

II Status Reports of Research Activities

1. Subaru Telescope

The Subaru Telescope engages in open-use observations using the Subaru Telescope (an 8.2m large optical/infrared telescope) at the top of Mauna Kea on the island of Hawai'i; operation of an observational data archive system; observational research; and research and development for telescope systems, observational equipment, and data processing software.

A two-month downtime period was scheduled in August and September for FY 2013, during which time the telescope underwent major maintenance, including recoating of the primary mirror. As a new open-use instrument, the ultra-wide-field camera Hyper Suprime-Cam (HSC) continued test observations from the previous year, followed by the commencement of open-use observations in March 2014. Strategic programs include a wide-field imaging survey using the HSC that began this year; the Strategic Explorations of Exoplanets and Disks with Subaru (SEEDS) project using the High-Contrast Instrument for the Subaru Next Generation Adaptive Optics (HiCIAO), which was continued from FY 2009; and FastSound using the Fiber Multi-Object Spectrograph (FMOS), which began in FY 2011.

Open use for FY 2013 included a four-month period beginning April 1, 2013, as part of S13A (from February 1, 2013), a full six-month period of S13B starting on August 1, and the initial two months of S14A, which began February 1, 2014. This report contains statistics in relation to open use based on only S13A and S13B terms.

1. Subaru Telescope Staff

As of the end of FY 2013, the Subaru Telescope Project staff consisted of 19 dedicated faculty members including six stationed at Mitaka, four engineers, and three administrative staff members. Additional staff members include four research experts, three postdoctoral fellows, one research associate, and seven administration associates, all of whom stationed at Mitaka. Moreover, 11 research/teaching staff members, 10 of whom are stationed at Mitaka, and two engineers at Mitaka are posted concurrently. The project also has 72 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. Remarkable Observational Results

The following papers were published in FY 2013 on the important research results from observations using the Subaru telescope:

(1) In early Universe studies, a GRB which occurred only 1 billion years after the birth of the Universe was observed. This high-accuracy spectroscopic observation captured for the first time indications that the light emitted from the GRB was absorbed by hydrogen gas that was high in neutral atoms. This finding serves as an evidence of our exploration of the early Universe entering the epoch when the Universe was abundant in neutral hydrogen.

(2) In studies of the peak galactic evolution epoch, the project used Subaru's primary-focus wide-field near-infrared spectrograph, known as FMOS, to examine the activity level of star formation in the Universe 10 billion light years distant and the heavy elements and dust content in the ambient gas of the massive galaxies. The results indicate that the galaxies were in their maturity. In addition, by using Suprime-Cam, 12 galaxies at 9 billion light years which are releasing hot oxygen gas into the inter-galactic regions that was wider than the galaxies themselves were discovered. Such outflows would be driven by giant black holes in the center or by explosive star-formation in the midst of the galaxy formation process.

(3) In studies of black holes and accretion disks, an observation using gravitational lensing succeeded in observing a quasar at the distance of 10 billion light years from two different angles, elucidating varying gas emissions three-dimensionally. Moreover, a structural high-resolution infrared observation of colliding galaxies revealed that only 15 % of the objects had plural numbers of supergiant black holes within them. This finding is contrary to previous speculations. The galaxy collisions were previously believed to be closely related to the black hole activities; instead, the relationships had varieties.

(4) In protoplanetary disk observations, the strategic project SEEDS using HiCIAO with a direct imaging method succeeded in the world's first detection of a planet that was the darkest and of the lowest temperature ever observed orbiting around a sun-like star. It also discovered a planetary system that involved a planet in a retrograde motion together with other planets and accompanying stars, which serves as suggestive evidence of planet configurations in retrograde motion.

3. Open Use

Open use is conducted with proposals called for every six months. For the first and second halves of the year, the offered periods were from February 1 to July 31 (S13A) and from August 1 to January 31 (S13B), respectively. Applications were accepted at the NAOJ Mitaka campus. The Subaru Time Allocation Committee, under the NAOJ Advisory Committee for Optical and Infrared Astronomy, examines the proposals and determines projects for adoption with reference to referee evaluations from Japan and from overseas. The following proposals were adopted: 52 proposals (85.5 nights) for S13A, out of 143 submissions (368 nights), and 41 proposals (62.5 nights) for S13B out of 146 submissions (362.6 nights). Short-term projects were also conducted within the framework of service program observations. Of the aforementioned proposals accepted for open use in S13A and S13B (excluding University of Hawaii time), 12 (10 in S13A and 2 in S13B) were conducted by non-Japanese PIs. The cumulative total of respondents, including co-investigators, was 1,741 belonging to Japanese organizations and 532 belonging to overseas groups. The cumulative total of researchers among accepted projects was 605 from Japan and 225 from overseas.

A cumulative total of 342 open-use observers, including 40 from overseas, participated in S13A and S13B. Calls for observation proposals, examination of submissions, procedures for visiting the observatory, and domestic travel reimbursement for Japanese researchers on their observational trips were handled by the NAOJ Mitaka. The Subaru Telescope facility set observation schedules and provided researchers with support in arranging accommodations, travel, and observation in Hawaii. In open-use observations and UH time, 88.6% of the telescope time was operational, discounting weather-related factors and the downtime scheduled for maintenance work including the recoating of the primary mirror. Instruments, network system, and telescope problems resulted in downtimes of roughly 3.9%, 0.8%, and 6.7%, respectively.

No remote observation from the Hilo Operations Support Facility was conducted during S13A and S13B. Service observations were performed for 13 nights. Observing time was exchanged with the Gemini telescope and the Keck telescope in order to make effective use of the resources of the telescope group on Mauna Kea; two nights in S13A and 4.5 nights in S13B were exchanged with Gemini, and four nights in S13A and six nights in S13B with were exchanged with Keck.

4. Telescope Maintenance and Performance Improvement

The main features of the telescope have remained at the same performance levels as that in the previous year. Technicians were dispatched from NAOJ Mizusawa, Mitaka, and Nobeyama this year to give support in executing the primary mirror recoating. Before work began, however, some damage was discovered on the back of the primary mirror element near the edge, which was subsequently mended. The period of mirror

recoating served as a good opportunity for undertaking some of the difficult tasks while the telescope was in operation, such as replacement of the Cassegrain automatic connector and partial replacement of the pump for fluid static bearing. Other tasks difficult to pursue with the primary mirror in position were also completed, including maintenance work of the CO₂ cleaning facility, and repair and tuning of the Cassegrain atmospheric dispersion corrector optical system, which was affected by coolant leakage occurred in FY 2011.

Further improvement was made on the telescope's performance and operational efficiency by upgrading the telescope control devices that have been in use for at least 10 years. Local control devices submitted for upgrade or refurbishment this year include a mount control system, secondary mirror control system, tip-tilt motion control system, field rotation control system, cable wind-up drive/torque detection control system, AG/SH drive control system, and focus-field rotation control system. In addition, the aging windscreen's unstable coupling was improved. Moreover, an incident occurring in July was investigated in which the altitude axis lost control. The cause was determined to be the aging control circuit, which was subsequently resolved by replacing the mount control system. Furthermore, a power outage inside the dome related to the malfunctioning of a slip ring has been examined to identify the cause.

5. Instrument Operation and Development

All eight open-use instruments have been operating stably since last year. The HSC was introduced for open use and has been operating since the S14A term. The following instruments were provided for open use at the Subaru Telescope facility: a prime focus camera (Suprime-Cam), a faint object camera and spectrograph (FOCAS), a high-dispersion spectrograph (HDS), a near-infrared camera and spectrograph (IRCS), a cooled mid-infrared camera and spectrograph (COMICS), a multi-object infrared camera and spectrograph (MOIRCS), a Fiber Multi-Object Spectrograph (FMOS), and laser guide star adaptive optics (AO188/LGS).

The HSC was applied to test observations for seven nights in June and five nights in October, 2013, as well as eight nights in January and February 2014 for FY 2013. Despite the high incidence of inclement weather, conditions were sufficient for performing the test observations roughly half of the time. The issues identified through this testing included (1) scattering/stray light, (2) vacuum leak under extremely low humidity, and (3) partial movement defect in the CCD. The first issue was further investigated, and the result was attributed to certain light patterns due to the uneven filter permeability rather than scattering/stray light. The cause of the second issue was identified to be the aluminized groove on the O-ring. The third issue is still under investigation, and plans are underway to rectify the situation by adjusting the operational configurations. Basic performances including image quality and system throughput were confirmed to meet the requirements of the design. Therefore, the HSC was put to open use and strategic observations in late March

2014. The following tasks must be performed in the future: (a) realizing an auto-focus mechanism, (b) developing a throughput measurement system, (c) establishing operational stability of the filter exchange device, (d) addressing the malfunctioning CCD, and (e) establishing a data analysis support structure for open-use users. The following upgrades of the existing instruments were performed: development of multi-object unit for the HDS, replacement of the MOIRCS detectors and development of its integral field units, preparation for the introduction of an integral field unit for spectroscopy, and development of a polarizing plate for the COMICS.

With respect to PI-type instruments, the HiCIAO high-contrast coronagraphic imager and the Kyoto3DII visible integral field spectrograph were used in open-use observations. The HiCIAO continued to play a central role in the SEEDS strategic observational project, delivering successful results. Moreover, new technology to reduce quasi-static speckle noise was established for the Subaru Coronagraphic Extreme Adaptive Optic (SCEXAO), which is a high spatial resolution and contrast coronagraph, and performance tests in adaptive optics were conducted to achieve higher resolutions. Demonstrative observations were also performed for two optical interferometer modules known as VAMPIRES and FIRST that enabled observation at an even higher spatial resolution. The RAVEN, a multi-object adaptive optics system under joint development with Canadian research institutes, was transferred from Canada to the Hilo Base Facility of the Subaru Telescope, and fine tuning was executed in preparation for the test observation scheduled in FY 2014. The RAVEN will be the demonstration piece for the future Thirty-Meter Telescope (TMT) observational instrument.

Also under development are a near-infrared spectrograph (infrared Doppler, IRD) yielding high wavelength stability and CHARIS, an instrument for performing near-infrared integral field spectroscopic observation at high spatial resolution in combination with AO188 and the SCEXAO. Reviews for final designs and instrument acceptance were conducted for both systems. These devices promise further developments in exoplanet research. The IRD continues to be under consideration for onsite operation, given its impact on the observatory.

A development is underway for an ultra-wide-field prime focus spectrograph (PFS) for installation on the Subaru telescope as the main instrument of the facility following the HSC. The PFS uses 2,400 optical fiber positioners to divert the light of celestial objects from the prime focus to four sets of spectrographs installed in the dome, enabling simultaneous observation at wavelengths of $0.38\mu\text{m}$ – $1.26\mu\text{m}$. Progress was made in the design details in FY 2013, with some brought to production. The PFS is a complex international project with a large budget across several countries. Submitted for NAOJ review from the perspective of project management, it transpired because reconsideration was strongly recommended for realistic planning up to the project completion, in accordance with the budget status.

Following the HSC and PFS, another major project for future undertaking is Ground-Layer Adaptive Optics (GLAO),

which facilitates a correction of atmospheric turbulence in the wide field of view. This project involves the development of an adaptive secondary mirror and a new wide-field near-infrared camera and spectrograph. The Subaru Telescope aims to begin operation GLAO as its main instrument in the 2020s to coincide with the commencement of TMT observations. A review of concept design scheduled in FY 2013 was postponed; instead, possibilities for wider usage were explored with an eye on international collaborations.

6. Computer Systems/Software

The goal for FY 2013 was to achieve stable operation of the fourth-generation computer system, which was installed in February 2013. The system is running well with major error reported thus far. In January 2014, illegal access was detected to have been made to one of the Subaru Telescope's computers from a Mitaka computer that had been under cyber-attack. No sign of data leakage or falsification was detected, however. An inappropriate management of access log-in details on the user's part was a major factor leading to this incident. Therefore, computer log-in details were changed at the Subaru Telescope facility as an emergency countermeasure. Ways to monitor and record access from the Mitaka network are under discussion. The data archive, which had been running on the basis of public test operations since FY 2011, moved into a full-scale operation under the new system. No major issues have been reported thus far, and the new system is operating smoothly. An easy-to-use interface was developed for this system to accommodate the actual level of utilization of the archive system. By installing an inexpensive database engine, the operational cost was significantly reduced.

Along with the data archive management at Mitaka, the Mitaka subsystem continues to provide support for the Subaru telescope users, including remote observation monitoring. The Web-based proposal application system, which was introduced in the S11B term, continues to operate with some improvements. A system error occurred in March 2014 in the proposal application for the S14B term due to insufficient testing after the system update. Following the incident, the management manual was reviewed to mandate sufficient testing after system upgrades.

New computer systems were installed in FYs 2010 and 2011 for enhanced efficiency in processing data from the HSC, which generated a massive volume of data. For FY 2013, test operations and modifications were undertaken for the processing programs.

The license agreement for the dedicated network line between Mitaka and the Subaru Telescope facility will expire in March 2014. Therefore, an application was made to procure the dedicated network line for use from April 2014.

Development commenced this year for a new computer system to process Web-based applications for observational visits, replacing the current system based on paper forms/FAX. The new system is expected to be launched in the latter half of FY 2014.

7. University/Graduate School Education

The number of research/teaching staff members posted concurrently in Hawaii from the Graduate University for Advanced Studies increased by two to a total of 11 members. The number of graduate students of the Graduate University for Advanced Studies who are supervised by the Subaru Telescope teaching staff (including concurrent posts) increased to 16, accounting for roughly half of all postgraduate students engaged at the NAOJ. Full-time teaching staff at the Subaru Telescope facility supervise nine graduate students.

Four graduate students were stationed at the Subaru Telescope facility on a long-term basis in FY 2013, two of whom were from the Graduate University for Advanced Studies. Educational activities for graduate students were also active at Mitaka, in cooperation with the Division of Optical and Infrared Astronomy. Eleven graduate students across Japan obtained degrees for their research using Subaru telescope, marking an increase by four from last year. Four students among them belonged to the NAOJ optical/infrared group.

The Subaru Winter School was held for the first time at the recommendation of the Subaru Advisory Committee in February 2014. As a joint project with Korean KASI, it was held at the KASI in Daejeon, South Korea, and a total of 25 Japanese and Korean postdoctoral researchers, as well as postgraduate and undergraduate students, participated. This school provided workshops on data analysis and lectures on telescopes, instruments, operation, science, and other topics. The Subaru Observation Experience Program for undergraduate students around the country and the Subaru Observation Workshop for the Graduate University for Advanced Studies were also conducted in November.

The Subaru Telescope facility also organizes Subaru Seminars twice or three times per month (in English), in which participants in open-use projects, visitors, and Subaru Telescope staff report their latest research results. Other seminars are held at Mitaka, in collaboration with NAOJ staff from different sections or neighboring universities.

8. Public Information and Outreach Activities

A major social responsibility of the Subaru Telescope facility is the response to or increase of the high levels of interest in astronomical research among the general public. The Public Information and Outreach (PIO) Office has been established in order to contribute to short- and long-term successes of projects and engages in three basic types of activities. Particular care is taken in engaging with the local populace, as their understanding of the activities being conducted at the Subaru Telescope facility is a key factor for acceptance of these activities and next-generation projects by the local community. The primary activity of the PIO Office is information sharing. The office has created a website in order to reach a wider audience with the scientific results produced by the Subaru Telescope researchers and observatory activities as well as press releases for public announcements and information

disclosure. This year, 21 research reports (10 in Japanese and 19 in English) and 84 articles (43 in Japanese and 41 in English) on topics such as instrumental development, observatory activities, and news items were published on the website. Information is distributed to the media in Japan or locally in Hawaii directly or worldwide via the mailing service of the American Astronomical Society, as appropriate. Apart from the website, the use of new communication tools is increasing regularly, including social media such as Twitter and Facebook and video-streaming on YouTube. Other continuing PIO activities include media interviews (seven in Japanese and three in English), responses to media inquiries (nine in Japanese and four in English), and response to various questions asked by officials from educational institutions or science museums.

The second pillar of the Office's activities is offering facility tours to familiarize wide audience with the observatory's activities. For the Subaru Telescope (summit facility) tour program offered since FY 2004, full-time specialist staff plays a major role in promoting timely communications with visitors and prospective visitors. The general visit program, which can now be booked online, welcomed 521 people this year excluding August and September, when general visitor reception was suspended due to the deposition work of the primary mirror. Special visits were arranged for 138 people, and the total number was 1,269 visitors.

In addition to offering facility tours, the Operations Support Facility provided lectures and occupational mentoring by staff members and guidance by researchers to visiting students on their research presentations. Facility tours were provided to 526 people in 50 groups this year.

The third pillar of the Office's activities is educational and promotional activities in the form of lectures and teaching visits targeting the local community, as well as remote lectures and courses conducted with participants in Japan via teleconferencing. A total of 100 lectures and classes were given at the Operations Support Facility, the Imiloa Astronomy Center, and other local venues, while eight guest lectures and 16 remote lectures were given outside Hawaii Island such as in Japan. Local school visits included 69 classes allocated to the Subaru Telescope facility during a special one-week intensive course with the participation of the Mauna Kea Astronomical Outreach Committee. This program enabled the promotion of astronomy to more than 1,600 students.

Although the Subaru Telescope facility does not hold open house events, it participated in two local events in Hilo together with the Mauna Kea observatories to offer science workshops, exhibitions, demonstrations and explanations. These events, in which the Mauna Kea observatories participate annually, offer good opportunities for socializing with approximately 2,000 citizens, including families, school students, and teaching staff.

2. Okayama Astrophysical Observatory

The 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 of astronomy research at the universities. Concurrently, the observatory pursues its own research activities, taking advantage of its location and observational environment.

About 220 nights at the 188-cm telescope are exploited for observations by researchers from across the country through the open use every year. The observatory maintains and operates the observing instruments and provides the observers with supports for observations, travel expenses, accommodations, every day needs, etc. It also engages in improving the open-use observing instruments, developing new open-use instruments, and supporting brought-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) and it engages in a comprehensive survey of infrared-variable objects on 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).

The personnel breakdown as of March 2014 was six full-time staff members, including two associate professors, one assistant professor, one chief research engineer, one engineer, and one chief clerk; eleven contracted staff members, including two research experts, two postdoctoral fellows, two research supporters, three administrative supporters, and two administrative maintenance staffs; and one temporary staff member.

1. Open Use

(1) Overview

The open use of the 188-cm telescope was suspended between January and April to allow the major upgrade of the telescope functionalities in 2013. The numbers of nights allotted to the open use in 2013 were 25 nights in the first semester (May to June this year) and 95.5 nights for the second semester (August to December). Observing proposals were called for publicly. The Okayama program subcommittee reviewed the submitted

proposals and accepted one project observation program and 17 general observation proposals. Open-use observation generally proceeded without incident. The successful upgrade of the 188-cm telescope significantly reduced the occurrence of troubles during observations. Discussions were held on the validity of the anonymous application system, which was introduced in 2006, whereby the names of proposal applicants were concealed from referees. The discussion was initiated at the program subcommittee in June and was passed to the users' meeting in August. These discussions were followed by judgment at the program subcommittee in November, which considered the user survey of October. The final plan was to abolish the system and revert to the previous method, starting from the call for observing proposals for the second semester of 2014.

(2) Observation/Research results

The majority of objects observed through the open use in 2013 were stellar sources. Others included Solar System objects, interstellar media, quasi-stellar objects, and AGN. The following primary observation themes were noted: searching for exoplanets via precise radial velocity measurement; elemental abundance analysis of stars via high-dispersion spectroscopic observation; and the observation of exoplanet transits by precise near-infrared differential photometry, which increased precipitously in recent years. Also increased were optical low-dispersion spectroscopic observations of stars for classification and of sudden phenomena for follow-ups. 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. Please see the proceedings of the users' meeting and relevant conferences and the reports made at the annual meetings of the astronomical society of Japan.

(3) Facility and Instrument Maintenance/Management

The high-dispersion Echelle spectrograph (HIDES) and its fiber link system were connected to the 188-cm telescope in April so that research data could be obtained smoothly. During the maintenance period in June, the annual re-aluminization of the primary mirror of the 188-cm telescope was passed. Instead, the April work was continued, this time, to connect the near-infrared imager/spectrograph (ISLE) and the Kyoto–Okayama optical low-dispersion spectrograph (KOOLS) to the telescope. Moreover, utmost efforts were made to maintain high observation efficiency by conducting monthly cleaning of the primary, secondary, and tertiary mirrors of the 188-cm telescope. The dome was checked daily. Other maintenance work was also performed, including a repair of the external panels of the dome hemisphere and maintenance of the lifter floor controller in June, replacement of the chiller for the aluminization chamber in August, repair of the upper/lower slit guiding rails in September and March, servicing of the tro-reel in September, maintenance

of the controller of the aluminization chamber in October, maintenance of the dome controlling system in November, and replacement of the power supply cables for the air-conditioners and dome's rotation brake in December. A failure of the power collection points in the tro-reel occurred in October and a countermeasure based on the subsequent investigation of the cause was installed in the surrounding area during December–March. Lubrication of the telescope and dome, scheduled for September maintenance every year, was missed this year. The observatory, however, responded to the request for re-aluminization of the primary mirror of the 1.5-m Kanata telescope at Hiroshima University in October. Work safety was given priority in accomplishing the aforementioned maintenance work and observing instrument exchanges. One potentially dangerous incident and four accidents occurred during FY 2013. No one was injured on any of these occasions, and all five cases were reported to the Industrial Health and Safety Committee.

(4) Conferences

The program subcommittee met on June 24 and November 14 to evaluate proposals for the open use of the second semester of 2013 and the first semester of 2014, respectively, and formulated an observation program for each semester. The Okayama Users Meeting, also known as the 24th Optical and Infrared Users Meeting, was held at the Kurashiki City Art Museum between August 1 and 3. The observatory reported its present activities and overall conditions, particularly the status of the 188-cm telescope following last year's refurbishment. Reports by others included research results from open-use projects and user-led plans to develop new observational instruments. Also discussed were the operations of other optical and infrared observational facilities such as the Higashi–Hiroshima Observatory and the networking of small- and mid-sized telescopes. On day three of the meeting, a report was given on the progress of Kyoto University's Okayama 3.8-m new technology optical and infrared telescope project and proposals were presented on the initial research themes, observing instrument plan, and operation systems before and after completion. The proposals were followed by a stimulating debate.

2. Developing 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. Its observing capability is currently being improved by introducing fiber links. The high-efficiency fiber link with approximately 50-K wavelength resolution now 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 test observation of the link was conducted in 2010, and it has been provided to the open use since 2011. The number of its use increased steadily, and three academic journal papers and two doctoral theses based on data taken using the fiber link were

published in FY 2013. Major work pursued in FY 2013 included connecting the HIDES to the refurbished 188-cm telescope system and website updates to enhance its user-friendliness. Regarding the development of a nearly 100 K wavelength resolution fiber link, some fine adjustments were made, and preparations for test observations are in progress.

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

The instrument ISLE is a near-infrared imager and low- or mid-dispersion spectrograph, and has been available for the project observations and the academic degree support programs since the second semester of 2011. 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). Having achieved a high precision for relative photometry of one milli-magnitude level, the ISLE has been in greater demand for observations of exoplanet transits. Of the eight open-use observations actually conducted in 2013, four were spectroscopic observations and the other four were exoplanet transit observations, including one for the academic degree support program.

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

This instrument was made available for open use as a PI-type instrument in FY 2008 and has since been in stable operation. The CCD output linearity, which had previously been a concern, was improved in FY 2009, relaxing the limitations on imaging observations and on spectroscopic observations of bright objects, in particular. Software improvements have allowed for observations of non-sidereal motion objects and long integration time is feasible for observations of Solar System objects. The open-use applications for KOOLS have increased due to a recent rise in demand for spectral classification and monitoring observations.

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 Nagoya University and Nano Optonics Energy 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 dome through weekly TV conferences and in-person meetings held every three months. The supplemental budget for FY 2013 allowed for the cost of constructing the main telescope for the project, bringing the project into full action.

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

This program has entered its third year since its commencement in 2011. The Okayama astrophysical 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. The observatory provided a total of 41 nights worth of observational data on three objects this year. It also took an active role in the information sharing, system developing, and actual observations for the cooperative observation and education network, which the project aimed to establish. The observatory was also actively involved in leading the actual observations. Furthermore, it welcomed short-stay workshop programs from other universities and gave hands-on instructions to the postgraduate students. One peer-reviewed paper, in which data taken with the 50-cm telescope were also used, on a GRB was published in the scientific journal *Science* in FY 2013, while GRBs have the highest priority among the project's scientific targets. Further, three additional papers were published in relation to the project.

(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 2013, the automatic observation scheduler performed observations on nearly every possible night; 34 GRBs were observed, with optical afterglows successfully detected in four. Observation results were published as 17 GRB Coordinates Network (GCN) circulars. The monitoring of cataclysmic variables and Mira variables and observations of exoplanet transits were concurrently performed in addition, which resulted in publication of five peer-reviewed papers.

(4) Other

The observatory welcomed five third-year undergraduate students from the University of Tokyo between August 5 and 7 and provided them with an opportunity to conduct high-dispersion spectroscopic observation using the 188-cm telescope during the early half night on August 5.

4. Unique Research Projects

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

A project is underway to identify infrared counterparts for objects such as distant GRBs and gravitational wave sources and comprehensively survey infrared variable stars in the Galactic plane by converting the 91-cm telescope into an infrared camera with an ultra-wide field of view of 1 square degree. New variable objects were successfully detected in a K-band image obtained at the Galactic plane with the camera by subtracting a corresponding Two Micron All Sky Survey (2MASS) image from it, indicating the promising prospect of achieving the initial objective. Fine optical adjustment was conducted in FY 2013 in order to widen the area of good imaging quality within the field of view for higher survey efficiency.

(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. Successful upgrade was conducted last year on the drive and control systems as well as the dome control system of the same telescope. This year, integration work was undertaken on the observation system, including the observing instruments, to achieve significantly higher reliability and an improved observing efficiency by approximately 20 % while maintaining the excellent ease available before the upgrade.

(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. The efforts continued in FY 2013 to secure telescope time for the Korean 1.8-m telescope, Chinese 2.16-m telescope, Turkish 1.5-m telescope, and the observatory's own 1.88-m telescope for continued searches for exoplanetary systems around G-type giant stars. Moreover, a conference on exoplanet search based on precise radial velocity measurement and asteroseismology was held on Ishigaki Island on Sept. 4–6, 2013 with 16 participants from South Korea, China, Germany, and Japan.

5. PR/Awareness Promotion Activities

An observatory representative delivered a lecture to nearly 60 people in Okayama City on July 7 as part of the Nation-Wide Tanabata Participatory Lectures. Nearly 70 astronomy-related questions were posed and answered at this year's event. The 4D2U screening, co-hosted with the Okayama Astronomical Museum, attracted 4,721 visitors. Seventeen observatory tours were conducted for pupils from local elementary schools in Asakuchi city and Yakage town. The observatory also responded to eight lecture requests made by local boards of education and community centers.

6. Contract Staff Transfers

The following transfers of contract staff members took place in FY 2013: Hironori Tsutsui joined in April as a Research Expert member and subsequently left the position at the end of February 2014 to be an Engineer at NAOJ beginning in March. Akira Imada, a Postdoctoral Fellow, departed at the end of FY 2013 upon completion of his term.

3. Nobeyama Radio Observatory

1. 45-m Radio Telescope

(1) Open Use

The 32nd open-use observation period began on December 16, 2013. The accepted proposals are listed below.

- General proposals for the first term: 20 including 2 from overseas (of 47 applications)
- General proposals for the second term: 14 including 3 from overseas (of 30 applications)
- Proposals for short programs: 12 including 2 from overseas (of 26 applications)
- Educational support (first and second terms): no proposal was adopted (one application)

Two backup programs (of two applications) were accepted for use in the case of inclement weather preventing ideal observation. Of the two, one was taken as a backup program for general application for the second term.

One open-use project with VERA was also conducted.

(2) Device Repair/Development

Maintenance work on and development of a new observational system continued from the previous year.

