III Status Reports of Research Activities

1. Mizusawa VLBI Observatory

1. Project Overview

Regular maintenance for FY 2012 was performed from October to December, rather than from June to August as in previous years, because the designated contractor at the end of the previous year had its bid participation eligibility suspended. As part of reconstruction work on the Ibaraki Station, which was damaged in the Great East Japan Earthquake that occurred on March 11, 2011, emergency work was performed on the azimuth rail retaining mechanism of the 32 m Hitachi telescope, which at the beginning of 2011 had been in danger of collapsing. That was followed by primary reconstruction work, enabling test operation by the end of 2011. Secondary reconstruction work was subsequently performed, leading to complete reconstruction nu the end of FY 2012.

VERA Project observation continued without interruption despite the change in the maintenance work schedule. In FY 2012, a ceremony to celebrate the 10th anniversary of VERA and a report session on observational results were held, as well as a press conference about the observational results. Notable results include a revision to the value for the orbital speed of the Solar System in the Milky Way galaxy used up until now by the IAU. The IAU had previously recommended the orbital speed of the Solar System as 220 km/s, but following analysis of VERA observational results from 2007 onward, a roughly 10 % faster speed of 240 km/s was reported.

Scientific evaluation and observation were also actively pursued in cooperation with the Korean VLBI Network (KVN), and a joint Japanese/Korean science working group meeting was held in Mizusawa in July 2012. The Optical Fiber-Connected VLBI Project; projects to establish the Japanese VLBI Network and the East Asia VLBI Network; gravitational observation and research projects; and research activities at the Ishigakijima Astronomical Observatory were also implemented as in previous years. An overview of the activities for each project will be given below.

Other activities include the collaborative effort to install a supercomputer at Mizusawa. Massive additions to the structure previously used to maintain the 20 m radio telescope, and a framework was established for receiving the supercomputer scheduled to go into operation starting in FY 2013. We used this opportunity to develop research ties with the Center for Computational Astrophysics (CfCA), which is to manage the operation of the supercomputer. Successful results were obtained from introductingVERA observational results into the 4D2U project and from cooperating with galactic rotation simulations. An ultra-high-speed optical line (JGN line) node was also set up in Mizusawa with the cooperation of the Astronomical Data Center, allowing for 10 Gbit/s data transmission. A plan is in place at the Mizusawa VLBI Observatory to move of the correlator currently in operation at Mitaka to Mizusawa in the future. The Mitaka-Mizusawa ultra-high-speed data transmission line is expected to be an important tool for correlation calculations in Mizusawa using observational data collected in Mitaka from stations in the Japanese VLBI Network.

(1) VERA

The scientific goal of the VERA Project is to engage in astrometric observation of objects in the Milky Way and to shed light on the spatial and velocity structures of the Milky Way as a whole via the highest level of phase-referencing VLBI observation worldwide. To achieve this goal, distances throughout the entire Milky Way must be measured with a relative uncertainty of no more than 20 %; thus, astrometric observation will be performed with 10-microarcsecond accuracy, 100 times more precise than before. The annual parallax and proper motion of approximately 1,000 astrophysical maser sources in the Milky Way galaxy will thus be measured, thereby revealing the three-dimensional structure and dynamics of the Milky Way. Research goals of the project include development of a rotation curve for the Milky Way a priori symmetry or other assumptions used in previous curves, and clarification of the kinematic mass distribution within the Milky Way and an understanding of the distribution of spiral arm structures and dark matter. Another major scientific goal of the project is to verify that the relationship between absolute luminosity and variation period seen in late-type stars in the Large Magellanic Cloud also applies in the Milky Way.

Observational station positions must be measured with high precision in order to perform these types of astrometric observations. Comprehensive, precise measurements performed via VLBI, GPS, gravimeters, and the like are also expected to contribute to geodesic and geophysical research.

The observational system consists of four 20 m radio telescopes installed at the Mizusawa VLBI Observatory at Oshu in Iwate Prefecture, the Iriki Ranch of Kagoshima University in Satsuma-sendai, Kagoshima Prefecture, the island of Chichijima in Ogasawara, Tokyo Prefecture, and Nagura in Ishigaki, Okinawa Prefecture, which perform observations as a single unified VLBI observational apparatus. The greatest characteristic of VERA is its dual-beam observational system, which is capable of simultaneously observing two objects having an angular separation of 0.3°–2.2°, allowing for high-precision phare-referencing VLBI observations. Observational data is recorded via magnetic tape recorders at a rate of 1 Gbps. A disk recording system has also been introduced and brought online in order to increase recording speed. Magnetic tape and magnetic disk correlation is performed using the conventional correlator (FX correlator) at the Mitaka VLBI correlation center. But in response to the aging of the facility, a transition to a computer-

based software correlation system is underway. Verifications including comparisons of processing results from the old and new correlators have been made, and the transition to regular operation is underway. Data obtained from Japan-Korea and East Asian VLBI observations is processed at the Seoul correlation center jointly developed by Japan and Korea. Research and development for next-generation VLBI observational devices is also underway, as is the development of recording systems capable of 8 Gbps recording and playback.

(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. A 34 m radio telescope at the Kashima Space Technology Center of the National Institute of Information and Communications Technology (NICT), 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 National Astronomical Observatory of Japan (NAOJ), and an 11 m radio telescope at the Tomakomai Space Observatory of Hokkaido University are connected via an optical communications network.

One 2.4 Gbps line for the Tomakomai station and two 2.4 Gbps lines for each of the other stations are used for dual polarization observation. The goals of the project are to overcome the 1 Gbps limit on observational speed imposed by magnetic tape, to construct a high-sensitivity VLBI observational network, and to perform foundational observations for expanding VLBI observation to include new objects such as faint astronomical radio sources. The Science Information Network (SINET) of the National Institute of Informatics (NII) is used for the optical communication network. The system converted from SINET3 to SINET4 in FY 2011, so a transmission test for a 10 GbE general connection was performed in FY 2012. Successful results in ultra-high-speed data transmission tests from the 32 m radio telescope at Yamaguchi, the 32 m radio telescope at GSI Tsukuba, the 11 m radio telescope at Gifu University, and the 11 m radio telescope at Hokkaido University Tomakomai to Mitaka have already been obtained.

