 2015; and the other from the FTP University in Vietnam from January through March 2016.

4. Public Outreach Activities

Approximately 35 newspaper/journal articles were published in Japan, reporting the achievements of scientific observations and test observations with ALMA, while there were 14 Japanese television/radio programs that featured ALMA. In these programs, they showed the results of ALMA observations in various fields of astronomy; in particular, a news program called "News 7" on NHK G channel covered ALMA focusing on the field of astrobiology. In online media, "IFLScience!" (a scientific website with a great number of subscribers) posted an article on ALMA observation results delivered by Japanese researchers, which was shared and liked on Facebook by 17,000 users. As seen in this example, the scientific results by Japanese researchers have been increasingly propagated worldwide.

The NAOJ ALMA website posted 43 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 27,500 followers as of the end of FY 2015.

In May 2015, NAOJ Chile Observatory hosted a week-long ALMA booth at the Japanese Geoscience Union Meeting held in Makuhari Messe. NAOJ Chile Observatory organized public lectures and science cafe events on 26 occasions in FY 2015 to provide updated information and increase interest in ALMA and its scientific achievements through conversation with a large number of visitors. Especially, the 21st ALMA public lecture titled "Star and Planet Formation Explored by ALMA" held in Osaka Science Museum on December 12, 2015 attracted a big audience exceeding 200, which was a great opportunity to provide the latest scientific results to the public.

As part of the construction film project continuing since FY 2003, NAOJ Chile Observatory produced a new film that shows the development of the receivers at the Advanced Technology Center (ATC), focusing on the development and production of receiver cartridges in FY 2014. In addition to this, interviews with developers of the ACA correlators were also filmed.

The NAOJ newsletter featured ALMA in the September 2015 issue with an article summarizing the ALMA project and its scientific achievements so far, including interviews with ALMA staff members at the ALMA Regional Center to widely cover the staff members supporting the open use and promoting their scientific activities, including their enthusiasm and passion for the work.

From mid-March 2015, ALMA started to welcome public visits to the ALMA Operations Support Facility (OSF) at an altitude of 2900 meters. Every Saturday and Sunday, ALMA admits up to 40 people/day (advance registration is required). Visitors to the OSF can have a guided tour including the control room, and watch videos on ALMA. Each time, registration reaches full capacity soon after the start of registration. Public visits to ALMA are now becoming good opportunities to provide many people live experience of the workplace of ALMA researchers.

5. International Collaboration (committees, etc.)

Two agreements concerning the operations and development of ALMA were concluded between the National Institutes of Natural Sciences (NINS) and Academia Sinica in Taiwan (AS) on July 21, 2015, and between the National Astronomical Observatory of Japan (NAOJ) and Academia Sinica Institute of Astronomy and Astrophysics in Taiwan (ASIAA) on July 27, 2015 respectively. On December 15, 2015, representatives of the National Institutes of Natural Sciences (NINS), the European Southern Observatory (ESO) and the U.S. National Science Foundation (NSF) gathered in Tokyo and signed a trilateral agreement concerning the operations of ALMA.

Since ALMA is an international collaboration project, meetings are held frequently by various committees. In FY 2015, 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. In addition, face-to-face meetings and teleconferences have been held on a quarterly basis among the East-Asia ALMA Science Advisory Committee (EASAC). Each working group holds meetings and teleconferences more frequently to maintain close communication in implementing their tasks in the international project.

6. Workshops and Town Meetings

- July 28 to 30, 2015 NAOJ Nobeyama Radio Observatory (NRO)
  NRO-ALMA Science/Development Workshop 2015
- October 20 to 22, 2015 NAOJ Mitaka
  ALMA/45-m/ASTE/Mopra Users Meeting
- December 8 to 11, 2015 I-site Nanba
  International Workshop "EA ALMA Science Workshop"
- March 9, 2016 Ehime University
  ALMA Cycle 4 Town Meeting
- March 22 to 23, 2016 Kagoshima University
  ALMA Cycle 4 Town Meeting
- March 25, 2016 Kyoto University
  ALMA Cycle 4 Town Meeting
- April 4, 2016 NAOJ Mitaka
  ALMA Cycle 4 Town Meeting

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

- Daisuke Iono: Inamori Grant Program by the Inamori Foundation
- Satoru Iguchi: Grant for Japan-related Research Projects by the Sumitomo Foundation

8. Research Staff Changes

(1) Hired
- Kana Matsui: specially appointed research staff
- Fumi Egusa: specially appointed research staff
- Tatsuya Takekoshi: specially appointed research staff

(2) Departed or transferred
- Rie Miura: specially appointed research staff, hired as a specially appointed assistant professor at NAOJ Chile Observatory
- Junko Ueda: specially appointed research staff, transferred to the Harvard-Smithsonian Center for Astrophysics as a post-doctoral fellow
- Yasutaka Kurono: specially appointed research staff

9. Main Visitors

- April 23, 2015
  Mr. Naoto Nikai Ambassador of Japan to Chile, visited the ALMA Operations Support Facility (OSF) and the Array Operations Site (AOS)
- May 6, 2015
  A group of researchers from universities in Taiwan visited the OSF and AOS
- May 8, 2015
  Mr. Kosaburo Nishime, State Minister for Internal Affairs and Communications (MIC) and his party; Dr. Fumihiko Tomita, Vice President of the National Institute of Information and Communications Technology (NICT), Dr. Shinro Mashiko, Vice President of NICT, and Mr. Pedro Huichalaf, Vice Minister (Undersecretary) of Telecommunications, visited the OSF and AOS
- October 16 to 18, 2015
  Dr. Akihiro Kubota, Professor at Tama Art University visited the OSF and AOS

10. Progress of ASTE Telescope

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

Other than ALMA, there are only two large-scale submillimeter telescopes with a 10-m-class antenna that can observe the southern sky in the world: one is ASTE and the other is APEX operated by ESO. Therefore, having ASTE operated by Japan will be a big advantage in strengthening ALMA proposals and in implementing our strategies for further extending the capabilities of observing equipment. Looking to 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 Radio Telescope.

Three public calls were made in FY 2015 for open-use observation proposals: the first call (2015a) for spectroscopic observations in 345 and 460 GHz bands was from June to September, the second call (2015b) and an additional call for spectroscopic observations only in the 345 GHz band (2015c) from October to December. To render support for researchers contributing to enhancing the observational performance of ASTE, the Guaranteed Time Observation (GTO) scheme has been offered since FY 2013. This allows them exclusively to make proposals for the GTO slots. A total of 53 proposals for open-use observations and GTO slots had been made including 25 for open use and one for GTO in the first call; 12 for open use in the second call; and 15 for open use in the additional call. These proposals were reviewed by the NAOJ Chile Observatory program subcommittee and 41 proposals were subsequently adopted, including 22 for open use and one for GTO in the first call; 11 for open use in the second call; and seven in the additional call. Open-use observations were carried out from the ASTE Mitaka operation room, other universities or research institutes between June 8 and December 18, 2015.

7. Center for Computational Astrophysics

1. Overview

The Center for Computational Astrophysics (CfCA) has been operating a system of open-use computers for simulations centered around a general-purpose supercomputer and the special-purpose computers for gravitational many-body problems; carrying out research and development of computational astrophysics; and performing astronomical research with simulations. The main supercomputer of the present system, ATERUI (Cray XC30), has a theoretical peak performance of 1 Pflops, which makes it 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. Efforts in visualizing astronomical data also continue.

2. Open Use

(1) Computer Systems

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

While XC30 is leased 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 cluster 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, to encourage effective open use of the GRAPE system, the Center undertook development, improvement, and maintenance of both hardware and software for the system this year. Major events of this year were the end of GRAPE-7 operations and the official operation of GRAPE-9. This system offers a roughly 10-fold performance improvement over GRAPE-7.

Computational resources are allocated from the XC30, GRAPEs, and smaller computational PC cluster 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 2014 on studies that involved the project's open-use computers. It turned out that 75 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, for providing users with information and transmitting various application forms as necessary. 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. No paper was accepted in FY 2014 for payout in FY 2015, while four papers were accepted in FY 2015 for payout in the same year at approximately 500,000 JPY.

□ Statistics on the Cray XC30
Operating hours
- Annual operating hours: 8561.0
- Annual core operating ratio: 87.13 %

Users
- Category S: 1 adopted in the first term, 0 in the second term; total 1
- Category A: 13 adopted at the beginning of the year, 2 in the second term; total 15
- Category B: 70 adopted at the beginning of the year, 15 in the second term; total 85
- Category MD: 15 adopted at the beginning of the year, 3 in the second term; total 18
- Category Trial: 45, year total
- Category I: 0, year total

□ Statistics on the GRAPE system
Users
- Category A: 3 adopted at the beginning of the year, 0 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: 0, year total

□ Statistics on PC cluster
Operating hours
- Annual operating hours: 7764.7
- Annual job operating ratio: 73.3 %

Total users: 37, 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. Note that in FY 2015, the CfCA Users Meeting was held at Mizusawa VLBI Observatory, Iwate.

□ Cray XC30 workshop for intermediate users: January 15, 2016, 4 attendees

□ N-body simulation Winter School: January 20-22, 2016, 16 attendees

□ Users meeting: January 28-29, 2016, 63 attendees

3. PR Activities

CfCA took part in the special open house of Mizusawa Campus, Iwate Galaxy Festival 2015, held on August 22, 2015. About 150 visitors attended the ATERUI guided tours and experienced a close-up look at the facility. Dr. Tomoaki Ishiyama, Associate Professor at Chiba University and one of the users of ATERUI, was invited to this event as a special lecturer and talked about the latest results of his research obtained through ATERUI's simulations. At the Mitaka open house held on October 24, 2015, CfCA made the computer room accessible to the public and introduced simulation astronomy with GRAPE and the PC cluster. A live broadcast was also arranged by connecting the supercomputer operation room in Mizusawa Campus to Mitaka Campus to introduce ATERUI to those visiting Mitaka. In addition to the open house, CfCA has accepted two groups of high school students to tour the computer room in Mitaka Campus. Moreover, CfCA ran a booth at the 19th NINS Symposium "From the Universe to Brains "Big Bang" of the Natural Science Researches" held at Nagoya University on September 20, 2015 and introduced research results from simulation astronomy calculated by the CfCA system.

In FY 2015, two press releases were issued from CfCA: "The World's Largest Scale Dark Matter Simulation from the Beginning of the Universe to the Present Performed by Supercomputers" (May 1, 2015, Tomoaki Ishiyama, Associate Professor at Chiba University) and "Origin of Saturn's F Ring and Its Shepherd Satellites Revealed" (August 18, 2015, Ryuki Hyodo, Graduate Student at Kobe University). In addition, the press release from the NAOJ Hinode Science Center, "Hinode, IRIS, and ATERUI Cooperate on 70 year old Solar Mystery, Magnetically driven resonance helps heat the Sun's atmosphere!" (August 24th, 2015), included a result of calculations by ATERUI (Dr. Patrick Antolin, NAOJ). A Twitter account @ CfCA_NAOJ and YouTube channel have been operated to provide information about CfCA.

4. 4D2U Project

In FY 2015, the 4D2U project continued to develop and provide movie contents and software. A movie about simulations titled "Formation and Evolution of Dark Matter Halos (II. Formation of the Large-Scale Structure of the Universe) ver.2" was released on the 4D2U website in May 2015. Distribution of the dome master format data was also started. Other movies, "Giant Impact of protoplanets", "Dynamics of Saturn's Ring (II. Propeller Structure)", and "Formation of plametesimals" have been developed. Updated versions of the four-dimensional digital universe viewer, "Mitaka," were released in June 2015 (ver.1.2.4), July 2015 (ver.1.2.5), November 2015 (ver.1.3.0) and March 2016 (ver.1.3.1). These versions of Mitaka included the new functions, e.g. displaying probes like New Horizons and Hayabusa2, multilingual displays, and depiction of solar and lunar eclipses. On February 9, 2016, the 4D2U Project put out a press release about the multilingualization of Mitaka. The imaging speed of Mitaka was made faster and faster with every update.

On April 2, 2015, the 4D2U Project and Public Relations Center (PRC) held a press tour of the renewed 4D2U Dome Theater. A total of 26 of media affiliates from 22 companies attended and various news outlets picked up the renewed theater as news. In cooperation with PRC, we enhanced English contents, such as the English websites of 4D2U and Mitaka, the English manual of Mitaka, English instructions for 4D2U movies, and terms of use. We started to accept applications for usage of 4D2U contents in English in October 2015. The 4D2U Project supported and provided content for exhibitions held in museums and galleries, including "Moon + Sun Exhibition" (Konica Minolta Plaza, Apr. 22 - May 8, 2015), "The Feeling of the Four-Dimensional Universe" (Ehime University Museum, May 20 - Jul. 27, 2015) and "Forms of the state-of-the-art Network" (Chiba Museum of Science and Industry, Oct. 17 - Dec. 6, 2015). The dome master data of the latest movie contents "Formation and Evolution of Dark Matter Halos (II. Formation of the Large-Scale Structure of the Universe) ver.2", "Giant Impact of Protoplanets," and "Dynamics of Saturn's Ring (II. Propeller Structure)" were provided for a planetarium program "Cyber Universe Ver.2" screened at Katsushika City Museum (Oct. 6 - Dec. 27, 2015). In addition, Mitaka and some movie contents were used in the 5 minute TV program "Planet Kanko (Site seeing) Taxi" (total 5 stories, produced by Office Raft) broadcast on NHK. Moreover, 4D2U contents were provided for TV programs, planetarium programs, lecture presentations, books, and so on. In FY 2015, the 4D2U Project gave Mitaka (Standard version and Head Mounted Display version) demonstrations at the open houses of Mizusawa and Mitaka campuses and the 19th NINS Symposium "From the Universe to Brains "Big Bang" of the Natural Science Researches." Many visitors enjoyed Mitaka outside of the 4D2U Dome Theater. A Twitter account @4d2u and YouTube Channel have been operated to provide information about 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: the Center for Computational Sciences (CCS) of the University of Tsukuba; the High Energy Accelerator Research Organization, known as KEK; and NAOJ to provide active support for computational scientific research. The CfCA forms the core of NAOJ's contribution to the JICFuS. In particular, the institute engages primarily in computer-aided theoretical research into 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 abilities as a single organization, a major feature of the institute is the cooperation of its three member organizations and their communities to provide considerate and rigorous support to present and future researchers. Another important mission of the institute is to provide researchers around Japan with advice regarding efficient supercomputer use and the development of novel high-performance computing algorithms to meet research goals from the perspective of computer specialists. In addition in FY 2014, JICFuS was adopted as one of the "Research and Development, Application Development of scientific/social issues that require particular attention by the use of a Post-K computer." The program started this year.

In order to implement research plans, Hiroyuki Takahashi was engaged as a project assistant professor, and Tomohisa Kawashima was engaged as a project researcher. Takahashi developed a new plasma simulation code to solve basic equations of general relativistic radiation magnetohydrodynamics (MHD). By performing global simulations of black hole accretion disks, he revealed that jet power and gas temperature increase via the extraction of the rotational energy of the black hole. He also developed a radiation-MHD code by which the radiation transport is more exactly solved. Kawashima developed a radiation transfer code in curved space-time. In addition, he performed numerical simulations of gas accretion onto neutron stars polar regions, since some of the candidates thought to be black holes have been identified as neutron stars instead. As a result, he revealed that the observed large luminosities can be reproduced even in the neutron star accretion flows.