- Following test runs, the computer update was implemented during the summer to be able to conduct open-use observations.
- The cable of a lightning arrester system installed in the antenna exhibited partial dislocation. Therefore, it was removed completely to eliminate the risk for safety reasons.
- Improvement was made to the dual-beam receiver TZ, and beam 2 was released to open use in addition to beam 1 (the main beam). This receiver became widely used as a primary receiver for the 100-GHz region.
- A 70-GHz receiver, T70, was released for open use.
- A new multi-beam receiver, the Four-beam Receiver System on 45-m Telescope (FOREST), was installed and was commissioned to do performance evaluations as well as test observations.
- The Nobeyama Radio Observatory (NRO) supported the Z45 team in the installation of a 45-GHz receiver, Z45, funded by a Grand-in-Aid for Scientific Research, particularly with hardware and software connections and test runs.
- The NRO added functions in the software related to the new receivers.
- Remote observation from Mitaka was made available for open use.

(3) Research Results

Two main projects, a star-formation project and a distant galaxies project, pursued the 45-m telescope legacy project. Their accomplishments are listed below.

(a) Legacy star-forming project: The Beam Array Receiver System (BEARS) and TZ receivers were employed for mapping

observations of the nearby star-forming region Orion A and the Aquila Rift in the W40 region. The filaments and shell-shaped structures within the nebula in Orion A were observed in detail in ^{13}CO . Furthermore, the data on Orion A is currently used for a high-resolution, large-scale map through combination of 45-m telescope and interferometer data in a joint research project with the Combined Array for Research in Millimeter-wave Astronomy (CARMA). A scientific paper (Shimajiri et al. 2014) was published using the data from the previous season, and a figure from the manuscript appeared on the cover of the journal *Astronomy and Astrophysics*.

In the W40 observation, the molecular emission line data of ^{13}CO elucidated the formation of the shell-shaped high-density gases in the vicinity of the HII region, resulting in star formation in the high-density region.

(b) Submillimeter galaxies are important objects for the study of galactic formation at the beginning of the Universe. However, because they are surrounded by large amount of dust, they are extremely faint in the visible and infrared spectra, making it extremely difficult to accurately determine their redshifts. CO line observations of submillimeter galaxies are currently underway using the SAM45 spectrometer and the dual-beam receiver newly installed on the 45-m telescope, which has enabled direct determination of the redshift of astronomical objects. A blind redshift search was implemented this year on four objects with unidentified redshifts including two submillimeter galaxies discovered through an AsTEC camera and two detected by the Herschel Space Observatory.

2. NMA-F (SPART project)

A group from Osaka Prefecture University is pursuing the Solar Planetary Atmosphere Research Telescope (SPART) project to observe the Solar System's planetary and atmospheric conditions by reusing the Nobeyama millimeter wave interferometer 10-m radio telescope. This project is expected to provide important and unique knowledge regarding the influences of core star activities on the internal and external planetary environments and habitable zones in addition to information about climatic conditions of our Solar System. The azimuth actuator broke down at the end of last year, but it was repaired this year by replacing a motor and adjusting the azimuth gear. Motor vibration in the vertical direction was observed, which was amended by replacing the motor adjustment. This allowed for resuming the SPART operation, which had been suspended since 2012. Additionally, a standing wave removal filter was developed, and together with the improvement made to the LO/IF system, the Osaka Prefecture University group commenced stationary observation in the 200-GHz region. This has enabled dual-band observation in the 100-GHz and 200-GHz bands, which includes observation of isotopologues and trace species at different levels of ^{12}CO and ^{13}CO with J

= 2–1, 1–0). As a result, a more accurate retrieval analysis is possible, allowing for calculation of the mixing ratio and altitude distributions of molecular probes, unlike that in the conventional 100-GHz band observation. The UNIX-based computers of the old NMA were all replaced by Linux, controlled by Python language, and brought entirely under remote operation.

3. Development of a Multicolor Millimeter/Submillimeter Camera for Atacama Submillimeter Telescope Experiment (ASTE)

Simultaneous imaging in multiple wavelengths in the millimeter/submillimeter bands is vital tool for estimating the redshift of submillimeter galaxies and in studying the internal structure of hot plasma in clusters of galaxies using the Sunyaev–Zel’dovich effect. Moreover, it is crucial for constraining physical quantities of the dust in star-forming regions and setting a limit to the spectral index of the initial submillimeter afterglow of GRBs. Thus, in order to succeed in large-scale sky surveys with a continuum camera, the development of a multicolor millimeter/submillimeter camera with a Transition Edge Sensor (TES) bolometer for observation at wavelengths of 1.1mm, 0.87mm, and 0.46mm is underway in collaboration with the University of Tokyo, Hokkaido University, University of California Berkeley, and McGill University.

The Atacama Submillimeter Telescope Experiment (ASTE) telescope was equipped with this bolometer camera receiver and succeeded in acquiring the “first light” image last year. This year, test installation and observation were conducted from late October 2013 to early January 2014 in order to examine in detail the improved bolometer arrays and the optics. Countermeasures were put in place against difficulties faced last year in the receiver installation and cryocooler startability, which opened a way to the smooth commencement of observation. It should be noted, however, due to bad observing conditions under atmospheric instability during the period, tests were repeated again between early March and mid-April 2014. In contrast to last year’s session, where the prototype bolometer arrays managed to image only bright planets, the celestial signals were clearly identified from the massive star-forming region NGC 6334 (NRO bulletin No. 132) within short 20 minutes integration time. Other objects observed include submillimeter galaxies and GRBs outside our Galaxy. The data are currently under analysis.

The efforts in installation test runs, observation, and data analyses has brought out the effective methods for enhancing observational efficiency. Accordingly, the NRO engaged in studies and basic designs regarding further optimization of the bolometer design, improvement of the software for tuning the bolometer to its optimal operating configurations, and improvement of readout system by doubling the number of bolometer pixels per readout channel from 8 to 16, aiming to reach overall bolometer pixels of 1,000. Study is underway for adding more colors based on the latest superconducting technology, in preparation for a future upgrade to the final version.

4. Other

(1) PR Activities at the Nobeyama Campus

Nobeyama has made the campus accessible to the public at all times since the inauguration of the radio observatory in 1982. With the exception of a few days in late February of this year, when heavy snowfall forced the campus to close to the public, the campus received a cumulative total of 58,543 visitors throughout the year, including participants of special open house events. Staff members conducted 18 guided tours, including participants of Science Partnership Programs (SPPs) and Super Science High School (SSH) students, while two requests for lectures and 14 requests for on-site filming and interviews were granted. In response to public request, the opening hours for viewing were extended by one hour, to 18:00 during the summer months (July 20–August 31).

The Campus Tour Week was launched during the summer and was aimed at educational institutions (elementary, junior high, and high schools). Staff members gave guided tours for this program as well. Due to the insufficient length of the application period, only two groups took advantage of this opportunity. However, visitors from the participating schools said they thoroughly enjoyed their visits. For the workplace visit initiative conducted between June and October, 10 students from 5 schools, primarily local junior high schools, visited the observatory and had a chance to experience the observatory’s routine work under staff guidance. For SPP/SSH initiatives, seven schools visited the NRO and participated in lectures, student presentations, and hands-on guidance of future activities. Furthermore, The workshop of Radio Astronomical Observation using the 45-m radio telescope was held again this year from September 17 to 21, with 12 undergraduate students in attendance. While guidance to 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.

In the area for permanent public access, an antenna experience facility is available along with posters and panel displays. A video continuously played in the visitor room shows various facilities, introduces the history of the NRO, and explains research results. For Internet-based PR activities, the NRO runs a website with thorough explanation of the observational equipment in operation onsite, and content is increasing to include observational results as well as introductory descriptions of radio astronomy.

(2) The Record 3 Million Visitors at Nobeyama Campus

Since the opening of the campus to the general public 32 years ago, the cumulative total of visitors to the campus reached 3 million on October 17. A ceremony was organized to celebrate this achievement, with the 3 millionth visitor treated as an honorable guest.

(3) Cooperation with Local Communities

The annual Nobeyama Special Open House was held as usual, with contributions by Minamimaki village, the

Minamimaki Chamber of Commerce, and its youth division. Special sponsorship was made to the sora-girl event Tebura de Hoshizora Kansho-kai, or drop-by star gazing event, hosted by the Minamimaki Tourism Association. The NRO also joined the Japan Three Major Scenic Location for Star Gazing with the Minamimaki Tourism Association: Night Sky Summit that took place in Bisei-cho, Okayama prefecture.

(4) NRO Conference Workshops

- July 24–25, 2013: The 31st NRO Users Meeting (representative: Tomofumi Umemoto)
- July 29–August 1, 2013: The 43rd Summer School for Young Researchers on Astronomy and Astrophysics 2013 (representative Keisuke Nakagawa)

- November 8, 2013: NRO Galactic Plane Survey Workshop (representative: Aya Higuchi)
- December 6, 2013: CO Multiline Imaging of Nearby Galaxies (COMING) mini-workshop (representative: Kazuo Sorai)

(5) Part-Time Research Staff Transfers

○Researchers

Akihiko Hirota: assistant professor, NAOJ Chile Observatory

Tatsuhiko Sato: engineer, NAOJ Subaru Telescope

4. Nobeyama Solar Radio Observatory

1. Radioheliograph- and Radio Polarimeter-Based Solar Observation and Solar Activity Status

After a long period of minimal solar activity, the 24th solar activity cycle is approaching a peak period. According to observational data, the first high point occurred at the beginning of 2012, followed by the second in early 2014. The first peak was mainly due to activities in the northern hemisphere, whereas the second peak was mainly attributed to activities in the southern hemisphere; the latter superseded the former. Similarity in the activity pattern to that of the previous cycle was noted. However, the active regions are small and short-lived compared with those in the previous cycles.

The radioheliograph, in continual use since 1992 with very few failures, provides high-quality, constant data for open use. One of the front-end receiver boxes installed behind the antenna incurred a water leak, which resulted in damage to certain parts. The situation has been rectified by parts replacement. Data reception from all antennas is still good after 22 years, and there is no sign of data deterioration. The radio polarimeter has also produced well-calibrated data during the last 62 years, since it started at Nagoya University's Research Institute of Atmospherics.

Influences from the decreased solar activities are recognized in many different forms because there is heightened interest in constant, well-calibrated radio observational data, which the Nobeyama Solar Radio Observatory (NSRO) has provided over an extended period. Officials from the observatory are invited more often to deliver lectures at conferences on space climate.

2. Continuing Radioheliograph Operation

Given such circumstances regarding solar activities, researchers across the world have requested continuing operation of the Nobeyama radioheliograph. The chairpersons of the Scientific Committee on Solar-Terrestrial Physics (SCSTEP),

the International Astronomical Union, Division II (IAU, Div II), and the European Solar Physics Division (ESPD) of the European Physical Society have submitted written requests to the president of the National Institutes of Natural Sciences (NINS) and the director general of NAOJ for continued radioheliograph operation in FY 2015 and thereafter. Domestically, the solar community in Japan proposes the inter-university Next-Generation Heliospheric Environment Variation Observation Network Plan to the Astronomy and Astrophysics Subcommittee of Science Council of Japan, and the continuation of the radioheliograph operation at Nobeyama is included as a part of the plan. Discussions are underway for the realization of the continuous operation from 2015, consideration such frameworks as funding by an international consortium, management by Nagoya University's Solar-Terrestrial Environment Laboratory, and provision of equipment by NAOJ.

3. Open Use, Joint Research, and Consortium Activities

All observational data are made available to the public, and researchers working in relevant fields in Japan and abroad have utilized the information for their studies on solar phenomena, space weather, and space climate. The data is also leveraged for the purposes of education and PR. A consortium of university users, represented by Satoshi Masuda, promotes open use in Japan (http://solar.nro.nao.ac.jp/HeliCon_wiki/). A data analysis workshop (CDAW13: September 30–October 4, 2013) held to actively promote open use in Japan had 21 participants. With lectures and exercises offered, four groups practiced data analysis, and attendees subsequently reported the experience at various research conferences and to the astronomical society. The Japan Solar Physics Community held a symposium titled Solar Research at Activity Maximums: chromospheric plasma analysis, space weather, and Solar-C at Kyoto University from February 17 to 19, and the observatory presented its

undertakings as well as studies conducted during CSAW13.

Twenty papers were published in December in the special edition SP1 of the Astronomical Society of Japan's English publication PASJ, volume 65, with a title "Twenty Years of Nobeyama Radioheliograph." Among the papers included was an original paper presented at the International Symposium Solar physics research by radio observation: radioheliograph over the past 20 years and the future (Nagoya University: November 20–23, 2012).

Visiting international researchers included four representatives of the Korea Astronomy and Space Science Institute (KASI), who stayed for three days to participate in a joint research program. Others participating in open-use and joint research during a few weeks include E. Kuprianova from the Pulkovo Astronomical Observatory in Russia, B. Ryabov from the Ventspils International Radio Astronomy Centre in Latvia, A. Warmuth from the Leibniz Institute for Astrophysics Potsdam in Germany, and V. Nakariakov from the UK.

4. Other

The NSRO participated in the summer student program of the Graduate University for Advanced Studies. It accepted one undergraduate student for three weeks during summer and provided him with research guidance on solar activity and space climate using data available at the observatory. The Cutting Edge Solar Research Experience Tour, which was organized jointly by solar-related research institutions in Japan, offered lectures and a guided tour of the observatory to 13 participants. Regarding initiatives aimed for high schools, students from Hakuyo High School in Kanagawa and Komagane Technical High School in Nagano participated in the SPP program, for which the observatory provided lectures and workshops. In addition, Komagane Technical High School installed its own radio telescope, for which the observatory rendered support. The observation results from this telescope were presented to the junior session of the Annual Spring Meeting of ASJ.

Further, K. Sujin, a research fellow, departed upon completion of his term.

5. Mizusawa VLBI Observatory

1. Project Overview

The main purpose of the Mizusawa VLBI Observatory, referred to in this section as "the Observatory," is to promote observational astronomy using Very Long Baseline Interferometry (VLBI). The Observatory mainly pursues analyses of the Milky Way based on the observational results of VLBI Exploration of Radio Astrometry (VERA), consisting of four 20-m radio telescopes of the National Astronomical Observatory of Japan (NAOJ). It also co-operates several 32-m radio telescopes installed at the Yamaguchi station in Yamaguchi prefecture and Hitachi and Takahagi stations in Ibaraki prefecture in collaboration with local universities in respective regions. The Observatory performs the role of a key base for VLBI research in Japan and East Asia, conducting joint research as well as open-use observations with VERA in combination with those radio telescopes, in collaboration with the Japanese VLBI Network, and it extends activities to the East Asia VLBI array in collaboration with Korea and China. Furthermore, the Observatory maintains and displays Japan Central Standard Time at its Timekeeping Office.

In 2013, the Observatory began joint operation of ATERUI, Center for Computational Astrophysics (CfCA) super computer installed at the Mizusawa campus.

(1) VERA

VERA is a project created mainly for elucidating the three-dimensional structure of the Milky Way based on high-precision astrometric observations of the maser sources within the galaxy. It has been producing astrometric observation data regularly

since 2007, using an unprecedented method of dual-beam phase-referencing that utilizes four 20-m radio telescopes located respectively at the Mizusawa, Iriki, Ogasawara, and Ishigakijima stations. In FY 2013, the Observatory performed the operation and maintenance of the observation array as scheduled and pursued scientific research based on the observational data.

The current main correlator for VERA, an FX correlator set up at the Mitaka station, is coming to the end of its lifetime and is showing some difficulties in operation even with maintenance and parts replacement. Therefore, a process is underway for replacement with a software-based correlator hereafter referred to as software correlator.

(2) Optical Fiber-connected VLBI

In the Optical Fiber-Connected VLBI observational system, signals received by radio telescopes at multiple stations are connected via a high-speed fiber optics network, allowing for a real-time broadband observational system. This system connects a 32-m radio telescope at the Geospatial Information Authority of Japan (GSI) in Tsukuba, an 11-m radio telescope at Gifu University, a 32-m radio telescope at the Yamaguchi Station of the NAOJ, and an 11-m radio telescope at the Tomakomai Space Observatory of Hokkaido University via an optical communications network. Signals are transmitted to the NAOJ Mitaka campus via the Security Innovation Network (SINET) of a 10-GbE line at 2.4 Gbps. The NAOJ Mitaka campus is equipped with a real-time correlator and disk recording devices; therefore, it has the capacity for correlation both in real time and post-processing, as dictated by necessity such as the need for immediate information distribution. The Mitaka campus

receives live broadband observational data from university-based stations, records the information on magnetic devices, and forwards it to the East Asia correlation center in South Korea.

(3) Japanese VLBI network Observation

A network is developing between twelve VLBI observation stations in Japan that includes four NAOJ VERA stations, the 11-m radio telescope at Hokkaido University Tomakomai, the 34-m radio telescope at the National Institute of Information and Communications Technology (NICT) Kashima, the 32-m radio telescope at GSI Tsukuba, the 64-m radio telescope at the Usuda Deep Space Center of Japan Aerospace Exploration Agency (JAXA), the 45-m radio telescope at NAOJ Nobeyama, the 11-m radio telescope at Gifu University, the 32-m radio telescope at NAOJ Yamaguchi, and the two 32-m radio telescopes of the NAOJ Ibaraki Observatory respectively in Hitachi and Takahagi. The objectives are to conduct high-precision mapping at a high dynamic range in the regions of 6.7 GHz, 8 GHz, and 22 GHz and to observe methanol masers in the 6.7-GHz band and water masers in the 22-GHz band.

(4) Japan–Korea, East Asia VLBI Observation

The Japan–Korea VLBI observation utilizes the Japan–Korea VLBI array (KaVA), which combines VERA and the Korean VLBI Network (KVN) with three 21-m radio telescopes of the Korea Astronomy and Space Science Institute, to pursue high-sensitivity, high-precision VLBI observations. A pilot case of its open use commenced in FY 2013.

The East Asia VLBI Network includes VERA, KVN, and the Japanese VLBI Network as well as the Chinese VLBI Network (CVN) with its four observation stations in China. This VLBI observational network is the world's largest, involving more than 20 stations and a baseline of 6,000 km.

(5) Gravitational Observation and Geodetic VLBI Research

The Mizusawa station conducts VLBI/GPS-based positioning as well as gravitational observations using a superconducting gravimeter. The Ishigakijima station conducts continued observation also using a superconducting gravimeter.

The geodetic VLBI observations employ a method for recording at 1 Gbps in the 22-GHz region. This method was developed uniquely for geodetic observation and was applied for practical use, achieving stable maximal positional precision on a regular basis. Geodetic observations were implemented several times for open-use observation between VERA and KVN to connect their networks, and KVN's coordinates were subsequently provided. Mizusawa and Ishigakijima stations regularly participate in the international observations conducted by an international project for the VLBI observations (JADE, IVS-T2) in order to connect the coordinates for the VERA network to the global coordinate system.

(6) Ishigakijima Astronomical Observatory

This observatory has a 105-cm optical infrared telescope known as Murikabushi, which is equipped with the MITSuME three-color simultaneous imaging camera system. Taking

advantage of the locational conditions at latitude 24° N and longitude 124° E, it engages in gamma-ray burst (GRB) afterglow observations as well as observational studies of supernova explosions and sudden phenomena that occur in comets and planetoids. The Observatory plays an important role in the Optical and Infrared Synergetic Telescopes for Education and Research (OISTER), an observational network established in 2011.

The Observatory also provides the general public with opportunities for astronomical observations on weekends and national holidays. It also makes educational contributions by offering extracurricular activities for high school students and a joint course given at the University of the Ryukyus.

2. Project Progress

(1) VERA

1) Overall Research

VERA has been active for a little more than a decade. It continued astrometric observations in FY 2013 at a pace of approximately 40 celestial objects per year. A cumulative total of more than 170 object observations was completed by the end of FY 2013. Ten papers were published in FY2 2013, including nine papers featured in the *Astronomical Herald* special edition on VERA, published by the Astronomical Society of Japan.

These papers discussed the VERA project and galactic astronomy and included a wide range of activities and research covering the areas of fixed stars, new-star forming regions, active galactic nuclei (AGN), and open-use research between the Atacama Large Millimeter/submillimeter Array (ALMA) and KaVA. Some topics are relevant to the research described below. Another special edition of *PASJ*, the Astronomical Society of Japan's English publication, is under preparation and will focus on VERA. The society is planning to include astrometric observations, detailed observations of maser objects, and results from AGN observations using VERA. Also noteworthy for 2013 is the capturing of a massive protoplanetary disk structure in the Orion region by combining the data of ALMA and VERA, which has enabled the research to enter a new stage.

For the VERA astrometric observations, Imai et al. (2013) measured the annual parallax of the celestial object IRAS 18286-0959. Known as “the water fountain,” this object is moving from the last stage of stellar evolution, which is a red giant Asymptotic Giant Branch (AGB) star to a planetary nebula at a reported distance of approximately 3.61 kpc (11,700 light-years). This study not only determined the mass of celestial objects based on accurate distance data but also presented a clear image of a water maser bipolar outflow being ejected like a fountain, thus rendering itself as a valuable model case for studying the rare water fountain phenomenon. VERA actively engages in AGB star investigation. Takeuti et al. (2013) also pursued theoretical research of AGB stars based on such investigations. In the area of star-formation, Kim et al. (2013) conducted an observation of water masers in the massive star-forming region W75N. They were the first to indicate an on-going evolutionary

process in which the celestial object's typical shell-shaped outflow transformed into a bipolar form. Furthermore, they used dual-beam simultaneous observation to monitor radio flares of the X-ray binary star Cygnus X-3 (CygX-3) including a black hole and neutron stars (Kim et al. 2013). The study indicated the possibility of structural changes during radio flares within CygX-3 and obtained evidence of concurrent jet projection with X-ray spectral status change through simultaneous observation.

An open-use study conducted with the Japanese VLBI Network (JVN), released an observational report of methanol masers in the 6.7-GHz band within a massive star-forming region. Sawada-Satoh et al. (2013) successfully identified that activities of methanol masers in S269 are driven by outflows from young stars,

whereas Sugiyama et al. (2013) succeeded in capturing an image of the gas surrounding a radio source in Cepheus A that revolved concentrically and fell into the center. Both studies are significant because they succeeded in measuring three-dimensional motions of methanol masers in which the proper motion is difficult to measure. These outcomes are substantial additions to the knowledge of mass radiation and accretion in massive-star formation.

Additionally, a study has begun with a new perspective of combining VERA and the emerging observational outcomes of the ALMA cycle 0 in FY 2013. In their study concerning the massive-star-forming region Orion KL, Hirota et al. (2014) combined the submillimeter water molecular emission line data obtained during ALMA cycle 0 with the SiO maser data obtained through VERA and succeeded in high-definition imaging of a circumstellar gas disk near the massive protostar known as "radio source I" and an emerging jet. This achievement has been published on the NAOJ website. Hagiwara et al. (2013) succeeded in detecting the world's first submillimeter water masers at the AGN Circinus during ALMA cycle 0, adding to a growing anticipation for advancement in VLBI-based research of external galaxies.

Moreover, the Gamma-Ray Emitting Notable AGN Monitoring by Japanese VLBI (GENJI) project, created to monitor AGN at a high frequency, leveraging calibrated celestial data as part of VERA project observations, began regular operation in FY 2010; its first report was given by Nagai et al. (2013). Many studies have reported observations of AGN at high spatial resolution using VERA, including multi-wavelength observations of PKS 1510-089, a study conducted jointly with an Italian group (Oriente et al. 2013); an observation combined with an X-ray of the gamma ray undetermined celestial object 2FGL J1502.1+5548 (Takahashi et al. 2013); an observation of objects with high-speed absorption lines by outflows known as Broad Absorption Line (BAL) quasars (Doi et al. 2013); and an observation of the supermassive black hole at the center of the Milky Way, Sgr A* (Akiyama et al. 2013). With discussions for prospective studies of AGN underway, members of the Observatory are making good contributions to the international VLBI observations in the millimeter/submillimeter region (Lu et al. 2013).

The aforementioned VLBI observational studies have

been extended to KaVA. The first KaVA open-use observation commenced in FY 2013. Developmental phases of the East Asia VLBI Network (EAVN) has been discussed at various conferences for installment of the antenna in Shanghai.

2) Geophysical/Geodetic Research

Because VERA is in a transitional period toward a new recording system and correlators, a geodetic VLBI observation/analysis system is undergoing preparation for adaptation to VERA's new recording/correlation system. The new system has been tested for verification. The observatory developed a system for obtaining geodetic data from the software correlator outputs, and the results successfully verified that the new system attained the same level of accuracy as the existing VERA geodetic solutions. Furthermore, the geodetic solution demonstrated improvement through an application of ionospheric delay obtained from the global total electron content (TEC) model to the 22-GHz band geodetic VLBI, which was hitherto being observed at a single frequency in the 22-GHz band.

The coordinates of each VERA station are provided in a daily coordinate catalog containing the Earth's crust shift data obtained from continuous observations of VLBI and Global Positioning System (GPS). The coordinates of the Mizusawa station have not as yet been stabilized under the ongoing post-fluctuation following the Tohoku Pacific Coast Earthquake (Great East Japan Earthquake). The coordinates of VERA are calculated by fixing its coordinates and displacement rates between 2005 and 2008 to the global coordinate solution provided by the Geospatial Information Authority of Japan and by obtaining the relative positions and displacement values.

The marginal error in VERA astrometric observations is caused by radio wave propagation delay owing to annual surface displacement and moisture in the atmosphere. The annual fluctuation is not considered in the VERA positioning catalog because although there is a degree of annual millimeter-level fluctuation in the coordinates obtained through continuous GPS observations conducted at the VERA station, such fluctuations are not recognized in the VERA solutions; in addition, their causes are not verified. An improvement must be made in the future in the perpendicular accuracy of the solutions by deploying the data on solutions of propagation delay in the atmospheric moisture produced through the GPS analysis as well as the Meteorological Agency's objective data, as well as external data by ray tracing. To improve the accuracy of geodetic solutions, some issues must be addressed such as an improvement in observational methods by increasing the recording bandwidth of VERA's new system and adopting a new international VLBI observational system.

The displacement velocity field of the Japanese Archipelago was significantly altered over a broad range by the Tohoku Pacific Coast Earthquake that occurred on March 11, 2011. The coordinates of the Mizusawa station had exhibited a gradual southwesterly movement of just more than 10 mm per annum before the earthquake; however, the movement was altered dramatically to east-southeast after the earthquake, continuing even three years later. Similar findings are confirmed from the

Earth crust strain observations conducted at the Esashi Earth Tides Station. Such observational data are being accumulated because they are invaluable for understanding the strain-releasing process in the Earth's crust or upper mantle during a large-scale earthquake.

3) Operation History

Observations at the four VERA stations are performed remotely from the array operation center at Mizusawa, with 4,115 hours of observations performed over 504 sessions in FY 2013. These included VERA open-use observations, VERA project observations for measuring annual parallax to calculate the distances to astronomical objects, fringe detection test observations for maser objects, and candidates for continuum sources constituting positional references, geodetic observations, Japanese VLBI Network observations, and open-use observations with KaVA as well as test observations. The number and length of these VLBI observations are as follows:

- VERA open-use observation (including open use with KVN): 516 hours over 69 sessions
- VERA project, test observations: 2,358 hours over 336 sessions
- VERA geodetic observations: 664 hours over 27 sessions
- Japanese VLBI Network observations: 189 hours over 22 sessions
- KaVA project (excluding open use): 388 hours over 50 sessions.

The VLBI observational data was correlated at the Mitaka VLBI correlation center; the correlation data for the open use observations and Japanese VLBI Network observations were sent to the principal investigators; and those for the Project observations and geodetic observations were sent to the analysts in charge.

4) Maintenance

Regular observations continued in FY 2013 using the VERA and other telescopes or instruments. The Observatory undertook necessary maintenance and repairs to ensure stable operations.

The VERA Maintenance Group undertook systematic performance checks, repairs, and maintenance of broadband magnetic tape recording devices and also arranged for maintenance by the manufacturer once a year. Everyday upkeep such as antenna greasing, painting, and repairs was performed by each station. The antennas at stations on remote islands require frequent repainting and mechanical maintenance, for which necessary arrangements were made for timely execution.