A JGN line from Otemachi to Mizusawa was laid in tandem with moving the supercomputer to Mizusawa. The JGN line and the SINET line are connected at Otemachi, allowing for optical connection of the 34 m radio telescope at NICT Kashima which is connected by a JGN line.

(3) Japanese VLBI Network Observation

Activity is underway to organize a network of twelve VLBI observation stations in Japan: four NAOJ VERA stations, the 11 m radio telescope at Hokkaido University Tomakomai, the 34 m radio telescope at 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 radio telescopes at the NAOJ Ibaraki Observatory (32 m in Hitachi, 32 m in Takahagi). Of these radio telescopes, the 34 m radio telescope at NICT Kashima sustained major damage to its azimuth rotation wheels in the 2011 earthquake, and reconstruction work was performed with a target date of end of FY 2012. The Ibaraki Observatory was completely restored at the end of FY 2012.

VLBI observation goals in Japan include high-precision mapping at a high map dynamic range in the 8 GHz band and the 22 GHz band, as well as the observation of methanol masers in the 6.7 GHz band and water masers in the 22 GHz band. There are also plans for sustained participation in observations of flares caused by gas accretion into the center of the Milkey Way galaxy, currently a major topic of discussion, by the 10 m Mizusawa telescope, as well as the Ibaraki, Kashima, and Usuda stations.

Inter-university personnel transfers were also performed, with graduating students from Hokkaido University and the University of Tsukuba being sent to Yamaguchi University to participate in Japanese VLBI Network research activities as research fellows of the Japan Society for the Promotion of Science (JSPS) or extraordinary assistant professors. Kagoshima University graduates were hired as specially-appointed research fellows at the NAOJ Chile Observatory to participate in the ALMA Project, as well as VLBI observational research. In FY 2012, two graduate students from Gifu University were stationed at the Mizusawa VLBI Observatory (Mitaka) and published their masters' theses on the development of broadband VLBI observational devices.

(4) Japan/Korea, East Asia VLBI Observation

Along with collaboration to establish the Korean VLBI Network (KVN), joint Japan-Korea development efforts for a next-generation large VLBI correlator proceeded apace on the campus of Yongsei University in Seoul. The correlator was moved to the East Asia VLBI Research Center of the Korea Astronomy and Space Science Institute (KASI) and put into normal operation in October 2012. Using a combined array formed in cooperation between KVN and VERA in Japan, test observations were performed and the resulting data was successfully processed. Regular meetings about the operation of the combined array are being held. Conferences between the Directors of the Japanese and Korean observatories and correlation station operation conferences are held once every three months regarding the operation of the Seoul correlation station developed jointly by Japan and Korea.

With regard to the East Asia VLBI Network, concrete discussions on the state of observational research and future observation plans are being held at the East Asia VLBI Consortium.

(5) Gravitational Observation / Geodetic VLBI Research

In order to increase the accuracy of VERA-based mm-level geodesy, collocation observations are being performed using various means – namely, VLBI, GPS, and gravitational – and research and development into precise geodetic observation is underway. Superconducting gravimeter (SG) observations are

also being performed within the framework of the international project GGP under the auspices of IAG, with the obtained data being shared by researchers both inside and outside Japan. Research is being conducted into the rotation of the Earth, the tides, the coupling dynamics between the lithosphere and hydrosphere of the Earth, and the relationship between fluctuations in the gravitational and displacement fields. Research is also being conducted into the close relationship between these phenomena and fluctuations in the Earth's environment. To realize these goals, a compact absolute gravimeter and a model for gravitational changes arising from environmental changes commensurate with SG observational precision are also being developed.

(6) Ishigakijima Astronomical Observatory

This observatory has the largest (105 cm aperture) optical infrared telescope in the Kyushu-Okinawa area, nicknamed "Murikabushi," and takes advantage of the locational conditions at latitude 24 ° N and longitude 124° E to engage in gamma-ray burst (GRB) afterglow observation in collaboration with the MITSuME three-color simultaneous imaging camera system (at Okayama Astrophysical Observatory), as well as engaging observational studies of supernova explosions and sudden phenomena occurring in comets and planetoids. The observatory also plays an important role in the Optical and Infrared Synergetic Telescopes for Education and Research (OISTER) observational network established in 2011.

The Observatory also functions as a public astronomical observatory where astronomical observation events for the general public are held on weekends and holidays; welcoming over 9,000 visitors annually. The Observatory also contributes to primary and continuing education. Lectures in astronomy and observation workshops are held every year on Ishigakijima as part of an educational series conducted jointly with the University of the Ryukyus, with whom a partnership was formed in 2009. The Observatory also collaborates in the Open University of Japan's Ishigakijima Campus Project. The Observatory is also cooperating in the city of Ishigaki's "Starry Sky Educational Room" project being constructed at the Ishigakijima Astronomical Observatory and scheduled for completion in FY 2013.

Starting in FY 2013, organizational restructuring is underway to merge Ishigakijima Astronomical Observatory subprojects with projects at the Mizusawa VLBI Observatory.

2. Project Progress

(1) VERA

1) Overall Research

In FY 2012, astrometric observations were performed for astronomical objects on the approximately 400-item project object list updated the preceding year. As in previous years observations were performed at a pace of roughly 40 object/year, and monitoring observational data has been obtained for a total of more than 150 objects as of FY 2012. Particularly noteworthy among the fruits of this observational data is the publication of the first structural analysis of the Milky Way (Honma et al. 2012). An evaluation of the basic structure of the Milky Way using a total of 52 objects sampled from the observational results yielded thus far by VERA, as well as from the VLBA in the United States and the EVN in Europe, resulted in a Galactic center distance of $R0 = 8.05 \pm 0.45$ kpc and an LSR Galactic angular velocity of $\Theta 0 = 238 \pm 14$ km/s/kpc. These results suggest that the value of 220 km/s recommended by the IAU for LSR angular velocity $\Theta 0$ should be corrected upwards. These results also suggest that the mass of the Milky Way is 20% greater than previously believed. This is highly significant for dark matter research. A press conference on this research was held in October 2012, and reports appeared in newspapers across Japan, contributing to increased awareness and PR for the results yielded by VERA and the NAOJ.