Representing the CfCA, Professor Kohji Tomisaka and Assistant Professors Ken Ohsuga and Tsuyoshi Inoue of NAOJ participate in bimonthly JICFuS steering committee meetings to engage in deliberations on 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. 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 a Post-K computer as mentioned in (1), the activities in the HPCI consortium are 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 lack 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 discussed a next-generation national supercomputing framework to follow the "K." As of this year, the post-K project has officially started with some budget from the Ministry of Education, Culture, Sports, Science, and Technology (MEXT). The concrete details of its operation are being disused actively. 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 after FY 2019. In principle, therefore, it is possible for 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) Yuta Asahina
(Research associates) n/a

The following contract staff members departed in this FY:
(Research experts) Yayoi Narazaki
(Postdoctoral fellows) Shun Furusawa, Tomohisa Kawashima
(Research associates) Yukihiko Hasegawa, Yuji Matsumoto

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 three from the Hinode Science Center (HSC) including Sakurai, Chairman/project scientist; Suematsu, SOT; and Watanabe, EIS. Science Schedule Coordinators have been organized to leverage the open-use observation system. Many of the Japanese coordinators are NAOJ staff members, including Watanabe (Chairman/EIS) and Sekii (SOT).

FY 2015 marks the ninth year since the satellite's launch. The 2015 NASA Senior Review results for Hinode were ranked in the top 3 among 15 missions under the control of NASA's Heliophysics Division, which assured adequate NASA funding for the near future. ESA will continue to support Hinode with the current level of funding at least until the end of FY 2017. The funding from STFC was also renewed for Hinode until March 2019. The request for the Hinode mission extension will also be submitted to ISAS/JAXA in FY 2016.

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 longterm 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 stopped operation since then. Currently the cause of the trouble and the possibility for recovery are under investigation.

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 2015 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 200 days in FY 2015, 119 days of which were for contracted work. Moreover, the contribution rates to the scientific operation of the HSC were 27.3 % (domestic) and 17.2 % (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 2016, a total of 302 applications have been accepted. In particular, core HOP proposals made by members of the scientific instrument team became refined over multiple implementations, and systematic observations have yielded extensive results that can help develop studies on solar activity cycles.

2. Hinode Satellite Data Analysis

NAOJ HSC aims to construct an analytical environment and database for scientific analysis of data from the Hinode satellite in a central organization, allowing it to function as a research center. The 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 thorugh 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 9 peer-reviewed papers related to Hinode (among the total of 20 papers), bringing the total to 250 papers by the end of March 2016. Cumulatively, a total of 887 peer-reviewed papers have been published on Hinode-related topics. Publications of papers in this category continue at a pace of nearly 100 papers per year 9 1/2 years after the satellite's launch. Intensified collaborative research with newly launched missions and advanced ground-based facilities near the solar activity maximum will further enhance the number of research papers for solar activity.

3. Other Activities

In FY 2015, two postdoctoral fellows were engaged as members of HSC, and both of them were project assistant professors. One fellow was hired as a ministry office college lecturer in September. The contract term of the other fellow expired at the end of March 2016, but he had an offer to become a researcher at the University of St. Andrews in the United Kingdom.

The Hinode Science meetings for Japanese and international researchers have been held regularly to advance reserarch in fields related to solar physics thorugh use of the Hinode satellite. The ninth Hinode Science meeting took place during September 14 – 18, 2015, in Queen's University, Belfast (Northern Ireland, UK).

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)
Cheung, Mark C. M.	Lockeed Martin Solar and Astrophysical Laboratory (USA)
Gizon, Lorent	Max-Planck Institut für Sonnensystem (Germany)

Table 1. Long-term Visitors.

9. Gravitational Wave Project Office

2015 has been marked by the first detection of a gravitational wave from the coalescence and merger of binary black holes made by LIGO in the United States. This observation, announced by the LIGO and Virgo collaborations last February, demonstrates that gravitational wave observatories able to detect the coalescence of binary black holes within 1 Gpc can contribute to the start of gravitational wave astronomy. In the meantime, the Gravitational Wave Project Office (GWPO) of NAOJ has pursued the construction of KAGRA in Kamioka. In particular, the office contributed to the installation of initial KAGRA and its operation. To facilitate this activity, a branch of the office was opened at Kamioka. In parallel, the preparation of the components for baseline KAGRA (bKAGRA) continued with the goal of starting its operation in 2018.

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. At the end of FY 2015, KAGRA successfully conducted the first test operation of the 3 km interferometer at room temperature with a simplified interferometer configuration called iKAGRA. The test run provided us with opportunities to test some of the key facility issues, such as the alignment of the 3 km beam ducts, and to gain important insights into the upgrade of the interferometer to the final configuration.

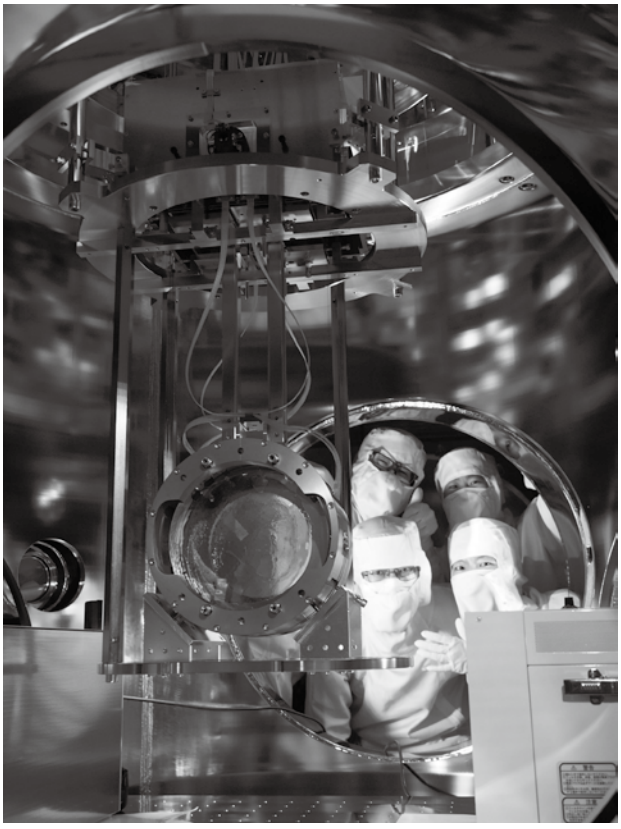

Figure 1: Happy faces after the installation of the PR3 suspension system into a vacuum chamber.

NAOJ is contributing to several aspects of KAGRA. 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 system engineering office, the committee for publication control, the publication relation committee, the safety committee, and the KAGRA Scientific Congress (KSC) board.

(1) Vibration Isolation

The vibration isolation system (VIS) is composed of the suspensions required to isolate all the interferometer 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. In FY 2015, one of the large suspensions was installed into a KAGRA vacuum chamber to support a mirror called PR3. The suspension worked successfully during the iKAGRA test operation. Based on the experience gained from the installation and operation of the PR3 suspension, we are preparing other large suspensions for the upgraded interferometer (bKAGRA). In addition to this, a total of five small suspensions were prepared and used for the mode cleaner mirrors and the end test masses of iKAGRA.

(2) Auxiliary Optics

The auxiliary optics subsystem consists of several kinds of optical components including optical baffles, beam dumps, beam reducing telescopes (BRT), high quality viewports, cameras to monitor the beam spots on the mirrors, and the optical local sensors (optical levers) for the mirrors. Many view ports were installed in FY 2015 and used in iKAGRA. Seven optical levers were installed and reliably provided the alignment information of the mirrors during the operation of iKAGRA. Ten digital video cameras were also installed to provide real-time, on-demand, pictures of the interferometer beams at various locations.

Tests of materials for high quality optical baffles and high power beam dumps continued using scatterometers developed by our group. Some of the additional large baffles necessary for bKAGRA were designed and delivered. Optical parts of the beam reducing telescopes (BRTs) for bKAGRA were purchased and the design work of the vibration isolation stage for them has progressed.

(3) Mirror Characterization

The optical absorption measurement system delivered last year was adjusted and is fully operational now. Validation of the calibration and simulations to separate the absorptions on the surface and the absorptions in the bulk of a sample were performed. We measured a small sample of a candidate sapphire crystal for KAGRA mirrors and found a very low absorption value. Preparation for the measurement of large size samples is ongoing.

(4) iKAGRA Interferometer Operation

The KAGRA main interferometer commissioning team, including GWPO members, successfully aligned and locked the iKAGRA interferometer in a relatively short time (3 weeks). The calibration of the interferometer was also performed by GWPO members. GWPO members took shifts at the Kamioka site to operate the interferometer during the test run.

2. R&D

(1) R&D for Upgrades of KAGRA

While building bKAGRA, the GWPO pursues research and development to investigate and prepare for future upgrades to 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-m long high-finesse cavity is 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 investigations are also the objective of another experiment now starting at ATC and aiming at the direct measurement of mirror thermal noise at cryogenic temperature. Finally, crackling noise is being investigated in collaboration with ICRR.

(2) DECIGO

The DECIGO group continued discussion on the design of DECIGO satellites as well as its precursor, Pre-DECIGO. After the first detection of gravitational waves, we started to reconsider the sensitivity of Pre-DECIGO and its achievable angular resolution for the signals based on its orbit from the viewpoint of science.

3. Education

In FY 2015 the office includes three PhD students and one master's student. In addition, we received an undergraduate student from Toyama University under the SOKENDAI summer students program. We also received a visit by a master's student from Beijing Normal University for 1.5 months and a PhD student from CNRS/APC (France) for a duration of three months.

4. Outreach

KAGRA held an inauguration ceremony for the completion of the 1st phase facility in November. GWPO members contributed to the organization and the operation of this ceremony. Some GWPO members were featured in broadcast programs on NHK international TV and NHK radio. The NAOJ annual lecture was organized as part of the lecture series celebrating 100 years of general relativity. A GWPO member gave a talk at the event. GWPO members also gave public lectures at the NINS president's press conference, Tamarokuto Science Center, and the National Science Museum. The office contributed to the NAOJ open house days in October by showing the TAMA facility and the ATC clean room for assembling KAGRA components to the public. TAMA300 continued to serve as one of the featured facilities for visitors to Mitaka Campus by accepting many of them throughout the year. GWPO Kamioka branch members took care of some of the visitors to the KAGRA site.

5. International Collaboration and Visitors

GWPO is a member of the KAGRA collaboration, a scientific collaboration which includes also members from abroad. Apart from KAGRA, GWPO has collaborations with CNRS/APC (France), Beijing Normal University (BNU, China), the University of Hamburg (Germany), and CNRS/LMA (France) in the context of R&D for future upgrades to KAGRA. In this framework we received visits by Dr. Barsuglia from CNRS and by Prof. Zhu from BNU. We also had several exchanges with the Virgo collaboration, with which one of the office members is affiliated. We received a visit by Dr. Vocca from the University of Perugia (Italy) who then joined the KAGRA collaboration. As usual we received several visitors at TAMA including Dr. Nguyen Quynh Lan from Hanoi (Vietnam), Dr. Gilles Hammond from the University of Glasgow (Scotland), the Japan Society of Mechanical Engineering, and a group of students from an educational project in Romania.

6. Publications, Presentations and Workshops Organization

The members of the office have authored 17 peer reviewed publications, including the paper reporting the "Observation of a binary black hole merger" which received a lot of interest both in the scientific community and in the public. Moreover 9 presentations were given by the office members at international conferences. On the occasion of the 100th anniversary of the establishment of general relativity, we participated in organizing a series of public lectures across Japan.

7. Acquisition of External Funds

GWPO did not receive external funds apart from those related to 8 grants allocated by JSPS.

8. Staff

There were no transfers of non-regular staff members. One administrative supporter and one research engineer retired and were replaced this year. One JSPS postdoc joined the Project in April 2015 to work on KAGRA. Overall in FY 2015 the Project included 2 faculty members, 8 research staff, 4 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 commenced. Japan is responsible for the fabrication of the telescope primary mirror, the design and fabrication of the telescope structure as well performing its onsite installation and adjustment, and the design and production of science instruments.

Although the commencement of full-fledged construction was planned for Fiscal Year 2015, construction was halted due to a protest movement against construction. Additionally, the Supreme Court of Hawai`i ruled in favor of a claim that cited a problem in the approval process of the land use permit for the Maunakea Conservation District and remanded it in December 2015. Although this has caused delays to construction onsite, mass production of the telescope primary mirror, detailed design of the telescope structure, and the design and development of science instruments have proceeded according to plan in Japan for Fiscal Year 2015.

The TMT-J Project Office currently has 2 Professors, 4 Associate Professors, 1 Chief Research Engineer, 1 Specially Appointed Associate Professor, 3 Specially Appointed Senior Specialists, 1 URA employee, 2 Research Experts, 2 Research Supporters, 2 Specially Appointed Research Staff Members, 2 Administrative Supporters, and 1 RCUH employee in full-time positions. In addition, 1 Professor, 5 Associate Professors, 2 Assistant Professors, and 1 Research Engineer from the Advanced Technology Center, Subaru Telescope, and the NAOJ Chili Observatory (ALMA) 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 taking steps for the USA to eventually participate as 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 were attended by 3 representatives from Japan, one of whom served as the Vice Chairperson of the Board.

Although full-fledged construction at the summit of Maunakea was slated to begin in April 2015, construction was forced to halt due to building momentum in the protest movement at Maunakea. Efforts were made to resume construction with the aid of the University of Hawai`i, but in December the Supreme Court of Hawai`i ruled the land use permission approval process for the Maunakea Conservation District, the site of planned construction, to be flawed, consequently invalidating the Conservation District Use Permit. The permit was initially approved by the State of Hawai`i in April 2013, but a claim was filed regarding the permit review process. Although the ruling did not find fault in the content of the permit itself, because a redo of the review process is necessary, a new review process will be commenced by the State of Hawai`i sometime after February 2016, the month in which the ruling was officially remanded.

In Japan, the construction of TMT was approved as one of the new projects for the Promotion of Large Scientific Research Projects in Fiscal Year 2013. Fabrication of the primary mirror and design of the telescope structure have been performed since then. In Fiscal Year 2015, along with making progress in the fabrication of the primary mirror, detailed design of the telescope structure, and development of science instruments (explained below), payments were initiated as part of Japan's contribution to cover operating expenses for the TMT International Observatory and contribute to the progress of this international-scale construction.

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

For the construction of TMT, Japan is responsible for the design/fabrication of the telescope structure and a portion of the fabrication of the primary mirror and science instruments as according to the executed agreements. Progress made in Fiscal Year 2015 is described below.

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

The TMT primary mirror is comprised of 492 mirrors segments. Including replacements, 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, polishing of the back surface, aspherical surface grinding/polishing, machining and mounting them onto a support assembly. These processes are followed by the final finish and coating process before a mirror segment is 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 2015, 65 mirror blanks were fabricated and spherical grinding was performed on 63. The plan is also for Japan to perform aspherical grinding/polishing and mounting to a support assembly for approximately 30% of the mirror segments. In Fiscal Year 2015, aspherical grinding was completed for 33 mirrors, and a mass production line for aspherical polishing had begun, producing 6 polished mirrors.

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

Japan is responsible for the design and production of the telescope structure which functions as a 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. The first international design review was held in February 2015 and was followed by international reviews of the control system and detailed design held respectively in July 2015 and February 2016, all of which were passed.

(3) Science instruments

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

In regards to the Infrared Imaging Spectrometer (IRIS), Japan is responsible for fabricating its imaging component. Work in Fiscal Year 2015 included preliminary design and performance assessment of the optics in the imager and preliminary design for the mechanics of the support system of the optics. Also, in coordination with the team of IRIS international collaborators, Japan made contributions toward preparation of a requirements document for the overall instrument and evaluation of the system. Vibration analysis of the overall IRIS system in particular was spearheaded by Japan's development team.