It has been more than 10 years since the VERA antennas were installed, and the wear to their directional rails in the azimuth (AZ) has resulted in lower AZ platforms. This effect is particularly recognizable at the Ishigakijima station, where a major height adjustment of the AZ platform was executed during the antenna maintenance work. Similarly, the drive systems have deteriorated to cause instability to observational operations. As preventive measures, deteriorated expendable parts in the drive system such as power modules and condensers were replaced. Given the finite maintenance budget, the annual maintenance was divided into two phase. The first phase excluded electrical

system maintenance as much as possible and included only mechanical annual maintenance procedures; replacement of oil sealant for gear boxes; replacement of jack motors for dual-beams, which have failed on occasion; and AZ platform height adjustment at the Ishigakijima station. The second phase included expendable parts replacements within the drive system, together with a limited range of electrical system maintenance work. Regarding the dual-beam jack motor failure, 2B motor cables were also replaced.

Regular maintenance work was undertaken for receiver performance. In addition, a high-spec, low-noise amplifier replaced the old amplifier on the Left Hand Circularly Polarized (LHCP) side to be utilized for the regular VERA operation because high-performance, low-noise amplifiers had been installed at the Mizusawa and Iriki stations when they introduced dual-polarization observation in the 43-GHz band. This has successfully lowered the receiver-end noise temperature by approximately 30 K at these stations.

A pin-point repainting was executed at the Ogasawara station, whereas an overall repainting was conducted at the Iriki station. The Ishigakijima station underwent waterproofing of the foundation; replacement of the feedome membrane, which was developed by the observatory; and an overhaul of the hydrogen maser atomic clock.

5) Technological Development

The agenda for major technological development includes the development of a software-based correlator to replace the aging FX correlator and a disk-based recording/playback device to replace the magnetic tape recording device for which the manufacturer warranty has expired.

In the development of the software correlator, performance evaluation is close to completion, albeit only in the FX correlator compatible mode. This will constitute the basis for a regular operation in addition to the current tape correlator processing. The SiO maser multi-line observations, enabled by the software correlator's wide bandwidth and spectroscopic function, confirmed some possibilities for new scientific endeavor. Considerations on details commenced in FY 2013, and preparations for a plan to install the software correlator at Mizusawa are underway including the necessary arrangements for purchases and installation of power systems and air conditioning in the room. Once the software correlator is in operation, it will be possible to process more than 1 Gbps of broadband data recordings and to significantly increase the number of spectral points, bringing considerable advantages to VERA's astrometric observations.

In parallel to the replacement of the software correlators, aged tape recording devices are scheduled to be replaced by hard-disk-based devices. This will enable 2–4 Gbps recording, well exceeding the current 1 Gbps; performance tests and test operations will be conducted to verify this speed.

Disk recording/playback device development has focused on two observational modes: an OCTAVIA- and OCTADISK-based 2 Gbps, 2 channel broadband recording system and a 1 Gbps recording system serving as a replacement for DIR2000.

This equipment has already been introduced at the various stations in parallel with existing systems. This year, test runs were performed in tandem with observations to standardize and stabilize the operation of the existing systems. As a result, some valuable outcomes for stable operation were obtained, including the discovery that certain hard drive disks (HDDs) caused system failures when run under the OCTADISK-based system.

In addition, an 8-Gbps ultra-broadband system structure has been rolled out at the four VERA stations, and research and development (R&D) is aimed at improving VLBI performance in an attempt to increase the bandwidth for future deployment. Imaging performance and sensitivity improvement were evaluated to demonstrate the value of the ultra-broadband observations. Development of the Korea–Japan Joint VLBI Correlator (KJJVC) is also underway. The development of a disk buffer system, for which Japan was primarily responsible, was completed. Test observations with KVN were performed, and the correlation of data from KVN was handled using the FX correlator, thereby making contributions toward regular execution of the correlation.

(2) Optical Fiber-connected VLBI

In FY 2013, the optical fiber-connected VLBI was deployed mainly in scientific operations used as a sub-array of the Japanese VLBI Network. Real-time observations, together with broadband observations, played an important part in improving the sensitivity of the Japanese VLBI Network and constructing an interferometer array that connected a diversity of stations. In particular, disk recording and correlation were conducted at Mitaka in a VERA-compatible mode during the observation, using the same digital filters as those of VERA. Support was given to each station for operating broadband recording devices, in assistance with the Japanese VLBI Network.

A JGN line from Otemachi to Mizusawa was installed in tandem with movement of the supercomputer to Mizusawa. At the Mitaka campus, researchers verified a 4-Gbps real-time recording of the data from Mizusawa in FY 2013 after connecting the JGN and SINET lines at Otemachi.

(3) Japanese VLBI Network Observation

Defects were found in the Takahagi 32-m telescope's elevation axis motor and the bearing for the coupling, which are now under repair.

At the Ibaraki station, a single-dish observation of methanol maser sources is ongoing daily, using a 6–9 GHz band receiver. In FY 2013, the Yamaguchi and Ibaraki stations participated in the East Asia VLBI Network observations that employed broadband recording systems. These stations also participated in the test observation of the global VLBI network, using the Internet protocol (IP)-VLBI system.

A short baseline VLBI observation is undertaken nearly daily with participations by the NAOJ Mizusawa 10-m telescope and other telescopes at the Ibaraki, Kashima, and Gifu stations with the objective of capturing the flares accompanying the gas accretion at the center of the galaxy, which has been of great interest in recent years. Exchanges between universities and

research institutes have been actively pursued. Postgraduate students at Nagoya University and the University of Tsukuba joined research teams at Ibaraki University and the University of Tsukuba. Two researchers have exchanged their positions between Ibaraki and Yamaguchi Universities, and they engage in the Japanese VLBI Network research activities at their respective institutions. In FY 2013, one postgraduate student from Ibaraki University was stationed at the Mizusawa VLBI Observatory (Mitaka) to study the data analysis of the Japanese VLBI Network and subsequently published a master's thesis. In addition, several postgraduate students from Yamaguchi and Ibaraki Universities published their master's theses on the Japanese VLBI Network and research based at the Ibaraki station.

The Japanese VLBI Network observation projects continued in FY 2013, and four peer-reviewed papers were published. Funds transferred to the concerned universities allowed officials at these universities to perform telescope maintenance and to hire postdoctoral fellows at their discretion. An operation meeting is held biweekly, in which stations report their situations and discuss operational conditions and policies. Observations adopted through the proposal system are conducted approximately 150 hours per year. An operational core group was formed for a regular holding of observations. Osaka Prefecture University also participated in the receiver development that started in 2007. Ibaraki University joined in 2008, and a framework was established for Ibaraki University to take charge of observational operations in tandem with the transfer of two 32-m radio telescopes belonging to the KDDI Ibaraki Satellite Communications Center to the NAOJ. In 2009, a 6.7-GHz receiver was installed, followed by successful methanol maser observation. Since FY 2010, VLBI observations in the frequency bands of 6.7–9 GHz and 22 GHz using two 32-m telescopes have been made possible at the Ibaraki station. The Ibaraki station suspended operations temporarily following the 2011 Great East Japan Earthquake. However, it resumed a test operation after the initial reconstruction efforts at the beginning of FY 2012, followed by a full recovery after the second reconstruction work executed at the end of FY 2012. JAXA held a workshop on the use of antennas in scientific observation, and the Japanese VLBI Network reported that the same Usuda 64-m radio telescope was in great demand for continued use. The methanol maser VLBI survey observation since 2008 was joined by the Shanghai station and was successful in capturing images of maser sources in 35 regions. Expectations are high for the future elucidation of the maser sources' internal proper motions of the gas that surrounds young, massive objects. A radio exploration of blazar objects that radiate high-energy gamma rays was conducted using the optical fiber-connected VLBI broadband recording system. At the Asia–Pacific Radio Science Conference (AP–RASC 2013), the Young Scientist Awards were given for observation of methanol masers through the Japanese VLBI Network (Koichiro Sugiyama, Yamaguchi University) and the VLBI observation of gamma ray objects (Kotaro Niinuma, Yamaguchi University) in order to achieve high spacial resolution, which cannot be attained

within the Japanese VLBI Network, the Yamaguchi and Ibaraki stations participated in the East Asia VLBI Network three times; the Korean and Chinese VLBI networks also took part. Those stations commenced operation of observations utilizing the broadband disk recording devices installed at their sites. The hydrogen maser atomic clock of the 11-m telescope at Gifu University was serviced to correct defects.

(4) Japan/Korea, East Asia VLBI Observation

As the KaVA performance tests progressed, three science working groups (WGs) for AGN, star formation, and late-type stars proactively pursued test observations and gained fruitful results. Concurrently, the first open-use proposals were called for by the end of FY 2013. Test observations have produced results in AGN as well as study results of methanol maser objects in the 6.7-GHz band. The Korea Astronomy and Space Science Institute accommodates the KJJVC for correlating these data, which are available for open use. Director meetings between Japan and Korea were held as necessary to discuss issues in this regard.

(5) Ishigakijima Astronomical Observatory

The three-color simultaneous imaging camera MITSuME was developed through joint research between the Tokyo Institute of Technology and Okayama Astrophysical Observatory (OAO). The camera was moved to the Ishigakijima Observatory this year, and the Observatory is now responsible for its maintenance. This camera system is in full use today, producing immediate results in observing afterglow of GRBs and sudden phenomena of supernova, planetoids, and comets to international acclaim.

A course conducted in cooperation with the University of the Ryukyus has entered its fifth year. It is particularly popular for the classroom lectures at the university and the observational workshops at Ishigakijima, attracting twice as many applicants as available spots. In FY 2014, the Observatory will collaborate in broadcasting university lectures to be viewed in Ishigakijima. In February, an exchange agreement was made with the Nayoro City Observatory, which house a 1.6-m telescope belonging to Hokkaido University. The “Chura-boshi (beautiful star) Research Team” workshop for local high school students, joined by students from Fukushima prefecture achieved discoveries of new planetoids and radio stars.

In July, the city of Ishigaki’s Starry Sky Educational Room, set up at the observatory site, commenced screening of NAOJ’s four-dimensional digital universe known as 4D2U. A rapid increase of interest in celestial observations has been noted among residents of Ishigakijima

Island, and coinciding with the opening of a new airport, the Observatory attracted 13,000 visitors this year, marking a 30% increase over that in the previous year.

Collaboration with the Nayoro City Observatory is also underway, where a 1.6-m telescope belonging to Hokkaido University is installed. Officials have organized civic lectures on astronomy and other events jointly with “Gurukun-Juku,” a group of local people who follow a course at Japan’s Open

University. In response to the request, collaboration with officials of local Chambers of Commerce and tourism in Ishigaki city and Taketomi town is developing to leverage the night sky in community revitalization.

3. Open Use/Joint Research

(1) Open Use

The Observatory began to arrange a semiannual call for open use in FY 2013. Nine proposals were made for a total of 458 hours of observation for the FY 2014 first half-period open-use 22- GHz, 43- GHz, and 6.7-GHz band observations. One proposal for 88 hours was made from abroad. These proposals were considered by a VLBI program subcommittee based on judgments of referees selected from researchers in relevant fields in Japan. Subsequently, they selected four proposals for a total of 120 hours.

Observations commenced in January 2014.

Open use of the KaVA was also called for at the same time for the first half-period of FY 2014, and 13 proposals were received for a total of 477 hours. These proposals were considered by referees from both VERA and the KVN and were forwarded to the VERA/KVN joint time allocation committee for assessment. Seven proposals were selected for a total of 240 hours, and the first observation started in February 2014. Observational data produced through an open use of the KVN will be correlated using the KJJVC installed at the Korea Astronomy and Space Science Institute.

(2) Japanese VLBI Network

In tandem with observation via the Japanese VLBI Network, a joint research agreement was entered by Hokkaido University, the University of Tsukuba, Gifu University, Yamaguchi University, Kagoshima University, Ibaraki University, Osaka Prefecture University, GSI, and NICT. This joint research is in progress. The Institute of Space and Astronautical Science (ISAS) at JAXA is also in a close collaborative relationship.

(3) Joint Research between Japan and Korea

Researchers in Japan and Korea engaged in science WGs for AGN, star formation and late-type stars using KaVA. A general science WG was held twice in Korea for this purpose, in which the KaVA project observation plan was developed. Furthermore, KJJVC performance tests and evaluation of functions compatible with various observational modes were jointly conducted for a regular operation of 1 Gbps and 16-station correlation.

(4) Joint Research

The joint research agreement with GSI provides for geodetic VLBI observations (JADE observations) within Japan. A research agreement with the Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences (GFZ–Potsdam) in Germany is the basis of the GPS and Galileo satellite observations. The data obtained through the GPS observations have been made public as International GPS Service (IGS) observational points. The Esashi Earth Tides Station distributes strain meter data

and other information from the driftway in real time to relevant research organizations as part of a research agreement with the Earthquake Research Institute of the University of Tokyo. Facilities are applied to open use in a broad sense of the term.

4. Public Relations (PR) and Awareness Promotion Activities

(1) Open house events

April 14: The fourth Open Observatory event (a special open house event at the Ibaraki University Center for Astronomy and the Ibaraki station of the Mizusawa VLBI Observatory, NAOJ) was held with approximately 1,000 visitors.

July 7: NAOJ Mizusawa VLBI Observatory Kagoshima station at Kinkowan Koen, Kagoshima City, held Tanabata Matsuri in collaboration with the city of Kagoshima and Kagoshima University, which featured a 6-m radio telescope. Approximately 300 people attended.

August 10: The VERA Iriki station was opened to the public as part of the Yaeyama Kogen Star Festival 2013 with more than 1,500 visitors in attendance.

August 3–18: The 2013 South Island Star Festival was held simultaneously with a special open house of the VERA Ishigaki station and the Ishigakijima Astronomical Observatory; the dimmed-light stargazing event received approximately 8,500 visitors. An astronomical observation party at the Ishigakijima Astronomical Observatory was attended by 851 visitors, and a special public opening of the VERA station had 246 visitors.

August 24: The Iwate Galaxy Festival 2013, a special open house of the Mizusawa station, was held with nearly 3,000 visitors.

November 7–9: A special open house of the VERA Ogasawara station, Star Island 2013, was held in conjunction with JAXA Space Education Center for the first time and attracted 433 visitors during the three-day event.

February 16, 2014: The Ishigakijima Astronomical Observatory entered into an exchange agreement with the Nayoro City Observatory in Hokkaido.

(2) High School Student Hands-on Events

June 29–30: The Seventh Z Star Research Team event was organized to use the VERA Mizusawa station radio telescope, for which a preliminary session was held with five prospective participants.

August 3–5: The Seventh Z Star Research Team event was held for high school students in Iwate prefecture, including those from the disaster-stricken areas. Five students participated and discovered new celestial objects successfully.

August 7–9: The VERA Ishigakijima station and the Ishigakijima Astronomical Observatory held the Churaboshi Research Team workshop for high school students from Okinawa and Fukushima prefectures with 21 attendees. One group engaged in radio observation and discovered two new maser objects for the first time in three years. Moreover, another group undertook visible light observation using the Murikabushi telescope and discovered five planetoids.

The University of the Ryukyus and NAOJ began offering this joint course in 2009; 2014 marks the program's fifth year. Classroom lectures at the university took place between August 12 and 15, and observational workshops were held in Ishigakijima from August 26 to 29 with a total of 32 participants. A hands-on radio observation program was conducted at the VERA observation station using a 20-m radio telescope. The Murikabushi was also deployed to observe a nebula, and participants learned about image processing.

(3) Other

The Observatory contributed to extracurricular activities and workplace visits offered to elementary and junior high school students in Oshu City. It also provided hands-on workshops for high school students from Iwate prefecture, Tokyo, and Fukushima.

The Ishigakijima VERA station and Ishigakijima Astronomical Observatory contributed to the education of elementary, junior high, and high school students, as well as tertiary education for elderly groups and women's societies. In addition to the commemorative lecture delivered by NAOJ Director General Hayashiat the South Island Star Festival, a lecture on astronomy was given by guest lecturer Yuko Kakazu on March 30 near the Subaru Telescope at NAOJ. Other lectures by request included a night sky workshop offered to tours from the Japanese Open University, the NHK Academy of Distance Learning, and Sundai Gakuen Senior High School.

Observatory officials participated as panelists at the Starry Sky Summit and gave a preliminary lecture on astronomy organized at Bisei Astronomical Observatory. In addition, the Observatory offered internships to local high school students and gave guided tours. Other public relations (PR)/awareness promotion activities included presentations and consultations organized for hotel and travel agencies, and members of tourism associations in Ishigaki city and Taketomi town adopted "Stars in the sky are brilliant resources for local tourism" as a thematic slogan.

5. Timekeeping Office Operations

The Timekeeping Office operates four cesium atomic clocks together with a hydrogen maser atomic clock at the Mizusawa VERA station. The four cesium atomic clocks and the timekeeping operation system were moved downstairs in the main building last year into the underground atomic clock room and the atomic clock management room, respectively. No breakdown or other problems occurred as a result of the move, and the facilities have been operating stably, contributing to determine Coordinated Universal Time through continuous management and operation of the time system. The beam tube in the cesium clock Cs6 was replaced because it approaching its warranty expiration. Moreover, changes were made to the procedures for submitting comparative time data to the International Bureau of Weights and Measures (BIPM), which keeps the international atomic time (TAI). The NTP protocol provides Japan Central Standard Time on a network. This

service has been in great demand; more than 900,000 daily visits have been recorded this year.

6. Educational Activities

Regarding postgraduate education, the Observatory assisted three graduate students each from the University of Tokyo and the Graduate University for Advanced Studies. Two students,

one each from these universities, were conferred PhDs. One master's student from Tokai University was accepted as a visiting graduate student. Undergraduate students from the University of Tokyo, Meisei University, and the University of the Ryukyus were accepted as summer students of the Graduate University for Advanced Studies and received research guidance. In addition, staff members at the station visited these universities to deliver lectures.

6. Solar Observatory

The Solar Observatory primarily engages in the operation of solar observational facilities on the west side of the Mitaka campus. 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 development of new observational instruments and 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 the Mitaka campus, had continued the observation of active region photospheric vector magnetic fields and H-alpha flares since its completion of 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 lens and performs slit scanning observations using infrared spectral lines (photosphere: iron, 1.56 μm line; chromosphere: helium, 1.08 μm line), which are highly sensitive to the magnetic field. This allows for constant acquisition of unprecedented infrared polarization data of the photosphere and chromosphere of the entire solar disk. However, the infrared camera was damaged by lightning in August this year, and subsequent observation was suspended. Although the repair required a considerable amount of time, the camera's condition currently has been sufficiently restored for resuming observation. An emergency replacement camera has been installed to complement the system so that observation can continue in the event of camera failure.

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

Sunspot observations have been performed continually since 1929. This observation is currently conducted via automatic detection of sunspots on digital images captured with a 10-cm refractor and a 2 k \times 2 k pixel charge coupled device (CCD) camera mounted on the new (full-disk) sunspot telescope. Observations were conducted for 267 days in 2013, from January to December.

Although full-disk solar image data are a widely needed resource in the astrophysics/geophysics community, some of these synoptic instruments are getting out of date. Efforts are underway to update the photospheric and chromospheric imaging instruments and to further flesh out data. For instance, the SFT has started advanced observations in the H-alpha line to acquire full-disk, high-resolution images. It enables to obtain Doppler velocity information based on imaging at multiple wavelengths around H-alpha with high temporal resolution allowing for more completely capturing active phenomena and a broad dynamic range by a combination of multiple exposure times. This advancement has enabled us to observe many phenomena in recent heightened solar activities such as flares and prominence eruptions. The observatory also uses the SFT to conduct regular imaging observation at the G-band (430 nm) and continuum wavelengths. 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 observation, including more quantitative velocity and magnetic field observations. A laboratory for this project was set up this year.

The observatory maintains other existing equipment to allow for everyday observation, as well as experimental use.

2. Opening of Data Archives to 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 and 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 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 are of importance of their own. The observatory will make these also available to the public because 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.

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

The Norikura Solar Observatory ceased operation in 2009, and its facilities were transferred to the NINS. However, the Norikura Green-line Imaging System (NOGIS) coronagraph, which allows for advanced observations such as coronal velocity field measurements, can be put to better use if it is allowed to continue observations at a suitable location overseas. Therefore, it is in the process of being transferred to the Yunnan Astronomical Observatory in China. This year, the

entire coronagraph, including the refurbished telescope tube, was transferred to the Lijian (Gaomeigu) Observatory, and temporary installation has been completed. Closely following this, a joint test observation between Japan and China took place locally and produced good results. Staff on the Chinese side are currently continuing test observations. Other international cooperation includes support for the Japan–Peru collaborative solar observations, with which the Solar Observatory has been involved since 2004.

A research plus business conference, dubbed as the annual users meeting, has been held every year jointly with other organizations. Beginning this year, however, the meeting is combined with the solar research symposium for the entire solar community, where topics in relation to open use and future plans are also discussed. This year, the conference was held at Kyoto University between February 17 and 19.

Because the observatory deals with fundamental solar data, images in the solar observatory database are often used in school textbooks. The observatory actively responded to approximately 20 applications for image use in FY 2013.

Regarding personnel transfers, Chief Engineer, Toshihiko Kobiki, who was engaged part-time in work for the Chile Observatory, has been transferred to the Chile Observatory full-time due to increased workload there. Moreover, research expert Kentaro Yaji replaced a staff member who departed last year, and Isao Suzuki departed upon completion of his term.

7. NAOJ Chile Observatory

The ALMA project involves a plan for operating a gigantic radio telescope for receiving millimeter and submillimeter waves by deploying 66 high-precision parabolic antennas in the 5,000-m altitude Atacama highlands in northern Chile. This international collaborative project includes East Asia, Europe, and North America, and NAOJ plays the central role in the East Asian part. ALMA is projected to have an observational resolution of nearly ten times higher than that of the Subaru telescope or the Hubble Space Telescope. Early scientific observations with ALMA began in FY 2011 with some of the telescopes, and full operation commenced in FY 2012. This report describes progress made in the construction in Japan and for the entire project and includes the progress of the scientific observations and other activities such as public information and outreach initiatives. The ASTE telescope is a single-dish 10-m submillimeter telescope installed in the Atacama highlands. It is operated to make headway into submillimeter observations in the southern hemisphere in preparation of the approaching ALMA era. The ASTE telescope had been operated by the Nobeyama Radio Observatory until FY 2011. In FY 2012, the operation was transferred to the Chile Observatory to have an organic liaison with the ALMA telescope. This report also describes progress regarding the ASTE telescope.

1. ALMA Project Progress

(1) Overall progress

Construction of the ALMA telescope is in its final stage. The 66th antenna was delivered to the Joint ALMA Observatory in September 2013. A full-scale scientific observation began its Cycle 1 in January 2013. The call for observation proposals for Cycle 2, due to begin in June 2014, was closed on December 5, 2013, and the submitted proposals were given to the referees for consideration.

The commissioning observations to be run concurrently with the scientific observations have shown good progress. These include an interferometer test via long baseline, test observations using Band-4, Band-8, and Band-10 receivers developed in Japan, polarimetric observation tests, and solar observation tests.

In tandem with the inauguration ceremony held in Chile in March 2013, a special lecture event was organized in Japan at Hitotsubashi Hall, Tokyo, on May 15, 2013, to celebrate the inauguration. This event was attended by approximately 200 guests including members of the Japanese Diet, researchers, and corporate representatives, who were all deeply involved in the ALMA project. The memorial lecture delivered by Tetsuo Hasegawa, Director of NAOJ Chile Observatory, was broadcast

via the Internet.

(2) Progress in development in Japan

The 16 antennas developed in Japan, including four 12-m and twelve 7-m antennas, were delivered to the Joint ALMA Observatory by the end of FY 2012. These antennas have been installed at the AOS at an altitude of 5,000 m and were deployed in testing and scientific observations.

Fabrication of the Band-4, Band-8, and Band-10 receivers was completed in FY 2013, and the receivers were shipped to Chile. The Band-8 and Band-10 receivers successfully obtained their first interferometer images in September 2013 and February 2014, respectively. These receivers are currently deployed in test observations. Cycle 2, due to commence in June 2014, is scheduled to employ the Band-4 and Band-8 receivers for open-use observations.

2. ALMA Open-Use and Scientific Observation

The second round of open-use observations of the ALMA telescope commenced in January 2013 for Cycle 1. The details of Cycle 1 include interferometric observations using at least thirty-two 12-m parabolic antennas with a maximum baseline of 1 km, Atacama Compact Array (ACA) observations, and four frequency bands (Band-3, -6, -7, and -9), in addition to a maximum of 150 fields of view for mosaic observation. The ACA observations are interferometric observations using at least nine 7-m parabolic antennas and single-dish observations using at least two 12-m antennas. Several impediments followed the start of the open-use observations such as inclement weather, technical troubles in the local infrastructure including power outages, and a labor strike by the local staff; thus, the number of observations conducted was very low until September 2013. These adverse conditions considerably delayed the completion of Cycle 1, which ended in May 2014 rather than the scheduled date of October 2013. Cycle 1 reached a completion rate of only 60 % at the time of its termination. Therefore, it was decided that approved but uncompleted observation programs were carried over to Cycle 2.

An open call for the third round of open-use observations was issued for Cycle 2. The details of Cycle 2 as advertised include interferometric observations using at least thirty-four 12-m parabolic antennas with a maximum baseline of 1.5 km, ACA observations, six frequency bands (Band-3, -4, -6, -7, -8, and -9), and a maximum of 150 fields of view for mosaic, and polarimetric observation. Before the public call was closed at 00:00 JST on December 5, 2013, 1,381 proposals were submitted, 273 of which were from East Asia. Scientific evaluation of the observation proposals took place between March 10 and 14, 2014, in London, Ontario. Proposals were reviewed by 78 science assessors, 17 of whom were from East Asia. Of the 1,381 proposals, 353 were designated as “highest priority.” Of these 353 proposals, 83 (23.5 %) were from East Asia, and the proportion of observation time allocated for East Asian projects was 22.3 %. Cycle 2 is scheduled to commence in June 2014.

ALMA open use has produced a number of scientific achievements. Those focusing mainly on East Asian projects are described below. Nami Sakai of the University of Tokyo and others conducted an observation of a young protostar in the Taurus constellation L1527 and made the world’s first discovery of a centrifugal barrier creating a ring-shaped shocked region formed in the protoplanetary disk. Misato Fukagawa of Osaka University and her team observed a young star known as HD 142527 in the constellation Lupus, and they identified the dust continuum, potential planetary components, and formation of an asymmetrical ring of protoplanetary disks around the star. This convincing evidence of planet-formation occurring far from its primary star was captured successfully for the first time ever. Lai Shih-Ping of the National Tsing Hua University in Taiwan and her team discovered the youngest protoplanetary disk ever observed. Takeshi Sakai and others of the University of Electro-Communications observed an infrared dark cloud in the Aquila to discover a high-temperature molecular cloud, known as a Hot Core, that was 10 times larger in size than those conventionally reported. Masami Ouchi of the University of Tokyo and others conducted an observation of the early cosmic giant blob Himiko by using ALMA and the Hubble Space Telescope. With the latter, they discovered three giant blue galaxies. With ALMA, they confirmed that no radio wave was detected in fine solid particles (dust) or atomic carbons. Their observation led to the suggestion that Himiko is highly likely in a very early phase of galaxy formation because it is composed mainly of primitive hydrogen and helium gases. Takuma Izumi and others of the University of Tokyo observed dense gas surrounding the active, giant nucleus of NGC 1097 and reported that the high volume of HCN around the AGN is due to the high temperature of the environment under the influence of a black hole. Bunyo Hatsukade of Kyoto University and his team successfully detected 15 new, extremely dark galaxies, revealing that nearly 80 % of hitherto unidentified millimeter waves from the Universe originated in dust particles in faint galaxies.

3. Educational Activities and Internship

The Chile Observatory held a graduate school guidance session on June 15, 2013. Four undergraduate students attended the session, engaging in lectures given by teachers and socializing with current graduate students.

4. Public Outreach Activities

In May 2013, the Chile Observatory hosted a week-long ALMA booth at the Japanese Geoscience Union Meeting. Civic lectures and a Science Cafe were organized on 17 occasions in FY 2013 to communicate ALMA’s current activities to numerous visitors through conversation and to popularize ALMA and its results.

The project website published 47 news articles and seven press releases. A mailing-list-based newsletter also continues on a monthly basis with approximately 2,500 subscribers. Updated, detailed information is available on Twitter (@ALMA_Japan),

with nearly 16,300 followers as of the end of FY 2013.