Apart from researches into the structure of the Milky Way, numerous results were also obtained in the field of astrometry observations. Sakai et al. (2012) presents an accurate measurement of the distance to star-forming region IRAS 05168+3634. Previously this object was kinematically estimated to have a distance of 6 kpc, but VERA observational results revealed a value of roughly 1.88 kpc, roughly 1/3 that of the previous value. This reiterates the importance of precise triangulation-based distance determination. Based on the distance and proper motion of this object, limits were successfully placed upon the rotational velocity of the Milky Way outside the solar circle, the movement of the Perseus Arm, and the like. Systematic noncircular motion has started to become apparent in this object along with multiple other objects near the Perseus Arm. VERA observational results are expected to contribute greatly to the study of noncircular spiral components in the future. Results based on astrometry were obtained not only for regions with star formation but also for late-type star observation, such as a determination of the distance to the late-type star IRAS 22480+6002 (Imai et al. 2012) leading to the physical mass of this object being revised and showing that this star is a K-type red supergiant.

Along with research into the structure of the Milky Way and astrometric observations, research into maser phenomena and maser objects is also being conducted. Chibueze et al. (2012) discovered a new water maser bipolar outflow in the massive star-forming region Cep-A, leading to new discoveries regarding massive star formation in this region. The massive star-forming region G353.273+0.641 was observed using ATCA in Australia and the 45 m telescope at Nobeyama in addition to maser observation by VERA, revealing that this object releases a high-velocity bipolar jet roughly along the line of sight (Motogi et al. 2013). Combining data from VERA and ALMA led to the successful detection of a new water maser in the 232 GHz band in the Orion Nebula (Hirota et al. 2012), along with expanding results obtained by VERA for application to ALMA-based observation. In the field of maser observation, Japan and Korea are jointly conducting test observation using VERA and KVN, promising further research developments in this field by using high-sensitivity imaging.

Meanwhile, AGN research using VERA has become active in recent years. High-frequency monitoring of gamma ray-emitting AGNs (called "blazars") is being conducted in the GENJI Project, which makes systematic use of fringe finder data from VERA Project observation. The first paper on the results of GENJI was published this year. VERA observational results played an important role in multi-frequency observations in the paper discussing radio brightening accompanying gamma-ray flares from the blazar PKS 1510-089 (Orienti et al. 2012), as well as in a paper providing an overview of the GENJI Project (Nagai et al. 2013). Members of the Mizusawa VLBI Observatory also contributed to international millimeter- and submillimeter-wave VLBI observations for future AGN research, and VLBI observation of AGNs in the 1 mm band are starting to yield intriguing results (Doeleman et al. 2012, Lu et al. 2012). Joint observations by VERA and KVN, with expanded contributions from VERA, show promise for VLBI-based AGN research, and the Japanese-Korean team is actively engaging in scientific inquiry and evaluation of test observational results in this field as well.

2) Geophysical / Geodetic Research

Geodetic VLBI observations have been made stable in the 22 GHz band, the highest frequency used worldwide, achieving maximal positional precision. This observation was continued in FY 2012. In ordinary geodetic observation in the S/X band, the effects of the ionosphere are estimated from dual-frequency observational data but cannot be observationally obtained from single-frequency observation in the 22 GHz band. It was shown that, although the ionosphere exhibits little effect in the 22 GHz band, incorporation of ionosphere models found using other means, such as GPS, into analysis allows for further improvement to geodetic observational results in the 22 GHz band.

The displacement velocity field of the Japanese Archipelago was greatly altered over a broad range by the Tohoku Pacific Coast Earthquake (Great East Japan Earthquake) that occurred on March 11, 2011. The coordinates of the VERA Mizusawa station, as found via VLBI and GPS, had exhibited a gradual southwesterly movement of over 10 mm per annum before the earthquake, but exhibited dramatic movement in the east-southeast direction after the earthquake, and log(t) fluctuations continue even two years later. This suggests that these fluctuations will continue over a considerable period into the future. Results for observations of distortion in the Earth's crust at the Esashi Earth Tides Station suggest that the annual east-west compression field of approximately 2×10^{-7} prior to the earthquake had shifted following the earthquake to an east-west expansion field of approximately 1.2×10^{-6} at the end of 2011 and 4×10^{-7} at the end of 2012. This may be the first case in which continuous observation using precise geodetic technology has been used to determine how the crust and upper mantle deform following a large-scale earthquake, and whether they continue to deform. The continuing accumulation of observational data is expected to be a valuable future resource.

To determine the coordinates for the various VERA stations, displacement velocity from data 2005 to 2008 at the Iriki station, where coordinate fluctuations are believed to be relatively stable, is assumed to be linearly representable and coordinates for the other three stations are found based on this assumption. In order to join VERA station coordinates with the global coordinate system, the two stations at Mizusawa and Ishigakijima are participating in geodetic observations within Japan (JADE observation) and international observations (IVS-T2 observation); however, coordinate fluctuations at these stations exhibit some degree of irregularity, complicating the process of determining coordinates considerably. Sustained GPS observations at the observation stations reveal a certain degree of annual mm-level fluctuations in the coordinates, but the causes for are unknown, and annual variations are not applied to the coordinates of the VERA stations. The purpose of VERA is to measure the annual parallax of celestial objects, but the presence of an annual variation in the coordinates carries a risk of introducing systematic errors into annual parallax measurement. Therefore the annual fluctuations must be carefully investigated. A coordinate precision of 2 mm is estimated to be necessary for VERA in the strictest observational conditions; annual fluctuation is roughly equal in level. Based on the observational conditions, this level may be negligible, but modeling of the annual fluctuations will be necessary in the future in order to achieve maximum VERA precision.