For the Wide Field Optical Spectrometer (WFOS), conceptual study is underway with Japan expected to be responsible for the camera system. In Fiscal Year 2015, corrections were made to the assumed effects of the heterogeneous properties of the fluorite lens on the imaging performance as well as corrections to the optics design of the camera system associated with the change in the layout of WFOS.

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

Japan held a key role in the TMT scientific research evaluation spearheaded by the Science Advisory Committee of TMT International Observatory through continued participation in the International Science Development Teams (ISDTs) established in 2013. In Fiscal Year 2015, a report (Thirty Meter Telescope Detailed Science Case: 2015) was compiled and published. The TMT Science Forum held once a year since 2013 was held in Washington DC in June 2015 where the possibilities of key scientific observation programs were debated. Preparations were made for the 2016 TMT Science Forum expected to be held in Kyoto in May.

In Japan, continued effort is being made to reflect the

Figure 1: Conceptual image of a constructed TMT.

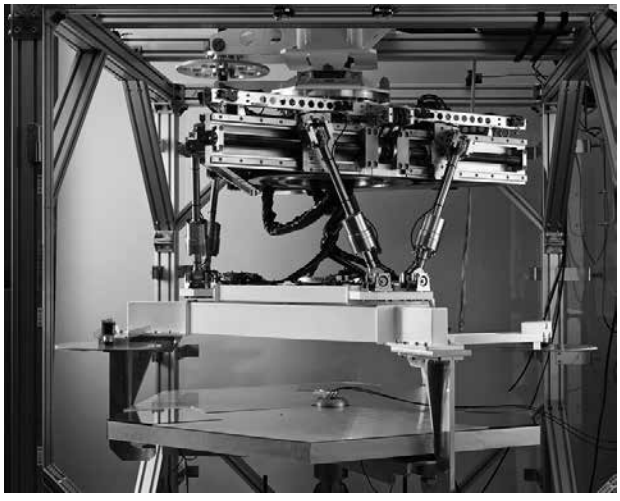

Figure 2: Segment Handling System (SHS) (provided by Mitsubishi Electric).

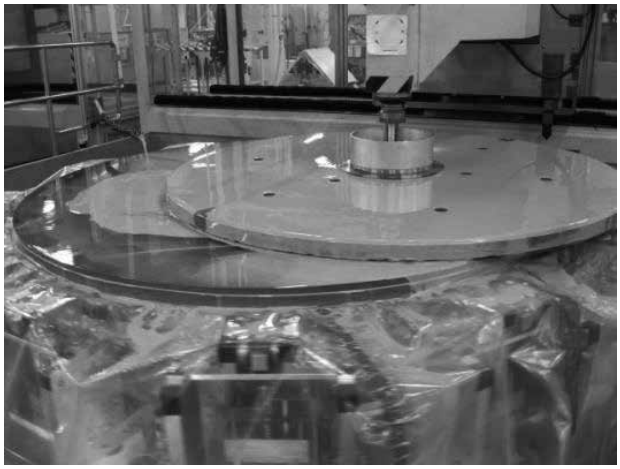

Figure 3: Aspherical grinding of a mirror segment of the primary mirror (provided by Canon).

opinions of the community through organizations such as the TMT-J Science Advisory Committee (JSAC). Public chances to support TMT related science meetings were offered for the purpose of promoting plan proposals for scientific observation research and new science instruments utilizing TMT. Additionally, the strategic fundamental research fund for the purpose of elementary technology development for the development and design of next generation science instruments continued to be made available. As a result, funding support was awarded to 5 development plans, including those requested by universities.

The TMT Project, particularly Japan's role in the project and the status of the project itself are introduced in the TMT-J Project Office website. Additionally, TMT Newsletters No.44 through 46 were delivered. Efforts were made in public awareness 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 an on-demand lecturer available for the science/technology education and PR event "Journey through the Universe" (March 2016) held in Hawai`i where TMT is to be constructed.

Donations to the TMT project raised continually; one corporation and approximately 1000 individuals provided donations in 2015 (from January to December).

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 accuracy of 1/100,000 arcsecond (10 μas) in order to determine with high reliability the distances and transverse velocities of stars within approximately 10 kpc of the Earth in the surveyed direction. Nearly 1 million stars can be measured with high precision in the Galactic Bulge with a relative error for annual parallaxes less than 10 %. This is necessary for accurate distance determination. By using observational data to construct a phase space distribution of gravitational matter, astrometric surveys of the bulge of the Milky Way promise to make major scientific breakthroughs in our understanding of the structure of galactic bulges and the causes of their formation; the history of star formation within bulges; and the co-evolution of bulges and supermassive black holes, which is closely related to the aforementioned phenomena.

Prior to commencement of the JASMINE mid-sized scientific satellite project, an ultra-small size project and a small size project were implemented to progressively build up scientific results and to accumulate the necessary technical knowledge and expertise. The Nano-JASMINE micro-satellite project, with a primary mirror aperture of 5 cm is currently underway. It aims to test part of the technologies to be used in JASMINE and to produce scientific results based on the astrometric information for bright objects in nearby space. Despite its small aperture, the satellite is capable of observational precision comparable to the Hipparcos satellite. The combination of observational data from Nano-JASMINE and the Hipparcos Catalogue is expected to produce more precise data on proper motion and annual parallax. The satellite is scheduled for launch in the near future. An additional plan is underway to launch a small-scale JASMINE satellite (Small-JASMINE), with a primary mirror aperture of about 30 cm, in FY 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 2015

1) Organization of the Office

The JASMINE Project Office is composed of five full-time staff members, six staff members with concurrent posts, two postdoctoral fellows, one research associate, one technical associate, and five graduate students. Significant contributions were made by members of the following organizations: Kyoto University's Graduate School of Science; the Systems Engineering (SE) Office, Aerospace R&D Directorate (ARD), and ISAS at JAXA; the University of Tokyo's School of Engineering; Tokyo University of Marine Science and Technology; the University of Tsukuba; and the Institute of Statistical Mathematics.

2) Progress of the Nano-JASMINE Project

The project will engage in spaceborne observations using an ultra-small satellite to accomplish the following objectives: to make Japan's first foray into space astrometry; to accumulate 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. 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 less than or equal to 50 μas/year in the direction of an area of

a few degrees from the Galactic Center within the bulge and in the directions of a number of specific astronomical objects of interest in order to create a catalogue of the positions and movements of stars within these regions. The project is unique in that unlike the Gaia Project, the same astronomical object can be observed frequently and observation will be performed in the near-infrared band, in which the effect of absorption by dust is weak. This project will help to achieve revolutionary breakthroughs in astronomy and basic physics, including the formation history of the superrmassive black hole at the Galactic Center; the gravitational field in the Galactic Nuclear Bulge and the activity around the Galactic Center; the orbital elements of X-ray binary stars and the identification of 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, ARD, and ISAS with a focus on the satellite's vital elements such as thermal structure, attitude control, and orbit.

Against this background, in-house discussions and manufacturers' propositions, which started in 2009, continued to consider the design of the satellite system to ascertain the target precision in astrometric measurement as a general objective in preparation for submitting a mission proposal to the ISAS call for small-sized scientific satellite mission proposals. 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 and members of the fourth Sloan Digital Sky Survey (SDSS-IV) Collaboration and Small-JASMINE to strengthen international partnerships and to achieve scientific goals related to the Galactic Bulge.

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.

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.

There were 38 refereed papers in English, 2 non-refereed papers in English, 36 presentations in English, 1 refereed paper in Japanese, 8 non-refereed papers in Japanese, 2 books in Japanese, and 57 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. 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. In this year, HiCIAO was used mainly in combination with SCExAO.

(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). Fiber experiments, laser frequency comb completion, and total assemble were conducted. It was then shipped to Hawai`i. Science discussions on habitable planets around M dwarfs are also proceeding.

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

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

2. Exoplanet instrument development for future space and ground-based telescopes and international collaborations

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

These missions aim to directly image and characterize the Earth-like planets and super-Earths for signatures of life. As a member of the WACO working group (currently WFIRST

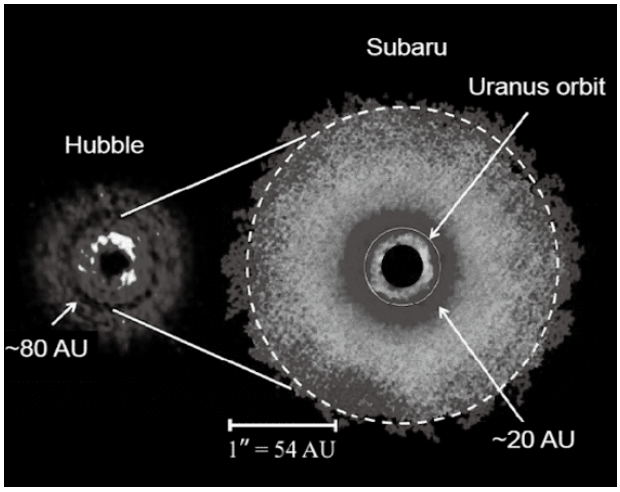

Figure 1: Multiple gaps in the TW Hya disk observed in near-IR.

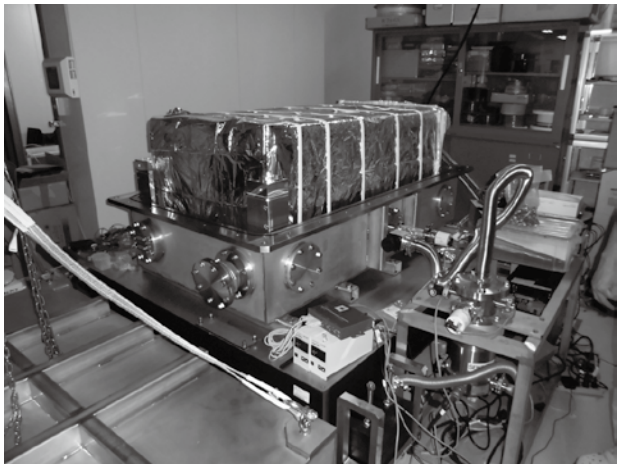

Figure 2: IRD spectrometer. Top cover removed.

WG), a coronagraph performance test at JPL testbed is being conducted with collaborators.

(2) SEIT (Second Earth Imager for TMT)

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

3. Science research, education, and outreach

The SEEDS project successfully finished in January 2015 without any major troubles. A review paper was published. Other major results are: direct imaging discovery of a gap at 20 au in the protoplanetary disk around TW Hya (multiple gaps); direct imaging discovery of a unique disk around SU Aur; revealing gapped disks around DoAr 28 and HD 169142; and discovery of a tilted inner disk around LkCa 15.

International collaborations using HiCIAO brought the discovery of interesting features originating from gravitational instabilities arising from mass accretion in the disks around FU Ori stars.

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.

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

1. Project Overview

In FY 2015, calibration data for the Laser Altimeter (LIDAR) of Hayabusa2 was collected and its laser-link experiment was carried out. Also, a conceptual design of the Ganymede Laser Altimeter (GALA) for the Jupiter Icy Moons Explorer (JUICE) mission was made. The Hayabusa2 asteroid explorer was launched on December 3, 2014; initial test operations finished in January; and Hayabusa-2 is underway to C-type asteroid, Ryugu. Before rendezvous with Ryugu will start in the summer of 2018, the RISE Project Office collected calibration data necessary for two major scientific goals of the laser altimeter, that is, albedo observation and dust detection. An engineering model of the laser altimeter was used for this calibration. The collected data and their evaluation were published in January in an international journal for future use with observation results. From October to December in FY 2015, taking advantage of Hayabusa2's Earth swing-by, RISE Project Office members attempted a laser-link experiment with Hayabusa2. Laser pulses transmitted from Mt. Stromlo station in Canberra were successfully received by Hayabusa2's laser altimeter, and established a one-way link over 6.6 million km between a ground station on the Earth and the spacecraft in interplanetary space. This is the third successful experiment conducted beyond the lunar orbit. For GALA, the RISE Project Office members developed a tool to simulate the quality of laser signals starting from the laser oscillator, reflecting on the surface of the icy satellite, and finally being received by the electric circuits of the receiver system. An increase of noise in the laser signal is taken into account in the simulation. Thus this tool allows us to constrain the instrument requirements quantitatively. At the same time, the members studied variations of slope and roughness at the surface of the icy satellites using the highest resolution images in order to narrow the most ambiguous options of the simulation.

2. Educational Activities/Internship

Seven RISE members delivered 18 lectures on a part-time basis to graduate students at the University of Aizu; and two RISE members served as part-time lecturers at Iwate University for half a year each. Also at Kyoto University and Kyushu University, two members served as part-time lecturers. The Office accepted two third-year undergraduate students of Iwate University for a week, and one fourth-year undergraduate student from Kazan University in Russia for a 2 month-long internship. As summer students of the Graduate University for Advanced Studies, two third-year undergraduate students of the University of Aizu and the University of Tokyo were accepted for three weeks. In January, a third-year undergraduate student of Taiwan Central University visited the Office for 3 weeks and studied crater statistics of the Moon under the supervision of the Office members.

3. Outreach/PR

In FY 2015, the Office members volunteered for Ihatove Science School of Oshu City 11 times as well as Fureai Astronomy classes 4 times.

4. Joint Research/International Collaborations

One member of the RISE Project Office served as a section president of Asia Oceania Geosciences Society. From Russia, a researcher of Vernadsky Institute of Geochemistry and Analytical Chemistry visited the Office for two months for joint research on thermo-mineralogical modeling of the lunar interior. The RISE Project Office invited five researchers from Russia, the U.S.A., Germany, South Korea, and China to promote international partnerships.

5. Career Development

One research expert left the RISE Project Office in March as his term ended. To fill this vacancy, the Office opened an announcement of a job opportunity for specially appointed research staff. On the other hand, another specially appointed research staff member left the Office in March and is now employed as a lecturer at Kougakuin University.

14. Solar-C Project Office

The SOLAR-C Project Office has engaged in planning the next solar observation satellite project, SOLAR-C, and has executed the launch operation of a sounding-rocket experiment, the Chromospheric Lyman-Alpha SpectroPolarimeter (CLASP). In addition, since the middle of Fiscal Year 2015, the Project has started preparatory activity for proposing a re-flight program of a German solar balloon experiment, Sunrise-3.

1. SOLAR-C Project

SOLAR-C is a planned project and may become Japan's fourth solar observation satellite, after Hinotori, Yohkoh, and Hinode. The plan is to realize the launch in the mid-2020's. The project is intended to investigate the solar magnetic plasma activities that influence the 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 previously achieved. The themes include major problems in solar research: the heating of the chromosphere/corona, the origin of solar explosive events, and the variation of solar spectral irradiance. Since its establishment, the SOLAR-C project WG has involved many non-Japanese specialists in addition to Japanese researchers. Provisionally, Japan will be responsible for the launch vehicle, satellite, and one of the major science instruments, whereas the US and European space agencies and institutions will deal with the other major instruments through international collaborations.

The main body in this project is the Next Solar Observation Satellite Project Working Group led by Prof. Watanabe, NAOJ, set up within the Advisory Committee for Space Science at ISAS/JAXA; NAOJ researchers play key roles in the project activities. The SOLAR-C Planning Office was set up at NAOJ in FY 2008 as a sub-project in the Hinode Science Center (HSC), dedicated to the SOLAR-C project. It was promoted to the SOLAR-C Project Office in FY 2013 as an A-project independent from HSC, continuing the preparatory work for the realization of the satellite project with five full-time staff members and eleven members with concurrent positions/ postdoctoral fellows.