Approximately 60 newspaper/journal articles were posted, reporting scientific discoveries from the Early Science observations. ALMA was featured in television programs 14 times. In addition to news reports on ALMA's observational achievements, composite programs such as "Tanken Bakumon" on Nippon Housou Kyokai (NHK) and "Yume no Tobira+" ("Gates to Dream") on Tokyo Broadcasting System (TBS) featured ALMA as the main topic, introducing the project in depth and showing people involved in its operation. Such programs effectively conveyed ALMA's virtues to a mass audience.

As part of the construction film project continuing since FY 2003, the observatory produced two films that were screened in FY 2013: film footage of the inauguration ceremony in Chile and a promotional film recorded in 2011 that shows the development processes of the ALMA antennas. The development of the receivers at the Advanced Technology Center (ATC) was also filmed together with developer interviews.

The series "Bienvenido a ALMA," in which ALMA staff members discuss their work, continues to be featured in the NAOJ newsletter, which is also published on the ALMA website.

ACA, which was developed by Japan, was awarded a 2013 Good Design Gold Award, endorsed by the Ministry of Economy, Trade and Industry of Japan. Replicas of a band-10 receiver and a superconductor-insulator-superconductor (SIS) receiver, together with description panels, were displayed at the Good Design Exhibition 2014 held from October 30 to November 4 at Tokyo Midtown in Tokyo. As a Good Design Award candidate institute, we delivered a speech at the designers' presentations held at the event venue.

5. International Collaboration (committees, etc.)

Various committees are frequently organized for international collaboration in the ALMA project. The ALMA board has met twice, and the ALMA Scientific Advisory Committee was summoned three times in FY 2013. In addition, teleconferences been conducted for both groups on a near-monthly basis. Moreover, the ALMA Annual External Review met over the course of one week in October 2013, and the ALMA East Asian Scientific Advisory Committee has also conducted teleconferences nearly each month. To maintain close communication in implementing the international project, meetings and teleconferences are held more frequently for individual areas of concern.

6. Workshops and Town Meetings

- July 8-9, 2013 NAOJ Mitaka
East Asian (EA) ALMA Development Workshop
- September 24, 2013 Ehime University
ALMA Cycle 2 Town Meeting
- September 24, 2013 JAXA/ISAS
ALMA Cycle 2 Town Meeting

- September 26, 2013 Kagoshima University
ALMA Cycle 2 Town Meeting
- October 3, 2013 University of Tokyo Institute for Cosmic Ray Research/Institute for the Physics and Mathematics of the Universe (IPMU)
ALMA Cycle 2 Town Meeting
- October 2, 2013 Nagoya University
ALMA Cycle 2 Town Meeting
- October 3, 2013 Kyoto University
ALMA Cycle 2 Town Meeting
- October 7, 2013 Hiroshima University
ALMA Cycle 2 Town Meeting
- October 9, 2013 Tohoku University
ALMA Cycle 2 Town Meeting
- October 9-10, 2013 NAOJ Subaru Telescope
ALMA Cycle 2 Town Meeting
- October 17, 2013 Osaka Prefecture University
ALMA Cycle 2 Town Meeting
- October 28, 2013 KASI, South Korea
ALMA Cycle 2 Town Meeting
- October 30, 2013 Hokkaido University
ALMA Cycle 2 Town Meeting
- November 18, 2013 NAOJ Mitaka
ALMA Cycle 2 Town Meeting (first session)
- November 22, 2013 NAOJ Mitaka
ALMA Cycle 2 Town Meeting (second session)

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

Kiuchi, Hitoshi; Ministry of Internal Affairs and Communications (SCOPE): R&D of chromatic dispersion compensation using round-trip phase measurement

8. Research Staff Changes

(1) Hired

Rie Miura: project assistant researcher
James Chibueze: project assistant researcher
Cinthya Herrera: project assistant researcher
Yiping Ao: project assistant researcher

(2) Departed or transferred

Hiroshi Nagai: postdoctoral fellow, transferred to the Chile Observatory to assume the position of project assistant professor

Eiji Akiyama: postdoctoral fellow, transferred to the Chile Observatory to assume the position of a project assistant professor

9. Main Visitors

May 1-3, 2013

Mr. Akito Arima, a former Minister of Education of Japan, visited the ALMA Operations Support Facility, Array Operations Site, and JAO (Joint ALMA Office) Santiago Central Office.

10. Progress of ASTE telescope

The ASTE telescope is designed to promote full-fledged submillimeter astronomical research in the southern hemisphere and to develop/verify observational equipment and support methods. With the ALMA construction entering its final stages and early science observations successfully beginning, the ASTE telescope will be engaged mainly to provide observational evidence for strengthening ALMA observation proposals. Development will be pursued for extension of ALMA's future performance.

A public call was made in FY 2013 for open-use observation proposals for spectroscopic observations in the 345-GHz band with the goal of making the astronomical community more accessible. To render support for researchers contributing to the observational performance enhancement for the ASTE telescope, the Guaranteed Time Observation (GTO) scheme was established, which allowed these researchers to offer

suggestions. When the application call was closed on June 10, 2013, 47 proposals for open-use observations and GTO slots had been made including 39 for open use and eight for GTO. These proposals were considered by officials at the Chile Observatory, and 21 proposals were subsequently adopted including 13 for open use and eight for GTO. Two proposals intended for GTO had to be canceled due to facility breakdown. Open-use observation was conducted from the ASTE Mitaka operation room between August 19 and October 7, 2013.

A group of researchers from the University of Tokyo and the University of Electro-Communications conducted a test observation using the 0.9/1.5-THz receivers for one month in October 2013. Finally, a group led by the Nobeyama Radio Observatory, the University of Tokyo, and Hokkaido University conducted a test observation of the 270/350-GHz band TES bolometer camera from November 2013 through April 2014 in preparation for its release for open-use observations due to begin in 2015.

8. Center for Computational Astrophysics

1. Overview

The Center for Computational Astrophysics (CfCA) carried out the management of a group of open-use simulation computers centered around a general-purpose supercomputer and the special purpose computer for gravitational N -body problems; implementation of new open-use computer systems; research and development for computational astrophysics applications; and promotional activities for astronomical numerical simulation and their results. The supercomputer was updated this year. The new supercomputer that is installed at the Mizusawa VLBI Observatory, Cray XC30 (as known as ATERUI), is endowed with the world's highest computational capacity for supercomputers for astronomy at 500 Tflops. The center also continued operation of other computers such as GRAPE-7 and GRAPE-DR, which are dedicated for gravitational N -body problems, in addition to servers including small-scale computational PC clusters. Efforts in visualizing astronomical data also continue.

2. Open Use

(1) Computer Systems

This year marked the first usage of the upgraded astronomical simulation system, which includes the main supercomputers of the open-use computers for this project. Circumstances necessitated this system to be installed at the Mizusawa VLBI Observatory. Thus, the Cray XC30 with theoretical peak performance of more than 500 Tflops was introduced with partial support by the Mizusawa VLBI Observatory. This system realized a performance improvement

of approximately 20-fold over the systems operated for the same purpose until last year. With the dedicated work of all involved, difficult tasks of system upgrade and installation at the Mizusawa VLBI Observatory were successfully completed, and the new equipment has performed with no major issues, enabling its users to make academically significant progress.

While XC30 is leased from Cray Japan Inc, the center has built the following equipment to aid the open-use operations: a series of dedicated computers for gravitational N -body problems, known as GRAPEs; PC clusters for small to medium-scale computation; large-scale file servers; a group of servers for processing computational output data; and networking instruments to encompass the overall computer system. These components are central to numerical simulations by researchers in Japan and overseas. In particular, the GRAPE system, also known as the Mitaka Underground Vineyard (MUV) system, is promoted for its effective open use. The center undertook development, improvement, and maintenance for both hardware and software for the system this year. One of the major events of this year was the test operation of GRAPE-9. This system has a performance improvement of roughly 10-fold over the current GRAPE-7.

Computational resources are allocated to the XC30, GRAPEs, and minor computational PC clusters in accordance with a formal evaluation process. Their usage and application/results for this year are listed below. The CfCA conducted a survey this year on the number of peer-reviewed papers published in English in FY 2012 on studies that involved the project's open-use computers. It was revealed that 82 such papers were published.

Drupal, a content management system introduced for data

exchange with users of open-use computers, is presently used for providing information and transmitting various application forms as necessary. The periodical “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 in which the results were obtained by using the center’s computers. Although no case was adopted in FY 2012 for payout in FY 2013, three papers were accepted in FY 2013 for payout in the same year at approximately 250,000 JPY.

□ Statistics on Cray XC30

Operating hours

- Annual operating hours: 8506.8
- Annual core operating ratio: 84.83%

Users

- Category S: 3 adopted in the first term, 0 in the second term; total 3
- Category A: 11 adopted at the beginning of the year, 2 in the second term; total 13
- Category B: 60 adopted at the beginning of the year, 4 in the second term; total 64
- Category D: 10 adopted at the beginning of the year, 2 in the second term; total 12
- Category Trial: 32, year total
- Category I: 1, year total

□ Statistics on the GRAPE system

Users

- Category A: 4 adopted at the beginning of the year, 1 in the second term; total 5
- Category B: 5 adopted at the beginning of the year, 0 in the second term; total 5
- Category Trial: 2, year total

□ Statistics on the PC cluster

Operating hours

- Annual operating hours: 7117.0
- Annual job operating ratio: 75.7%
- Total users: 34, 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, a users meeting was held to serve as a forum for direct information exchange. Many participated in the meeting, and discussions were fruitful.

- Cray XC30 system workshop: April 16, 2013, 43 attendees
- Cray XC30 workshop for intermediate users: June 27, 2013, 27 attendees
- Cray XC30 optimization seminar: October 31, 2013, 7 attendees

- *N*-body simulation Winter School: January 15–17, 2014, 18 attendees
- Users meeting: January 28–29, 2014, 47 attendees

3. PR Activities

In tandem with the commencement of open use of the Cray XC30 ATERUI, press conferences were held at the Mizusawa VLBI Observatory (May 27, 2013, Iwate prefecture) and the National Institute of Informatics (May 29, 2013, Tokyo). The events were broadcasted on two local television stations and were featured in the “Space News” program on TV Tokyo. Many other media outlets also reported the news, including “Asahi” and “Yomiuri” newspapers, other local newspapers, and the astronomy journal “Hoshi Navi.” The CfCA took part in the special open house event of the Mizusawa VLBI Observatory, Iwate Galaxy Festival 2013, held on August 24 this year. About 600 visitors attended a guided tour of the ATERUI and experienced a close-up observation of the facility. Lectures were also organized at the Oshu Space and Astronomy Museum, also known as Yugakukan, to coincide with the event. In addition, Assistant Professor Takashi Ito, spoke on numerical simulations for astronomy, and Assistant Professor Tomoya Takiwaki, spoke on research of supernova explosions simulated using the ATERUI. These occasions in this event were featured on local television and in newspapers, constituting considerable coverage with vibrant local enthusiasm. The ATERUI was also introduced to people visiting the Nobeyama campus for its open house event on the same day by using live broadcasting via Mizusawa’s supercomputer operation room.

At the Mitaka open house event held in October 2013, the CfCA made the computer room accessible to the public and provided an informative project on simulation astronomy with commentaries about the GRAPE and the PC cluster. A live broadcast was also arranged by connecting the supercomputer operation room of the Mizusawa VLBI Observatory to the Mitaka campus to introduce the ATERUI to those visiting Mitaka. The CfCA has begun to accept group tours of their computer room in the Mitaka campus, in which visitors are given explanations of the GRAPE and the PC cluster in the main room. In preparation for press release articles, support has been given on the results gained from open-use projects. The CfCA published a web release about a research using the PC cluster in November 2013. Titled “Crowding Out of Giants by Dwarfs: an Origin for the Lack of Companion Planets in Hot Jupiter Systems,” the study was conducted by Masahiro Ogihara, postdoctoral fellow from Nagoya University. Moreover, a Twitter account was created for the CfCA (@CfCA_NAOJ) as part of the PR activities, and news on research results, lecture informations, media appearances, and other topics are disseminated through this channel.

4. 4D2U Project

The 4D2U project continued content development this year. A movie on simulation titled “Electromagnetic Radiation from

Neutron Star Mergers” was released on the website in March 2014. For the four-dimensional digital universe viewer, “Mitaka,” a new feature was developed to display comets in response to high user demand, although the viewer itself did not undergo a version update. The Starry Sky Educational Room was launched at the Ishigakijima Astronomical Observatory in July 2013, for which the 4D2U project provided all compatible 4D2U contents. The 4D2U demonstration using the dispatch system was conducted at the VERA Ogasawara station for its open house event. Local residents who visited the station on this occasion enjoyed a special program to experience the latest astronomy findings through stereoscopic vision. The 4D2U contents were also provided to the Science Hills Komatsu (Komatsu city, Ishikawa prefecture), where a stereoscopic dome projection system was recently installed. This installation is the fourth of its kind in Japan. The management of regular and group screenings of the 4D2U Dome Theater has moved to the Public Relations Center this year, and the 4D2U project has begun a discussion on a new dome projection system. In particular, a stereoscopic system using active shutter was discussed as a possible practical application because its projection is brighter than that of the stereoscopic spectroscopy currently used in the Dome Theater. This measure to upgrade the system of the Dome Theater in the latter half of this year was discussed with the Public Relations Center. Moreover, a Twitter account was created for the 4D2U (@4d2u) as part of the PR activities. The information disseminated through this channel includes regular screening enrollments, events featuring 4D2U contents, and media appearances.

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 such as the Center for Computational Sciences (CCS) of the University of Tsukuba, the High Energy Accelerator Research Organization, known as KEK, and the 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 the fundamental physics in the elementary particle physics, nuclear physics, and astrophysics. The scientific goal of the institute is to promote fundamental research based on computational science by encouraging interdisciplinary research between elementary particle physics, and astrophysics. In addition to its ability as a single organization, a major feature of the institute is the cooperation of its three member organizations and their community to provide considerate and rigorous support to the present and future researchers. Another important mission of the institute is to provide researchers around Japan with advice regarding efficient supercomputer use and the high-performance computing development of novel algorithms to meet research goals from the perspective of computer specialists.

In FY 2013, Hiroyuki Takahashi and Tomoya Takiwaki were engaged as project assistant professors to implement research plans. Takahashi newly developed a plasma simulation code to solve basic equations of relativistic radiation magnetohydrodynamics (MHD) based on the first principle. By performing the global simulations of black hole accretion disks, he revealed that the black holes are able to rapidly grow up via mass accretion. This is closely related the unresolved issue in astrophysics: how the stellar mass black holes grow to the supermassive black holes. Takiwaki carried on the three-dimensional simulations of core-collapse supernovae using the supercomputer “K.” His research is key for various studies within the framework of the JICFuS because supernovae are closely related to elementary particle and nuclear physics. Although the mechanism of supernova explosions is a long-standing enigma that has been debated problem for more than 60 years, the research of the supernovae is considerably progressed by numerical simulations with most realistic setting using supercomputer K.

Representing the CfCA, Professor Kohji Tomisaka and Assistant Professor Ken Ohsuga of the 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. Although the center is involved with the JICFuS-led HPCI Strategic Program Field 5 as mentioned in (1), the activity in the HPCI consortium is fundamentally independent. The HPCI consortium is an incorporated association established in April 2012, and the center is currently an associate member able to express views, obtain information, and observe overall trends in the planning: however, it is devoid of voting rights as well as the obligation to pay membership fees. Continuing from last year, a number of conferences and WGs have been held in which participants discuss a next-generation national supercomputing framework to follow the K. At present, discussions are underway about a plan to replace a set of multiple large-scale systems serving as the second layer in addition to adoption of a top-level national system like K within five or six years. The approval of the Ministry of Education, Culture, Sports, Science, and Technology (MEXT) was given by the end of the year to allocate a budget for the development of a next-generation system. Post-K generation equipment is scheduled to commence operation after FY 2019. In principle, therefore, it is possible for the NAOJ to play a central role in the post-K generation HPC through participation in this discourse.

6. Contract Staff Transfers

The following staff members were hired on a contract basis in FY 2013.

Research experts : Jin Matsumoto, Shigeru Wakita, and Yayoi Narazaki

Research associates: Yuya Ariyoshi, Taira Oogi, and Hinako Fukushi

The following contract staff members departed in FY 2013.

Research experts: Jin Matsumoto, Shigeru Wakita, and Yayoi Narazaki

Postdoctoral fellow: Akihiro Suzuki

Research associates: Yuya Ariyoshi and Taira Oogi

9. 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). The NAOJ has been implemented this satellite project under a joint research agreement with the ISAS/JAXA. A major theme of the scientific goals of the Hinode satellite is to shed light on the coronal heating mechanism through a more multifaceted understanding of magnetohydrodynamic MHD phenomena occurring in the solar atmosphere.

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 corona. The onboard telescopes were developed as part of a wide-ranging international collaboration with assistance from the ISAS/JAXA. The SOT was developed mainly by the 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. The 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. The NAOJ actively participated in the development of EIS/satellite interface, satellite integration testing, and launch experiments. After a successful launch, the NAOJ has continued its active involvement by acting as the main institution for collecting and analyzing data acquired by the satellite.

The Hinode Science Working Group (SWG), composed of representatives from the international team, offers support in scientific operation and data analysis. Together with two members from the European Space Agency (ESA), the WG has

a total of 15 members, including three from the Hinode Science Center (HSC) such as Sakurai, chairman from November/project scientist; Suematsu, SOT; 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 2013 marks the seventh year since the satellite's launch. Extremely good evaluations were received from the evaluation committees of a senior review class held at respective space agencies during FY 2012–2013. These accolades made it possible for the satellite to continue operation for the next few years at the current operational level. The operation of the Focused Mode will commence in FY 2014. A test run was conducted in January 2014.

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 the maintenance of a sound field of view even in the narrow band filter imager system, in which image degradation was detected initially in part of the field of view.

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 through 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 observation from the chromosphere and the transition region, located between the photosphere and the corona, to the corona.

A mission data processor (MDP) was installed to manage observations and to acquire data via the three telescopes. The coordinated observation using the three telescopes is vital to achieve the scientific goals of the Hinode satellite, in which the MDP plays a crucial oversight role. 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 the ESA, allowing for data acquisition for every orbit. Scientific operation was again performed in FY 2013 via S-band data reception. The S-band reception frequency was increased with help from the ESA and NASA, allowing for continuation of regular, stable scientific operation.

Obtained data is collected at the 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 243 days in FY 2013, 70 days of which were for contracted work. Moreover, the contribution rates to the scientific operation of the HSC were 27.8 % (domestic) and 16.8 % (overall). Instantaneous publication of all data acquired by Hinode began on May 27, 2007, with stable continuation, implemented by the HSC.

Calls for Hinode Operation Plans (HOP), which encourages proposals for open-use observation together with other satellites and terrestrial observational equipment, promotes joint observations among solar researchers worldwide. As of March 2014, 254 applications have been received. 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 be amplified to studies on solar activity cycles.

2. Hinode Satellite Data Analysis

The 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 purpose is to promote rigorous collaborative research between researchers in Japan and abroad by maximizing the scientific outputs gained from the Hinode satellite by providing a suitable environment for analyzing the satellite data, facilitating access to Hinode observational data by distributing the analyzed data, and constructing a data search system.

As part of its educational and public outreach (E/PO)

activities, the 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 2013, HSC staff members and students published 18 peer-reviewed papers related to Hinode, bringing the total to 227 papers by the end of March 2014. Cumulatively, 725 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 7 1/2 years after the satellite's launch.

3. Deliberations on the Solar-C Project

In April 2013, the sub-project Solar-C Planning Office, headed by Hara, was promoted to the Solar-C Project Office (A-project, also headed by Hara). Details of its activities are described in the office's own report.

4. Other Activities

In FY 2013, four postdoctoral fellows were engaged as members of the HSC including one project assistant professor, one project assistant researcher, one postdoctoral fellow, and one Japan Society for the Promotion of Science (JSPS) fellow. Hinode Science Meetings for Japanese and international solar researchers are held on a regular basis to promote heliophysical research using the Hinode scientific satellite. The seventh meeting took place between November 12 and 15, 2013, in the city of Takayama, Gifu prefecture. The Hida Observatory of Kyoto University's School of Science was a co-organizer.

In addition to the aforementioned activities, HSC research and educational staff members have presented scientific observation results at numerous symposia of solar-related subjects either by invitation or by active participation. The 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)
Eric Priest	University of St. Andrews (UK)
Bruce Lites	High Altitude Observatory (USA)
Robert Cameron	Max Planck Institute for Solar System Research (Germany)

Table 1. Long-term Visitors.

10. Gravitational Wave Project Office

1. Research

(1) Development of KAGRA

1) Introduction

The activity of the gravitational wave project office is focused on the realization of the KAGRA project. KAGRA is a gravitational wave detector based on a laser interferometer with arms 3km in length. It is currently under construction in the Kamioka mine (Gifu prefecture). At the end of FY 2013 the excavation of the tunnels and caverns that will host the detector, an important milestone for the project, had been completed (see Fig. 1). In parallel, most of the vacuum envelope and cryostats have been built and their installation will be one of the main activities in FY 2014. The completion of iKAGRA and a short observation run will be the main milestones in FY 2015.

At NAOJ the activity was focused on the design, prototyping and tests of the components for the vibration isolation system, the auxiliary optics system and the mirror characterization. The GW project office is also involved in the project management through the system engineering office and the executive office. In addition the team has been contributing in the field of safety, public relations and project publications control.

2) Vibration isolation

The vibration isolation is a very important system for the success of KAGRA. It should provide the seismic noise attenuation in the detection band and should reduce the mirror speed at low frequencies. It consists of several components including the pre-isolator, the mechanical filters based on the geometric anti-spring filter, and the so called “payload”, which includes the mirror and all the components required for its suspension and control.

During FY 2013 the prototype of the “payload” was assembled and it was tested in the 20m lab. The test of one of the KAGRA vibration isolation chains was started at TAMA. A frame around one of the TAMA vacuum chambers was built and tested for this purpose. The prototype of the pre-isolator



Figure 1: Picture of one of the KAGRA tunnels. The KAGRA tunnels excavation was completed in FY 2013.

was also moved to TAMA and its installation will start soon. In parallel the prototype of one of the mechanical filters, the so-called bottom filter, was successfully built thanks to a very effective collaboration with ATC.

3) Auxiliary optics system

The Auxiliary Optics Subsystem (AOS) consists of several kinds of optics including the baffles and beam dumps for stray light mitigation, the beam reducing telescopes, the high quality viewports and the optical local sensors (optical lever) for measuring the interferometer mirrors positions.

The optical simulations to estimate the stray-light noise with the designed optical baffle system in the arm cavities have been completed and the performance was estimated to fulfill the KAGRA’s requirement. One of the large baffles (400mm diameter) should be installed in a cryostat (20K); the structure to support such a baffle was studied. The 250 baffles for the arm -ducts, which will be installed along with 3-km arm ducts in 2014, were all delivered to the Kamioka site as planned.

The beam reducing telescope will sense the tilts of the sapphire mirrors for the 3-km arms and it is indispensable for the long-term stability of the interferometer operation. Its conceptual design effort is ongoing.

4) Mirror development

Development of coatings for KAGRA optics is progressing. The scattering loss of the last coatings were as small as 8ppm. This value is only a factor of two from the best levels in the world. Power tolerance of the coating reached to 446 J/cm². To our knowledge, this value is the best ever for laser wavelength of 1064 nm. The mirrors for the pre-mode-cleaner were delivered to the KAGRA project and will be tested soon.

(2) Data analysis and theory

1) Data analysis preparation

Based on the approved Grant-in-Aid for Scientific Research on Innovative Areas “New Developments in Astrophysics through Multi-Messenger Observations of Gravitational Wave Sources”, preparations for multi-messenger analysis are in progress. The multi-messenger means collaborative observation with infra-red light, neutrino, gamma-ray and X-ray detectors. The group aims to survey KAGRA detector noises and to reduce the false alarm rate of the detector.

2) Theoretical research on General Relativity

General-relativistic higher-order perturbation theories have very wide applications in cosmology, black hole, and gravitational waves. In spite of these many applications, the “gauge issue” in general-relativistic perturbations is a delicate problem. Therefore, it has been discussed in the framework of general-relativistic higher-order gauge-invariant perturbation theory from a general point of view. In 2013, a full paper was

published showing that the general framework developed by Dr. Kouji Nakamura is applicable to perturbations on an arbitrary background space-time.

(3) R&D

1) R&D for upgrades of KAGRA

TAMA is one of the core laboratories where R&D with excellent interferometric sensors and controls can be conducted. Among other features, the long optical cavities of 10 m and 300 m long are especially valuable. To make maximum use of it, a filter cavity experiment was planned. The key item of this experiment is high-quality (ultra-low loss) mirrors. In the last couple of years, such mirrors have been developed in collaboration with Sigma Koki in Japan as described in the previous section, and further studies are in progress now. If is filter cavity with squeezed vacuum light is introduced to KAGRA, event rates of not only double neutron stars binary coalescences but also double black-holes binaries will increase by factor of 10. In parallel, a proposal to develop crystalline coatings for low loss mirrors was submitted to JSPS and approved.

2) DECIGO/DPF

Following the change of JAXA's concept for the small scientific satellite series, we revised our plan for DECIGO/DPF. The mission's main goals were changed slightly so that the main objective of DPF will be to test several key technologies like drag-free flight, stabilized laser source in space, and interferometric displacement sensor in space as a precursor to DECIGO, rather than a gravimeter for the geophysical purposes. With these changes, we have submitted our proposal of DPF to JAXA.

At NAOJ we are developing the interferometric sensor. In FY 2013 a test bench to simulate free-falling test masses in some degrees of freedom by means of a torsion pendulum was realized. According to our evaluations, the main force noise on the interferometer test masses will be caused by residual gases. By finite element analysis, we designed a housing box around the test mass to mitigate this noise

2. Education

The gravitational wave project office contributed to the teaching of general relativity and gravitational waves at SOKENDAI. We also contributed to the teaching of "Fluid mechanics and the group motion model" at Hosei University.

The office supported the SOKENDAI Asian winter school on Astrophysics with a lecture on Gravitational Waves research and a visit of the TAMA facility. Many students visited the TAMA facility: during FY 2013 we received 173 university students and 181 high school students.

One graduate student from SOKENDAI and one undergraduate student from Ochanomizu University did their research projects in our office. We are encouraging NAOJ to start an internship program to attract more students from abroad

in general and from other Asian countries in particular.

3. Publications, presentations and workshops organization

The office members were authors of 12 publications on international journals and of 13 presentations to international conferences. 59 presentations were also given to conferences in Japan.

During FY 2013 we started the organization of the 6th Korea-Japan workshop that will take place at NAOJ on June the 20th and 21st, 2014. We also contributed to the organization of the Gravitational Wave Advanced Detector Workshop that is took place in Takayama in May 2014.

4. Outreach

The gravitational wave project office contributed to a special issue of the NAOJ news devoted to gravitational wave research that was published on March 2013. The office contributed to the NAOJ open days on October by opening the TAMA facility to the public. Visits of the TAMA facility were also given to officials from MEXT, from the Space Telescope Science Institute and from the Italian Embassy. Finally a press release was issued jointly with ICRR and KEK when the KAGRA tunnel excavation was completed.

5. Relationships with industry

We have been supporting the development of techniques for ultra-high quality optics by collaborating with a few Japanese companies. In particular work was done in collaboration with Sigma Koki. The company is aiming at improving the polishing of substrates and the quality of coatings. The NAOJ mirror group evaluate coatings qualities, and the results are fed back to the process.

6. Personnel

At the beginning of FY 2013 the project had a total of 12 personnel including one affiliated associate professor, five assistant professors (two of which were on secondment to ICRR), three engineers, two administrators (shared with the Jasmine project) and one postdoc plus 2 students. During the year, one professor and two postdocs joined the team. One of the postdocs left for a permanent position at the end of February and another arrived at the end of his contract at the end of March. One of the two assistant professors on loan to ICRR ended his term and returned to NAOJ to take the lead of the vibration isolation tests.

11. TMT Project Office

The TMT Project Office of Japan is pursuing the construction of a giant telescope with an aperture of 30 m in a collaborative project formed by researchers from countries including Japan, USA, Canada, China, and India. Preparation for construction, a key phase in the project, due to commence in FY 2014 is underway, and mass production of segment mirrors for the primary mirror was initiated in FY 2013. The Project Office was further reinforced with the recruitment of additional staff members. At the end of FY 2013, full-time staff at the TMT Project Office included four professors, three associate professors, one chief research engineer, one specially appointed senior specialist, two research experts, one research associate, one project research expert, and two administration associates joined by three associate professors and three assistant professors by concurrent appointments.