The greatest cause of error in VERA astrometric observations is radio wave propagation delay due to moisture in the atmosphere. An estimated value for zenith delay has been obtained as a by-product of GPS analysis. Improving the analysis is presumed to have slightly improved the estimation precision. Objective 5 km mesh analytical data has also been purchased from the Japan Meteorological Agency (JMA), and comparison with the zenith delay estimated from meteorological data is underway.

3) Operation History

Observation at the four VERA stations is performed via remote control from the array operation center at Mizusawa, with 3,828 hours of observations being performed over 440 sessions in FY 2012. Performed observation included VERA open use observations; VERA Project observations for measuring annual parallax in order 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 test observations together with arrays such as the Korean VLBI Network (KVN). The number and length of these VLBI observations are as follows:

VERA open use observations: 45 sessions, 354 hours
VERA Project, test observations: 325 sessions, 2,493 hours
VERA geodetic observations: 24 sessions, 591 hours
Japanese VLBI Network observations: 12 sessions, 118 hours
Joint VLBI observations with KVN: 34 sessions, 272 hours

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 respective observers; and those for the Project observations and geodetic observations were sent to the analysts in charge.

4) Maintenance

The VERA Maintenance Group performed systematic performance checks and manufacturer maintenance work once annually, while everyday upkeep (antenna greasing, painting, repairs) was performed independently at each station.

The bid participation eligibility of the previous industrial contractor was suspended at the end of the previous year, prohibiting the annual antenna maintenance, which constitutes a large portion of annual VERA maintenance work. The contract guidelines provided by the observatory response meeting were for "work that must be performed immediately, work that can only be performed by a certain contractor, and work for which there are clearly no past contract violations." Now that 10 years have elapsed since VERA was constructed, antenna actuation difficulties and oil leakage from motor actuation parts are occurring, and since this is the last year that overhauls of the motor and actuation control apparatus can be requested from the manufacturer, the motor and actuation control device exhibiting problems must be overhauled this year. In addition, because the motor is integrated with the antenna, it can only be changed out by the same contractor as before. It was proved via documentation that there were no violations in the past, and explanatory materials for 2006–2011 were prepared and submitted to National Institutes of Natural Sciences (NINS), and received approval. However, it took time to prepare the explanatory materials, forcing the maintenance period to be shifted from the period from June through August, which is not suited for annual radio astronomical observation, to the period from October through December. Annual antenna maintenance work was limited to an overhaul of the defective motor actuation system. Ordinary maintenance of the receiver system was performed, but a high level of phase fluctuation was exhibited at the Mizusawa station, requiring the insertion of an isolator.

At the Iriki station, the feedome membrane developed for VERA was replaced. At the Mizusawa station, the foundation was reinforced with a waterproof coating.

Ordinary antenna maintenance work, which was to be performed at the end of this year, will be performed next year, and efforts will be made to improve the efficiency of maintenance and maintenance parts purchases. Large-scale refurbishing of the observational system as a whole remains the most important task at hand.

5) Technological Development

Major technological development agenda items include developing a software-based correlator to replace the aging FX correlator, and developing a disk-based recording/playback device to replace the magnetic tape recording device, for which the manufacturer warranty period has run out.

As part of software correlator development, bugs in related software developed in previous years were fixed, and the performance was evaluated using observational data. The performance evaluation observation process also doubled as a test run. The limited human resources for development were primarily focused on developing a correlator compatible with the FX correlator. The performance evaluation confirmed that delay, phase, and SNR all matched. Software correlation featuring a dramatically increased number of spectral points allowed for maser component breakdowns in 6.7 GHz band methanol maser observations, confirming the potential for new scientific developments. Correlator operation by an external corporation has been begun, and a framework allowing full-fledged operation is being established.

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. Fringes were successfully obtained by the previous year, and basic performance was confirmed. This year, disk recording test runs were performed in tandem with observations to standardize and stabilize the operation of existing systems. A number of bugs were discovered, the causes of which were determined and corrected with manufacturer assistance. Major advances were obtained related to control problems arising from packets being discarded in competing control processes, and other problems only occurring in states similar to actual operation. Some problems remain to be addressed, and we are working to determine the causes while collecting information about the conditions in which they occur.

In addition, although it is an agenda item for future projects, an 8 Gbps ultra-broadband system structure has been rolled out at four VERA stations, and research and development into improving VLBI performance by increasing bandwidth was performed. Results include, indications of a roughly threefold improvement in overall sensitivity due to an eightfold increase in bandwidth, the lack of the digital filter loss which the system currently suffers, etc. Previously undetectable faint reference radio sources can now be used in phare-referencing observation, and it was shown that, probabilistically speaking, at least one reference radio source is present for any given maser source.

In other news, in ultra-high-speed AD converter development, one test model was installed on the 20 m and 10 m antennas at Mizusawa; direct AD conversion was performed on the 22 GHz signal of the 20 m antenna without converting frequency, correlation with a signal consisting of the AD-converted baseband of the 10 m antenna was performed, and a fringe was successfully obtained. This experiment used a software recording PC into which VDIF-format data transmitted at 10 GbE was directly inputted, indicating usefulness in actual software recording operation.

Development of the Korea-Japan Joint VLBI Correlator (KJJVC) is also underway in cooperation with Korea. System construction for 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. Data analysis study and

evaluation for the VCS and post-processing/archival software, which Korea was primarily in charge of developing, was also performed along with the assigned Japanese manufacturer. This contributed greatly to the overall progress of the KJJVC, such as by allowing for correlation results comparable to those yielded by the FX correlator at Mitaka.