2. CLASP Project

The CLASP project is an observational sounding rocket experiment aiming to detect solar magnetic fields in the chromosphere and transition region through polarization observations of the hydrogen Lyman-alpha (H Lyα) spectrum. Planning and basic development of the project started in FY 2009. The project involves an international research team with participation from Japan, the USA, and other countries. The CLASP project entered the development stage fully in the latter half of FY 2012 and carried out its first flight experiment in mid-2015. The payload consists of a far-ultraviolet (FUV) telescope and a spectro-polarimeter that were prepared in Japan to conduct polarization observations, with components contributed by the USA (CCD cameras and control computers) and France (a spherical concave grating). In the CLASP program, an American sounding rocket is used for the flight operation at the US White Sands launch site.

3. Major Activity in FY 2015

The SOLAR-C proposal, which was submitted to JAXA in February 2015, was not selected in the mission definition review as the candidate of the 1st JAXA Strategic Middle-class Satellite Mission. The SOLAR-C plan involves large international contributions, but in January of the same year, a proposal aiming to win approval for these international collaborations was not adopted by the European Space Agency (ESA). One of the major reasons cited in the JAXA review is that the large international collaborations assumed in the proposal have not yet been established. So the SOLAR-C WG is conducting the refinement of science objectives and the optimization of the mission size for the next opportunity. In FY 2015, the Project also studied the feasibility and cost estimate for a large telescope of reduced aperture and the thermal structure of the spectropolarimeter, and carried out test production of polarimetric optical components for performance verification.

The CLASP sounding-rocket experiment was carried out on September 3, 2015 at the US White Sands launch site. The flight was successful, returning the world's first polarimetric spectra of the H Lyα lines with a high precision of 0.1%. While doing the data analysis, the international CLASP team has started the preparations for the 2nd flight.

After receiving notification that the JAXA review committee for the Strategic Middle-class Satellite Mission had not adopted the SOLAR-C proposal, the Project received an invitation from a German solar research group to participate in the German balloon re-flight project, Sunrise-3, scheduled for around 2020. A spectropolarimeter with a performance similar to the SOLAR-C payload is to be developed. The Project aims to demonstrate the development of the state-of-the–art remote-sensing instrument needed for SOLAR-C and overcome the challenges of conducting leading-edge science observatinos from an experiment balloon.

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 experiment of onboard instruments, and research grants from the private sector.

Prof. K. Ichimoto of Kyoto University became a

concurrently appointed professor in the Project in April 2015. T. Bando moved to Subaru Telescope after April 2015. R. Kano got promoted to associated professor in October. Prof. T. Sakurai retired at the end of FY 2015. K. Watanabe, who started as a project research fellow in April 2015, left NAOJ in October 2015 to become a faculty member of a university.

15. Astronomy Data Center

1. Introduction

The Astronomy Data Center (ADC) is a central core of computing and archiving for astronomical data. It 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 are organized into the DB/DA Project, Network Project, JVO Project, HSC Data Analysis/Archiving Software Development Project, and open-use computer system service.

2. ADC Report

(1) DB/DA Project

The DB/DA-project conducts research and development on astronomical Data Bases and Data Analysis. Various astronomy data are made available to the public, such as astronomical catalogs, the Astrophysical Data System (ADS), and all-sky imaging data (DSS, DSS2). It also makes various astronomical data available to researchers and educators (http://dbc.nao.ac.jp/).

SMOKA (http://smoka.nao.ac.jp/) is the core of the DB/DA-project. It provides archival data of the Subaru Telescope, OAO 188-cm Telescope, Kiso 105-cm Schmidt Telescope (the University of Tokyo), MITSuME 50-cm telescopes (Tokyo Institute of Technology), and KANATA 150-cm Telescope (Hiroshima University). Stable operation continued through cooperation with each observatory, producing many scientific results. The total amount of open data (excluding environmental and atmospheric data) is more than 12 million frames (71 TB) as of May 2016. There were 16 papers published in major peer reviewed journals which were produced using SMOKA data. The cumulative number of refereed papers using SMOKA data is 192. Continuing from the previous year, in 2015 system improvements were implemented to develop and streamline advanced retrieval functions (e.g. moving celestial object retrieval). In addition, in September 2015, data from HONIR on the Kanata Telescope at Higashi-Hiroshima Observatory was opened to the public; and starting from January 2016, position correction data for the Tokyo Institute of Technology MITSuME Telescopes was offered.

(2) HSC Data Analysis/Archiving Software Development Project

This project started in January 2009. The main purpose is to develop the data analysis pipeline and data archiving software for the Subaru Telescope's wide-field-of-view prime-focus camera, Hyper Suprime Cam (HSC), using 104 CCD's. Most of our efforts are concentrated on the implementation of the software for: effective data analysis/archiving by parallel and distributed processing; precise photometric and astrometric calibrations; and correction of various effects originating from the camera system.

From March 2014, the Strategic Survey Program (SSP) using HSC started and we began to have consistent large data output (about 300–400 GB per night). We preformed data analysis of the SSP data, produced a database storing the results, and made the third and fourth data releases to the SSP team collaborators during this fiscal year (in September 2015 and January 2016). In the latest data release in January 2016, the image data involve 1.5 million files with a total size reaching about 200 TB. The catalog database stores about 280 million objects in a 10 TB database volume. We have developed various user interface software for retrieving image or catalog data using the database through web browsers; many of these functions have been offered to collaborators. The computers/hardware for the data release are in stable operation and the software is in the operational phase with minimum functions. Major problems in the pipeline software have been significantly reduced, although further improvements to functions in the pipeline software are still necessary to achieve the planned accuracies for calibrations/measurements of celestial objects in the images. The on-site data analysis system developed from 2011 is now in the operational phase, and performed well in the SSP and open-use observations. It features observer support tools, such as the observation log viewer, which allows browsing of the data analysis results through a web browser. Although there are still little problems, this system has made large contributions to the smooth operation of the Subaru Telescope.

(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) 100 Gbps Network service development and operation: We acquired and operated circuit links faster than 100 Gbps between Otemachi—Mitaka, Otemachi—Higashi-Shinagawa and Mizusawa–Sendai. Transmission equipment has been constructed and operated for each link. Between Mizusawa and Sendai 40 Gbps of the 160 Gbps cables, and 100 Gbps cables between Mitaka—Otemachi and Otemachi—Higashi-Shinagawa were laid and have started operation. The Mizusawa–Sendai circuit has been connected to SINET5 and JGN. The Mitaka—Otemachi circuit increased the Data Center's base connection speed. The Otemachi—Higashi-Shinagawa circuit has been connected to the 100 Gbps circuit to the United States of America.

2)100 Gbps capability network beta service: Wide area 100 Gbps circuits such as the 100 Gbps circuit to the USA, WIDE, and SINET were maintained. To make the best use of these circuits, equipment has been increased in part of the host network, making capability on the NAOJ network service equivalent to 100 Gbps.

3) ADC Relocation: For more effective network operation, racks

to consolidate the circuits and transmission devices located in the Otemachi data center were relocated next to the racks operated by the WIDE project's data center.

(4) JVO Project

The trial version of JVO portal 2, with a greatly revised user interface to improve its usability, was released. JVOSky, where data can be retrieved from a map of the sky, was updated from a GoogleSky base to a new sky-map GUI using Aladin-Lite developed by CDS. This update enabled it to display the data taken at high latitude without distortion. All of the observation data of Suprime-Cam taken before April 6, 2014 was reprocessed using the most recent reduction pipeline. The data was released on the JVO portal. JVO ALMA archive was updated to implement a new feature that enables users to search data based on object names defined in the Simbad database. ALMA WebQL for quick-look images of ALMA data was updated. Utilizing ultra-high-speed SSDs with a PCI-Express interface enabled users to start a quick look of an ALMA data cube within a few second, even for 10 GB of data. The design of the GUI was greatly modified and improved, as a result access to the ALMA archive was significantly increased.

(5) HSC Data Analysis/Archiving Software Development Project

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(6) Open-use Computer System and Services

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 the "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 JFY 2015, the total number of users was 372 (including 53 users of overseas institutes).

In the course of inter-university research we held and supported some workshops on using the software and systems, and offered a computer environment for data reduction practice. The dates and numbers of participants in JFY 2015 were as follows.

1. SOKENDAI Summer School (Reduction Environment Support), Aug. 3–Sep. 4 2015, 7 users
2. IDL School for FITS Data Analysis (Sponsor), Sep. 15–16 2015, 9 users
3. Subaru Autumn School 2015 (Co-sponsor), Sep. 28–Oct. 1 2015, 13 users
4. Subaru Experiential Observation and Research (Reduction Environment Support), Nov. 11, 2015–Mar. 31 2016, 8 users
5. C Language School (Sponsor), Nov. 17–19 2015, 10 users
6. N-body Simulation School (Co-sponsor), Jan. 20–22 2016, 16 users
7. SOKENDAI Asian Solar Physics Winter School (Co-sponsor), Jan. 26–28 2016, 30 users
8. IRAF/PyRAF School (Sponsor), Feb. 16–17 2016, 10 users
9. ALMA Data Science Experience (Reduction Environments Support), Mar. 7–11 2016, 3 users

The total number of participants of the schools in JFY 2015 was 106 users.

3. Others

As part of outreach and promotion activities, 45 issues of "ADC News" were published from No. 437 to No. 482 in JFY 2015. The newsletters were 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

The Advanced Technology Center has been working on developments for astronomy instruments in general. Our programs are divided into "prioritized area developments" and "advanced technology developments" to meet requirements both for current on-going astronomy programs and for future programs.

Development, fabrication, and shipment of the ALMA receivers for band-4, 8, and 10, which had proceeded as "prioritized area developments," were concluded in FY 2013. In the middle of FY 2014, the ALMA receiver development group was reformed and divided into three groups: the ALMA receiver maintenance group, the ALMA advanced receiver development group, and the telescope receiver development group. In FY 2015, the ALMA receiver maintenance group was responsible for repairing the problems in shipped receivers; the ALMA advanced receiver development group conducted basic research on the extension of RF and IF frequencies as well as the multi-beam receiver; and the telescope receiver development group was responsible for upgrading the performance of the 45-m FOREST receiver and ASTE receivers. In the middle of FY 2015, the ASTE radio camera development group was moved to ATC from Nobeyama Radio Observatory to strongly support its activity for the commissioning observations at the ASTE telescope to be held in early FY 2016.

For prioritized area development, in FY 2015 we pushed forward the development of Thirty Meter Telescope (TMT) observation equipment such as IRIS, WFOS/MOBIE, and the development of control and vibration isolation equipment and mirror holders for the gravity wave telescope, KAGRA. The design and production of those devices have been supported by the mechanical engineering shop (ME Shop). The optical system of IRIS has been largely modified utilizing all reflective mirrors, followed by the re-design and re-analysis of opto-mechanical system and optical performance. In parallel, experiments using prototype system are proceeding. Since Hyper Suprime-Cam (HSC) has started observing runs from March, 2014, HSC was moved to "advanced technology development" from "prioritized area development" and the HSC development group was responsible for improvements and repairing the problems of HSC.

The "advanced technology developments" includes developments for radio imaging arrays, the solar-observing rocket-borne instrument CLASP, and others. Concerning CLASP, the development of the device was completed in 2014 and it was sent to the White Sands launching site in early 2015. Then it was successfully launched in September, 2015 and successful observation of the solar chromosphere has been achieved.

The oversight committee of ATC, including non-NAOJ members, has been discussing about ATC activities on current projects and R&D for future programs, based on requests from the Director General. In FY 2015, ATC activities for the development of TMT and KAGRA were reviewed and will feedback to ongoing programs. R&D programs for the radio camera and infrared detectors were also reviewed in FY 2015 accordingly.

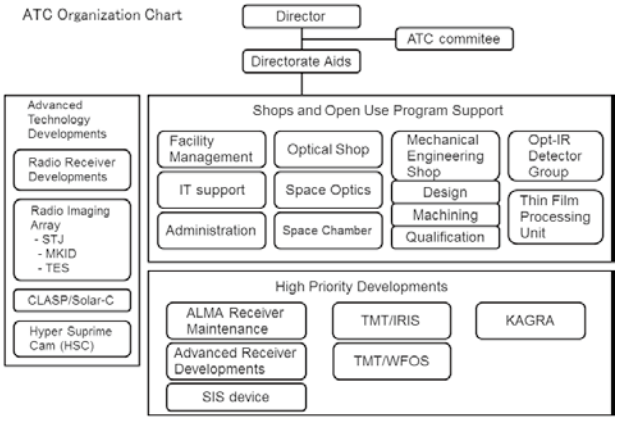

Figure 1: New Organization Chart of ATC (FY 2015).

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 shape measurements. Three teams including design, fabrication, and measuring/ultra-precision fabrication teams, cooperate to advance projects by leveraging their expertise.

The design team has been taking charge of mechanical designs for KAGRA auxiliary optics and TMT/IRIS imager and working on several challenges such as

[Mechanical design of KAGRA]
- Design of the vibration isolation table for the Beam Reducing Telescope
- Design of the five-axis lens positioner for the Beam Reducing Telescope
- Design of the winch mechanism for the main mirrors in the Power Recycler and Beam Splitter
- Assembly of Bottom Filters for the vibration isolation system for the KAGRA auxiliary optics subsystem

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

- Cryogenic endurance test of a drive mechanism on the filter exchanger for the Imager for TMT/IRIS.

The fabrication team has been working on the vibration isolation system of KAGRA since last year, and delivered internal parts for 11 sets of Bottom Filters. And the cylinders, made of Ti-6Al-4V, to be used as Recoil Masses for payloads of the suspension systems were also delivered. Fabrication of the five axis-lens positioner for the Beam Reducing Telescope has started recently. For TMT/IRIS, mechanical parts for the cryogenic endurance test were machined and supplied upon request from the design team. In addition, the team finished test parts made of super invar for thermal testing of the Small-JASMINE structure. And, as for the holders of the pupil mirror array and the slit mirror array for the integral field unit on the Subaru Telescope, final production has started based on experience gained from prototyping. Manufacturing of a 37-pixel corrugated horn array was initiated in collaboration with the ultra-precision fabrication team.

The ultra-precision fabrication and measurement team has responded to fabrication requests and also has enhanced collaborative research with external institutes. The team established an ultra-precision milling process for the wideband corrugated horn array, the development of which has been led by ATC, and the horn array with 4 pixels was successfully finished. Manufacturing has started for the 37-pixel horn array that is regarded as the next subject. Also, in regards to the corrugated horn for the ALMA Band 10 receiver, the data required for machining was obtained and manufacturing is about to start. Regarding the collaborative research with the Mechanical Engineering Center of KEK, ultra-precision milling using single-crystal diamond cutting tools has been discussed. Technical cooperation in trial machining and evaluation was conducted to investigate the specific machinery that is capable of an efficient mirror finishing for the X-band acceleration disk. The collaborative research with the Institute for Molecular Science and Nagoya University has continued in consideration of achievements up until present.

The ME Shop accepted 90 machining or repair requests in FY 2015. With 4 programs carried over from FY 2014, 89 out of 94 programs have been concluded and 5 programs are carried over to FY 2016. There were 9 programs requested from external organizations. The following table shows the requests in FY 2015.

Table 1: The requests in FY 2015.

	From FY2014	FY2015	To FY2016
ATC	1	22	1
TMT/IRIS		4	
KAGRA	2	9	2
ALMA		5	
ASTE		2	
CLASP, CLASP2, SOLAR-C		6	
HSC		1	
JASMINE		3	
Exoplanet Project Office		17	
Public Relations Center		1	
Solar Observatory		9	
Nobeyama Radio Observatory		1	
Subaru Telescope		1	1
External organizations			
IoA, Univ. of Tokyo		5	
JAXA/ISAS	1	2	
Ibaraki University		1	1
Other		1	
Total	4	90	5

(2) Optical Shop

1) Management and maintenance
- Maintenance of measuring instruments (such as daily inspections)
- Technical consulting for users (47)
- Repair and upgrade
  - Exchange of PC for NH-3SP (Mitaka Kohki Co. Ltd.)
  - Installation of Keyence VR-3000.