1. TMT Project Developments in Japan and Overseas

NAOJ TMT Project Office staff members participated in TMT board meetings, science advisory committees, and external reviews, held quarterly since 2007 in Pasadena, California, and contributed to discussions for formulating an international collaboration. To assist in the evaluation of this large-scale academic research project, the Project Office collaborated with the Science Council of Japan to prepare the project's milestone scheme, which was subsequently developed into a plan at the MEXT Council for Science and Technology. NAOJ's participation in the TMT project was approved in FY 2012 as one of the new projects for advancing the large-scale academic research frontier. In addition to the inclusion in the national budget for FY 2013, this allowed for budgeting of the materials for the primary mirror and a TMT-related facility installation in the supplementary budget for FY 2012, respectively giving impetus to the processes of preliminary telescope structure design and mirror material polishing. Japan is the first country

to officially commence TMT construction and is thus in the position to lead the international collaboration project.

In July 2013, a board meeting was held in Hawaii in which officials from the six participating institutions finalized the TMT master agreement with its signing by their respective representative scientific authorities. Additional agreements that need to be finalized prior to the inauguration of the TMT International Observatory were drafted by the Hogan Lovells international law firm, and deliberations were conducted. The preparation of all of the agreements was completed by March of 2014 following successful negotiations to make the agreements consistent with the Japanese budgetary frameworks and to clarify entitlements and obligations therein. Officials from Japan, China, the California Institute of Technology, and the University of California are expected to sign the agreements, and those from India and Canada are expected to sign the agreements at a later date. When all necessary signatures are in place, the TMT International Observatory will be inaugurated. As soon as official permission for the construction is issued, the observatory will announce the beginning of the construction work.

2. Research Conferences and Lectures

An international workshop to discuss scientific research by TMT was held in Tokyo in October. Also, a large group from Japan participated in the TMT Science Forum held in Hawaii in July. In Japan, a special TMT session was conducted at the Annual Spring Meeting of the ASJ held in March. Through a TMT Project Office subcommittee, the Project Office continues to engage in its effort to incorporate opinions from the science community. The dissemination of information about TMT has been improved in particular by renewing the TMT Project Office website, which publishes updates on the project progress as well as Japan's role in the project. TMT newsletter vols. 37, 38, and 39 were published. The Project Office has also published pamphlets in both Japanese and English and has worked to raise public awareness of the project through events such as lectures delivered at various places around the country and by displaying informative panels at various events including the NINS Symposium and Inter-University Research Institute Symposium. The Project Office has continued to be committed in raising donations for the TMT project. A plaque listing the names of donors for the first term (up to March 2013), including six corporations and 1,583 individuals, is currently displayed at the Subaru Telescope Hilo base facility. The office has screened TMT promotion films and delivered lectures at various science centers and planetariums throughout the country with the help of Club TMT, a community launched two years ago. The Project Office has also provided approximately 50 lectures and visiting workshops for the public.



Figure 1: Signing of the Thirty-Meter Telescope (TMT) major agreement in July 2013. In attendance were officials from the National Astronomical Observatory of Japan (NAOJ) and international chief scientists representing five countries and six institutions.

3. Promotion of Tasks Assigned to Japan: the Construction of the Main Telescope and Primary Mirror as well as the Development of Observational Instruments

In the overall scheme of constructing the TMT, Japan is provisionally assigned the tasks of constructing the main structure of the telescope and primary mirror and fabrication of parts of observational instruments.

For the primary mirror, Japan is expected to provide all of the mirror blanks for the segment mirrors. The production of the first 60 mirror blanks was completed in FY 2013. The task of polishing the segment mirrors is also partially delegated to Japan, and the first batch of 12 mirrors has undergone the process of aspherical surface grinding. The development and verification of the technology for mass production was initiated in preparation for aspherical surface polishing that will be conducted in the future.

The main TMT telescope must weigh significantly less than if it were to be built as a straightforward scale up in size of a conventional large-scale telescope and at the same time achieve higher tracking accuracy. The Project Office undertook the work of preliminary design including the optimization of the preliminary structure design for the main telescope and planning of its onsite assembly procedures, a base-isolation system to withstand a giant once in a millennium earthquake, and mechanical interfaces for observational devices. The resulting preliminary design passed the international assessment conducted in November, allowing the project to commence the detailed design phase in FY 2014.

Japan will perform the task of fabricating a near-infrared imaging camera and spectrograph known as IRIS, which is one of the three components of the first observational instruments to be installed prior to the commencement of TMT observation. Prototypes fabricated in FY 2013 include optical components and its supporting structure, a low temperature drive system, and a vibration-proof system. These components are necessary for attaining relative astrometry within a wavefront error of 30 nm and 30 μ s. Discussions are underway for Japan to perform the fabrication of a camera system and other mechanisms such as the WFOS/MOBIE (Multi-Object Broadband Imaging Echellette), and conceptual designs were created in preparation of their construction.



Figure 2: Preliminary design developed for the telescope's main structure.

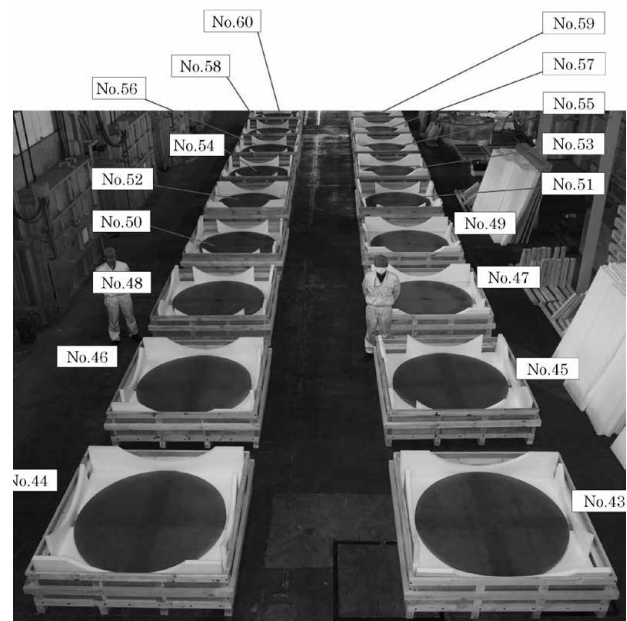


Figure 3: 60 mass-produced mirror blanks.

12. 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 $20^\circ \times 10^\circ$ Galactic bulge around the center of the Galaxy (the Milky Way) and to perform infrared (K_W-band: $1.5\text{--}2.5\ \mu\text{m}$) measurements of annual parallaxes, proper motions, and positions of stars at a high precision of $1/100,000$ as ($10\ \mu\text{as}$) in order to determine with high reliability the distances and transverse velocities of the stars within approximately 10 kpc from the Earth in the surveyed direction. Nearly 1 million stars can be measured with high precisions in the Galactic bulge with a relative error of annual parallax within 10%, which is necessary for accurate determination of the distance. By using observational data to construct a phase space distribution of gravitational matters, astrometric surveys of the bulge forming the core of the Galaxy promise to be 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 these phenomena.

Prior to commencement of the JASMINE mid-sized scientific satellite project, two projects of small size and ultra-small size are implemented to progressively build up the 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 class, is currently underway to test part of the technologies used for the JASMINE and to produce scientific results based on the astrometric information of bright objects in the neighboring space. Despite its small aperture, the satellite is capable of a level of observational precision comparable to the Hipparcos satellite, and the combination of the observational data from Nano-JASMINE and the Hipparcos Catalogue is expected to produce more precise data on proper motions and annual parallaxes. The satellite is scheduled for launch in the second half of 2015. An additional plan is underway to launch a small-scale JASMINE satellite (Small-JASMINE), with a primary mirror aperture of 30-cm class, in around FY 2019. This satellite will engage in observations of only a limited area around the bulge and certain specific astronomical objects. This small-sized version has a goal of obtaining advanced scientific results at an early stage. A 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 2020s. Internationally, Japan shares responsibilities with the ESA by engaging in infrared observation of the bulge, which is a method suitable for observations in the direction of the Galactic center, whereas the ESA performs visible-light observation of the entire sky at a precision of $10\ \mu\text{as}$ with the Gaia Project.

(2) Major Progress in FY 2012

1) Organization of the office

The JASMINE Project Office is composed of four full-time staff members, seven staff members with concurrent posts, two postdoctoral fellows, one research associate, one technical associate, and three graduate students. Significant contributions were made by members of the following organizations: the NAOJ TAMA Project Office; 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; and the University of Tsukuba.

2) Progress of the Nano-JASMINE Project

The project will engage in an actual space mission using an ultra-small satellite to accomplish the following objectives: to make Japan's first foray into space astrometry, to accumulate technical experience in onboard data acquisition and the like necessary for the upcoming JASMINE project, and to achieve scientific results on, for example, the dynamical structure in the neighborhood of the Solar System.

The satellite is 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 postponed due to delays in construction work at the Alcantara Space Center launch site in Brazil; at present, launching is scheduled for the second half of 2015. Moreover, the construction of the rocket has been completed, and work on interface adjustment between the rocket and the satellite is in progress. Assembly of the flight model that will be actually launched into space was completed in FY 2010, and additional testing was conducted using the extra time yielded by the launch delay to further ensure project success. Maintenance of the satellite has also been performed. The project continued with the preparation of ground communication stations in relation to the satellite operation. The second operation training program, simulating the actual operation, was held for one month, during which operational issues were identified and addressed.

Steady progress was also made in the development of 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 was conducted smoothly. The Gaia Project involves observational and analytical methods similar to those of the Nano-JASMINE. A Japanese WG led by Ryoichi Nishi of Niigata University continued to engage actively in investigating the scientific results expected by the Nano-JASMINE.

3) Overview of planning and developing Small-JASMINE

The objective of the Small-JASMINE project is to use a

three-mirror optical system telescope with a primary mirror aperture of 30 cm to perform infrared astrometric observations (H_w band: 1.1–1.7 μm). An additional goal is to measure annual parallaxes at precisions of 10–20 μas and proper motions, or transverse angular velocities across the celestial sphere, at precisions of 10–50 $\mu\text{as}/\text{year}$ in the direction of an area of few square degrees from the Galactic center within the bulge and the direction of a number of specific astronomical objects of interest in order to create a catalogue of the positions and their movements of stars on the celestial sphere within these regions. The project is unique in that unlike the Gaia Project, observation will be performed in the near-infrared band, in which the effect of absorption by dust is weak, and the same astronomical object can be observed frequently. This project will help to achieve revolutionary breakthroughs in astronomy and basic physics, including the structure and history of the formation of the Galactic bulge; the co-evolution of the Galactic bulge and the massive black hole in the Galactic center; the orbital elements of X-ray binary stars; the physics of fixed stars, star formations, and planetary systems; and gravitational lensing. Such data will allow for the compilation of a more meaningful catalog when combined with data from ground-based 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 manufacturer's propositions that started in 2009 continued to consider the design of the satellite system to ascertain the target precision in astrometric measurements in preparation for submitting a mission proposal for the ISAS call for small-sized scientific satellite mission proposals. The name and submission requirements were altered in FY 2013; it is now known as Epsilon onboard Space Science Missions. The SWG, led by Masayuki Umemura of the University of Tsukuba and including volunteers from diverse fields in Japan, continued to make scientific considerations and other activities such as conceptual planning and design and technical testing. International project collaboration continued in FY 2013. As planning progressed, the mission proposal was fully prepared and submitted in February 2014, and the ISAS public call began accepting enrollments on December 28, 2013.

International partnerships to gain further understanding of the Galactic bulge have been formed with multiple overseas groups engaging in ground-based high-dispersion spectroscopic observations 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, an identical model to that of APOGEE. The joint proposal was subsequently submitted. An official memorandum of understanding was 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.

13. Extrasolar Planet Detection Project Office

The Extrasolar Planet Detection Project Office cooperates with researchers interested in exoplanet science at universities around the country under the NAOJ's initiative to promote the development of technologies in general for observing exoplanets and their formation processes as well as to organize exoplanet related observations. It engages in the development of observational equipment, the promotion of research, mission planning, and R&D of common core technologies. The project also spearheads some exoplanet-related international collaborations. Specifically, the R&D focuses on the following core areas:

- (1) Development, maintenance, and operation of HiCIAO and implementation of SEEDS.
- (2) Development of the next novel observation instrument, the IRD, for the Subaru telescope and observation planning to detect terrestrial exoplanets.
- (3) Technical planning of the TMT/Second Earth Imager for TMT (SEIT) instruments and the missions of WFIRST-AFTA Coronagraph (WACO) and the Japanese Terrestrial Planet Finder (JPTF) for direct observations of terrestrial planets as well as promotion of relevant international collaborations.
- (4) Research in the interstellar medium and the formation of stars and planets via wide-field imaging polarization observations using the Infrared Survey Facility (IRSF) telescope in South Africa.

The office was served by five full-time staff members, three staff members with concurrent positions, and six full-time postdoctoral fellows in FY 2013. It published 26 peer-reviewed papers and 11 non-refereed papers and issued 39 reports including speeches at international conferences, all in English. In the Japanese language, it published one peer-reviewed paper, three standard papers, and 57 reports including academic conference presentations.

1. Development of the Next Observational Instruments Intended for Exoplanet Research for the Subaru Telescope and Implementation of Observational Research

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

Development of the HiCIAO modular high-contrast observational instrument has been completed. This instrument is designed for direct observation of exoplanets and circumstellar disks, where the exoplanets are formed, using an 8.2-m telescope, for which the system is equipped with a coronagraph and simultaneous differential imaging technologies such as polarizations and multiple wavelengths and angles. Design and fabrication began in FY 2004. Performance test observations were completed in FY 2009, and SEEDS, the first strategic

project using Subaru, commenced in October 2009 with cooperation from more than 100 researchers across Japan and worldwide. Observations are continuing smoothly.

- (2) Infrared Doppler Instrument (IRD)

Development is underway for a high-precision high-dispersion infrared spectrometer equipped with a radial velocity precision of approximately 1 m/s. It aims to realize an IRD instrument for detecting habitable terrestrial planets around the M-type and other low-mass stars. The budget for the project is based on a JSPS Specially Promoted Research project led by Motohide Tamura and funded by Grants-in-Aid for Scientific Research for FYs 2010–2014. The optical system was fabricated, fiber selection was conducted for guiding light from astronomical objects and comb light, and experiments for optical frequency comb generation were pursued. Planning for investigations of planets around the M-type stars also progressed.

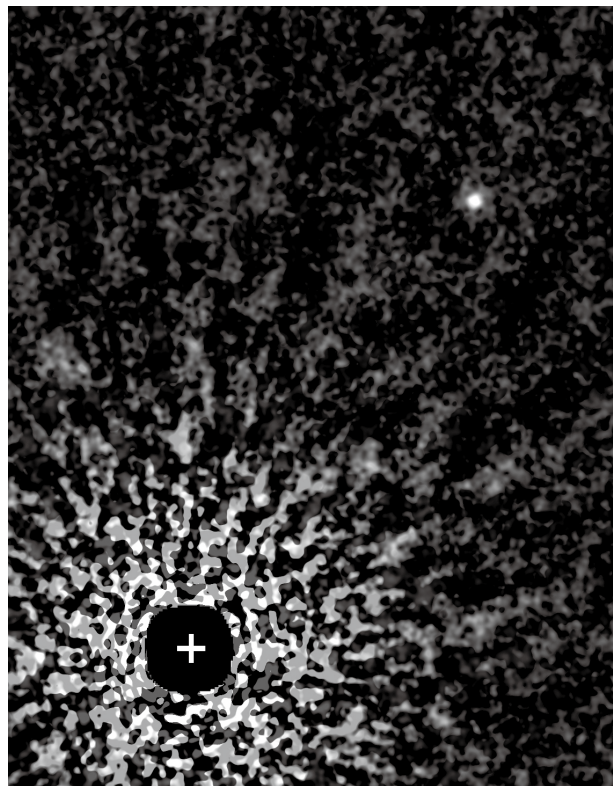


Figure 1: High-Contrast Instrument for the Subaru Next Generation Adaptive Optics (HiCIAO) image capturing an exoplanet orbiting around the solar-type star GJ 504, visible as the white spot at the top right. The mass of this planet is estimated to be 3–5 times that of Jupiter, and due to its older age it has one of the lowest uncertainties of mass estimates among planets ever observed directly. The central star with suppressed brightness and its positional indicator, represented by a cross, are shown at the bottom left.

2. Technical Planning of a Space Mission and Next-Generation Observational Instruments for Extremely Large Terrestrial Telescopes for the Direct Observation of Terrestrial Planets, including International Collaboration

(1) WFIRST-AFTA Coronagraph (WACO) and Japanese Terrestrial Planet Finder (JTPF)

The scientific goal of the WACO and JTPF missions is to observe low-mass planets such as terrestrial planets and super earths via direct imaging in the search for signs of life. The WACO WG was established as the main body to conduct basic experiments of WACO. Jet Propulsion Laboratory (JPL) test beds were employed to implement performance tests with collaborators.

(2) Second Earth Imager for TMT (SEIT)

Technical and scientific planning of the new SEIT observational instrument continued to realize the detection of terrestrial planets using the 30-m next-generation TMT. A proof-of-concept optical system was constructed for the SEIT observational method, and demonstrations were performed.

3. Research/Educational/Outreach Activities

Research was conducted into exoplanets, the disks in which they form, and related fields including rogue planets, brown dwarfs, star/planet formation, and normal stars. A total of 26 peer-reviewed scientific papers were published. In particular, eight papers addressed the SEEDS project. Two noteworthy results were made. In the first, first-ever clear direct imaging of solar planet GJ 504b using the HiCIAO led to a discovery and successful capture of a second Jupiter (Fig. 1) with multi-color imaging. In the second, detailed structures of SR21, RY Tau, and Sz91 were elucidated through high-resolution observation of a protoplanetary disk, again using the HiCIAO. Other activities include a planet and brown dwarf search in the Pleiades by SEEDS, research on the planetary atmosphere using infrared transit observation, and brown dwarfs and/or star-forming research by the UK Infrared Deep Sky Survey/VISTA Variables in the Via Lactea (UKIDSS/VVV) project. SEEDS continued to follow its procedures smoothly this year. Theoretical research and research via Doppler methods were also conducted.

Twelve graduate students were offered research guidance and engaged in exoplanet research and related R&D. Numerous lectures, publications for the general public, and press releases were delivered on exoplanets, disks, and general astronomy.

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

1. Lunar explorer Kaguya (SELENE): Publication of Data and Lunar Research

(1) Publication of Kaguya data

Data from the RISE Project on the topography and the free-air gravity anomaly, as well as processed data for Bouguer gravity anomalies and crustal thickness, have been available to the public on the NAOJ website since July 2010, where gravity field and topographic data are occasionally updated. Data can be accessed at the following sites:

Japanese: <http://www.miz.nao.ac.jp/rise-pub/>

English: <http://www.miz.nao.ac.jp/rise-pub/en>

(2) Study of the Internal Structure of the Moon

The internal structure and composition of the Moon have significant impacts on understanding the lunar origin and evolution. Hitherto, attempts have been made to estimate the internal structure by using the data from Apollo seismic network, as well as gravity fields, tidal Love number, and rotational variation data. NASA's Gravity Recovery and Interior Laboratory (GRAIL) data have further improved the accuracy of the tidal Love number k_2 . In view of this, geodetic data such as mass, the moment of inertia, and tidal Love numbers h_2 and k_2 were used together with the P- and S-wave travel times of moonquakes to recalculate the internal structure of the Moon. With the assumption of a five-layer model including the crust,

upper, middle and lower mantles, and core, the Markov chain Monte Carlo (MCMC) methods yielded a larger core radius of the Moon than the constraints obtained through Kaguya's magnetic field observation. This discrepancy is now under consideration for possible explanations, including the existence of a low-velocity zone near the core-mantle boundary.

2. Future Lunar/Planetary Exploration Projects

(1) High-precision VLBI Observation of Lunar Gravity field: Planning and Component Technology Development

The GRAIL lunar explorer has significantly improved the lunar gravity field model; therefore, we were required to revise our scientific goal regarding the improvement of a lunar gravity field model by SELENE-2 VLBI. Before doing this, our current research results were summarized and published as a paper focusing on the following four points: (a) designing a radio source to be installed on the lunar lander and consideration for saving of electric power, (b) estimating the accuracy of VLBI observation, (c) estimating the accuracy of lunar gravity field recovery, and (d) designing a thermal-proof antenna to survive the temperature environment on the lunar surface for electrical property analysis. In addition, the following items were considered from the perspective of future lunar/planetary explorations and component technology development:

i) Antenna thermal tolerance

Since last year, investigation continued in developing an antenna to survive the lunar surface temperature ranging from -200°C to $+120^{\circ}\text{C}$. Macor (dielectric material) considered for the base substrate material has been confirmed to meet the performance requirements under the above temperature conditions after thermal vacuum tests.

ii) Discussion for providing two beams for the S and X bands in the 20-m VERA antenna

Same-beam S-band VLBI observation had been considered for the primary method of differential VLBI observation between the orbiter and the lander in the SELENE-2 mission. In order to achieve more precise dual-beam S/X band VLBI observations, the RISE Project Office and the Mizusawa VLBI Observatory continued planning of the joint project using a Grant-in-Aid for Scientific Research, Category A ('Research on Lunar/Planetary Inner Structures via Satellite VLBI Observation: Size, State, and Origin of Metal Cores').

The Vivaldi antenna was selected as a model for adoption. An antenna element was designed using electromagnetic analysis software, and its shape was optimized. A computer simulation confirmed that the antenna is able to perform at the required performance level. A prototype single-element device was fabricated and subjected to a performance test, followed by fabrication of a multi-element version, which was integrated to form a phased-array antenna. Tests confirmed that the antenna achieved almost all of the target performances.

(2) Development Experiment for Lunar Laser Ranging (LLR) and Studies of the Internal Structure of the Moon

The distance between the Moon and the Earth can be accurately measured by transmitting a laser from a telescope on Earth to laser retroreflectors that were placed on the lunar surface by the US Apollo missions and Soviet lunar exploration missions and observing the reflected photons, thereby allowing for investigation of lunar rotational variations.

Due to the lack of reflectors in the southern hemisphere and the time difference between the two ends of reflector arrays generated by libration, the level of precision has hitherto been insufficient for determining small variations in the process of energy dissipation in the lunar interior. As part of SELENE-2, a proposal has been made to set up a new single reflector mirror in the southern hemisphere away from the reflectors already in place, allowing for high-precision measurement of lunar rotational variation.

Investigations in FY 2013 focused on the following points:

i) Retroreflector mirrors

Material selection and mirror-forming methods were investigated for the fabrication of an LLR retroreflector to be mounted on the lander. Monocrystalline silicon was selected as the best mirror material for thermal-structural and optical analyses after tests under the simulated lunar surface environment. A thermal vacuum test under the lunar surface environment further verified the suitability of this material.

Three-plane bonding and single-piece manufacturing were considered as methods of forming the mirror. In three-plane bonding, the critical issues are minimal distortion during the bonding process and lasting stability after bonding. However, it turned out that optical contact bonding, which was considered as preferred candidate, requires a curing temperature of more than 800°C to improve the bonding strength, which remains as a challenge for the future work. For a single-piece mirror, preparatory technological development was pursued in conjunction with a tri-party agreement with the Chiba Institute of Technology and Tokyo University of Science, aiming to utilize Ion Beam Figuring (IBF).

ii) Terrestrial ranging station tests

To realize LLR observation, experimental lunar laser ranging was conducted jointly with NICT, using the upgraded NICT Koganei satellite laser ranging (SLR) system for lunar observation. The experiments included not only actual lunar ranging, but also experimental ranging to retroreflectors aboard Earth-orbiting satellites.

iii) LLR data analysis simulation

A group formed mainly of first-year graduate students of the Graduate University for Advanced Studies started the development of software for the analysis of the LLR data through lunar tidal deformation and rotational variation to improve the precision level of estimating the internal structure of the Moon. The three stages of the development consist of the construction of an observational model, generation of an ephemeris, and estimation of initial values and parameters. For the first stage, a model with residual error between -10 and $+10$ cm has been developed, which is comparable to the latest planetary and lunar ephemeris DE430.

(3) Development of In Situ Lunar Orientation Measurement (ILOM) telescope

Research is underway to install an ILOM, which is like a small Photographic Zenith Tube (PZT) telescope, on the lunar surface and to perform high-precision observation of lunar rotational variations to constrain the internal structure of the Moon. Because measurement can be conducted independently of lunar orbital motion, this small telescope is capable of detecting miniscule variations in the rotation of the Moon, allowing for determination of whether the lunar core is molten.

In FY 2013, the RISE Project Office and Iwate University jointly conducted in-laboratory overall testing of the terrestrial observational model known as the Breadboard Model (BBM), an improved version of the model telescope, by using an artificial light source with the goal of conducting actual star observations. The testing involved imaging of a mock star created under an artificial light source, using mercury pool developed during FY 2012 which is less susceptible to vibration, and determining the relationship between variations of star-image center, ground vibration, and inclination of the telescope tube.

(4) Development of the Laser Altimeter (LIDAR) of Hayabusa 2 and Studies of Shape and Gravity Fields of Asteroid

The RISE Project Office participated in the development of LIDAR together with the Chiba Institute of Technology and the University of Aizu. LIDAR, a laser altimeter used to estimate asteroid shape and gravity fields, is scheduled to be on board the Hayabusa 2 asteroid explorer slated for launch at the end of 2014. Investigation is underway for science promotion and a hardware testing plan for scientific maturation. The project is planned to make scientific contributions in gravity (object mass) determination and photometry.

The investigations in FY 2013 focused on the following points:

i) ranging tests using a flight model, hardware tests using ground support equipment, and accuracy estimation of asteroid surface albedo calculated through the intensity ratio of transmitting and receiving laser.

ii) detail planning of a laser link experiment in which the laser is transmitted from the ground SLR station toward Hayabusa 2 spacecraft.

iii) development of a quick-look software and verification at the integration tests.

iv) theoretical calculation of size and density of circum-asteroid dust for hardware development.

v) extension of SLR data analysis software (c5++) developed by a team led by Hitotsubashi University to interplanetary use for orbit and gravity field estimation of the asteroid.

vi) discussions at the Shape Model Team Meeting on methods for shape estimation of the asteroid using LIDAR and the Optical Navigation Camera (ONC).

vii) scientific discussions at the Integrated Science WG on how to combine the data obtained by other scientific instruments with those by LIDAR.

(5) Development of a Ganymede Laser Altimeter (GALA) for the Jupiter Icy Moon Explorer (JUICE) mission and studies of the internal structures of Jovian moons

As the GALA was officially selected by the ESA as one of the JUICE mission payloads following a proposal submission in FY 2012, the RISE Project Office officially commenced activities as a main GALA-Japan team member. Japan will undertake the development of receiving telescope as a part of the laser altimeter system. Dr. Matsumoto of the RISE Project Office also leads the gravity/rotational variation subgroup within the Japanese part of the science team. The following points were considered in FY 2013:

i) detailed laser link calculation (performance model) to serve as the basis for the hardware design.

ii) deliberation on the specifications of thermal–structural analysis to be outsourced to a manufacturer.

3. Educational Activities/PR

One student enrolled at the Graduate University for Advanced Studies for the RISE Project Office, and the office provided the student with seminars. Five RISE members delivered 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 year each. The office accepted a first-year graduate student of the Graduate University for Advanced Studies for lab rotation.

The RISE Project Office continues to engage in raising public awareness regarding the Kaguya project. The office's website, <http://www.miz.nao.ac.jp/rise/en>, was revamped to allow for regular posting of updated information.

4. Joint Research/International Collaborations

Joint research into the basic development of a lunar lander/explorer (LLR and ILOM) is conducted by the Faculty of Engineering at Iwate University, with monthly meetings held alternately at Iwate University and the NAOJ Mizusawa. This collaboration is in accordance with 'the Memorandum on Basic Issues Concerning Research and Development of Scientific Instruments for Lunar Landing Exploration', which was exchanged between members of the RISE Project Office and the Faculty of Engineering at Iwate University. The memorandum was renewed in 2010. The two groups will continue collaborating in the R&D of scientific instruments for lunar landing exploration.