(2) Optical Fiber-Connected VLBI

In the Optical Fiber-Connected VLBI Project, the NII network constituting the main line (SINET3) was switched to SINET4 in April 2011. The NICT network JGN2+ was upgraded to JGN-X. And communication protocols were altered, requiring adjustments at all observational stations. Migration at Yamaguchi University, Gifu University, and GSI was completed by the previous year, and was performed at the other stations in FY 2012.

For the 11 m radio telescope at Hokkaido University Tomakomai, K5PC equipment owned by Hokkaido University and a local access line were modified to perform a data transmission test rather than using OCTAVIA, thereby showing that optically joined observation was possible.

Data from the Kashima station was transmitted via a local access line and a JGN line to the NICT Koganei station, which was connected to Mitaka via a GEMNET2 line, but it was discovered that various circumstances inhibited line maintenance, and efforts were made to find a method to connect the JGN-X line and the SINET4 line at Otemachi. As a result, approval was obtained from the various concerned organizations, and efforts to establish the necessary infrastructure are currently underway.

Effects from the earthquake were still present in the Ibaraki station and Kashima station connections, but a temporary broadband disk recording device was installed at the Ibaraki station as a broadband observation device and used to perform a fringe test, demonstrating the capability for that quasi-real-time observation and observation combined with data transportation.

Using the broadband X-band observation device which had been maintained up to now at the Usuda station, Japanese VLBI Network observation was performed as normal. Especially, observations like a survey of stars emitting non-thermal radiation demonstrated the developments made in a new array fusing fiber optics and VERA by using VERA and X-band observations.

(3) Japanese VLBI Network Observation

Japanese VLBI Network observation projects were continued in FY 2012. Monetary transfers to the universities concerned allowed for the performance of telescope maintenance and the hiring of postdoctoral fellows at these universities without impediment. Osaka Prefecture University also participated in receiver development starting from 2007. Ibaraki University joined in 2008, and a framework for Ibaraki University to take charge of observational operations was established 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, and methanol maser objects were successfully observed. In 2010, VLBI observation was successfully performed using the 32 m radio telescope at Hitachi, but operation was suspended following the Great East Japan Earthquake in March 2011. Entering FY 2012, primary reconstruction of the Ibaraki station was performed and test operations began. Secondary reconstruction was performed at the end of FY 2012, leading to complete reconstruction.

Methanol maser observation has been continuously performed since 2008, with VERA observation stations participating. The rotational motion of gas as it accreted was successfully observed in the massive star-forming region Cep-A. Results published in scholarly journals include the successful detection of 36 objects in surveying observations which included the Shanghai station. Monitoring observations results for the blazar PKS 1510-089 (short-period intensity fluctuations) and VLBI observational results immediately following Mrk-421 flares were also published as papers.

Observational bandwidth was also increased; broadband disk recording devices were introduced at the Yamaguchi and Ibaraki stations; and tools for designing a new power supply device were introduced at Osaka Prefecture University. The drive device for the 32 m telescope in Yamaguchi was also refurbished using the budget from Yamaguchi University. A receiver cooling device for the 11 m telescope at Gifu University was also provided as part of the maintenance.

Guidelines for the open use of the Japanese VLBI Observation Network were discussed at biweekly operation meetings, and a policy of calling for public applications for roughly 100 hours of annual observation time once year was settled upon.

(4) Japan/Korea, East Asia VLBI Observation

Along with assisting in setting up KVN in Korea, we assisted in standardizing the next-generation large VLBI correlator (KJVC) being jointly developed by Japan and Korea. After setting up the KJVC at Yongsei University in Seoul, the KJVC was moved to the East Asia VLBI Research Center of KASI in Daejon in October 2012 to start normal correlation processing.

Scientific test observations were performed using a combined array formed by cooperation between KVN and VERA in Japan, and resulting data was successfully processed. Japanese and Korean researchers formed investigative work groups for four fields (star-forming regions, late-type stars, active galactic nuclei, and astrometry) and held regular monthly report sessions and regular conferences on the operation of the combined array. Scientific evaluation test observations proposed by these working groups were performed, and significant improvements in imaging performance and sensitivity were demonstrated by joining the Japanese and Korean VLBI observation networks. In particular, a more than twofold increase in detectable spots was reported in maser spot observations. The capability to image the microstructure of jets emitted from galactic nuclei in AGN observation was also demonstrated. In January 2013, a Japan/Korea scientific conference was held at Seoul National University, and scientific evaluation test observation results were discussed. Particular attention was devoted to 43 GHz-band

methanol maser observation results.

Meetings of the Directors of the Japanese and Korean Observatories regarding the operation of the correlation station jointly developed by Japan and Korea in Seoul are held on a quarterly basis. For FY 2012, the meetings were held in April, July, and November 2012 and January 2013. Quarterly operations history and the apportionment of operating expenses between Japan and Korea are discussed at the correlator operation meetings.

Concrete discussions on future observation plans are being held at the East Asia VLBI Consortium regarding the East Asia VLBI Network. East Asia VLBI observation network workshops are also held once annually. The FY 2012 workshop was held in May in Taiwan, and the FY 2013 workshop is to be held in June in Korea's Jeju Province.

(5) Ishigakijima Astronomical Observatory

Rapid response to sudden, spontaneous phenomena was performed using the three-color simultaneous imaging camera MITSuME introduced for joint research at Tokyo Institute of Technology and Okayama Astrophysical Observatory. Internationally noteworthy results were published in Astrophys. J. (vol. 757, No. 2, 176, 2012). Observations of the Kopff comet (22P/Kopff) revealed its neckline and jet structures, and the results were published in the journal PASJ (Astronomical Society of Japan, vol. 64, 134, 2012). The observatory also made important contributions to physics discoveries as part of cooperative interuniversity observations of GRBs, supernovas, planetoids, comets, and other sudden objects by providing rapid response and capturing increases and decreases in luminosity.