And others

2) Open use of measurement instruments (April 2015 - March 2016)
- Number of user: 286
  NAOJ: 211(including 107 from ATC)
  External organizations: 75
- Use of LEGEX910 (large-scale 3-D measurement machine): 6
  Number of operating days: 10

(3) Thin Film Processing Unit

We evaluated the wideband anti-reflection coating on the microlenses in front of the optical fiber input for the SuMIRe (Subaru Measurement of Images and Redshifts) project, which was fabricated in the last fiscal year. We confirmed the required quality and performance for this purpose, but also determined that we have reached the limits of current techniques. For further improvement of anti-reflection coatings, fundamental experiments are carried out to design and develop the concrete processes for coating, which takes into account the application and expected performance of inhomogeneous multilayers.

(4) Optical and Infrared Detector Group

We have executed a joint purchasing program for MESSIA6, a focal plane array controller for astronomical instruments, as one of the open-use devices 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). It is optimized for general purpose to control astronomical instruments which use focal plane arrays. In this year, a total of 14 sets were purchased for 2 divisions of NAOJ and 4 other organizations. We are providing the documentation, and will support the users for installing MESSIA6 onto their instruments.

(5) Space Optics

Activities to observe astronomical objects from space by sounding rockets and science satellites have been pursued to realize future space science missions. In FY 2015, basic development was conducted for flight operation of a sounding rocket mission CLASP, which aimed to observe magnetic fields at the height of the solar chromosphere and the transition region, and for a future satellite mission SOLAR-C. The development activity for a future satellite mission WISH has terminated within ATC.

Immediately after the completion of the CLASP instrument, it was transported to the U.S. at the beginning of the fiscal year. The flight experiment was executed on September 3, 2015 at a sounding-rocket launch site in the U.S. It has become the first successful flight for observing high-precision polarimetry of the H Lyα from the Sun. The design and fundamental experiments for the next flight started in the latter half of the fiscal year.

For a planned future solar observing satellite mission SOLAR-C, the development and testing of prototype components have been carried out for the waveplate and narrow-bandpass filters meeting space-qualified specifications, in addition to the performance evaluation of a near-infrared imaging device for the high-speed spectro-polarimetry.

(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.

Concerning the buildings facilities and equipment, we replaced four draft chambers. We attached a scrubber decontamination device to the draft chamber using hydrogen fluoride-based solvent for washing in order to remove the toxic substances included in the exhaust, so that the amount in the exhaust gas is less than the regulation value. Because the discharge ventilation performance was lower than the regulation value, we changed the motor of the blower and increased the ventilation performance to more than the regulation values. In the other 3 draft chambers, we changed the motors of the blowers to increase the ventilation performance to more than the regulation value as well. Many problems occurred in the air conditioner. Three rooms in the radio development laboratory were broken at the same time and restoration required two months. Because deterioration of the water pipes increases the degree of coolant pollution, we increased checks of the circulation coolant facilities to prevent pollution of the water. We cooperated with an advanced technology experiment building (TMT) construction plan completed in March 2015.

The main users of the laboratories were 11 projects including ATC members, KAGRA, TMT, Radio Department/Chile Observatory, HSC, JASMINE, Optical and Infrared Department, Exo-planet team, Subaru Telescope, Hinode Science team, and SOLAR-C/CLASP. Programs that used clean rooms were KAGRA in the south building and CLASP in the north building. After completion in March, CLASP was launched in the United States in September 2015 and successfully observed the Sun.

3. Open Use Programs

In FY 2015, ATC called for and accepted open use programs twice a year. ATC facilities were used for 8 “collaborative development programs” and 30 “facilities use programs”. Information about these programs is presented in “Common use of ATC facilities” with the names and research titles of the program leaders. Reports from the open use programs are also presented on the ATC homepage.

4. Prioritized Area Developments

(1) ALMA 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 are operating 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 to correct receiver defects, and repaired one Band 8 receiver and six Band10 receivers during FY 2015.

Table 2: Total number of failed receivers.

Receiver	Total	Breakdown	
		Initial failure	Aging failure
Band 4	6	3	3
Band 8	17	14	3
Band 10	15	6	9

Table 2 shows the total number of failed receivers broken down into “initial failure” and “aging failure.” The initial failures of Band 4 receivers included improper design at the initial development phase, and the number of failures has decreased after the design was revised. Similarly, most of the initial failures of Band 8 receivers were due to the improper design, and the number of failures has decreased after the design was revised. In contrast, the initial failures of Band 10 receivers pertained to the turn-on sequence for several amplifiers. This problem was handled by replacing the amplifiers. The aging failure of Band 10 receivers is from degradation of electrical devices; we have already identified the lots with high degradation possibilities. It is expected that the defects will decrease by replacing the devices from such lots with those from lots with low degradation possibilities.

Although the number of failing Band 4 and Band 8 receivers seems to be decreasing in FY 2015, this is not enough to judge the defect frequency owing to aging failure, because it has not been long since they started operation in ALMA. It is very important to keep the long-term maintenance system in ATC.

(2) Development of advanced receivers

Development of ultra-wideband, terahertz, and multibeam

heterodyne receivers has been started as future ALMA upgrades. Dr. Wenlei Shan was appointed Associate Professor in the Advanced Technology Center in November 2015, and consequently, the structure of the receiver development team has been reorganized.

1) Ultra wideband receiver

We have proceeded with the development of a band 7+8 receiver covering the frequency range 275-500 GHz. We have successfully fabricated SIS junctions with high current density, ranging from 10 to 50 kA/ cm2, and high quality, which is one of the key technologies for future receiver development. Based on this new junction technology, we have also demonstrated low-noise and wider RF band mixer performance than typical band-8 mass-produced SIS mixers. As a parallel project, we have started research and development of a multiband low-noise receiver aiming at improved sensitivity and simultaneous observation of multi-line spectra.

2) Terahertz receivers

We have pushed forward with the establishment of a reconfigurable beam pattern measurement system and with the development of superconducting mixers and corrugated feed horns for the 1.2-1.6 THz band. We have demonstrated heterodyne response using a waveguide HEB mixer in collaboration with the University of Tokyo. We have also demonstrated competitive performance of the corrugated horn antenna with respect to ALMA specifications by using the established beam pattern measurement system.

3) Multibeam receiver

We have started the conceptual design of a novel multibeam receiver based on planar circuits. Additionally, together with the Korea Astronomy and Space Science Institute (KASI), we have started collaborative research and development aiming at the installation of a wideband multibeam receiver on the ASTE telescope. This later project is led by KASI.

(3) SIS junction development

In order to fabricate a millimeter- and sub-millimeter-wave low-noise receiver having either an octave signal bandwidth or a signal frequency higher than 1 THz, we conducted research and development for high quality Nb/Al type SIS junctions with extremely high current densities (15 – 30 kA/ cm2), which are expected to be essential key devices for those receivers. According to the study of I-V characteristics as well as the detailed analysis of the distribution profiles of Al and Nb observed by the STEM (scanning transmission electron microscope) for the conventional Nb/Al/AlOx/Nb type SIS junction, we found that the AlOx is considerably damaged by the upper Nb, and that an increase of the subgap leakage current might result from such damage. A Nb/Al/AlOx/Al/Nb type SIS junction with an ultra-thin (~ 5 nm) Al film inserted between the AlOx film and the upper Nb film was designed to prevent direct contact between the Nb and AlOx film to minimize the damage to the AlOx film. We tried to make the Nb/Al/AlOx/Al/Nb type SIS junction and found that a very high-quality (RSG/RN>20) SIS junction with an extremely high current density (~45 kA/ cm2) can be obtained in this way. Although, up to now, it has been considered quite difficult to produce a high-quality SIS junctions with such an extremely high current density, we have recently succeeded in producing a SIS junction, which has not only a high quality but also an extremely high current density, for the first time in the world. This achievement gives us a bright outlook, particularly for the development of receivers covering the frequency band (275-500 GHz) of ALMA band 7 and 8.

(4) TMT

We have been continuing development of the first generation Thirty Meter Telescope (TMT) instrument IRIS since 2011.

Light Preliminary Design Phase extension, LPDP-E (Jan. – Dec. 2015) and Light Preliminary Design Phase 2016 extension, LPDP-2016E (Jan. – Dec. 2016) continued in FY 2015. We proceed with the optical design of the IRIS imager which NAOJ has a responsibility to develop, focusing on the opto-mechanical design. We have improved the optical design with all reflective surfaces, which meet the requirements for wave-front error across the entire field of view of 34 arcsec square by optimizing the symmetry of optical parameters. Further, we proposed a solution for packaging the imager optics into the science cryostat and started designing the opto-mechanical components to support all optics.

We introduced the progress and status of opto-mechanical design of the IRIS imager and integration plan at the mechanical and integration mini review on August 13, 2015 in Pasadena California. Also we presented the latest optical design in the face-to-face meeting on November 5 and 6, 2015. IRIS team members have approved the solution for the optical design of the IRIS imager.

In parallel, the IRIS-J team has been continuing vibration analysis for IRIS combined with the adaptive optics system for TMT, NFIRAOS. In prototype experiments and trial fabrications looking ahead to the coming final design phase and fabrication phase, major issues are the durability of the bearings under the cryogenic conditions, the cooling characteristics of the optical substrate, and trail production of the high-reflectivity coating.

We have been working on a conceptual study for a camera system of WFOS, which is another first generation instrument of TMT. We have investigated the degradation of image quality caused by the inhomogeneity of lens made of fluorite crystal. Also we made a modification and upgrade to the optical design for the camera system due to a change in the layout of WFOS.

(5) Gravitational wave telescope KAGRA

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

About AOS, we have continued the design and manufacture of some parts of the transmission monitor system (TMS). The telescope 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. The

beam reducing telescope (BRT), which is a part of the TMS, need to be aligned in ultra high vacuum after laser light will be finally resonant in the 3-km optical cavities; for example, 5-axes lens holders have been designed for the BRTs. In addition, the BRTs need to be isolated from vibrations as done for the other mirrors of the KAGRA interferometer, and the design of the vibration isolation stages for BRTs are ongoing.

KAGRA-VIS is a system to suspend mirrors required for the KAGRA interferometer to isolate them from seismic fluctuation. The system consists of multi-stage isolation mechanical filters; ME shop has finished manufacturing all the parts for the bottom filters, and also done assembly works, tests before the shipping. The ME shop has also manufactured all the pieces of recoil masses (made of 64-Ti), which will be suspended to reduce fluctuations of the mirrors. In addition, design, manufacture, and the tests of some jigs to hang the mirrors (the hanging frame) and winch system for the mirrors and recoil masses have been done. Then, ME shop have involved in the final design, manufacture, and the tests of most of the suspension chain by which the PR3 mirror (among the main mirrors, only this mirror in initial-phase KAGRA will be also used for the next stage) has been suspended and the hanging jig. As a result, iKAGRA was able to start the test run in the end of March of 2016.

5. Advanced Technology Developments

(1) Telescope Receiver Developments

Based on the technical skills acquired through the development of ALMA receivers, the "telescope receiver development" team has responsibility for the development of the Nobeyama FOREST receiver and the fabrication and tests of a cryostat for enabling simultaneous use of multiple receivers in the ASTE telescope. And also, we maintain good collaboration with other radio telescopes pursued by universities, such as NANTEN2 pursued by Nagoya University and the receiver for the Greenland Telescope (GLT) pursued by Osaka Prefecture University.

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

(2) MKID Camera

The MKID (Microwave Kinetic Inductance Detector) group of the Advanced Technology Center is developing a superconducting camera in millimeter and submillimeter wavelengths for the Antarctica terahertz telescope, which observes distant galaxies with a wide field of view, and for the LiteBIRD satellite, which detects CMB B-mode polarization, in collaboration with the University of Tsukuba, Saitama University, KEK, ISAS, Kavli IPMU, and RIKEN. The following papers were published in FY 2015.

1) Study of superconducting Bi-layer MKID (A. Dominjon et al. 2016 IEEE AS)
2) Broadband (Octave band) corrugated horn array (S. Sekiguchi et al. 2015 LTD)
3) Design of MKID focal plane array for LiteBIRD (Y. Sekimoto et al. 2015)
4) Radiation tolerance of MKID (K. Karatsu et al. 2016 JLTP)

(3) Hyper Suprime-Cam (HSC)

HSC has been used for regular science operations since March 24, 2014. This includes both the Subaru Strategic Program and the normal open-use observations. During FY 2015, 111 nights were allocated to HSC programs (among these 53 nights were for Subaru Strategic Programs). Minor problems occurred in the mechanism of shutter and filter exchange and some of the main CCDs, however, there were no nights where instrument problems completely prevented observations, fortunately. These problems were handled and settled through the comprehensive support from the ATC engineering staff. On-site maintenance service of the filter exchanger was conducted. Fabrication, integration, testing and adjustment of a spare for the shutter was completed in Mitaka. This spare is scheduled to be shipped to Hawai`i early in FY 2016. For the CCD failures, it has to be coped with changes in the operating conditions, by verifying the testing unit of CCD in a Mitaka laboratory. On the other hand, it turned out that the uniformity of the existing flat lamp modules on the telescope was not sufficiently good considering the target accuracy of HSC photometry. So a new flat lamp produced by a single light source has been installed on the ceiling of the camera. Some adjustments related to this flat lamp still remain and underway. In the next fiscal year, FY 2016, we plan to install new

calibration unit for HSC camera using monochrometer.

(4) Near-IR Imaging Sensor Developments

In areas of electronics and detector developments, we have made a trial chip of a low noise Indium Gallium Arsenide (InGaAs) image sensor based on a commercial product, for which the cost is expected to be lower than existing near-infrared sensors, in cooperate with KEK, Hiroshima University, and Kagoshima University. We also investigated making a larger format sensor and new readout electronics to use the InGaAs image sensor in a near-infrared wide field camera.

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. Starting from FY 2014 with the addition of the IAU Office for Astronomy Outreach (OAO), the Center has been comprised of 7 offices and 1 unit: the Public Relations Office, the Outreach and Education Office, the Ephemeris Computation Office, the Museum Project Office, the Library Unit, the Publications Office, the IAU Office for Astronomy Outreach (OAO), and the General Affairs Office.

2. Personnel

In FY 2015, the Public Relations Center was composed of Director Toshio Fukushima and the following staff members: 2 professors, 1 associate professor, 2 assistant professors (both hold concurrent posts), 2 research engineers, 1 senior engineer, 1 engineer, 1 Chief of the Library, 2 specially appointed senior specialist, 4 research experts (1 holding a concurrent post), 20 public outreach officials, 1 research supporter, and 2 administrative supporters.

On April 1, 2015 Chief of the Library Tatsuya Todoriki arrived and public outreach official Takao Ibaraki and public outreach official Taiga Hamura arrived in the Outreach and Education Office. On April 6, 2015, specially appointed senior specialist Pires Canas Lina Isabel arrived in the IAU Office for Astronomy Outreach; on June 1, research supporter Chie Tsuchiya arrived; on September 1, Naomi Ishikawa was promoted to specially appointed senior specialist; on October 1, public outreach official Noriko Takabatake arrived in the Outreach and Education Office; and on December 8, public outreach official Diaz Rosas Elian Abril arrived in the IAU Office of Astronomy Outreach.

On March 31, research engineer Goro Sasaki and public outreach official Diaz Rosas Elian Abril finished their terms. In addition research supporter Chie Tsuchiya transferred to the Hinode Science Center.

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 Project, first and foremost ALMA and Subaru Telescope, including open use and collaborative results with other universities and research institutes. In addition, 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 solar eclipse and meteor showers.

(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.