The RISE Project Office continues to collaborate with a group from Shanghai Astronomical Observatory in China, which has been a collaborator in the observation of the Kaguya spacecraft. The parties further engage in data analysis and joint research into future projects on the basis of 'the Memorandum of Understanding for Cooperative VLBI Observations between Shanghai Astronomical Observatory and National Astronomical Observatory of Japan', which was renewed in 2009.

With a group of Kazan Federal University, Russia, which is well reputed in theoretical investigation into the internal structure of the Moon, joint research continues to establish a new theory of lunar rotation, along 'the Memorandum of Understanding for Cooperative Research between Kazan Federal University and National Astronomical Observatory of Japan on VLBI and Astrometrical Observations', which was renewed in 2010. Possible collaborations between the two countries were explored for future lunar exploration projects.

15. Solar-C Project Office

The Solar-C Project Office engaged in planning the next solar observation satellite project, Solar-C, and implemented the preparation of the flight components for the Chromospheric Lyman Alpha SpectroPolarimeter (CLASP) sounding rocket experiment.

1. Solar-C Project

The 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 early years of 2020s. The project is intended to investigate the solar magnetic plasma activities that influence space weather and space climate around the Earth. The investigations will involve the chromospheric magnetic-field and high-resolution imaging/spectroscopic observations that have not been achieved. The themes include three major problems in solar research: solar flares, chromospheric/coronal heating, and solar magnetic cycle activity. An additional theme is magnetic plasma processes such as magnetic reconnection and MHD waves. The tasks include revealing the fundamental small-scale magnetic structures derived directly or indirectly from the Hinode observations and visualizing the magnetic structures in terms of activities and interactions. The Solar-C will conduct high-resolution (0.1–0.3 arcsecs) observations of images, polarization, and spectroscopy over the area from the photosphere to corona by using onboard instruments. The observational instruments for the Solar-C consist of SUVIT with 1.4-m aperture for observing the photosphere and chromosphere, EUVST for spectroscopic observation from the chromosphere to corona, and XIT for capturing images of the transition region and corona. Since its establishment, the Solar-C project WG has involved Japanese researchers in addition to many non-Japanese specialists. Provisionally, Japan will be responsible for the launch vehicle, satellite, and one of major science instruments, whereas the US and European institutions will deal with other major instruments through a large-scale international collaboration.

The main body in this project is the Next Solar Observation Satellite Project Working Group managed by Prof. Watanabe, NAOJ, set up within the Steering Committee for Space Science at the ISAS/JAXA; NAOJ researchers play key roles in the project activities. The Solar-C Planning Office was set up at the NAOJ in FY 2008 as a sub-project to the 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 the HSC, continuing the preparatory work for realization of the satellite project with five full-time staff members and 11 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 observation of the hydrogen Lyman alpha spectrum. Planning and basic development of the project started in FY 2009. The project involves an international research team with participation from Japan, the US, and other countries. The payload consists of a far-ultraviolet (FUV) telescope and a spectro-polarimeter that are prepared in Japan to conduct a polarization observation, with components contributed by the US (CCD cameras) and France (concave grating). The system then will be mounted on an American sounding rocket for the launch in the US. The Japanese PI is Kano, assistant professor at the NAOJ, who leads postdoctoral fellows and assistant professors to pursue designing, equipment development, and testing.

3. Major Activities in FY 2013

Although the progress was made in the feasibility studies and component developments of the large optical telescope and satellite system, much of the time was used for making amendments to the mission proposal. The office organized a Solar-C Science Meeting in Takayama on November 11, 2013, one day before the Seventh Hinode Science Meeting (Hinode-7), with 143 participants including 91 international participants. Deliberations on the large telescope and satellite system yielded the following developments:

(1) A budget for wavefront error was proposed during the discussion on equipping the primary mirror, which will be directly exposed to the solar light, with heat pipes for thermal exhaust in order to achieve the diffraction limit of the large telescope. (2) Reflective systems were considered as the base of the collimator at the rear end of the telescope, and its design was discussed for fabrication. (3) Tolerance of the instrument positions against the telescope and ideas for tolerance distribution of the built-in optical elements were derived from the optical design of spectro-polarimeter with physical processes of diffraction and polarization. (4) Progress was made in the development of the mechanisms indispensable for the polarization observation. (5) The degradation of Hinode's throughput was further understood, the investigation into which would help to understand the throughput degradation of the Solar-C telescope. (6) The conformity of the strength of the optical bench for the telescope was verified. (7) Investigations on component technologies for realizing the pointing stability superior to that of the Hinode led to clarification of the specifications of new components. (8) Progress was made in planning the methods for testing at the system level. (9) Issues were identified through studies on mission data processing after receipt from the observational system. Preparation was also in progress for testing of the near infrared detector intended for the spectro-polarimeter.

The CLASP project entered the development stage fully in the latter half of FY 2012, and it anticipates a prospective development budget for the flight equipment during FY 2013,

aiming for the launch at the summer of FY 2015. In FY 2013, the developed elements were measured at the synchrotron radiation facility of the Institute for Molecular Science, and flight models were delivered for examinations including review of design and fabrication and testing of the assembly. The CLASP project has received a significant contribution from the ATC in terms of the design, fabrication of necessary components, and testing of some of the flight models.

4. Other

The CLASP project has offered an invaluable opportunity

for graduate students and postdoctoral fellows to engage in and experience the development of observational instruments. These young researchers can use this opportunity as a valuable steppingstone for the future development in space instrumentation, including the Solar-C.

Although the Solar-C Project Office is reimbursed by the 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.

16. Astronomy Data Center

1. Overview

The role of the Astronomy Data Center (hereafter ADC) is not only to maintain a research infrastructure via the smooth operation of a group of fundamental systems, but also to engage in research and development towards future expansions of open-use computer system and research infrastructure. Its activity consists of DB/DA Project, Network Project, Japanese Virtual Observatory (JVO) Project, Hyper Suprime-Cam Data Analysis Software Development Project, and works related to the open-use computer system.

2. Accomplishments

(1) DB/DA Project

The DB/DA Project engages in database- and database analysis-related research and development, as well as the handling (collection / management / sharing) of astronomical data. The DB/DA project has made various types of astronomical data public, such as astronomical catalogues, the SAO/NASA Astrophysics Data System (ADS), and all-sky image data (DSS, DSS2), for use by astronomers and educators in Japan and overseas (<http://dbc.nao.ac.jp/>).

The Subaru–Mitaka–Okayama–Kiso Archive (SMOKA) database (<http://smoka.nao.ac.jp/>), the key player of the project, provides access to various archival data from the Subaru telescope, the 188-cm telescope of the OAO, the 105-cm Schmidt telescope at the University of Tokyo Kiso Observatory, the MITSuME telescope operated by the Tokyo Institute of Technology (two 50-cm telescopes) and the Kanata telescope (150 cm) at the Higashi–Hiroshima Observatory of Hiroshima University. It has yielded numerous research breakthroughs. Nearly 8.77 million frames and 46 TB of observational data (excluding environmental and meteorological data) are available for viewing in the SMOKA as of May 2014. In FY 2013, 23 papers using SMOKA data were published in peer-reviewed journals, amounting to 158 published papers as of May 2014. System improvement continued on the SMOKA in FY 2013

for developing an advanced search function and enhanced operational efficiency. The Kiso Observatory made its wide-field camera (KWFC) accessible to the public, and the DB/DA project developed a system for publicizing all-sky monitoring images (Okayama and Hiroshima).

(2) Network Project

The ADC operates network systems that connect its headquarters at the Mitaka Campus with branches distributed around Japan and with a wide-area network connecting with regional ones. We report the following noteworthy operational results for FY 2013:

1) High-speed connection for inter-observatory network:

For the purpose of R&D of next-generation communication technology in relation to the NICT's JGN-X project, the Mizusawa station installed a 10-Gbps telecommunication circuit, which was connected to the JGN-X network in April 2013. The network speed of more than 10 Gbps was achieved between the Mizusawa and Tokyo bases, and the network is utilized for the CfCA, the VERA project, and the post-2011 earthquake recovery efforts, among others.

2) R&D system designed for the CfCA supercomputer system:

The CfCA supercomputer system stretches over the Mizusawa and Mitaka campuses. The ADC in collaboration with the CfCA developed a highly cost-efficient high-speed router (40 Gbps) and storage cache (accelerator) for efficient communication between the bases. This system, known as Renjaku, won the Fujitsu Award at the Open Router Competition during the Interop 2013 Conference.

3) Special classes for students from elementary and junior high schools in the earthquake-affected areas:

The ADC held three special classes primarily geared toward elementary and junior high schools in the earthquake-affected region, in which the classrooms were connected with the Subaru Telescope facility via a real-time link. These events were hosted

jointly with supporting enterprises in Japan and abroad, as well as with Mozilla Japan.

(3) Japanese Virtual Observatory (JVO) Project

The JVO project engaged in the development and operation of a portal site (<http://jvo.nao.ac.jp/portal>), providing worldwide access to astronomical data, in order to promote data-intensive astronomical research.

The following activities were pursued in FY 2013:

The interface design was revamped to improve usability of the JVO portal site; the JVO continued the dissemination of ALMA data; the WebQL, a program to display images and spectrum data from the ALMA telescope on web browsers, was equipped with almost all of the features planned at the beginning of its development and provides service in the public domain; the development of a desktop viewer, Vissage, also continues and is led by members from the Chile observatory (ALMA Japan); the JVO project members delivered presentations of the ALMA data distribution system on various occasions, including an annual meeting of the Astronomical Society of Japan, an International Virtual Observatory Alliance conference, and an Astronomical Data Analysis Software and Systems (ADASS) conference; the JVO project held VO workshops with eight participants; and the JVO underwent source code refactoring. Moreover, the JVO project members conducted scientific research using the JVO; the results were published as a refereed paper in the *Astrophysical Journal*, which was also published on the NAOJ website.

(4) Analysis Software Development Project for Hyper Suprime-Cam

The analysis software development project for the HSC began in January 2009, which engages the following tasks for enhancing the accuracy and efficiency of analysis of the data from the HSC: planning and implementation of parallelized and distributed processes, methods of correcting instrumental distortion, methods of calibrating object position and brightness in individual 104 CCDs.

Test observations using the HSC were fully implemented in FY 2013, during which time the software developed in 2011 for post-observational on-site analysis at the Subaru Telescope's Operations Support Facility was put to repeated actual operations. A problem brought forward from the previous year, such that the analysis process took roughly 5 min before completing all of the data from 104 CCDs, was addressed; various modifications reduced the time to 2.5 min. Furthermore, visualization was achieved almost instantaneously via a web browser, contributing to the construction of support tools for operating observations. Regarding the image processing, a series of tasks are now available — reduction of each CCD, mosaicking CCD images, and catalogue generation. Further work will involve the enhancement of precision levels for certain processes and introduction of new measurement algorithms. Other directions will be further explored.

The database for managing the post-analysis data has also been equipped with functions initially conceived, which brings the database construction agenda using the test observation data from the beginning of the project to close to its completion. The integration work with the analysis software was also implemented, and nearly all data processing procedures were installed. The database will further evolve with the goal of realizing a more efficient search engine and improved operations.

(5) Works Related to the Open-Use Computer System

It is one of primary responsibilities of the ADC, as an inter-university research institute, to operate the open-use computer system. The new rental computer system, the NAOJ Data Analysis–Archival–Publication System commenced its operation on March 1, 2013, and consists of a Multi-Wavelength Data Analysis subsystem; a Large-Scale Data Archival–Publication subsystem including MASTARS, SMOKA, HSC, and ALMA archives; a VO subsystem; a Solar Data Archival–Analysis–Publication subsystem; and the Mizusawa Data Analysis subsystem. The system is in good condition with no major problems. System improvement will continue in performance, usability, security, and management.

As of FY 2013, the Multi-Wavelength Data Analysis and Solar Data Archival–Analysis–Publication subsystems had 175 and 171 users, respectively. 145 refereed papers were produced using the open-use system in peer-reviewed journals in FY 2013.

The following workshops were held as part of the open-use activities, including joint events:

1. C (programming language) workshop: July 24–26, 2013: 12 participants
2. The Graduate University for Advanced Studies Summer School: workshop on radio observational data analysis (ADC provided the analysis environment)
August 12–September 9, 2013: four participants
3. IDL workshop: FITS analysis: September 17–18, 2013: 10 participants
4. Early Winter School on N-body simulation: January 15–17, 2014: 18 participants
5. VO workshop, Autumn 2014: January 27–28, 2014: eight participants
(total participants: 54)

3. Other

As part of PR activities, 61 issues of “Information from ADC” (Nos. 325–385) were published in FY 2013. These issues were published on the website and were distributed via e-mail.

17. Advanced Technology Center

1. Overview of the Organization and Activities

The ATC engages in the development of astronomical observation instruments, focusing on prioritized areas for developing instruments intended for supporting NAOJ projects and on advanced technology to contribute to future projects. The prioritized area development in FY 2013 included the development of the ALMA receivers, HSC, the Kamioka Gravitational Wave Detector (KAGRA) telescope, and an observational instrument of the InfraRed Imaging Spectrometer (IRIS) for TMT. Regarding the advanced technology development, the ATC pursued the preliminary development of a radio receiver in view of future post-ALMA projects and preliminary development for astronomical observations from space.

The Advisory Committee for Advanced Technology, including external committee members, discusses the ATC's involvement in NAOJ projects and human resource plans. The main agenda in FY 2013 was the center's involvement in the TMT projects. Issues concerning daily operation of the center are addressed on the basis of deliberations by the Advanced Technology Steering Committee. Various items were discussed at the meeting, including a request for a subsidy for strategic development expenses, a request for engineer reinforcement, the liaison with the TMT project, and progress reports regarding ATC's internal projects.

Fabrication of the ALMA receiver was completed in FY 2013, bringing the terms for many contract staff members to an end. The ATC needs to pursue the receiver's maintenance in collaboration with the Chile Astronomical Observatory in the future. The ATC is also in discussion regarding methods for maintaining and enhancing its performance as a domestic center for radio receiver development.

The HSC has been already entered an observation phase, and current issues include stabilizing the instrument operation and establishing a support structure for data analysis.

For the development of the TMT observational equipment, development of the optical system for the IRIS has made progress, and the ATC is engaged in information sharing with the TMT Project Office on development of the Wide-Field Optical Spectrometer (WFOS)/Multi-Object Broadband Imaging Echellette (MOBIE). Plans are underway on facility design and specifications of the Advanced Technology Experiment Building (TMT wing) to be constructed through these exchanges.

Regarding the KAGRA project, the main task was the development of baffles for an auxiliary optics system to support suppression of stray light. In FY 2013, the ATC began development of a plan to create and mass-produce a prototype of a multi-strata anti-spring filter for fitting the mirror and isolating vibration.

The joint development research and facility open-use continue status-quo, although difficulties in securing experiment space have persisted. Aging of the facilities at the Development Building (south) became apparent in FY 2013, and some

facilities that had been in use for more than 10 years at the Development Building (north) developed functional problems. A discussion is underway to renew the facilities at the completion of the TMT Building.

2. Workshops and Development Support Facilities

(1) Mechanical Engineering 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 leveraging their expertise.

The design team has handled the structural design of KAGRA's auxiliary optics system and the mechanical structure design of TMT/IRIS imaging parts since the previous year.

For KAGRA's auxiliary optics system, the following was performed:

- Design of the main mirror mount for i-KAGRA
- Design of a narrow-angle scattering baffle bench
- Thermal analysis of a wide-angle scattering baffle
- Design of an optical lever pylon
- Consultation for the fabrication of a prototype bottom filter

For mechanical design of TMT/IRIS imaging parts, the following were pursued:

- Design and testing of various mechanical testing instruments such as motors and bearings
- Creation and testing of a prototype cold-stop mechanism
- Creation and testing of a prototype kinematic lens cell
- Design of a filter-replacement mechanism

In addition, the ATC gave support to the launch of the HSC and dealt with some defects. In order to ensure compatibility with the IRIS imaging parts design, to be fully developed in FY 2014, the facilities were reinforced with an installation of software for nonlinear/irregular analyses.

The fabrication team accomplished fabrication of the mass-production parts for the ALMA receiver on time. Further, an additional order for spare parts (units for seven) was also accomplished on schedule. In tandem with the commencement of an element testing experiment for the IRIS, the team undertook fabrication of prototype parts for the low-temperature drive system.

For the KAGRA project, the team fulfilled the request for a prototype of a vibration isolation system bottom filter and undertook fabrication of main parts in an installable condition. The team also fabricated a special spring composed of maraging steel for the vibration isolation system and succeeded in creating a prototype in an installable condition.

The team also succeeded in high-precision fabrication of onboard parts for the CLASP rocket including three types of super Invar kinematic mounts in five units and delivered them of flight model parts. A continued attempt is made to create

improved prototypes of a mechanical deformable mirror, which has been under development since last year by ISAS/JAXA.

The ultra-precision fabrication team engaged in a joint development research project with external institutions and responded to fabrication requests. The joint development research was involved the development of an ultra-precision milling process using a monocrystalline diamond tool, in collaboration with the Mechanical Engineering Center of the KEK. Details have been discussed for achieving enhanced efficiency in mirror surface machining of an X-band accelerator tube disc.

A project continuing from last year with the Institute for Molecular Science and Nagoya University involves the grinding of MgF₂ aspherical lenses using a monocrystalline diamond bit. It is pursuing an investigation into machining conditions for practical applications.

For the prototype production of the Microwave Kinetic Inductance Detector (MKID) lens array, which the ATC pursues internally, a cutting process of the 721 elements array and anti-reflective (AR) film coating and was successfully achieved, advancing the project closer to testing. The fabrication of a corrugated horn array began, which works excellently in multi-band communication. The goal is to complete this project at the earliest opportunity.

The ME Shop handled with 107 requests for manufacturing or repairs in FY 2012, 16 of which were brought forward into FY 2013. Including these cases, 123 requests were received; 116 were completed while seven cases were forwarded to FY 2014. Eight cases were outsourced.

The following requests were received in FY 2013 (numbers in brackets are cases forwarded into FY 2014):

Brought forward from FY 2012	16 (2)
ATC	13 (2)
Subaru Telescope	3
HSC	1
TMT	10
Exoplanet Exploration Project	14 (1)
Solar Observatory	1
Hinode	2
Solar-C/CLASP	32 (1)
ALMA	11
RISE	2
VLBI	2
KAGRA	3
Gravitational Wave Project Office	4
Public Relations Center	1
External organizations	8 (1)
Institute of Astronomy, Tokyo	7
ISAS/JAXA	1
Total	107 (7)

(2) Optical Shop

A. Regular operation and maintenance

- Measurement equipment maintenance including daily inspection

- Measurement-related consultations (71)
- Repairs/updating of facilities (updating the digital camera for MM-40 microscope and replacing the laser and laser power source of Zygo GPI™ interferometer)
- Calibration of Legex 910 (January 20–24, 2014)
- Recording backups of the measurement data stored in the measurement equipment

B. Measurement instruments open use (including use in joint research) April 2013–March 2014

- Measurement equipment use: 412
 - Within ATC: 145
 - ALMA: 9
 - NAOJ and Institute of Astronomy of the University of Tokyo: 184
 - Outside NAOJ: 74
- Large three-dimensional measurement device Legex 910 use: 51
 - The Legex 910 was utilized regularly throughout the year for a total of 91 days.
 - For ALMA and HSC: 37 (by operators of each group)
 - Optics Shop use by request: 14

(3) Optical Infrared Detector Group

The optical infrared detector group mainly provides support for visible light detectors. The work related to HSC's CCD is gradually nearing its end, although worldwide inquiries remain regarding the usage instructions or properties of fully depleted CCD, which the group handled. The group also undertook replacement/upgrading of observational instruments. This year, it helped to upgrade the 3DII CCDs, one of the instruments transferred for the Subaru. The activities are conducted mainly by students of the Institute of Astronomy, University of Tokyo. The ATC's work involved a range of activities, from designing of a dewar to performance tests of CCDs, and provided support for handling the devices.

(4) Thin Film Deposition Unit

The ATC collaborated with the Institute for Cosmic Ray Research of the University of Tokyo in the development research of high-precision optical elements using thin-film coating technology, a project carried over from last year. This year, preliminary experiments were conducted on the functional properties of the mirror and thin film that changed during low-temperature cooling, in preparation for the mirror for gravitational wave interferometer. In a collaboration with the Kavli IPMU, the agenda was to develop a wide-band AR coating for the Subaru PFS; thus, the preliminary experiments were run, and equipment modification and adjustment was conducted.

(5) Space Chamber Shop

The Space Chamber workshop provides support for open use of the vacuum chamber, clean room, and other facilities belonging to the ATC. Some of the major results for open use are as follows: The ATC vacuum chamber was used in tests for the CLASP sounding rocket experiment performed by the Ultraviolet Synchrotron Radiation Facility (UVSOR)

synchrotron radiation facility, and the vacuum chamber was also used for various vacuum experiments performed as part of the next solar observation satellite SOLAR-C project. In addition, low-temperature motor tests for the filter exchange mechanism of the Wide-field Imaging Surveyor for High-Redshift (WISH) satellite were performed. Otherwise, small vacuum chambers were nearly in constant use for outgas measurement and other tests, whereas an environmental chamber was used in temperature cycling tests for parts of observational equipment.

(6) Facility Service Unit

Because the ATC has a limited number of lab rooms, projects are accepted according to availability. Lab capacity continued to be below the demand level in FY 2013, and the unit is managed with users' understanding. The shortage was eased slightly by swapping lab rooms for different projects during the term time.

The ATC's experiment facilities, including the clean room, were used in FY 2013 by the following projects or organizations: ATC, ALMA, KAGRA gravitational wave, TMT, Division of Radio Astronomy, HSC, JASMINE, Division of Optical and Infrared Astronomy, Extrasolar planet exploration, Subaru Telescope, Hinode Science, and Solar-C/CLASP. The clean room 101 in the Development Building (north) is dedicated to the development of satellites and is used for the development projects of the small-sized JASMINE (JASMINE Project Office), satellite Hodo-yoshi 3 (Nakasuga Lab, University of Tokyo), and CLASP (CLASP/Hinode Science).

A roof of the Development Building (south) incurred a water leak due to the decay of waterproofing materials on the roof. Because water leaks have occurred every year, the ATC is considering a complete refurbishment. Moreover, the Development Building (south) underwent a lighting refurbishment in which light sources have been replaced with LEDs in all labs and other rooms. The work started last year came and was completed except for that in one laboratory, where the LED brightness was deemed insufficient; the refurbishment work is continuing in FY 2014. The air conditioning system in the Development Building (north) has been in use for 10 years and has started to cause some facility breakdowns. In particular, the temperature control units failed, disabling the room temperature controls. Therefore, the units were all updated to newer models.

A clean booth was installed last year in a lab allocated to the KAGRA gravitational wave telescope, and its filter unit began to cause noise and vibration to the extent that it interfered with work conducted in adjacent labs. The lab resumed operation after the noise and vibration were reduced to a tolerable level through the installation of soundproofing, repositioning of equipment, and isolation of the vibration.

Annual inspections of cranes 0.5 ton or more are mandated by law and are duly performed. Due to tight schedules for lab usage, the annual inspections were conducted in two phases this year. Since load testing is mandatory for cranes of more than 3 tons, the 4.8-ton crane at the Development Building (north) is scheduled to undergo testing in 2014.

Rust-induced decay found in the leg of a cold evaporator (CE) through annual inspection was handled by application of a new layer of paint. Gas storage tanks with a capacity of 1,000 L or more are regulated by the High Pressure Gas Safety Act, which provides that a 20th-year pressure test is mandatory. The tank onsite is working normally 19 years after its fabrication; however, plans are under consideration for purchasing a new CE and installing a liquid nitrogen gas production facility in view of the Advanced Technology Building for the TMT, scheduled for operation in FY 2015. Major management duties are diverse and include mandatory day-to-day inspection and operational management of the buildings, electrical equipment, and CE equipment, as well as the management of clean rooms, fresh-air treatment units for the clean rooms, private power generators, operation of the Electrical Shop, management of chemical substances, and disposal of used chemicals. Some contributions were made to the architectural planning of the Advanced Technology Building for the TMT from the viewpoint of facility management.

Mr. Hiroshi Mikoshiba, who was responsible for facility maintenance and management, was transferred to Nobeya Radio Observatory in April 2013. His two-year contributions were much appreciated.

3. Project Support

Calls for open-use projects were held twice in FY 2013, resulting in the ATC equipment being used for five joint R&D projects and 27 other projects. Details of these uses are described in the section on Facility Open Use, including the names of project leaders and research themes. Results of these projects are posted on the ATC website.

4. Development in Prioritized Areas

(1) Development of SIS Device for ALMA

Fabrication of devices for the ALMA-specification band-4 and band-8 receivers continued from last year. By December 2013, devices were provided for 73 units of receivers to be shipped. Currently, further devices needed for receiver maintenance are in production.

The manufacturing equipment for the new SIS element introduced in FY 2012 underwent performance testing, and device prototypes were created, verifying the capacity to produce devices in good condition. A plan is currently under discussion to use the equipment for developing an SIS element for band-10 receivers and to create a prototype in terms of preferable conditions for manufacturing good devices.

(2) ALMA Band-4

At the production rate of 3.75 units per month, exceeding the target rate of three, the testing and production of 73 units was completed in November, and the receivers were delivered on schedule by the end of December 2013. A future task is to form a maintenance team in cooperation with the Chile Astronomical Observatory to handle failures and breakdowns.

(3) ALMA Band-8

73 units of band-8 cartridge receivers (385–500 GHz) were delivered to JAO by November 2013. Subsequently, the ATC handled the assembly of seven spare cartridge units and the repairs of returned units. Drawings and instructions were collated for maintenance purposes. Preparations were undertaken to lease the leak-rate measurement equipment to be used for the cartridge cooling system and vacuum base plate, in support of the mass-fabrication of band-1 receivers pursued by the Academia Sinica Institute of Astronomy and Astrophysics (ASIAA) in Taiwan.

(4) ALMA Band-10

At the astonishing production rate of four units per month, the testing and production of 73 units was completed by the end of December, and they were delivered on schedule by the end of March 2014. Future agendas include the formation of a maintenance team in cooperation with the Chile Astronomical Observatory and the pursuit of receiver upgrades as well as development of next-generation receivers.

(5) Hyper Supreme-Cam (HSC)

In FY 2013, the HSC was applied to test observations for seven nights in June, five nights in October, and eight nights in January and February 2014. Despite the high incidence of inclement weather, conditions were sufficient to perform the test observations roughly half of the time. The defects identified through this observation included (a) scattering/stray light, (b) vacuum leak under extremely low humidity, and (c) partial movement defect in CCDs. The (a) test was further investigated and the results indicated certain light patterns due to uneven filter permeability rather than scattering/stray light. The cause of the (b) test result was identified to be the alumited groove on the O-ring. The (c) test is still under monitoring, and an investigation is underway to rectify the situation by adjusting the operational configurations. Basic performances including image quality and system throughput were confirmed to meet the requirements to the design. Therefore, the HSC was put to open use and strategic observations in late March 2014. The following tasks must be pursued in the future: (a) realizing an auto-focus mechanism, (b) developing a detection efficiency measurement system, (c) establishing operational stability of a filter replacement device, (d) addressing the CCDs with movement defects, and (e) establishing a data analysis support structure for open-use users.