A course conducted in cooperation with the University of the Ryukyus entered its fourth year. The continuous popularity of the classroom lectures at the University and the observational workshops on Ishigakijima have led to them being so competitive that less than half of applicants are admitted, leading to discussions of expanding into a university for the study of astronomy. The "Chura-boshi (beautiful star) Research Team" workshop for local high school students also continues to deliver results. The observatory has also taken part in observation sessions and lectures for elementary and junior high school students, workplace visits for high school students, and social welfare organization study groups, thus contributing to both primary and adult education in the community. The observatory has also cooperated in study sessions for CEO groups and the travel and hospitality industries, helping to energize the local economy.

(6) VLBI Planetary Exploration

The lunar orbiter Kaguya (SELENE) performed differential VLBI observation via two sub-satellites, along with Doppler observations and distance measurements, revealing increases in gravitational field at the edges and rear of the Moon (Goossens et al. 2011).

The next lunar explorer (SELENE-2) is scheduled to perform differential VLBI observation using a lunar surface lander and a lunar orbiter, and to explore the interior of the Moon via variations in the lunar gravitational field and tides calculated from changes in the trajectory of the lunar orbiter. Information about whether the core and/or lower mantle of the moon are molten, along with the size of the core, is an important unresolved element in lunar evolution research. If the core is molten, might be caused by abundant sulfur in the core lowering its melting point. Likewise a molten lower mantle might be caused by abundant water lowering its melting point. Neither case can easily be explained by lunar formation models based on massive impacts.

In the SELENE-2 project, the lunar orbiter and the survival module to be placed on the surface of the moon will be installed with VLBI radio sources. Thus the development of necessary fundamental technologies, in particular a lunar surface radio source and protection for the antenna against cold temperatures, was conducted. In addition, since SELENE-2 will require that the path of the lunar orbiter be determined at high precision using the lunar surface radio source as a reference, a method is currently being developed to simultaneously track both radio sources via dual beams and eliminate the effects of the atmosphere and ionosphere. Development of an X-band dual-beam receiving system using scientific research expenditures has been underway since FY 2012.

3. Open Use / Joint Research

(1) Open Use

A call for proposals for FY 2012 open use 22 GHz band, 43 GHz band, and 6.7 GHz band observations was put out as in the previous year, and seven proposals for a total of 423 hours of observation were received. Four proposals for a total of 177 hours were received from overseas. These proposals were evaluated by a VLBI program subcommittee based on judgments of referees selected from researchers in relevant fields in Japan. Six proposals for a total of 359 hours were selected. Observation commenced in January 2013.

(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, and joint research is being conducted. A relationship of close cooperation has also been established with the Institute of Space and Astronautical Science (ISAS) at JAXA.

(3) Joint Japanese/Korean Research

NAOJ and KASI are engaged in joint development of an East Asia VLBI correlation center, and have developed a 16-channel correlator with 8 Gbps/channel. Following the tests performed in FY 2011, correlation tests were performed in FY 2012 using actual observational data in preparation for the shift to live operation, and correlation data outputted by the correlator is being jointly evaluated. Software improvements for computer storage of the correlation data in a format usable by analysis

software were also made. Correlation of VLBI test observations, which was performed using the combined array formed by VERA and KVN, was also performed using the FX correlator at NAOJ's Mitaka VLBI correlation center, and performance evaluations for the East Asia VLBI correlator and the combined array were also performed.

A working group to discuss the scientific goals of the VERA/KVN combined array was also begun, and the third joint science workshop was held in July 2012 at the Oshu Space and Astronomy Museum (Yugakukan) in the city of Oshu in Iwate Prefecture and the fourth was held in January 2013 at Seoul National University. At these joint science workshops, VERA/KVN combined array VLBI observational results and observation proposals were actively presented, and discussions were held to construct an observation plan which will exercise the full capabilities of the combined array.

(4) Joint Research

VERA stations are participating in geodetic VLBI observations (JADE observations) within Japan on the basis of a joint research agreement with GSI. The stations are also taking part in the international VLBI observation project IVS-T2, and efforts are being made to maintain VERA station coordinates.

GPS satellite and Galileo satellite observation are being performed as part of a research agreement with the Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences (GFZ-Potsdam) in Germany. GPS observational data has been made public as IGS observational points and are widely used by researchers. Galileo satellite observational data is positioned as observational points for determining satellite trajectory, and is widely utilized by geodetic researchers around the world, as well as by countless users of navigational data.

The term of the joint research agreement with the Norwegian Mapping Authority and the Australian National University Research School of Earth Sciences has run out, but exchange of superconducting gravimeter observational data with the Mt. Stromlo Observatory continues. This data is being used to conduct geodynamic research. Strain meter data and other information from the Esashi Earth Tides Station is being distributed in real-time to relevant research organizations via Tohoku University as part of a research agreement with the Earthquake Research Institute of the University of Tokyo. The data is used to study matters such as shifts in the Earth's crust resulting from earthquakes, and constitutes an open use of the facilities in the broad sense.

The University of Tokyo Earthquake Research Institute performed absolute and relative gravity measurements at the gravitational reference point of the Esashi Earth Tides Station in order to detect changes in gravity following the Tohoku Pacific Coast Earthquake.

4. PR / Awareness Promotion Activities

(1) Open House Events

April 15: The third "Open Observatory" event (a special open house at the Ibaraki University Center for Astronomy and the NAOJ Mizusawa VLBI Observatory Ibaraki Station) was held, with nearly 1,000 visitors attending.

August 11: The "Iwate Galaxy Festival 2012," a special open house of the Mizusawa station to the public was held, with nearly 2,200 visitors in attendance.

August 11: The VERA Iriki station was opened to the public as part of the "Yaeyama Kogen Star Festival 2012," with nearly 3,500 visitors in attendance.

August 18–26: The "2012 South Island Star Festival" (held simultaneously with a special open house of the VERA Ishigaki station and the Ishigakijima Astronomical Observatory) was held, starting with nearly 8,000 visitors to a dimmed-light stargazing event graced by a stunning night sky of unprecedented clarity; an astronomical observation party at the Ishigakijima Astronomical Observatory was also blessed with good weather and attended by 582 visitors; and a special public opening of the VERA station had 563 attendees; for a total festival participation of nearly 9,800 visitors.