NAOJ e-mail newsletters No.143-158 were issued, containing headlines for major news events with hyperlinks to pages with further details. The Astronomy Information Telephone Service, which provides voice news updated on a semimonthly basis, issued 24 messages in total. This service was discontinued at the end of this fiscal year.

Through the Twitter social networking service, employed since October 2010, the Office disseminates information on the status of various NAOJ projects such as open house events, regular stargazing parties at Mitaka Campus and position openings. As of the end of March 2016, the number of followers exceeds 60,000. Starting from this fiscal year,we utilized the English versions of Twitter and Facebook to strengthen our English language information distribution.

(2) Press Releases and Media Relations

There were 25 research result announcements (compared to 16 in FY 2014 and 26 in FY 2013). For press releases aimed towards overseas audiences, we have increased the use of the American Astronomical Society and AlphaGalileo which have been employed up to now, and from FY 2015 have started to use EurekAlert! which is operated by the American Association for the Advancement of Science.

In the perennially popular Astronomy Lectures for Science Journalists program, the 22nd lecture entitled "What does the Rikanenpyo (Chronological Scientific Tables) Tell Us Now" was held on November 24, 2015. Thirty-nine people

Month	Access counts	Month	Access counts	Month	Access counts
April 2015	1,187,930	August 2015	1,026,205	December 2015	850,441
May 2015	542,548	September 2015	544,748	January 2016	535,655
June 2015	513,154	October 2015	623,754	February 2016	523,145
July 2015	595,883	November 2015	466,582	March 2016	533,022
Total: 7,943,067					

Table 1: Monthly website access statistics for the Public Relations Office website, NAOJ Public Relations Center (April 2015–March 2016).

April 7, 2015	Unprecedented views of lensed galaxy and asteroid Juno taken with ALMA
May 12, 2015	Great Progress towards the Origin of R-process
June 1, 2015	Astronomers Discover a Young Solar System Around a Nearby Star
June 9, 2015	ALMA uses 'Natural Telescope' to Image Monstrous Galaxy near the Edge of the Universe
June 18, 2015	ALMA Precisely Measures Black Hole Mass
June 23, 2015	Astronomers Discover More than 800 Dark Galaxies in the Famous Coma Cluster
June 26, 2015	Unexpectedly Little Black-hole Monsters Rapidly Suck up Surrounding Matter
August 5, 2015	The Ghostly Remnants of Galaxy Interactions Uncovered in a Nearby Galaxy Group
August 24, 2015	Hinode, IRIS, and ATERUI Cooperate on 70 year old Solar Mystery: Magnetically driven resonance helps heat the Sun's atmosphere!
August 27, 2015	Discovering Dust-Obscured Active Galaxies as They Grow
September 10, 2015	Oxygen is not Definitive Evidence of Life on Habitable Extrasolar Planets
September 25, 2015	"Fossils" of galaxies reveal the formation and evolution of massive galaxies
September 30, 2015	Mechanism of explosions and plasma jets associated with sunspot formation revealed
October 15, 2015	ALMA telescope unveils rapid formation of new stars in distant galaxies
December 4, 2015	Event Horizon Telescope Reveals Magnetic Fields at Milky Way's Central Black Hole
December 5, 2015	ALMA Spots Monstrous Baby Galaxies Cradled in Dark Matter
December 7, 2015	Radio Shadow Reveals Tenuous Cosmic Gas Cloud
December 18, 2015	Final Results of NameExoWorlds Public Vote Released
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 2: Web releases.

July 2, 2015	Dark Matter Map Begins to Reveal the Universe's Early History
November 6, 2015	KAGRA's Initial Operation To Begin Soon

Table 3: Press Conferences.

Video Visualization of TMT When Complete	
The First Dark Matter Map Drawn by Hyper Suprime-Cam on the Subaru Telescope	
Undertaking Galactic Archeology in M81 using the Very Wide Field of View Prime Focus Camera	
Geminid meteor shower	Japanese, English Versions
ALMA 12-Meter Antenna Paper Model	Japanese, English Versions
What is a Meteor Shower? (Long version/Short version)*	Japanese, English Versions of Each
Mitaka Open House Day Report*	
Fureai (Friendly) Astronomy PR	
The Opening of the Information Space of Science and Astronomy	

Table 4: Table 4: Summary of Produced Videos (* in preparation for release)

participated in lectures and panel discussions about the history and articles of the Rikanenpyo, which started 90 years ago.

(3) Supporting NAOJ-wide Public Outreach Activities

The following activities were pursued in addition to the Center's regular task of aiding research result releases.

We continued to produce videos explaining research results, videos explaining astronomical phenomena, and videos introducing outreach and education activities. Including English versions, 14 were produced (including those in preparation for public release). These videos introduce a wide range of general activities, not just NAOJ research. As of the end of March 2016, these videos have accumulated a total of 15,000 views.

The Office also helped Projects with their own lectures for the general public. The NAOJ lecture meeting "The Challenge which Exceeded Space-Time: General Relativity's 100th Anniversary and Gravitational Wave Astronomy," was held on September 18, 2015 and the ALMA public lecture/Osaka Science Museum Special Night "Exploring the Mysteries

of Star and Galaxy Formation with ALMA" was held on November 4, 2015.

In addition, we provided media support for a facility tour and press conference on November 6, 2015, corresponding to the completion of the initial experiment facility for the large-scale gravitational wave telescope KAGRA; and for the opening ceremony for the Astrobiology Center National Institutes of Natural Sciences, held on November 20.

As cooperation for the renewal of NAOJ Project webpages, we provided support to the Gravitational Wave Project Office and the Hinode Science Center.

Last fiscal year, "Multiwavelength Universe" a special site providing explanations of astronomical observations for the general public was opened. This year we opened an English language version.

4. Outreach and Education Office

(1) Handling General Inquiries

The Office received inquiries from the media, government offices, and the general public. The Outreach and Education Office responded to 6,606 telephone inquiries (Table 5) and 156 letters, 66 of which were official documents. The Office stopped accepting inquiries via the internet in April 2014.

(2) Educational and Outreach Activities

The astronomical phenomena awareness campaigns started as bidirectional information sharing initiatives in FY 2004. This year, 3 were conducted: "Let's Observe the Total Lunar Eclipse 2015" April 2015 (434 responses); "Summer Nights: Let's Count Shooting Stars 2015" August 2015 (2,875 responses); "Let's Watch the Geminid Meteor Shower 2015" December 2015 (1,550 responses).

The "Fureai (Friendly) Astronomy" project, now in its 6th year, provided events to 60 schools out of the 71 which applied, reaching 5,743 students. A total of 42 lecturers participated.

On July 23 (Thursday) and July 24 (Friday) during summer vacation "Summer Vacation Junior Star-Gazing Party" events were held for elementary, junior high, and high school students (application required, maximum capacity 50 participants each day). Lectures about the assembly and use of planetarium projection machines and telescopes, and star gazing parties were held. A total of 103 people participated.

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 23 (Friday) and 24 (Saturday) with the theme "The Challenges Awaiting Astrobiology." 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 23rd was cloudy, but the 24th was clear. The event flourished: over the 2 days, a record high of 5,036 guests attended. Each Project offered a selection of activities based on their own expertise which were suitable for a wide range of age groups. Activities included the viewing of facilities not normally open to the public, interactive panel displays, mini-lectures, and popular quizzes and games.

The 6th International Science Film Festival was co-hosted between August 1 (Saturday) and September 30 (Wednesday), in cooperation with 69 collaborating organizations and groups, with the main theme of the "International Year of Light (IYL2015)" declared by the United Nations. Screenings of science films and other events such as a stamp-collection rally were held at 49 science museums, planetariums, and film theaters in Japan, with more than 1 million people participating. The Kickoff Event (Nakano Zero Planetarium) and Dome Festa (Koriyama City Fureai Science Center) were held as the core events.

The "NAOJ Tours" cohosted each year with Tamarokuto Science Center were held on Sunday March 20. They were popular with a total of 80 guests, 40 in the morning and 40 in the afternoon, participating in tours of the 4D2U Dome Theater, a sunspot observation event at the 20-cm Telescope Dome, and self-guided tours along the tour course. In addition, group tours (self-guided) held on Saturday July 18, Sunday July 19, and Saturday August 22 were well received with 70 guests attending each, for a total of 210.

From November 15 (Sunday) to 17, "The 11th Workshop for Popularizing Cutting-Edge

Astronomy" was held with the theme "Astrobiology" at NAOJ Mitaka Campus and Japan Agency for Marine-Earth Science and Technology Yokosuka Headquarters. A total of 67 researchers and people connected to education and outreach participated.

The "You are Galileo!" program received support from the Nonprofit Public Organization: Foundation for Promotion of Astronomy, and was held this year in Indonesia, in cooperation with the Office of International Relations and OAO. A "You are Galileo!" workshop was conducted on March 11 and a public lecture was conducted on March 12 at Mulawarman University in Samarinda City. The workshop was attended by 25 people, and the lecture by 140 people.

The data reduction software Makali`i, developed to enable FITS data obtained from Subaru Telescope science observations and other sources to be used in astronomy

	Solar info	Lunar info	Ephemeris info	Time	Solar System	Universe	Astronomy	Other	Total
April–June	210	118	50	21	201	81	102	827	1610
July–September	179	189	78	18	232	109	177	896	1878
October–December	201	133	84	5	361	99	125	665	1673
January–March	250	130	79	11	170	150	150	505	1445

Table 5: Telephone inquiries made to the Outreach and Education Office of the NAOJ Public Relations Center (April 2015–March 2016).

education and outreach, was distributed via the internet to domestic and international users. Starting from March 2016, the distribution method was changed so that the software can be downloaded freely without registering.

We participated in the International Year of Light 2015 "Cosmic Light" events: a special website "Matters of Cosmic Light" was opened to the public and updated; Cosmic Light astronomical object photo panels were produced and displayed; in cooperation with Konicaminolta Plaza, the "Hubble Space Telescope Astrophotography Exhibit" was held; etc.

(3) Community Activities

The "Mitaka Picture Book House in the Astronomical Observatory Forest" welcomed 42,401 visitors in FY 2015. The Outreach and Education Office is conducting events at Mitaka Picture Book House in the Astronomical Observatory Forest including the "Dou Ugoku? Ochiru Korogaru (How do You Move? Fall and Roll)" exhibit, modern and traditional Tanabata events, moon viewing, etc. in cooperation with the Mitaka City Municipal Office and local volunteers. 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 grand prize winner "Noboreboshisama (Rising Star, made by Tomoaki Kunii)" is scheduled to be published as part of the "Picture Book House in the Astronomical Observatory Forest Compilation Series" in FY 2016.

The Outreach and Education Office conducted the 7th "Mitaka Solar System Walk" in cooperation with Mitaka City and the non-profit organization (NPO) Mitaka Network University Promotion Organization. Held from September 20 (Saturday) to October 25 (Sunday). 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. Approximately 18,000 guide-maps/stamp-sheets were distributed, of which 3,296 people turned theirs in for a prize. The total number of stamps was 413,425; the average number of stamps collected was 125.4 per person. The number of participants who collected all of the stamps was 339. It was a good chance to tour the Solar System while promoting commerce and industry and providing families with a way to enjoy Mitaka and rediscover the city's charm.

The event "Astronomy Pub" has been held at Mitaka Network University and hosted by the NPO Mitaka Network University Promotion Organization since FY 2009. It provides for 25 participants at a time and is held in the evening on the 3rd Saturday of every month except August. The Outreach and Education Office also 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 in providing presentations, telescope operation workshops, and other related events.

With the aim of creating a meeting point suitable for "Mitaka, a Town with an Observatory," the "Information Space of Science and Astronomy" opened along Mitaka's Chuo Dori, near the South Exit of JR Mitaka Station, on September 26, 2015. Established jointly by 4 partners: NAOJ, Mitaka City, Mitaka Network University, and Mitaka City Planning Board, it depends of the coordinated efforts of 11 groups, including those aiming to invigorate the area in front of Mitaka Station and the groups related to science and astronomy. NAOJ offered photograph panels for the planned exhibitions; held collaborative lecture meetings; offered outreach and monthly astronomical information images through large-scale information displays; and cooperated on the M Marche Project conducted the 4th Sunday of every month. In addition, we are also conducting the "Cosmic Reading Bookstore Corner," a display of sample books available to read which changes themes once every 2 months. In the half-a-year from September 26 to March 31, the "Information Space of Science and Astronomy" welcomed 9,981 guests and was acknowledged as a location in town where science can be easily accessed.

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 2016 edition of the Calendar and Ephemeris, the 2016 version of the calendrical section of the Rikanenpyo (Chronological Scientific Tables), and the 2017 edition of the Reki Yoko (posted in the official gazette on February 1, 2016). The Calendar and Ephemeris webpage was updated to match what was published in the Reki Yoko. In addition the 22nd lecture entitled "What does the Rikanenpyo Tell Us Now" was held in cooperation with the Public Relations Office.

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

(3) The Japan Association for Calendars and Culture Promotion hosted its 5th General Meeting, the Calendar Presentation Ceremony, and a symposium on the Traditional Calendar 2033 A.D. Problem.

(4) ECO hosted regular exhibitions in collaboration with the Library, selecting from NAOJ's invaluable collection of historical archives written in Chinese/Japanese. The themes of the 52nd and 53rd exhibitions were "Official Documents from the Meiji Era to the beginning of the Showa Era" and

"Achievements of Harumi Shibukawa - II" respectively. These exhibits can also be viewed at the Rare Materials Exhibition of the Library's website, in Japanese only (http://library.nao.ac.jp/kichou/open/index.html).

(5) Four staff members, including 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 16 reports including confirmation requests for new celestial object candidates and other reports. The contents were: 9 novae/supernovae, 3 comets, 3 luminous objects, and 1 asteroid. Among the many examples of reporting a variable star or asteroid as a new object, 2 novae reported in October, were communicated via NAOJ to the IAU Central Bureau for Astronomical Telegrams and were recognized as an independent discovery of Nova Ophiuchi 2015 No. 2 (V2949 Oph) and the discovery of Nova Sagittarii 2015 No. 4 (V5850 Sgr). Again in November, a supernova was reported. The discoverer himself reported it to NAOJ and the IAU Central Bureau simultaneously. It was recognized as the discovery of Supernova 2015as.

6. Museum Project Office

For the 3 Fiscal Years from 2013 to 2015, part of the duties for managing public access to the facilities was separated from the Outreach and Education Office and handled as the "Museum Project Office." But at the end of fiscal year 2015, the mission of the Museum Project Office ended. So starting from FY 2016, it was reintegrated back into the Outreach and Education Office.

(1) Facility Opening Events

With regards to the opening of the 4D2U Dome Theater in FY 2015, at the end of the previous fiscal year, renovations were performed to repair equipment and increase seating. In April, it was reopened to the public. Starting from this fiscal year, regular showings were held at the 4D2U Dome Theater 3 times per month (the day before the 2nd Saturday, the 3rd Saturday, and the 4th Saturday). Advance reservations were required. In this 1 year period, a total of 35 events were held, in which 4,446 guests participated. An additional 70 group screenings were held with 1,983 participants, and 119 tours were organized with 1,670 participants. In total, 224 screenings were held and a total of 8,099 guests enjoyed 4D2U's stereoscopic images.

Regular stargazing parties held with the 50-cm Telescope for Public Outreach were held twice a month (the day before the 2nd Saturday and the 4th Saturday). These were held regardless of cloudy or rainy weather. Advance booking (300 people for each session) was introduced in FY 2012 for these events. A total of 23 sessions were held with 4,717 participants.