(6) IRIS, the TMT Onboard Observational Instrument

Development is underway for an imaging system for the IRIS, the first observational instrument for the next-generation extremely large TMT, which began in FY 2011. Currently at the preliminary designing stage, the IRIS system is on schedule to be submitted to external reviews in December 2014. Work continues from last year, with ME Shop staff members performing a leading role in prototype demonstrations of component technologies and designing the actual system based on the prototypes, as listed below:

- Performance tests of a prototype Cold Stop Stage for a low-temperature drive system
- Implementation and analysis of the vibration tests using prototype lens cells
- Fabrication of prototype off-axis aspherical mirrors
- Design of an actual filter-replacement mechanism
- Design of an actual lens cell assembly machine
- Packaging design of the actual IRIS

(7) KAGRA gravitational Wave Telescope

The development of KAGRA's auxiliary optics and vibration isolation systems are pursued in collaboration with the TAMA Project Office. The development relevant to the auxiliary optics system included the system design of KAGRA's interferometer against stray light and the relation baffles required. Five types of baffles were developed, the largest of which was 800 mm in diameter. Four types have particularly high sensitivity in converting gravitational wave signals into light signals and will be installed in KAGRA's vital 3-km arms. The plan is to install, in the order of closer to farther from the primary mirror of the interferometer, a wide-angle scattering baffle, a cryo-duct shield, and a narrow-angle scattering baffle. Furthermore, baffle arrays are to be installed in the arms at appropriate intervals. These baffles are designed to collectively keep stray light-induced noise under 1/100 of the total noise level. The ATC ME Shop helps with the development of the structural design and assembly methods because in countering the noise induced by stray light, careful attention must be paid not only to the baffle's noise absorption and scattering but also to its mechanical structure. The optics design is pursued primarily on the basis of ray tracing simulations performed with the assistance of external optics systems corporations. The vibration isolation system is a device to be mounted on the mirrors in the KAGRA to isolate them from vibrations and is composed of multi-strata anti-spring filters. The ATC planned to manufacture one of the filters, and a prototype was made in FY 2013. First, the ATC's Machine Shop fabricated some parts of the anti-spring filter. The most challenging part of this task was to develop a geometric anti-spring (GAS) filter that combined maraging steel board springs, a key structure for isolating vibration. However, the ATC succeeded in establishing the process from material procurement through fabrication to performance tuning. GAS filters were hitherto available only from very few overseas organizations with the capacity of material procurement and manufacturing. The establishment of the technology and process in Japan will serve as a foundation for future development of vibration isolation technology in the country.

Priority was also given to the development of the main KAGRA unit, and advanced technology development was pursued toward improving the performance of next-generation detectors for the KAGRA.

The ATC developed a torsion-bar antenna (TOBA), aiming to achieve an observation of gravitational waves at lower frequencies than those observed by the KAGRA and other large laser interferometer gravitational wave telescopes. At present, the world's highest known sensitivity has been attained in the 0.1-Hz

band. R&D continues for further improvement of the sensitivity.

Also in progress is the development of a main interferometer unit and a signal acquisition system for the DeciHertz Interferometer Gravitational wave Observatory (DECIGO) Pathfinder (DPF), a prelude satellite for the DECIGO space gravitational wave antenna project. Efforts were focused primarily on the design and fabrication of the interferometer module (BBM) for the gravitational wave sensor unit. It was determined recently that residual gas surrounding the test mass would produce noises similar to Brownian motion far more than previously speculated. Therefore, an encasement was designed to house the test mass in order to reduce such noises. The noise generation mechanism is relevant not only to gravitational wave observational satellites but also to terrestrial gravitational wave telescopes such as the KAGRA. The revised noise reduction method will contribute to the future enhancement of sensitivity in the KAGRA and other telescopes.

5. Advanced Technology Development

(1) Radio Cameras

Development of a millimeter/submillimeter microwave kinetic inductance detector (MKID) camera is in progress. The camera is intended for the LiteBIRD, with observation of the B-mode polarization in the cosmic microwave background (CMB) radiation, and for the Antarctic terahertz telescopes. A millimeter microwave 700 pixel MKID camera was developed with an integrated silicone lens array. Further design was developed by Mr. Tomu Nitta and others in 2013 to increase the lens array density to achieve 2,000 pixels. An AR coating for a silicone lens array was developed, a mix of two types of epoxy resins was applied, and the thickness was optimized by post-application machining the same group in 2014. Also pursued were the development of a low-temperature wide-angle optics system (1.0°) to connect the high-resolution camera and the telescope and prototyping of the 0.1 K cooling system. These advancements were reported in a PhD thesis by Mr. Tomu Nitta, University of Tsukuba, and an master's dissertation by Mr. Shigeyuki Sekiguchi, University of Tokyo.

A high-speed dual-element Fast Fourier Transform (FFT) circuit for MKID readout was developed and tested against a single-element readout circuit by Dr. Kenichi Karatsu and others in 2014, the results of which verified the former's sufficiently low noise level.

The development of the superconductive imaging submillimeter-wave camera (SISCAM), using an SIS ray detector and a gallium arsenide field-effect transistor (GaAs-JFET) ultra-low-temperature integrated circuit (IC), proceeded to the construction of a system to automatically control the 32-channel readout circuit module, which was performed to attain an extraction of parameters for optimal motion conditions by channels. Y. Hibi and others reported the testing of the integration with the detector and 32-channel module movements in 2013.

(2) Space Optics

Activities to observe astronomical bodies from the outer space are pursued by using rockets and artificial satellites

to facilitate the realization of future space projects. In FY 2013, foundational development was furthered toward the implementation of the CLASP rocket test project and the satellite projects of the WISH and Solar-C. As part of the WISH project, which involves observations in the near-infrared band, drive tests were performed for a low-temperature motor for the filter exchange mechanism under a low-temperature vacuum environment. Because the CLASP project seeks to perform magnetic field observation of the Solar chromosphere and transition region via hydrogen Lyman alpha spectrum, observational instruments were developed and a calibration test apparatus was conducted in preparation for flight tests in FY 2015. In the second half of FY 2013, a temporary assembly of the flight model also began.

Also in FY 2013, the testing of prototypes and prospective flight models of optical elements was conducted using synchrotron radiation. For this testing, the ATC transferred a measurement system developed onsite to the Institute for Molecular Science. In addition, resources at the ATC were mobilized to conduct various tests to verify the capacity and durability, in a mechanical environment, of the slit unit and the component products developed for the slit-jaw optics system in the CLASP polarization spectrometer; the rotational uniformity of the rotating wave plate drive mechanism, which is currently under development for use in flight; and contamination evaluation monitoring observation, among other things.

In relation to the Solar-C project, optical performance tests were conducted on the optical integral field unit (IFU) using fiber optic bundles and an image slicer model utilizing the reflective field. Both were developed during the foundational development of the polarizing spectrometer. Progress was also made in the preparations for low-temperature performance tests of the near-infrared sensor in order to develop a near-infrared camera.

(3) Development of Near-infrared and Visible CMOS Image Sensors

Image sensors for astronomical observations must maintain a low noise for detecting very subtle light, whereas readout ICs for consumer use presuppose high-speed readout, which makes it difficult to achieve a low noise level. Herein lies the necessity to develop an IC optimized for astronomical observations.

This year, the ATC participated in the Silicon on Insulator (SOI) Pixel Sensor Project pursued by the KEK, and produced a prototype of a visible complementary metal-oxide semiconductor (CMOS) image sensor based on the low-noise readout IC previously fabricated as a test piece. The SOI technology has enabled achievement of high sensitivity in the near-infrared band, which was hitherto unattainable by conventional CMOS image sensors. Si semiconductor detectors do not detect near-infrared. For the near-infrared image sensor to compensate for this limitation, the indium gallium arsenide (InGaAs) image sensor marketed by Hamamatsu Photonics was evaluated. In addition, the ATC undertook the assembly of quantum efficiency measurement equipment and pixel sensitivity distribution measurement equipment to be deployed in the testing of these near-infrared image sensors.

18. Public Relations Center

1. Overview

The Public Relations Center engages in the publication, promulgation, and promotion of scientific achievements made not only by the NAOJ but and by others in the field of astronomy in general to raise public awareness,; to respond to reports of discovery of new astronomical objects,; and to provide ephemeris and other astronomical information more directly relevant to people's everyday activities, such as sunrise and sunset times. The Center center is formed of six offices and one unit: including the Public Relations Office, the Outreach and Education Office, the Ephemeris Computation Office, the Museum Planning Office, the Library Unit, the Publications Office, and the General Affairs Office. The activities of each office will be reported hereafter.

2. Personnel

The Public Relations Center was served in FY 2013 by Director Toshio Fukushima and the following staff members: two professors, one associate professor, two assistant professors (one holding a concurrent post), four research engineers, one senior engineer, one engineer, one chief of the library, four research experts (one holding a concurrent post), 20 Public Relations and Outreach staff members, two research associates, and two administration associates. The following members joined the center:

Yuriko Watanabe, Public Relations and Outreach staff (Outreach and Education Office), April 1, 2013; Tamami Yamaguchi, Public Relations and Outreach staff (Outreach and Education Office), and Lundock Ramsey, research associate (Public Relations Office), June 1, 2013; Kumiko S. Usuda, research expert (Museum Planning Office), July 1, 2013; Naotsugu Mikami, Public Relations and Outreach staff (Public Relations Office), August 1, 2013; Yasuhisa Shioya, Public Relations and Outreach staff (Public Relations Office), September 1, 2013; and Osamu Okoshi, Public Relations and Outreach staff (Outreach and Education Office), January 10, 2014. Outgoing staff members included Takuya Okawa, Public Relations and Outreach staff, on May 31, 2013; Akira Hirai, Public Relations and Outreach staff, and Tamami Yamaguchi, Public Relations and Outreach staff, on December 31, 2013.

3. Public Relations Office

The Public Relations Office actively promoted scientific developments yielded through various projects conducted by the NAOJ, including the Chile Observatory, the Subaru Telescope, the HSC, the Extrasolar Planet Detection Project, and the Nobeyama Radio Observatory. It also promoted the results of joint research projects conducted with universities and other research organizations through press conferences and web releases. In cooperation with the Outreach and Education Office, the Public Relations Office also ran awareness campaigns on meteor showers and other astronomical phenomena of interest to the public.

Social networking services such as Twitter and Facebook have proven to be valuable new tools in sharing information.

(1) Multimedia-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 to the website.

NAOJ e-mail newsletters Nos. 103–128 were issued, containing headlines of 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.

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 and regular observation sessions at the Mitaka Campus and position openings. More than 35,000 followers were counted at the end of March 2014.

(2) Publicizing developments

Information releases were actively presented, totaling 26 articles (Tables 2, 3).

As part of the Astronomy Lecture for Science Journalists, the 19th lecture theme was “Comets: fascinating facts,” and the 20th was “Mapping the Universe.” The lectures were streamed over the Internet for journalists only. The lectures were also recorded to be viewed by journalists who missed the event and also by those journalists who attended and wish to review the material. The system is proving to be successful given the fact that more real-time viewers over the Internet were counted than the number of participants onsite at the 19th lecture.

Month	Access counts	Month	Access counts	Month	Access counts
April 2013	412,619	August 2013	1,335,182	December 2013	917,320
May 2013	450,406	September 2013	612,646	January 2014	634,935
June 2013	427,197	October 2013	818,752	February 2014	364,096
July 2013	519,303	November 2013	1,560,285	March 2014	452,907
Total: 8,505,648					

Table 1: Monthly website access statistics on Public Relations Office website, NAOJ Public Relations Center (April 2013–March 2014).

April 23, 2013	Ubiquitous infrared polarization in the star/planet-forming region and life homochirality
May 7, 2013	Completion of the installation of 16 Japan-made parabolic antennas for the ALMA telescope, at the Array Operations Site
May 31, 2013	'Population poll' of the galaxies behind dusts
June 4, 2013	Japan commences mainstream construction work on TMT
June 7, 2013	The ALMA discovers a comet crib
June 12, 2013	Sunny super-Earth? First successful observation of the atmosphere of a low-mass exoplanet GJ 3470 b
August 9, 2013	Success in a velocity measurement of the supernova shock wave traveling through interstellar molecular cloud
August 23, 2013	Star nursery gently wrapped in dust particles
September 4, 2013	The sky of the super-Earth in blue light
October 4, 2013	The ALMA telescope discovers giant hot cocoons surrounding a baby star
October 10, 2013	Urbanite massive black hole: 'observational' results from VO
October 23, 2013	Comet ISON viewed via the Subaru telescope
November 5, 2013	Population poll of asteroids on inclined orbital plane
November 11, 2013	[Breaking News] Comet ISON and comet Lovejoy reveal nuclei, captured by the Subaru telescope
November 15, 2013	Seven NAOJ Mitaka properties registered as tangible cultural heritage
November 18, 2013	[Breaking News] Ultra wide-field prime focus camera, High Suprime-Cam captured long tail of the comet ISON
November 22, 2013	[Breaking News] Subaru telescope investigates the comet ISON after luminous increase
December 6, 2013	Marching to the Beat: Subaru's FMOS reveals the well-orchestrated growth of massive galaxies in the early Universe
December 6, 2013	[Breaking News] The Subaru telescope reveals the detailed structure of Comet Lovejoy's tail
January 17, 2014	ALMA discovers a formation site of a giant planetary system
January 28, 2014	Subaru telescope scrutinizes active supermassive black holes revealed in merging galaxies
March 4, 2014	Origins of massive objects: Hot steam gas disks discovered around massive stars

Table 2: Web releases.

May 27 and 29, 2013	Go! The world's fastest astronomical supercomputer
July 31, 2013	Consummation of the brand-new ultra wide-field camera-the first light image
August 5, 2013	Subaru telescope's imaging discovery of a second Jupiter shows the power and significance of the SEEDS project
February 20, 2014	Subaru telescope detects rare form of nitrogen in comet ISON

Table 3: Press Conferences.

(3) Activities as NAOJ's public relations center

The following activities were pursued, in addition to the center's regular task of aiding research result releases: In tandem with the full commencement of the large-scale project of TMT construction, the center helped to revamp the website of the TMT. In response to the JASMINE Project Office's request to boost PR activities for small-sized JASMINE project, the center rendered support in creating new pamphlets as well as planning and conducting lectures for science journalists. Help was also given to the project's own lectures for the general public, from preparation to organization. In particular, creating an application form for online pre-registration and developing lists of applicants have become standard practices for the Public Relations Office.

4. Outreach and Education Office

(1) Handling general inquiries

Inquiries were made by the media, governmental offices, and the general public. The Outreach and Education Office responded to 7,094 telephone inquiries (Table 4) and 127 letters, 79 of which were official documents. The office also received 326 inquiries via the Internet (Table 5).

(2) Educational and Outreach Activities

The astronomical phenomena campaigns, which were bidirectional information-sharing initiatives, began in FY 2004. Two events were organized this year: "Perseid Meteors 2013" in August 2013 (with 1,312 reports), and "Let's Go Out and Find the Comet ISON" in November (with 1,963 reports).

The "Fureai (Friendly) Astronomy" project, in its fourth year, provided events to 47 schools, covering all that applied, with 4,865 pupils in attendance. Many feedback responses from the pupils expressed their interest in seeing stars or aspiration for becoming astronomers, suggesting that the event was a good opportunity to familiarize the children with astronomy and to inspire them by meeting and learning from astronomers. Forty-two lecturers participated.

The Summer Vacation Junior Astronomy Workshop was organized jointly with the "You are Galileo!" project on July 25 for elementary, junior high, and high school students. Enrollment was necessary, and 40 places were offered. Nearly 80 people participated, including accompanying adults, and enjoyed handcrafting telescopes with instructions on how to use them. Concurrently, lectures were delivered on the theme of the "You are Galileo!" project and astronomical phenomena in the summer sky. An additional observational event "Summer

	Solar info	Lunar info	Ephemeris info	Time	Solar System	Universe	Astronomy	Other	Total
April–June	248	104	58	22	178	78	117	790	1595
July–September	207	206	54	8	299	102	149	1021	2046
October–December	257	140	41	14	658	106	112	766	2094
January–March	233	129	71	11	165	66	101	583	1359

Table 4: Telephone inquiries made to the Public Relations Office of the NAOJ Public Relations Center (April 2013–March 2014).

	Solar info	Lunar info	Ephemeris info	Time	Solar System	Universe	Astronomy	Other	Total
April–June	11	4	1	2	13	7	21	20	79
July–September	4	5	1	2	13	21	29	14	89
October–December	3	3	2	1	29	14	34	7	93
January–March	2	7	2	0	4	18	18	14	65
Total	20	19	6	5	59	60	102	55	326

Table 5: Internet inquiries made to the Public Relations Office of the NAOJ Public Relations Center (April 2013–March 2014).

Vacation Junior Star-Gazing Party” was offered free to the public on July 25 and 26. Weather conditions were disappointing, however, leading to participation by 191 people including 64 on the first day and 127 on the second.

The Public Relations Center participated as the secretariat for the Mitaka Open House Day, a special public event held at Mitaka and organized by the steering committee. This two-day event was held on October 18 and 19 with the theme “Exploration of the roots of galaxies and planets through ALMA Telescope.” It was co-hosted by the Institute of Astronomy, 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. Despite the inclement weather on both days, the event was successful, attracting a total of 4,176 visitors. The success was owing to the effective consideration of each project’s program, achieving the same number of visitors as that in the previous year. The event catered to a wide range of age groups and offered viewing of facilities not open normally to the public, interactive panel displays, mini-lectures, and popular quizzes and games.

The fourth International Science Film Festival was co-held between August 1 and September 29, with more than 100 participating affiliates. Screenings of science films and other events such as a stamp-collection rally were held at 59 science museums, planetariums, and film theaters in Japan, with more than 1 million people participating. The central events were held in the forms of a kick-off event (National Museum of Emerging Science and Innovation), a science film cafe and workshop (Science Museum), a science film cafe and Riken Day (Science Museum), and Dome Festa (Hitachi Big Theater).

The annual event “Star Week: Getting to Know the Starry Sky” was presented during the first week of August, with the participation of 83 astronomy-related facilities providing 133 collaborative events.

The “Astronomy for Beginners” co-hosted every year with the Tamarokuto Science Center was held on December 1 and consisted of a lecture on comets, sunspot observation in the old equatorial telescope dome, and a regular guided tour around the facilities, with a total of 40 visitors enjoying their experience.

The NAOJ Research Conference, “The Second Conference on Universal Design for Astronomy Education” was organized and co-hosted by the Japanese Society for Education and Popularization of Astronomy on September 28 and 29 at the Mitaka headquarters. Participation from a diverse culture was achieved, from people engaging in promulgation of astronomy education to those with disabilities and their supporters, for a total of 124 individuals. Among the participants, eight were visually impaired, 14 were hearing impaired, and one required the use of a wheelchair. To ensure that information was made available to participants with disabilities, Information and Communication Media Support was provided in the forms of resources in Braille, sign language interpreters, and a PC-enabled note-taking system in which the essence of remarks is inputted via PC and projected onto a screen.

The Ninth Workshop for Popularizing Cutting-Edge Astronomy was held at the Kavli IPMU from November 17 to 19, with the main theme of cosmology. A total of 75 researchers and people engaging in education or promotion of astronomy took part.

The “You are Galileo!” event was organized jointly with the Office of International Relations and was held on March 2, 2014, at the Royal University of Phnom Penh, Cambodia. With roughly 100 educators and university students in attendance, the event included lectures, handcraft workshops to make telescopes, and celestial observation. For the event, 22 sets of telescope assemblies with tripods and one 10-cm equatorial reflecting telescope were donated for local use.

Makali’i image analysis software, developed for the purpose of applying FITS data obtained through the Subaru telescope and other research observations to astronomical education and outreach initiatives, is distributed by the Public Relations Center in Japan and overseas via the Internet. The poster “One in every home: Diagram of Our Universe 2013,” available in A1 and A2 sizes in Japanese with English on the reverse side, was transcribed to web pages in Japanese and English following its publication last year. A new poster “The Solar System,” available in A1 and A2 sizes in Japanese only, was also created in collaboration with the PCOST.

(3) Community activities

In FY 2013, 37,187 visitors were welcomed at the “Mitaka Picture Book House in the Astronomical Observatory Forest,” which opened on July 7, 2009, based on the Agreement on Mutual Cooperation concluded between the NAOJ and the city of Mitaka on February 4, 2009. Along with joint projects such as the “Ohisama Ippai (plenty suns)” exhibition held from July 2011 through June 2012 and the “Uchuu de Ikiteru (living in space)” exhibition held from July 2012 through June 2013, the Outreach and Education Office engaged in events at the Mitaka Picture Book House in the Astronomical Observatory Forest, including modern and traditional Tanabata celebrations and moon-viewing parties, in cooperation with staff members from the municipal office of Mitaka City and local volunteers.

The event “Astronomy Pub” has been held at Mitaka Network University and hosted by the non-profit organization (NPO) Mitaka Network University Promotion Organization since FY 2009. It provides for 20 participants at a time and is held in the evening on the third Saturday of every month except August. The Public Relations Office also assisted in presenting Star Sommelier Mitaka, an astronomical guide training course hosted by Mitaka Network University that provides telescope operation workshops and other related events.

5. Ephemeris Computation Office

The Ephemeris Computation Office estimates calendar-related phenomena such as the apparent positions of the Sun, Moon, and stars on the basis of international standards and publishes the “Calendar and Ephemeris” as part of the compilation of almanacs, which is one of the NAOJ’s *raison d’être*.

(1) The office published the 2014 edition of the Calendar and Ephemeris, the 2014 version of the calendrical section of the Rika Nenpyo, and the 2015 edition of the Reki Yoko (posted in the official gazette on February 3, 2014). The web-based Calendar and Ephemeris adopted the IAU WG Cartographic Coordinates and Rotational Elements (CCRE) Report 2009 for planetary axis of rotation to display a visual radius (excluding light penetration) on the solar-centric coordinates and a polar visual radius on the planet-centric coordinates.

(2) The website (<http://eco.mtk.nao.ac.jp/koyomi/>) published EphemerisWiki-Tonight’s Sky powered by Google Maps, and various tools were updated to Google Maps v3. New arrangements were made to the Today’s Sky, in tandem with annual events and campaigns, to display positions of various objects such as Comets Lemmon, ISON, Lovejoy and Encke; Nova Delphinus 2013/Nova Centauri 2013; and radiant points of the 2013 Perseid meteor shower/2013 Geminids meteor shower. As a result, the total access in FY 2013 reached 32 million hits.

(3) The Japan Association for Calendars and Culture Promotion hosted its third General Meeting and a Calendar Presentation Ceremony. The office also took part in the selection committee

for the Best 36 Words of the Season, hosted by the Japan Weather Association, and published the results.

(4) The office hosted regular exhibitions in collaboration with the library, selecting from the NAOJ’s invaluable collection of ancient archive in the Chinese/Japanese languages. The themes of the 48th and 49th exhibitions were “Tides” and “The Moon and Ephemeris,” respectively. These exhibits can also be viewed at the Rare Book section of the library’s website, in Japanese only (<http://library.nao.ac.jp/kichou/open/index.html>).

(5) Four staff members, including two full-time and two part-time, handled reports of new astronomical objects and other communications submitted to the NAOJ. This year, 20 reports were made including new object discoveries, verification requests, and others. Of these, seven were about new stars or supernovae, eight were on comets or comet-like objects, two were on fireballs, one was about planets, and two were on luminous objects.

Amid the many false alarms attributed to known supernovae, comets, ghost images of bright stars, and the like, a discovery of a supernova reported in July was relayed via the NAOJ to the IAU Central Bureau for Astronomical Telegrams. The reporter was subsequently recognized as the sole discoverer of Supernova 2013dy.

6. Museum Project Office

In FY 2013, the open house initiative team was reorganized from the Outreach and Education Office into the old Archive Office and was renamed as the Museum Project Office. Due to the nature of the work involved, some parts of the activities were conducted jointly with the Outreach and Education Office.

(1) Open House events

As in previous years, regular semimonthly screenings were held at the 4D2U Dome Theater on an advance booking basis for the second and fourth Saturdays of the month. A total of 22 sessions were held with 1,893 audience members. Moreover, 69 group screenings were held with 2,143 participants, and 59 tours were organized, attracting 635 visitors. The grand total for these events at the 4D2U Theater was 150 sessions with 4,671 viewers.

Annual observations featuring the 50-cm telescope for public use were organized concurrently with the 4D2U Dome Theater open house events, regardless of weather conditions. Advance booking (300 places for each session) was introduced in FY 2012 for these events. A total of 22 sessions were held with 4,740 participants. The Mitaka open house events held throughout FY 2013 had 18,552 visitors. Including workplace visits, 147 group tours were conducted with 5,828 visitors in FY 2013, and 284 media interviews were granted. Guided tours of the Mitaka campus began in June 2011 as part of the Archive Office/Open House initiative. Each tour is conducted on an advance booking basis with a group of 20 participants. Tours are organized in two courses: the Registered Tangible Cultural Heritage course on the

first Tuesday and second Sunday of the month and the Important Cultural Heritage and Geodesy-related Sites course on the third Tuesday and fourth Sunday. The office welcomed 469 people for the tours, and participants expressed their enjoyment.

(2) Planning Museum and Managing Archive

The Museum Project Office engaged in collecting and organizing historically important observational and measurement data and equipment for preservation. Improvements on the preservation and display methods were discussed, and the founding principles and organization of the NAOJ Museum (tentative name) were formulated. The Mizusawa and Nobeyama joined discussions for the preparation of the museum concept. Three meetings were held at respective campuses this year, and various requests and present circumstances of these bases were heard. The City of Mitaka made seven applications for registering the architectural properties at the NAOJ Mitaka for tangible cultural heritage and received responses from the committee on November 15. The Mitaka is now home to 10 cases of registered tangible cultural heritage items. A plan to engage volunteer guides on the NAOJ premises is under consideration in order to respond to an increasing demand for group tours and guided tours. The office gave support to the NAOJ Guide Volunteer Training Course organized by the NPO Mitaka Network University Promotion Organization, which was completed by nine people. Preparations are underway to commence guided tours conducted by these trained volunteers next year. The Astronomical Society of Japan Spring Meeting 2013 offered a program of lectures titled “The History of Astronomy: Collection of Historical Resources and Survey.” During the two-day event, 25 lectures were scheduled with more than 60 participants each day, revealing the popularity of this area of interest among researchers.

Function restoration work was performed on the Solar Tower Telescope as part of the fourth-year execution of the annual NINS president’s discretionary budget. The coelostat mirror and primary mirror were depositions, followed by a successful solar light introduction. Seismic isolators were installed for the display cases exhibiting lenses and glass objects. In addition, dehumidifiers with capacities appropriate for the exhibition rooms were installed to improve in-room conditions for the exhibits. For visitor reception improvements, a visit guide was prepared in Braille, and on-site explanation displays were reviewed for the Braille parts. An introduction movie was also created.

Preparations are underway for requesting an equipment upgrade for the 4D2U Dome Theater from the budget in FY 2014 in addition to a budgetary request for the Museum Project.,

7. Library Activities

Along with its regular work in collecting and organizing academic journals and literature on or related to astronomy for internal and external students and researchers, the library digitized rare documents in FY 2013 and made the data accessible to the public. The library also organized and released

an archive catalogue covering the period between roughly the late 19th century and the early 20th century. It also engaged in inspecting its collections and compiling an inventory and resource data. The library publishes a volume of literary collections and types of journals held at the Mitaka Library and other NAOJ observatories, together with the current status of NAOJ’s ongoing publications, in the publications of the NAOJ.

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, Nos. 237–248 (April 2013–March 2014)
- Annual Report of NAOJ Vol. 25, Fiscal 2012 (Japanese)
- Annual Report of NAOJ Vol. 15, Fiscal 2012 (English)

The office also continued its efforts in improving the NAOJ News content. In particular, strategic PR promotion of various projects, which were fully activated in FY 2012, was realized in increased printing volumes, with six projects as main features to further promote these projects including ALMA in May issue, TMT in June, CfCA in August, HSC in November, and Subaru in December, as well as KAGRA in the February 2014 issue. The office will continue its efforts in close collaboration with other offices to produce integrative, supporting articles so that the NAOJ News content will be shared and used creatively by each project to promote them in PR. The Publications Office is also pursuing the planning stage of an idea to develop NAOJ’s comprehensive PR/educational materials and its base platform by re-editing materials and articles published by the office, including NAOJ Pamphlets, Annual Reports, and other content of NAOJ News. Other publications included the 2014 ALMA Telescope calendar, which featured images captured by the telescope; this edition was the ninth since its first production in 2005. 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 Rika Nenpyo, a chronological scientific table. As part of the initiative to digitize publication content, the office developed a new e-book platform that allows for seamless content viewing by smartphones and PCs. Digitizing back publications and reorganizing them into electronic content are tasks for the future. The Publications Office will pursue dual-channel data dissemination of prints and Internet-based media.

19. Division of Optical and Infrared Astronomy

1. Overview

The Division of Optical and Infrared Astronomy oversees the Okayama Astrophysical Observatory and the Subaru Telescope (Project C); the TMT Project Office and the Gravitational Waves Project Office (Project B); and the JASMINE Project Office and Extrasolar Planet Detection Project Office (Project A). The primary purpose of the division is facilitating and invigorating projects and individual research through personnel exchanges to place researchers in environments more suitable for their individual projects. While pursuing seminal observational and developmental research, the division furthers these goals to launch new projects as necessary. The division also actively engages in graduate education efforts to foster next-generation talents. These activities are based on the concept that the Division of Optical and Infrared Astronomy is a center for personnel exchange between the Subaru Telescope facility engaging in open use, and universities and research institutes in Japan, focusing on developmental research into new instruments and observational research. This concept was developed when the Subaru telescope was constructed.