August 25: A special open house event was held in the Nobeyama district, where a VERA public booth was set up, with 3,308 visitors in attendance.

February 11, 2013: The "Star Island 2012" event, a special open house of the VERA Ogasawara station was held, with 244 visitors in attendance. A four-dimensional digital space theater show was presented using "4D2U" technology to great acclaim. The lecture on astronomy held the previous day also had a full house.

(2) High School Student Hands-On Events

August 7–9: The Sixth "Z Star Research Team" event for Iwate high school students was held. Invitations were extended again this year to high school students within the prefecture, including tsunami-damaged areas, and there was a total of seven attendees. One team was lucky enough to detect water maser radio waves.

August 15–17: The VERA Ishigakijima station and the Ishigakijima Astronomical Observatory held the "Chura-boshi Research Team" workshop for high school students in Okinawa Prefecture, with 21 attendees. Exploratory observations for water maser objects were performed at the VERA Ishigaki station, and an extrasolar planet observation and data analysis workshop was held using the Murikabushi telescope.

The joint course started by the University of the Ryukyus and NAOJ in 2009 was held again this year, with classroom lectures being held at the university from August 13 to 16 and observational workshops being held at Ishigakijima with 28 in attendance. A horn radio telescope was constructed by hand at the VERA station and used to experience radio wave observation of the Milky Way. A supernova was also observed using the Murikabushi Telescope, and an image processing workshop was also held.

(3) Other

The Observatory cooperated in field trips for elementary school students in Oshu city and in outdoors workshops for prefectural high school students. The Ishigakijima station

cooperated in a job shadowing project run by Okinawa Prefecture, holding lectures on astronomy and workplace visits for local middle school students. The station also accepted local high school students as interns.

5. Timekeeping Office Operations

The Timekeeping Office is operated using four cesium atomic clocks. A second Timekeeping Office operational system was constructed in the Observational Equipment Wing for use when anti-earthquake reinforcement was being performed, and was subsequently used as a backup system. It was later moved to the underground atomic clock room and atomic clock management room of the Main Hall in tandem with the movement of the supercomputer to the Division of Theoretical Astronomy at Mitaka to construct an integrated timekeeping operation system. To prevent interruptions in data acquisition during malfunctions, a backup device was also provided for the British-made GPS clock comparator/receiver for use in international clock comparison, for which data acquisition had been suspended during the previous year in order to perform repairs. The continuous management and operation of a time system contributed to determining Coordinated Universal Time. The NTP protocol, which functions as a service for indicating Japan Central Standard Time on a network, continued from the previous year to reach more than 900,000 accesses per day.

A report on the state of the NAOJ's new timekeeping operations system was presented at the Consultative Committee for Time and Frequency (CCTF) held once every three years at the International Bureau of Weights and Measures (BIPM) in France.

6. Educational Activities

As part of graduate student education, three graduate students from the University of Tokyo and three from the Graduate University for Advanced Studies were educated. Advice for masters' theses was also given to two visiting graduate students from Gifu University. Two undergraduate students from Kobe University and Waseda University were accepted as summer students of the Graduate University for Advanced Studies, and were given research guidance related to lunar radio waves.

7. VLBI Operation Subcommittee

The VLBI Operation Subcommittee is a subcommittee of the Radio Wave Specialist Committee set up to discuss the operation and guidelines of Japanese VLBI observation networks, including VERA. The subcommittee met four times in FY 2012 – in April, September, November, and February 2013 – to discuss the basic policy for open use of VERA, observational collaboration with KVN, research collaboration with RISE, and policies for VLBI research in Japan as a whole, which were reported to the Radio Wave Specialist Committee.

8. VERA Project 10th Anniversary Ceremony

An anniversary ceremony was held on October 5 at Oshu City Cultural Hall (Z-Hall) to commemorate 2012 as the 10th year since VERA Project observation began in earnest, as well as to present a report on the latest research results for the Milky Way Galaxy. The ceremony was attended by nearly 200, including representatives of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and NINS, previous Director Generals, and university representatives. A commemorative publication of research results over the past 10 years was also issued.

After the ceremony, a "VERA Summit" and celebratory banquet attended by the heads of the local governments hosting various VERA observation stations were held, bringing the ceremony to a grand conclusion.

2. Nobeyama Radio Observatory

1. 45 m Radio Telescope

(1) Open Use

The 31st open use observation period began on January 7, 2013. Twenty projects (out of 39 submissions) including three from overseas were selected for general observations during the first half of the year. Twelve projects (out of 20 submissions) including four from overseas were selected for general observations during the second half of the year. Nine projects for short programs (out of 15 submissions) including one from overseas, and one educational support project (out of three submissions) were selected for the first and second half-years periods combined.

One backup program (out of one submission) was adopted for use in case inclement weather prevented ideal observation. Two other open use projects utilizing VERA were also conducted.

(2) Device Repair/Development

Work on device maintenance and the development and stabilization of a new observational system was continued from the previous year.

- Parts were replaced due to a malfunction in the sub-reflector of the antenna, quickly restoring the antenna to a state where operation could continue unimpeded.

The following progress was made this year in developing a new observational system:

- The dual-beam receiver TZ was improved, and beam 1, the

main beam, was opened to public use. It became widely used as a primary receiver for the 100 GHz band.
- A new multi-beam receiver, FOREST, was installed, and tests and improvements were performed.
- The stability of the AD converter and the SAM45 spectrometer was improved.
- Software related to the new receivers was improved and supplemented.
- Remote observation from the Mitaka campus was allowed for open use on a limited basis.

(3) Research Results

Two projects (a) a star formation project and (b) a distant galaxies project were implemented as 45 m telescope legacy projects. Project results were as follows.