A total of 19,729 people visited the Mitaka Campus Visitors' Area in FY 2015. In addition the group tours in 2015, consisted of 129 general tours (4,797 guests), and 37 workplace visits by schools (536 guests), for a total of 166 tours accommodating 5,333 guests. Note that in the workplace visits, lectures by researchers and question-and-answer sessions also took place.

The name of the Mitaka Campus Tour was changed to "Tangible Cultural Heritage Tour." Advanced reservations are required, 20 person capacity. This year a total of 204 people participated. The "Tangible Cultural Heritage Tours" ceased operation at the end of March 2016.

(2) Museum Planning and Archive Management

To prevent historically important observations, measuring devices, and documents from being scattered and lost, the Office is conducting investigations to continue improving the collection, sorting, and preservation of articles and improve the methods and environment for displaying them. In cooperation with Mizusawa Campus and Nobeyama Campus, the Office also established the basic concept for the NAOJ Museum (tentative name) including both facility opening efforts and archive works.

The Office sponsored the International Symposium on the NAOJ Museum for 3 days, September 27-29, 2015, at Mitaka Headquarters. This symposium summarized the research results of the "Forming an International Space for Learning Based on Research in the Natural Sciences" Project (Discretionary Budget of the Head of National Institutes of Natural Science, provided from FY 2010 to FY 2015). It was also planned with the goals of domestic and international publicity and exchanging opinions about the "NAOJ Museum Concept Plan" focusing on the newly created limited time office "Museum Project Office" within the Public Relations Center. The symposium received support from the Nonprofit Public Organization: Foundation for Promotion of Astronomy. Ninety-four guests from 9 countries (China, South Korea, Thailand, Indonesia, Germany, Netherlands, Portugal, U.S.A., and Japan) attended the event in person while 7 people in 6 locations in Japan and overseas (Mizusawa, Nobeyama, Okayama, Subaru Telescope Summit Facility and Hilo Base Facility, Indonesia, and U.S.A.) participated via the TV conference system. The results of the 3 days of discussion are summarized in "The Mitaka Declaration." In addition, there were indications that the consensus among all participants regarding the NAOJ Museum Plan was that it should aim to be open by 2020.

Proposed at the initiative of the participants, "The Mitaka Declaration"is addressed to NAOJ and JAXA, urging them to change their copyright rules regarding astronomical images, videos, etc. to be more generous, in line with other organizations such as NASA and ESO/ESA.

7. 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 2015, 323 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 2015, photocopies or loans were provided in a total of 86 cases.

Important documents, especially those originating from the Edo Era Tenmonkata (Shogunate Astronomer), are preserved while taking into account the environment of a specialist 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, part of the Mitaka Library is opened to the public so that people can freely examine the documents, focusing primarily on documents which appeal to the general public and younger age groups.

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.

8. Publications Office

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

- NAOJ Pamphlet (Japanese)
- NAOJ Pamphlet (English)
- NAOJ News, No. 261–No. 272 (April 2015–March 2016)
- Annual Report of the National Astronomical Observatory of JAPAN Volume 27 Fiscal 2014 (Japanese)
- Annual Report of the National Astronomical Observatory of JAPAN Volume 17 Fiscal 2014 (English)
- Radio Astronomy Public Relations comic "Almar's Adventure" (#5)
- NAOJ Publicity Poster Series (#2, #3)

Continuing from the previous year, in FY 2015 the Publications Office strove to strengthen its international publication ability and digital publication ability. In particular, as the first step in the production of an international edition of the Rikanenpyo (Chronological Scientific Tables), an English translation of the entire volume was created. Accompanying this, a publishing partner was selected and a production schedule was set, putting us on a concrete business plan. In digitalization and the conversion of contents produced/published (to be published) to digital format, the Publications Office developed "NAOJ-Universal Multi-Publication System (NAO-JUMPS)" a system capable of automatically collecting material about any arbitrarily chosen subject. The digital data for the past 12 years of the ANNUAL REPORT OF THE NATIONAL ASTRONOMICAL OBSERVATORY OF JAPAN Research Highlights articles (approximately 1300 pages), and fixed layout NAOJ News articles (approximately 1300 pages) were input and test operations were conducted. In addition, looking ahead we developed a general-purpose electronic book distribution platform capable of distributing to the general market via the internet, "NAOJ-Delivering next-generation e-books (NAOJ-Deneb)," which will work in concert with JUMPS in the future; and we started production of the first book for 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 ("ALMA Special Edition" September; "Okayama Astrophysical Observatory/Search for Exoplanets Special Edition" October; "CLASP Solar Observations Special Edition" January; and "Solar Observatory Special Edition" March) were printed and these aided the outreach efforts of each project. From now on, to develop and share NAOJ News articles as a resource to be used as outreach content for each project, we plan to promote the production of overall, basic articles through close cooperation. Other than periodicals, the 2016 calendar "Collection of ALMA Observational Images" (the 11th since 2005) was created. In addition, like in other years the Office also helped to create the poster for the Mitaka Special Open House Event again this year, and support was also given to the publication of the "Rikanenpyo, Chronological of Scientific Tables)."

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

In FY 2012 the International Astronomical Union (IAU) and NAOJ exchanged a memorandum of understanding to establish the IAU Office for Astronomy Outreach (OAO) at NAOJ Mitaka Campus. In FY 2014 the IAU OAO was established in the Public Relations Center. In FY 2015 the Office primarily conducted International Year of Light 2015 "Cosmic Light" activities and the Name ExoWorlds Contest.

As advocated by the European Physical Society (EPS), on December 20, 2013 the United Nations declared the International Year of Light (IYL2015). IAU also decided to participate in the theme of Cosmic Light in March 2014. Overall, IYL2015 was conducted in 94 countries with over 100 organizations participating. Under the overall broad theme of "Light and Light-based Technologies" for the International Year of Light, IAU developed the stance of "Protecting the Darkness of the Night Sky." IAU solicited proposals from the entire world and selected the following 5 cornerstone projects: 1. Gallieoscope – 16,000 constructible telescopes were distributed. 2. Light Beyond the Bulb - Over 30 countries participated, holding astrophotography exhibits in approximately 675 locations. 3. EDU kit (Teaching Materials Related to Cosmic Light) – These materials were used at more than 140 events in more than 40 countries. 4. DARK SKY METER App. – This free to use 2015 edition application was downloaded 3,442 times, and 7,290 reports were filed. 5. Quality Lighting Teaching Kit – 100 sets of this light pollution study kit were shipped.

In addition OAO, in cooperation with the Japanese Society for Education and Popularization of Astronomy, sponsored the

Japanese closing ceremony of the International Year of Light on January 11, 2016 at Tokyo University of Science. There were a total of 95 participants, including the 15 oral presentations, 16 poster presentations, and 17 activity report power point presentations. In addition, in cooperation with the Outreach and Education Office and the Office of International Relations, on March 8, on the occasion of the March 9 Indonesia solar eclipse, the Office conducted a solar eclipse viewing workshop at SMK Negeri 2 (Technical Collage) Ternate City, Indonesia, for a total of 500 on-island school teachers and students.

As part of the Name ExoWorlds Contest, 644 groups (166 groups in Japan) registered in the worldwide call for group registration (deadline June 1, 2015). The 20 planetary systems to be named this time were chosen by a vote of the registered organizations. The planetary system names proposed by the registered groups were accepted until June 15 of the same year; 247 naming proposals were submitted from 45 countries. The proposals were received and a web election where everyone could vote was held from August 11 to October 31; 573,242 votes were cast from 182 countries. (A total of 5,411 votes were cast from Japan, 0.94 % of the total.) The results of this naming were published on December 15. Excluding tau Bootis (where the highest scoring name didn't meet the naming guidelines), 19 planetary systems (14 stars and 31 planets) had names decided.

In addition, OAO conducted the development of cooperative relations with National Outreach Contacts (NOC) (outreach facilitators in each country); construction of a network between skill-holders, including amateur astronomers and astronomy clubs, for the advancement of astronomy education; establishment and maintenance of a database of world astronomy clubs, observatories, and research institutions; production of information distribution media, such as the IAU Newsletter, pamphlets, videos, etc.; the management of IAU's social media; and cooperation for NAOJ's international relations and education and outreach activities.

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 to launch 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 and engage in either the Division or one of the A, B, or C Projects. At times, they may also have concurrent positions in other projects. The primary staff of the Division of Optical and Infrared Astronomy in FY 2015 consisted of two professors, four assistant professors (including one specially appointed assistant professor), and three JSPS research fellows.

The Division coordinates educational, research, and administrative activities for Subaru Telescope Mitaka Office and 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 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. Ionized hydrogen clouds around a nearby star-burst merger were observed, and the investigation into the merging history and gas ejection was published. The search for extrasolar planets continued using direct imaging methods. In cooperation with researchers in universities using the Optical and Infrared Synergetic Telescopes for Education and Research (OISTER) network, observational studies were conducted on transient objects and moving objects, which include Gamma-ray bursts, supernovae, X-ray novae, novae, dwarf novae, and Near-Earth Objects.

(2) International Cooperative Observational Research

The Division also engages in international collaborative studies with overseas researchers. A study on a companion dwarf galaxy was conducted with researchers in the USA, France, and Spain. The galaxy was found by chance in data acquired for studying star formation in the outer regions of nearby galaxies. The site survey in western Tibet continues 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. Installation work of the NDU (Notre Dame University-Louaize in Lebanon) 60-cm telescope, which was previously used at Geisei Observatory, Kochi Prefecture and refurbished by NAOJ were supported.

(3) Research Using Archives

The celestial map on the ceiling of the stone chamber of the Kitora Tumulus was analyzed in detail. Studies of astronomical phenomena based on old ephemerides and other documents continued. A statistical study on Ultra Diffuse Galaxies in the Coma Cluster was conducted using archive data from the Subaru Telescope. The study of the host galaxies of active galactic nucleus (AGN) using SDSS imaging/spectroscopy data continued. The catalog of Kiso Ultraviolet-excess Galaxies (KUG) was updated using recent image surveys such as SDSS. The results were opened to the public. Digitization of Kiso Schmidt plates was also started.

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. A fluid calculation and a water-flow experiment were performed, and the procedure to compare the results with the data from the Subaru Telescope environment sensors in the dome has been investigated. Analysis of the ghost images of bright stars in the

Subaru prime focus camera was conducted and a presentation was made about correction methods. Commissioning of the telescope at Hosei University and their 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 supported the Subaru Autumn School co-hosted with Subaru Telescope and Astronomy Data Center; and Subaru Telescope observation classes.

5. Research Environment Maintenance

The Division manages the printers and rented multi-function photocopiers in the Subaru Building; teleconferencing systems on the second and third floors; 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. A framework for collaboration between ISAS/JAXA (Institute of Space Astronautical Science) and NAOJ also needs to be established. The preparation for the assessment of new infrared detectors has started.

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. 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, Hiroshima University, Tokyo University of Agriculture and Technology, Nihon University, International Christian University, and Hosei University. Division staff members made active contributions to seminars and self-directed studies. Since April 2015 we have held a 30-minute seminar in the afternoon every day throughout the year. In December, we held the annual workshop of the Division of Optical and Infrared Astronomy so that staff members and graduate students can understand the current studies and interests of each other. The Division participated in the “Fureai 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.

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 its 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 the MIC within Japan and internationally by the International Telecommunication Union (ITU) Radiocommunication Sector (ITU-R) of the United Nations. As part of the activities for FY 2015 the Subcommittee took an active role in formulating the opinion of the Japanese radio astronomical community (on behalf of the Japanese radio astronomers) in these coordination efforts.

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

(2) Current Challenges

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

- Significant increase in wireless activities in response to natural disasters. New operations involving wireless communications have increased following the Great East Japan Earthquake in 2011, resulting in an increase in radio interference.
- Development of new radio applications. The ultra-wide-band (UWB) technology does not require an operator license because it is operated at low-levels and wide bandwidths. On the other hand, there has been a rapid increase in demand for higher frequencies. For example, 76 and 79 GHz automotive radars are being introduced, aiming to reduce car accidents resulting in injury or death. And, transportation of high speed and high volume data, such as HDTV quality video, is becoming possible through 60 GHz radio transmission systems.
- Reassigning of vacant frequency bands resulting from enhanced efficiency in radio use. The digitization of television broadcasting has created vacant frequency bands, which have been reassigned for mobile phones and other applications.

The effect of interference arising from such radio applications (e.g. wireless business) varies widely depending on

the frequency band used. 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. Unwanted out-of-band signals (spurious signals), even extremely faint ones, can have a chance of substantial adverse effects on radio astronomy observations.

Sources of interference that need to be addressed continue to increase and include the following devices and systems: the 23 GHz CATV wireless transmission system used in emergencies, where ammonia observations are affected; 21 GHz next-generation satellite broadcasting, where water maser observations are affected; 1600 MHz mobile satellite phones used in emergencies, where the observation of pulsars and the like are affected; a number of new UWB wireless applications used by logistics and manufacturing industries, where geodetic observations are affected; and high-speed power line communications (PLC), where decameter-band observations are affected. 79 GHz automotive radars around Nobeyama Radio Observatory will cause deterioration in its observation results, or rather tend to make its observations impossible in the near future. 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 2015, the Subcommittee participated in the ITU-R WP7D meetings held in May, the WP1A meeting in June, and WRC-15 meeting in November in Geneva.WRC-15 resolved to provide a wider regulatory option for realizing global flight tracking of commercial airplanes and allocated additional frequency bands to the Maritime-mobile satellite service and the Earth exploration-satellite (active) service.

One major point of contention in WRC-15 was additional frequency band allocation to international mobile telephones (IMT). Finally, an agreement was reached for possible allocation of some frequency bands in 30–50 GHz to IMT at WRC-19 to be held in 2019. Also, WRC-15 agreed to add the allocation of active services at frequencies above 275 GHz to the WRC-19 agenda.

(4) Activities in Japan

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

The committees and working groups hosted by the MIC are held to organize domestic tactics in preparation for international conferences, defining Japan's positions on various wireless issues. Other MIC-related meetings provide opportunities for discussing the radio application technologies related to MIC's wireless policy, and for negotiating with wireless operators on interference issues under MIC authorization. Negotiations directly affecting the protection of radio astronomy observations have been conducted concurrently to dealing with the interference problems 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, which may invite large scale commercial use of 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 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 is based in Chile and involves 66 high-performance radio telescopes at an altitude of 5,000 m. Since automotive radars are highly relevant to human life safety, negotiations have been conducted with careful analysis in order to reach a mutually acceptable agreement.

A new radio wave application is being planned for 21 GHz next-generation satellite broadcasting with a picture resolution 16-fold higher than that of the current HDTV. This band is near the 22 GHz radio astronomy band, which is important for water maser observation. The radio signals from the satellite approach the ground from outer space. Their detrimental effects need to be alleviated with a filter at the output stage of the satellite. In FY 2015, 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.

To further improve disaster measures, the MIC will evaluate the approval of a U.S. mobile satellite phone service using 1.6 GHz signals (Earth to space) in FY 2016. Its out-of-band signal, however, may affect the adjacent RAS band observing OH masers. In FY 2015, the Subcommittee started evaluation of new operating conditions proposed by Global Star Inc. (U.S.).

The Cabinet Office of the Japanese government is planning to launch three (#2–#4) Quasi-Zenith Satellites in FY 2017 to improve the accuracy of the radiolocation service. Since there was a risk that the message communications signal in the 2.2 GHz band could affect the VLBI observations, sharing and compatibility studies were performed by the Subcommittee and Cabinet Office. They found mutually agreeable operating conditions and signed a compatibility study confirmation document.

Additionally, radio astronomy observations could be adversely affected by some of the new wireless technologies: high speed image data transmissions from drones to ground receivers, wireless power transmission (WPT) for electric vehicle energy charging (non-beam), WPT from space-based solar power satellites to Earth (beam), and so on. The Subcommittee continues to monitor their progress and shares this information with related radio astronomers.