Almost all NAOJ members in optical- and infrared-related fields have positions at the division and engage in either the division or Projects A, B, or C. They may also have concurrent positions in at times many other projects. The division and the various projects carry equal weight in organizational terms. The primary staff of the Division of Optical and Infrared Astronomy in FY 2013 consisted of two professors, one associate professor, three assistant professors, and five JSPS research fellows.

The division coordinates educational, research, and administrative activities for all research divisions and projects except for the TAMA and JASMINE projects. The TMT project has come to an expansive stage in which the telescope fabrication has been started. Personnel transfer often occurs within the Optical and Infrared Astronomy Division in tandem with this progress. The division plays an increasingly important role in coordinating between the Subaru Telescope and TMT projects. The division as a whole maintains and operates facilities as auxiliaries to research such as mailing lists and web servers, for various optical- and infrared-related projects such as the Subaru Telescope, TMT, Extrasolar Planet Detection, TAMA, and JASMINE.

The remainder of this report will focus on the research projects conducted by full-time members of the Division of Optical and Infrared Astronomy and 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,

objects within the Solar System, structures around late-type stars, and the search for exoplanets. In addition to observations of the Comets ISON and Lovejoy, research was conducted on star formation in the Virgo Cluster and the ionization of gas ejected from galaxies. The search for extrasolar planets continued using direct imaging methods.

Research in other areas is also in progress, including astronomical phenomena based on old ephemeris and other documents and statistical research using astronomical archive data and the astronomical database, with a focus on AGN, or automatic identification and mechanical classification of galaxies treated as the important data.

As part of research using astronomical archive data, quantitative comparison research on photometric zero-points between the publicly available Subaru Deep Field/Subaru XMM Deep Field (SDF/SXDF) catalogs and the SDSS catalog was also performed. Another research undertaken was on the host galaxy of AGN using SDSS imaging/spectroscopy data.

(2) International Cooperative Observational Research

The division also engages in international collaborative studies with overseas researchers. Research on low-ionization nuclear emission regions (LINERs) was conducted along with Korean researchers. The site survey in western Tibet for constructing a telescope also continues in cooperation with the National Astronomical Observatory of China (NAOC).

3. Subaru Telescope-Related Observational Instrument Development

The division searched for planetary candidates using the HiCIAO infrared coronagraph, implemented hardware and software improvements for direct imaging and observation of protoplanetary discs, and participated in the development of the next-generation Extreme AO and a new coronagraph. In relation to the data archive, the division joins the file-system-based technology WG convened by the Society of Scientific Systems to explore the possibilities for overcoming difficulties arising from storage expansion, thus enhancing storage usage.

4. Operational Support for the 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, and management of open-use-related travel expenses, and promoting PR activities for the Subaru telescope. The division also gives support to the management of data analysis systems in collaboration with the Astronomy Data Center. Moreover, the division also supports the Subaru Spring/Autumn Schools co-hosted with the Subaru Telescope facility and the Astronomy Data Center, and Subaru telescope observation classes.

5. Research Environment Maintenance

The division manages the printers and rented multifunction photocopiers in the Subaru Building, teleconferencing systems on the second and third floors, sub-networks, and data backup servers for the Subaru Office as part of its efforts to maintain the research environment. In connection with the discontinued support for Windows XP, the office gave assistance in the OS upgrade to Windows 7. The teleconferencing system was also due for an upgrade because the service for the previous model was terminated. Currently, the Internet server is also undergoing an upgrade. Further, the division took a leading role in the response to an unauthorized access incident that occurred in January 2014.

6. Planning of the Next-generation Large-Scale Project

The Division of Optical and Infrared Astronomy is engaged in planning of post-Subaru large projects in optics and infrared astronomy such as the TMT and the JASMINE series. A framework for collaboration between the ISAS and the NAOJ also needs to be established.

A study group on next-generation large disc and computing systems was launched with the KEK, which handles voluminous data in five to 10 years ahead. Discussions revolve around archival hardware and software in 10 years in the future to serve as an astronomical database for the next-generation observational

instruments and TMT succeeding the Subaru telescope.

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

The division cooperates with the Public Relations Center in supporting PR/outreach activities such as publication of and press conferences on the Subaru telescope research results and discoveries of new astronomical objects. An active participant in a special public event held at Mitaka (Mitaka Open House Day), the Division of Optical and Infrared Astronomy provided mini-lectures and exhibits and planned projects appealing to elementary and junior high school students such as magnet puzzles.

8. Educational Activities

The Division of Optical and Infrared Astronomy provides postgraduate education to 26 graduate students from the Graduate University of Advanced Studies, the University of Tokyo, the Tokyo University of Agriculture and Technology, Nihon University, and other organizations.

Division staff members gave active contributions to seminars and self-directed studies. The division participated in the “Fureai Astronomy” project, providing pupils at elementary and junior high schools with opportunities to be familiarized and appreciate astronomy, dispatching lecturers to various schools around the country.

20. Division of Radio Astronomy

The Division of Radio Astronomy oversees the Nobeyama Radio Observatory, Mizusawa VLBI Observatory, RISE Lunar Exploration Project, and Atacama Large Millimeter Array (ALMA) in Japan; scientists and engineers of these projects are attached to the Division of Radio Astronomy. The division coordinates radio astronomy research between these radio astronomical projects. The respective project report shows details on the latest status and research results of each project. Keywords of scientific research in the Division of Radio Astronomy are Big Bang, early Universe, galaxy formation, black holes, galactic dynamics, star formation, planetary system formation, planets and satellites, the Moon, the material evolution in the universe, and the origin of life as the ultimate theme and so on. Radio astronomy unravels mysteries and phenomena of the universe by studying pictures taken at radio wavelengths invisible to human eyes. Details of each research result are reported in sections of these projects and the Scientific Highlights. The Radio Astronomy Frequency Subcommittee is 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. Karl Jansky of the US in 1932 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 that differ from those obtained through optical observations. Just as optical pollution from artificial light sources is an obstacle in optical observation, artificial radio interference generated by 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 and wireless LANs are ubiquitous. Television broadcasting services have also shifted into digital, providing various nice features. The areas of radio applications will further expand in the future owing to its efficiency: the wide and flexible applicability of this useful and finite resource. Therefore, further efforts will be necessary for maintaining the sky 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 mediation between the community of radio astronomy and commercial wireless operators is led by the MIC within Japan and internationally by the ITU Radiocommunication Sector (ITU-R) of the United Nations. As part of the activities for FY 2013, the subcommittee took an active role in representing the Japanese community of radio astronomy researchers on various occasions in these mediation efforts.

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

(2) Current Challenges

In order to handle issues of interference, the Radio Astronomy Frequency Subcommittee remains responsive to 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 necessitate that users are licensed because it operates in low-level, though its bandwidths is wide.
- 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 as the wireless business varies widely depending on the frequency band used. Fortunately, radio astronomy observations have been given priority in a number of frequency bands under the ITU Radio Regulations (RR). However, negotiations will be necessary between the radio application and the radio astronomy if the same priority level is to be shared within certain band. Radio astronomy observation involves detection of extremely faint radio waves from distant astronomical object. Terrestrial radio waves, even extremely faint and unwanted waves, can have a substantial adverse effect 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 connecting system in emergency, where ammonia observations are affected; 21 GHz next-generation

satellite broadcasting, where water maser observations are affected; 1600 MHz emergency satellite mobile phones, where the observation of pulsars and the like are affected; and 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.

(3) International Activities

The ITU's Radio Regulations (RR), which allocates radio frequencies to wireless applications, are revised once every three to four years in the World Radiocommunication Conference (WRC). The most recent meeting was WRC-12, held in February 2012. The RR include the frequency bands in which radio astronomy observation is prioritized. Preparatory conferences need to be held in Geneva annually in preparation for the upcoming WRC-15 to discuss necessary matters for the revision of the RR. 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. It has also contributed in opinion-forming through its regular attendance at the Asia/Pacific Region (APG) meetings in preparation for WRC-15, as a delegate representing Japan. In FY 2013, the subcommittee pursued the protection of radio astronomy frequency bands through the participations in the ITU-R WP7D meetings held in Geneva in June and September and the APG meeting held in Australia in June 2014, in addition to other relevant meetings and conferences.

(4) Activities in Japan

Two major domestic activities were pursued by the Radio Astronomy Frequency Subcommittee: participation in various committees hosted by the MIC and with MIC's authorization direct negotiations with wireless operators who generate radio interference. Negotiations with the interference sources represent a major part of the subcommittee's activities in Japan.

The committee hosted by the MIC organizes domestic tactics in preparation for international conferences, preparing Japan's positions on various wireless issues. Other MIC-related meetings provide opportunities for discussing the radio application technologies concerning the 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 up to the interference problems in regard to societal and technological trends.

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

One example is the advent of UWB wireless applications, used in positioning and tracking material flow in manufacturing and logistics industries. The applications in the UWB frequency band induces interference in VLBI geodetic observations to detect movement of plates in plate tectonics. Although this

band is not under RR protection, it is vital from the perspective of predicting earthquakes and is the subject of special consideration by the MIC. 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 areas at certain proximity to radio observatories. A wider scale of the distribution is predicted for 76-GHz and 79-GHz band automotive radars, which are currently under development status. Of particular concern are the possible effects of interference from these radars on the 45-m radio telescope at the Nobeyama Radio Observatory, which engages in observations of spectral-lines of deuterated and other molecules in interstellar matter. This 45-m telescope located in Japan carries its significance in relation to the ALMA international project, 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.

The 23-GHz band is deployed for emergency wireless communications at times of natural disasters that lead to a breakdown of CATV networks. Ammonia molecular lines (RR-protected band) overlap with the 23-GHz band due to redshifts under the expansion of the Universe. An additional point for consideration is that the 1.6-GHz band may be of important use at times of natural disasters for satellite-based mobile

communications rather than terrestrial wireless communications. The MIC performed as a mediator in discussions regarding interference issues caused by satellite phones using geostationary and non-geostationary (orbiting) satellites, and an agreement on usage conditions was concluded between the parties: service providers which create the interference and Radio Astronomy Frequency Subcommittee representing the radio astronomical observatories, bearing in mind the importance of the emergency use of satellite phones at times of natural disasters.

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 vapor observation. Because the radio signals from the satellite approach the ground from outer space, their detrimental effects are easily anticipated. PLC utilizing home power lines affects radio astronomy observations in low-frequency bands below 30 MHz. A petition against unduly hasty introduction of PLC was submitted to the MIC jointly with the ASJ and the Society of Geomagnetism and Earth, Planetary and Space Sciences. A press conference was organized to raise broad public awareness of the relevant facts.

Moreover, the subcommittee engaged in making applications to the MIC, requesting frequency protection of NAOJ telescopes in addition to those owned by the Japanese community of radio astronomy on their behalf.

21. Division of Solar and Plasma Astrophysics

The Division of Solar and Plasma Astrophysics is made of staff members from the Solar Observatory, the Hinode Science Center, and the Nobeyama Solar Radio Observatory, and the division conducts research on the Sun in close liaison with their respective projects. This year, all members in the division are again on a concurrent-posting basis.

The division conducts both theoretical and observational research into the inner structure of the Sun and outer solar atmosphere including the photosphere, chromosphere, corona, solar wind and various phenomena in the magnetized plasma such as flares, sunspots, solar faculae, and prominences. The division's theoretical research includes helioseismic explorations of the internal structure of the Sun, as well as the explorations of Sun-like stars and cosmic jets, taking MHD as a common methodology. The solar group at NAOJ started observations from space in the very early stage of Japan's space program. The division has been involved in the development of the Hinode satellite, which is currently in orbit, and plays a major role in its scientific operation. Research is also underway in the field of ground-based observation for developing new instruments for the Solar Flare Telescope and other telescopes. In addition, the division engages in sustained long-term observations of solar phenomena such as sunspots, flares, and corona and works with related overseas organizations to exchange data and release publications.

1. Integrated Solar Physics Research

The time is ripe for solar physics to integrate theoretical and observational studies from space and the ground. The Hinode satellite has been operated stably this year as well. Thanks to the high acclaim earned through reviews by space agencies around the world (FY 2012/13) for Hinode's scientific results, all of these organizations are committed to continuing operation of the Hinode in FY 2014 until FY 2015/16. The Division of Solar and Plasma Astrophysics hosted the seventh Hinode Science Meeting, held in Takayama city between November 12 and 15, 2013.

2. Educational Activities

Tutorials were provided to students under supervision of teachers who belonged to the Division of Solar and Plasma Astrophysics in FY 2013, including four students from the University of Tokyo, one of whom left prematurely, and two from the Graduate University for Advanced Studies. In addition, one graduate student was tutored at the division. The division also supported research activities such as attendance of international research conferences and observations in Japan and abroad, irrespective of the projects of division members and students. Moreover, the division also cooperated with Kyoto

University and Nagoya University with support from various NAOJ projects to plan and conduct tours for undergraduate students to visit solar-related research organizations and to experience the latest research in the field.

3. International Cooperation

The Hinode mission is an international endeavor involving NASA in the US, the UK STFC, the European ESA, and the Norwegian Space Centre (NSC) in Norway. Meetings of the Hinode Science Working Group (HSWG) are regularly held to discuss a framework for international cooperation and open use in the satellite's scientific operation in order to produce scientific results. The Division of Solar and Plasma Astrophysics continued its efforts in making all data obtained by the Hinode immediately available to the public. The Science Schedule Coordinators (SSCs: Sekii and Watanabe, NAOJ) hold monthly teleconferences in order to solicit observational projects such

as Hinode Operation Plans (HOPs) from solar researchers around the world to facilitate maximum observational results through projects using the scientific equipment on Hinode and joint observational projects in combination with other solar observation satellites/terrestrial equipment. With the establishment of the Solar-C Project Office as Category-A project this year (headed by Hara), the Solar-C mission proposal was prepared in anticipation for an international collaboration and was drafted with the help of ISAS/JAXA-WG (chief: Watanabe). Preparation is underway for submission of proposal to respond to an announcement of opportunity for the next strategic medium-sized satellite, which is expected to take place some time next year.

One member, Suematsu is taking part in the SWG meeting of the US Advanced Technology Solar Telescope (ATST). Several plans are under consideration for future terrestrial observation projects that would involve collaborations with various institutions in Japan and with East Asian countries

22. Division of Theoretical Astronomy

1. Overview

The Division of Theoretical Astronomy aimed at achieving exceptional international research results both in quality and quantity toward the accomplishment of the following four goals set by the NAOJ, and it engaged in research activities for FY 2013 accordingly:

- Advance the world's cutting-edge theoretical research.
- Pursue theoretical astronomy research, particularly in areas that involve the NAOJ supercomputer or large-scale observational equipment to give insight into new observational instruments.
- Encourage collaborations between researchers in Japan and strengthen the country's theoretical astronomy research.
- Invigorate postgraduate education.

The division handles a wide variety of themes in theoretical research, addressing a diversity of hierarchical structure of the Universe in terms of formation/evolution process, dynamics, and physical state of matter, covering a span from the early Universe to galaxies, stars, planetary formation, compact object activity, and astrophysical plasma phenomena. The Division of Theoretical Astronomy aims to facilitate Japan's high competitiveness on the international plane through continuous production of world's 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 particular, the division has fostered research developments to create an influential research center for young researchers and is actively engaged in personnel exchanges with universities and research institutes. The division's full-time,

associate, assistant, and project assistant professors, together with NAOJ postdoctoral fellows and JSPS fellows, conduct a variety of unique research projects involving postgraduate students from the Graduate University of Advanced Studies, the University of Tokyo, and the Graduate School of Ochanomizu University; joint research with observational astronomy using observational satellites of various frequency bands such as the Subaru, ALMA, and Nobeyama radio telescopes; and interdisciplinary research with physics of elementary particle/atomic nuclei. In addition, the division actively organizes numerous cross-disciplinary international conferences, domestic meetings, and seminars for the fields of theoretical astronomy, observational astronomy, and experimental physics, and it leads research activities in various fields of astronomical science.

2. Current Staff and Transfers

In FY 2013, the dedicated staff of the Division of Theoretical Astronomy included two professors, two associate professors, and four assistant professors in addition to one professor and one assistant professor who concurrently hold primary positions at the Center for Computation Astrophysics. In addition to research and educational staff, the division was served by three project assistant professors, including two NAOJ postdoctoral fellows and one JSPS fellow, in addition to one administration associate who gave support to research and the educational staff mentioned above. Takeshi Inoue and Michiko Fujii assumed the positions of assistant professor and project assistant professor in March 2014 and September 2013, respectively.

3. Research Results

The research papers published in the publication category IV with the Division member(s) as primary author(s) or presenter(s) are listed below. Categories with fewer than 10 publications have been omitted.

Peer-reviewed papers in English: 56

Papers in English (conference proceedings, non-reviewed papers): 34

Reports in English (speeches at international conferences): 72

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

- Ion nonlinear dynamics in collisionless magnetic reconnection (Seiji Zenitani et al.)
- Toward multi-messenger astronomy: radiative transfer simulation of binary star neutron star merger (Masaomi Tanaka et al.)
- New constraints on primordial magnetic fields from the CMB (Dai Yamazaki et al.)
- Cosmological constraint against the fourth-generation neutrino from Big Bang nucleosynthesis (Toshitaka Kajino et al.)
- Ionic excitation process in the early Universe and solution for the Big Bang lithium problem (Toshitaka Kajino et al.)
- R-process nucleosynthesis near GRB center object (collapsar jet) (Ko Nakamura, Toshitaka Kajino, G. J. Mathews et al.)
- Supernova neutrino formation of radioactive isotope ^{92}Nb and determination of time passage in the formation of the Solar System (Toshitaka Kajino, Ko Nakamura, G. H. Mathews et al.)
- Relative equilibria theory applied to asymmetrical neutrino generation, pulsar kick, and spin deceleration in the magnetized proto-neutron stars (Toshitaka Kajino, Jun Hidaka, G. J. Mathews et al.)
- Many-body quantum effects and neutrino response within neutron stars (Toshitaka Kajino et al.)
- $f(R)$ theory of gravitation and the structure of ultra-magnetized neutron stars (Toshitaka Kajino et al.)
- A new theoretical method to determine the unknown neutrino mass-hierarchy (Toshitaka Kajino et al.)
- Heavy neutron synchrotron radiation in the ultra-magnetic field and the origin of ultra-high-energy cosmic neutrinos (Toshitaka Kajino et al.)

The following research results are published on the Division's website (<http://th.nao.ac.jp/>) among research highlights:

- Solution to the lithium problem in Big-Bang nucleosynthesis in hybrid axion dark matter model (Toshitaka Kajino et al.)
- Static compression of porous dust aggregates (Akimasa Kataoka et al.)

- Early galactic chemical evolution and r-process nucleosynthesis in black-hole forming supernovae (Toshitaka Kajino et al.)
- Growth of Rayleigh–Taylor and Richtmyer–Meshkov instabilities in relativistic jets (Jin Matsumoto et al.)
- Optical/Infrared Emission from Neutron Star Merger (Masaomi Tanaka et al.)
- Ion nonlinear dynamics in magnetic reconnection (Seiji Zenitani et al.)
- The seeds of planets are fluffy (Akimasa Kataoka et al.)
- Stringent constraint on the 4th flavor-generation of neutrino from Big-Bang nucleosynthesis (Toshitaka Kajino et al.)
- New constraints on primordial magnetic fields from the CMB (Dai Yamazaki et al.)
- Theoretical explanation of the origin of Niobium 92 as supernova explosion neutrino: evaluation of the period 1–30 million years from supernova explosion to the birth of the Solar System (Toshitaka Kajino et al.)
- A new theoretical method to determine the unknown neutrino mass-hierarchy (selected as a highlight topical review of 2013 in Journal of Physics G) (Toshitaka Kajino et al.)
- The moment of core collapse in star clusters with a mass function (Michiko Fujii et al.)
- Structure of magnetized molecular filaments (Kohji Tomisaka et al.)
- Some remarks on the diffusion regions in magnetic reconnection (Seiji Zenitani et al.)
- CMB with the background primordial magnetic field (Dai Yamazaki et al.)

4. Educational Activities

To supplement Section III on activities of research and educational staff members as part-time lecturers at universities and graduate schools, the lecture subjects are listed below:

Toshitaka Kajino: Fundamentals of theoretical astronomy at the Graduate University for Advanced Studies; science of time, space, and matter, and fundamentals of physics at Gakushuin University; modern physics at Japan Women's University; astrophysics at Jissen Women's University; nuclear physics at Meiji University.

Tetsuhiro Kudoh: Space and Earth science at the University of Electro-Communications.

Eiichiro Kokubo: Introduction to planetary science at the Tokyo Institute of Technology; special lecture in celestial mechanics V at the Graduate School of the University of Tokyo.

Fumitaka Nakamura: Special lecture in physical sciences at Osaka Prefecture University; special lecture in space sciences 1 at Hokkaido University.

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

Yasunori Hori: Introduction to astronomy at Kanagawa University.

Grant J. Mathews: Special lecture titled “Cosmology and Astrophysics” at the Graduate School of the University of Tokyo.

Tetsuhiro Kudoh led a group of undergraduate students in visiting actual research sites during the Summer Student event of the Graduate University of Advanced Studies. Moreover, various contributions were made to education at the high-school level. Toshitaka Kajino delivered a Super Science High School lecture titled “Discovering the Birth of Matter” at Kashiwazaki Senior High School in Niigata, and Eiichiro Kokubo delivered a Super Science High School lecture titled “Cosmo-science: the Earth in the Universe” at Hibiya High School in Tokyo.

5. PR and 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: Ken Ohsuga: “Computational exploration to black holes” held at Asahi Culture Center, Yokohama; Toshitaka Kajino: “The birth of the Universe and origin of Life,” delivered at the First civic lecture Manabi no Mori hosted by Aomori University and Aomori Akenohoshi Junior College; “The birth of the Universe: tempospace and symmetry violation” and “Element traveling through Space: Neutrinos and Origin of Life” at the Professor Lecture hosted by Inagi City Board of Education; Eiichiro Kokubo: “The Origin of the Solar System: from Star Dust to Planet” at a science seminar of The Physical Society of Japan; “From Star Dust to the Planet Earth” as part of the ASJ open lecture “Uchu wa date janai!”; “From Star Dust to the Planet Earth and the Moon” for the Japan Association for Calendars and Culture Promotion; “Junior lecture: the Earth in the Universe” and “the Oort Cloud, the home of Comet ISON” at Asahi Culture Center Shinjuku; “Home of comets: the Oort Cloud” and “The Beauty in the Moon” at Ikebukuro Community College; “Experiment to create the Earth using Supercomputer” at the Koriyama City Fureai Science Center SPACEPARK and “From Star Dust to the Planet Earth” at an open lecture for pioneering the future of Iwate held in Morioka; Masaomi Tanaka: “Computational exploration of supernova explosions” at Asahi Culture Center, Yokohama, and “The destiny of Betelgeuse: will there be a supernova explosion?” for Civic Astronomy, Sumida; Takashi Hamana: “Dark matter and dark energy in Space” at Asahi Culture Center, Yokohama; Michiko Fujii: “Galaxies revealed through the latest astronomy” at Asahi Culture Center, Yokohama; and Dai Yamazaki: “Polarization of CMB and Next-Generation Cosmology” at Asahi Culture Center, Yokohama.

6. International Collaborations

Toshitaka Kajino performed duties of the following posts: editorial board member for the UK Institute of Physics “Journal of Physics”; review panel member of the European Science Foundation Euro GENESIS Project; international examiner 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 the Swiss National Science Foundation (SNSF). Eiichiro Kokubo

served as a member of the Organizing Committee of the IAU’s Extrasolar Planets Commission.

Research staff of the Division of Theoretical Astronomy played leading roles in organizing The 12th International Symposium on the Origin of Matter and Evolution of Galaxies at Tsukuba International Congress Center and the Sokendai Asian Winter School 2013: Science Eyes and Minds towards Cosmic Horizon, co-hosted by faculties of Astronomical Sciences and Space Sciences. These staff members made contributions of disseminating research progress made in Japan to the world and encouraged international exchanges.

An agreement was made between the NAOJ and ECT*, both signing the Memorandum of Understanding mediated through the Division of Theoretical Astronomy. This agreement encompasses the scientific advancement in bordering areas between astronomy and astro/nuclear/particle/condensed-matter physics by promoting an exchange of scientists and postgraduate students for international conferences, joint research projects, and university education programs in mutual collaboration. An international workshop is planned at the ECT* (Trento, Italy) in September 2014, titled “Nuclear Physics and Astrophysics of Neutron-Star Mergers and Supernovae and the Origin of R-Process Elements.”

7. Awards

Akimasa Kataoka was awarded the best presentation award by the Japanese Society for Planetary Sciences.

8. 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 an international astronomical 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 guest visitors. The main international visitors to the Division are listed below:

Akif B. Balantekin, (University of Wisconsin–Madison, US)
 Ramon Brasser, (Academia Sinica, Taiwan)
 Grant J. Mathews, (University of Notre Dame, US)
 Myung-Ki Cheoun, (Soongsil University, South Korea)
 Yamac Deliduman, (Mimar Sinan Fine Arts University, Turkey)
 Poshak Gandhi, (Durham University, UK)
 Motohiko Kusakabe, (Korea Aerospace University, South Korea)
 Roland Diehl, (Max Planck Institute, Germany)
 Chung-Yoel Ryu, (Hanyang University, South Korea)
 MacKenzie Warren, (University of Notre Dame, US)

23. Office of International Relations

The Office of International Relations strives in promoting autonomous research activities by planning and implementing strategies for the NAOJ's international research efforts characteristic to the institution as a whole. It also and supports efforts to strengthen the foundation for expanded internationalization. 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 research organizations for international partnerships.

1. International Collaborative Project Support

The office gathers and provides information necessary for pursuing well-organized international research collaborations on its own initiative, and it serves as a liaison point for international activities, engages in international agreements or provides support for doing so, and accumulates procedural and administrative knowledge. The office gathers and accumulates necessary and practical information for arranging agreements and contracts with overseas universities or research institutions, including precautions and problem solving, by means of conducting consultations or investigations on individual cases and provides such information as required. The Office of International Relations also offers advice and consultations and responds to inquiries on a case-by-case basis. Other matters handled by the office include signing agreements and memoranda for international collaborations and addressing export security control issues in relation to overseas joint research projects.

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) between June 28 and 29, 2013 at the Smithsonian Submillimeter Telescope, Hilo Island, Hawaii. The four institutions forming the EACOA include the NAOC, the NAOJ, KASI, and the ASIAA in Taiwan. The office also issued a public call for the EACOA postdoctoral fellowship program in 2014. In addition, it co-hosted the EACOA East Asia Workshop on Joint Research via Mid/Small-aperture Telescopes held June 21–25, 2013, at NAOC in Kunming, China.

In tandem with the agreement signed between the NAOJ and IAU to establish the IAU Office for Public Outreach, the Office undertook an international call for the positions of Public Outreach Coordinators. The Office of International Relations also cooperated with EACOA member organizations in supporting the activities of the IAU Office for Astronomy

Development (OAD) in the East Asia region.

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 the NAOJ. The work involves consultation and responses to inquiries regarding administrative issues. The office also offers advice to organizations or individuals for contact as appropriate, coordinating between organizations and gathering relevant information.

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. This involved consultation on visa applications and other procedures as well as general issues in relation to their stays in Japan to help in ensuring a pleasant experience. The office also provides general information useful for everyday activities.

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 the NINS to coordinate international collaborations. The office oversaw the Optical and Infrared Synergetic Telescopes for Education and Research (OISTER) project conducted by the OAO, the Ishigakijima Astronomical Observatory, and nine Japanese universities.

The collaboration with the Office of International Relations at the NINS yielded a workshop for international joint research associates in which the office was involved from the planning stages to the preparation of a manual for hosting international researchers and in giving English-language master seminars to various NINS organizations. The office also cooperated with the Administrative Bureau of the NINS to dispatch two NINS office administrators to the Subaru Telescope facility for overseas training.