Moreover, the Subcommittee engages in making applications to the MIC, requesting frequency protection for NAOJ telescopes, in addition to those owned by the Japanese community of radio astronomers on their behalf.

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

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. Research is also being carried out using the Solar Flare Telescope and other telescopes in Mitaka Campus. In ground based observations, the Division conducted research to introduce and utilize new technologies in the Solar Flare Telescope and has been conducting long-term monitoring observations of solar activity, and the obtained data are open to the community.

1. Research in Solar Physics

NAOJ fellow S. Toriumi published two papers in refereed journals as lead author. Both of them are on the energy release phenomena occurring suddenly and periodically at light-bridges in sunspots. In these papers he (1) revealed the energy release mechanism based on observational data taken with Hinode and IRIS, and (2) elucidated the cause of the periodicity based on numerical simulations. He also has been promoting collaborative research with international partners; he invited Dr. M. Cheung of the Lockheed Martin Solar and Astrophysical Laboratory as a guest associate professor, and organized two scientific meetings including Dr. M. Cheung as a guest.

The Division has a seminar (on Friday afternoon, roughly twice a month) whose speakers are from both inside and outside of the Division. This year's organizers were K. Watanabe and 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, Gabriel Giono obtained a Ph.D. in March. The Division, in cooperation with Kyoto University and Nagoya University, supported the annual "Leading-edge Solar Research-Experience Tour" in March for undergraduate students; about ten 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. 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 in FY 2015 aimed at achieving internationally outstanding research results in both quality and quantity, based on the following four goals that were set by the NAOJ Board:

- Advance world class cutting-edge theoretical research.
- Pursue theoretical astronomy research, particularly in areas that utilize the NAOJ supercomputer or large-scale observational instruments to give further insight into the development of new observational instruments.
- 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 the physical state of matter. This research covers a span from the early Universe to galaxies, stars, planetary formation, activities of compact objects, and plasma phenomena in astronomy and astrophysics. 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 a powerful research center for young researchers and is actively engaged in personnel exchanges with many universities and research institutes. The Division's full-time professors, associates, assistants, and project assistant professors, together with NAOJ postdoctoral fellows and JSPS fellows, conduct a variety of unique research projects involving postgraduate students from the Graduate University of Advanced Studies, the University of Tokyo, the Graduate School of Ochanomizu University and the Graduate School of Shizuoka University; joint research with observational astronomy using satellite campuses observing various frequency bands such as the Subaru Telescope, ALMA, and Nobeyama radio telescopes; and interdisciplinary research with the physics of elementary particles and atomic nuclei. In addition, the Division actively organizes numerous cross-disciplinary international conferences, domestic meetings, and seminars for the fields of theoretical astronomy and astrophysics, observational astronomy, and experimental physics. The Division also leads research activities in various fields related to astronomical science.

2. Current Members and Transfers

In FY 2015, the dedicated faculty of the Division of Theoretical Astronomy included two professors, two associate professors, and four assistant professors. In addition, one adjunct professor and one adjunct assistant professor concurrently hold primary positions at the Center for Computation Astrophysics. In addition to these research and educational members, the Division was served by five project assistant professors, one project research associate, one JSPS fellow, three EACOA fellows, and one administration associate who gave full support to all activities of the Division. Among these members, Michiko Fujii, a specially appointed Associate Professor, transferred to an associate professor position at the University of Tokyo; and Tomoya Takiwaki, an assistant professor, joined us from February in 2016.

3. Research Results

The number of research papers in listed Section IV, Publications, published by the Division member(s) as author(s) or presenter(s) are listed below. Categories with fewer than 10 publications have been omitted.

- Peer-reviewed papers in English: 89
- Papers in English (conference proceedings, non-reviewed papers, etc.): 14
- Reports in English (talks at international conferences): 65
- Reports in Japanese (talks at national meetings, etc.): 45

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

- Polarization Structure of Filamentary Clouds (Kohji Tomisaka)
- Rapidly Rising Transients from Subaru/HSC Transient Survey (Masaomi Tanaka, et al.)
- A New Multi-energy Neutrino Radiation-Hydrodynamics Code in Full General Relativity and Its Application to the Gravitational Collapse of Massive Stars (Tomoya Takiwaki, et al.)
- Enrichment of r-process Elements in Dwarf Spheroidal Galaxies in Chemo-dynamical Evolution Model (Yutaka Hirai, et al.)
- Physical Conditions of Supernova Ejecta as Viewed from the Sizes of Presolar Al_2O_3 Grains (Takaya Nozawa)
- Pitch Angle of Self-Gravity Wakes in Dense Planetary Ring (Shugo Michikoshi, et al.)
- Initializing relativistic velocity distribution functions in plasma simulations (Seiji Zenitani, et al.)
- All-sky simulations of gravitational lensing (Masato Shirasaki, et al.)

- A Numerical Scheme for Special Relativistic Radiation Magnetohydrodynamics Based on Solving Time-dependent Radiative Transfer Equation (Ken Ohsuga, et al.)
- Radiation Drag Effects in Black Hole Outflows from Super-critical Accretion Disks via Special Relativistic Radiation Magnetohydrodynamics Simulations (Hiroyuki Takahashi, et al.)
- Nuclear Fission and Solution of r-Process Underproduction Problem (Shota Shibagaki, et al.)
- Effect of Stellar Encounters on Comet Cloud Formation (Arika Higuchi, et al.)
- R-process Nucleosynthesis in the MHD+neutrino-heated Collapsar Jet (Toshitaka Kajino, et al.)
- Constraints on the birth of the universe and origin of cosmic dark flow (Toshitaka Kajino, et al.)
- Pion Production from Proton Synchrotron Radiation under Strong Magnetic Fields in Relativistic Quantum Approach (Toshitaka Kajino, et al.)
- Possible Evidence for Planck-scale Resonant Particle Production during Inflation from the CMB Power Spectrum (Toshitaka Kajino, et al.)
- Constraints on Pre-inflation Fluctuations in a Nearly Flat Open _CDM Cosmology (Toshitaka Kajino, et al.)
- Universality of the Supernova r-Process and Radioactive Nuclei (Toshitaka Kajino, et al.)

The following research results were released on the Division's website (http://th.nao.ac.jp/index_en.html) as research highlights:

- Conversion of Hadronic Matter to Quark Matter in Neutron Stars (Shun Furusawa, et al.)
- New Model on the Origin of the Heavy Elements: Solving the Underproduction Problem of the r-Process (Shota Shibagaki, Toshitaka Kajino, et al.)
- Galactic Spiral Arms by Swing Amplification (Shugo Michikoshi, Eiichiro Kokubo, et al.)
- Large-scale structure of magnetic reconnection by means of kinetic simulations (Keizo Fujimoto, et al.)
- Origin of r-process elements in galactic chemodynamical evolution (Yutaka Hirai, Michiko Fujii, Toshitaka Kajino, et al.)
- Pitch Angle of Self-Gravity Wakes in Saturn's rings (Shugo Michikoshi, Eiichiro Kokubo, et al.)
- Probing the Stellar Explosions with Presolar Grains (Takaya Nozawa, et al.)
- All sky simulations of gravitational lensing (Masato Shirasaki, Takashi Hamana, et al.)
- Polarization Structure of Magnetically Supported Molecular Filaments (Kohji Tomisaka)
- Great Progress towards the Origin of R-process (Shota Shibagaki, Toshitaka Kajino, et al.)
- Loading relativistic velocity distributions in particle simulations (Seiji Zenitani, et al.)
- The initial mass function of star clusters (Michiko Fujii, et al.)
- Quantum theoretic approach to in-medium effects on the neutrino scattering (Toshitaka Kajino, et al.)

4. Domestic Collaborations

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

- National Meeting on Galactic Evolution 2015, Sakata-Hirata Hall at Nagoya University, June 3 – 5 in 2015.
- UKAKUREN (Japan Forum of Nuclear Astrophysics) Meeting, NAOJ Mitaka Campus, February 22 – 24 in 2016.
- Winter School on Nuclear Matter in Neutron Stars investigated by Experiments and Astronomical Observations (Grant-In-Aid for Scientific Research on Innovative Areas), NAOJ Mitaka Campus, February 24 – 26 in 2016.
- National Meeting on Frontier of Cosmic Plasma; beyond Heliosphere, Solar-Terrestrial Environment Laboratory at Nagoya University, March 2 – 4 in 2016.
- TDA Symposium on Time-domain Astronomy, NAOJ Mitaka Campus, March 4 – 5 in 2016.
- National Meeting on Frontier and Perspective of the Research of Magnetic Reconnection, NAOJ Mitaka Campus, March 28 – 29 in 2016.

5. International Collaborations

Toshitaka Kajino performed duties in the following posts: review panel member of the Institute of Physics (Journal of Physics G.); international referee for the Science, Technology and Innovation Council of Canada; international associate for the European Centre for Theoretical Studies in Nuclear Physics and Related Areas (ECT*); and international referee for the Swiss National Science Foundation (SNSF).

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

- 3rd DTA Symposium on The Origins of Planetary Systems: from the Current View to New Horizons, NAOJ Mitaka Campus, June 1 – 4 in 2015.
- International Symposium on Physics and Astronomy of Neutron Stars and Supernovae, NAOJ Mitaka Campus, June 22 – 23 in 2015.
- Star Formation Workshop 2015, NAOJ Mitaka Campus, June 29 – July 1 in 2015.
- The 8th meeting on Cosmic Dust, Chiba Institute of Technology Sky Tree Campus, August 17 – 21 in 2015.
- Symposium on Hierarchy and Holism in Natural Science, NAOJ Mitaka Campus, February 5 – 6 in 2016.

6. Educational Activities

The basic information for the adjunct lecture-ship activities of research and education staff at universities and graduate schools is listed in Section III. The lecture subjects are listed below to supplement that information.

Eiichiro Kokubo: "Planetary Science" at the University

of Tokyo; "Origin and Structure of Planetary Systems" at the University of the Ryukyus.

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.

Takashi Hamana: "Geology" at the Tokyo University of Agriculture and Technology.

Keizo Fujimoto: "Computational Science and Genesis of Nature" at the Graduate University for Advanced Studies.

Eiichiro Kokubo delivered SSH lectures entitled "Simulation Astronomy" and "Cosmo-science" at Hibiya High School and Kanazawa Izumigaoka High School, respectively.

7. Outreach Activities

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

Eiichiro Kokubo; "Origin of the Solar System – Kyoto model" at Chushiro Hayashi Memorial Lecture; "What is Pluto?" at Ikebukuro Community College; "Hometown of Planets" Hiroshima University and Chiba University; and "Earth in the Universe" at Asahi Culture Center Fukuoka.

Toshitaka Kajino; "Frontiers in Cosmo-nuclear astrophysics" at Osaka City University, and "Introduction to Element Genesis: The birth of the Universe and origin of matter, elements in the cosmos" at Asahi Culture Center Yokohama.

Seiiji Zenitani; "The Importance is Invisible: looking at the explosive phenomena in Earth's backyard" at the National University Corporation Tsukuba University of Technology.

8. Awards

Masaomi Tanaka received a 2015 Research Encouragement Award of the Astronomical Society of Japan.

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, and the NAOJ budget for visiting research fellows and others. The main international visitors to the Division in FY 2015 are listed below:

Myung-Ki Cheoun (Soongsil University, South Korea)
Tjarda Boekholt (Laiden Observatory, Netherland)
Grant J. Mathews (University of Notre Dame, U.S.A.)
Motohiko Kusakabe (University of Notre Dame, U.S.A.)
Zhi-Yun Li (University of Virginia, U.S.A.)
Wing-Kit Lee (Academia Sinica, Taiwan)
Anaelle J. Maury (Saclay Nuclear Research Centre, France)
John J. Tobin (Laiden Observatory, Netherland)
Akif B. Balantekin (University of Wisconsin–Madison, U.S.A.)
Michael A. Famiano (Western Michigan University, U.S.A.)
Ghil-Seok Yang (Soongsil University, South Korea)
Eun-ja Ha (Soongsil University, South Korea)
Kyun-jin Kwak (Ulsan National Institute of Science & Technology, South Korea)
Yichen Zhang (University of Chile, Chile)
James M. Lattimer (State University of New York, U.S.A.)
Friedrich Thielemann (University of Basel, Switzerland)
Yamac Deliduman (Mimar Sinan Fine Arts University, Turkey)

22. Office of International Relations

The Office of International Relations, along with performing information-gathering/–provision and other activities related to international research and educational cooperation, strives to promote and facilitate further internationalization at NAOJ by providing the various services and environments required for multi-cultural researchers and students to engage in research and educational activities in cooperation with each other. Specifically, the office's main activities include supporting international collaborative projects; liaising with overseas astronomical research organizations; gathering and providing information on international activities; offering support for hosting international conferences, workshops, and seminars; providing support for visiting international researchers and students; and assisting Japanese universities and research organizations in international partnerships. In FY 2015 the Office's working scheme changed and the Office started working closely with the Executive Advisor to the Director General in charge of international research coordination.

1. International Collaborative Project Support

The Office gathers and provides information necessary for pursuing international research collaborations on its own initiative. It also serves as a liaison point for international activities; engages in international agreements or provides support for doing so; and accumulates procedural and administrative knowledge, 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, support for signing ceremonies, and export security control for the export of goods or transfer of technology. In FY 2015, ten international agreements, new and renewed, were signed including ones under the name of NINS. In the area of security export control, the activities included review and processing of 37 cases and security export control briefings for improving the knowledge and awareness of NAOJ staff held seven times at Mitaka, Mizusawa, Nobeyama, and Okayama with more than 100 attendees.

2. Liaison Work for Overseas Astronomical Research Organizations

The Office of International Relations organized the annual directorate meeting of the East Asian Core Observatories Association (EACOA) on October 11, 2015 at Incheon, South Korea. The signing ceremony for the renewed Memorandum of Understanding (MOU) of EACOA was held at the meeting. This MOU extends the term of EACOA activities, including the EACOA postdoctoral fellowship program, for another 5 years. The four institutions forming EACOA include NAOC (China), NAOJ (Japan), KASI (South Korea), and ASIAA (Taiwan). The Office also coordinated with the other 3 institutes for selection of 2016 EACOA postdoctoral fellowship program. The office also cooperated with NAOC for the East Asia Ground-based Telescope Construction Sites Survey. In addition, it presented NAOJ's projects and research results by displaying an exhibit at the 29th IAU General Assembly held August 3 - 15 at Honolulu, Hawai`i in the USA. Furthermore, the office supported the activities of the IAU Office for Astronomy Outreach. The Office of International Relations also cooperated with EACOA member organizations in supporting the activities of the IAU Office for Astronomy Development (OAD).

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 organizations or individuals to contact as appropriate, coordinates between organizations, and gathering relevant information. In FY 2015 the office supported international research conferences and other conferences by preparing the documentation required for Japanese visa applications for 50 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 offers support, on-site if required, covering various matters such as administrative procedures at municipal and other governmental offices; finding and moving into an apartment; various other procedures and applications for starting up a new life; consultation on shopping, children's education, health and other subjects; and gathering/providing useful information relating to everyday life. The Support Desk has been highly appreciated by users. Besides daily life matters, the office expanded its activities as an intermediary between administrative staff and non-Japanese speaking researchers by translating/interpreting in-house procedures, applications and notices. The office continued the Japanese language lessons, helping foreign members of NAOJ to acquire beginner level capability, for FY 2015 with E-learning features added to the classroom lessens. Including renewals, support was given to 37 visa applications: 8 for staff and family members, 13 for invited researchers, and 16 of visitor/long stay researchers.

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 OAO, Ishigakijima Astronomical Observatory, and nine Japanese universities.