(a) In the star formation legacy project, a T100 receiver was used to perform multiline observation of the nearby star-forming region Aquila Rift and protostar cores. The star cluster-forming region Serpens South was observed in the Aquila Rift, and a strong protostar outflow was identified by using SiO. Comparison with the SMA suggests that the source of this outflow is seen edge-on. In protostar core observations, the rotational movement of the circumstellar gas was detected from C18O. It was also found that compared to other lines, H13CO+ (1–0) was the optimal line for tracing the distribution of high-density gases around protostars.

(b) Submillimeter galaxies are important objects for the study of galactic formation at the beginning of the Universe. However, because they are enveloped by large quantities of dust, they are extremely dark in the visible and infrared spectra, making it extremely difficult to accurately determine their redshift. 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 made it possible to directly determine the redshift of astronomical objects. This year, a blind redshift search has been performed on four objects having undetermined redshifts. All these objects are believed to be subject to strong gravitational lensing, and CO emission line detection is expected.

2. NMA-F (SPART project)

A planetary atmospheric observation project (SPART project) for observation of the Solar System was implemented using Interferometer NMA-F (Grant-in-Aid for Scientific Research: Representative Maezawa), and work is underway on a paper detailing the results of the carbon monoxide analysis of Venus and Mars. In FY 2012, a number of Unix (Solaris) computers with conventional NMA COSMOS control system were consolidated into only three LINUX /Python–based machines to simplify the system, allowing for telescope control and remote observations from Osaka Prefecture University. Concurrently, on-the-fly mapping observations became possible for planets with large apparent diameters. In addition, a 200 GHz-band receiver system was set up and improved, and development is underway for allowing remote switching between 100 GHz/200 GHz RF/IF systems. This enables observations of multiple transition lines of molecular species, thereby allowing for a more accurate calculation of physical quantities such as short/long term temporal variability in the abundance of minor constituents and altitude distributions in planetary atmospheres. Meanwhile, malfunctions occurred in the SD unit, ACU unit, and azimuth gearing when operation of Interferometer F began in late autumn this season. The malfunction in the SD unit was remedied by repairing the aging power system and board for the 400 Hz reference signal with help from Tamagawa Seiki. Methods for refurbishing the ACU unit and azimuth gearing are under discussion with Mitsubishi.

3. Development of a Multicolor Millimeter/Submillimeter Camera for ASTE

Simultaneous imaging in multiple wavelengths in the millimeter/submillimeter bands is a vital tool in estimating the redshift of submillimeter galaxies, studying the internal structure of hot plasma in clusters of galaxies using the Sunyaev–Zel'dovich effect, and constraining physical quantities (temperature, index) of the dust in star-forming regions and the spectral index of the initial submillimeter afterglow of gamma ray bursts. Thus, the development of a multicolor millimeter/submillimeter camera for observation at wavelengths of 1.1 mm, 0.87 mm, and 0.46 mm is underway in order to further expand upon the success in large-scale sky surveys in a single color (wavelength 1.1 m) with the AzTEC continuum camera. The TES bolometer (a superconductive thermal detector that reads abrupt change in resistance resulting from absorption of incoming photons at the superconducting transition edge), which has undergone rapid technical advancement in large-scale arrays in recent years, is used as the detector. Output of the TESs are multiplexed in frequency domain and read out using a SQUID (superconducting quantum interference device). A millimeter/submillimeter dichroic filter enables the simultaneous observations at two wavelengths. First, a 450-pixel camera capable of simultaneous two-color imaging at 1.1 mm and 0.87 mm wavelengths was developed. The receiver was assembled and evaluated in the laboratory to prepare for the field test followed by the transportation to Atacama in Chile, and the successful installation on the ASTE telescope during May and June 2012. As the largest-ever system to occupy the receiver cabin of the ASTE, considerable effort was made not only to mount the camera in the receiver cabin, but also to reorganize the network infrastructure and to drastically improve the electromagnetically noisy environment in the cabin. Despite the limited man power, "first light" in two bands using astronomical signal was successfully acquired. Meanwhile, along with the unexpected difficulties such as problems during transportation and starting up the cryocooler in severe conditions, numerous issues to be solved were found, such as the possibility of lowering of the optical efficiency. Although problems remain to be addressed, the fact that everything from the camera

controls to the data acquisition and analysis systems were examined and first light was obtained lead to the giant leap for the development. Due to problems in the ASTE infrastructure system, decision was made to further evaluate the optical system in the laboratory while preparing for the commissioning run in FY 2013 (Takekoshi et al. 2012, IEEE Trans. THz Sci. Tech., vol. 2, 54; Oshima et al. 2013, IEEE Trans. Appl. Supercond., vol. 23, 2101004, Hirota et al. 2013, IEEE Trans. Appl. Supercond., vol. 23, 2101305).

4. Other

(1) PR Activities in the Nobeyama Campus

1) PR Activities in the Nobeyama Campus

The campus has been permanently open to the public since the founding of the observatory in 1982. This year 59,383 visitors, including participants in the special open house event, were welcomed. There were 13 tours of the facilities given by staff, 5 requests for lectures, and a total of 18 requests for photographs or interviews. In addition, 18 students from a total of six schools, primarily nearby junior high schools, came to the observatory as participants in workplace visits from June to October, and had a chance to experience working at the observatory under staff guidance. "The workshop of Radio Astronomical Observation" using the 45 m radio telescope was held again this year from July 30 to August 3, with 12 undergraduate students in attendance. Although the burden required in guiding the students from observations to presentation of the results is not insignificant, the event is a valuable opportunity for undergraduates to experience observations using a radio telescope.

Along with posters and panel displays in the permanently open areas of the facility, a movie introducing the various facilities of the observatory and research results plays constantly in the visitor room. For internet-based PR, the observatory runs a website focusing on explanations of the observational equipment in operation at the observatory.

2) Commemoration of the 30th Anniversary of the Nobeyama Radio Observatory

2012 marked the 30th anniversary since the Observatory opened. A 30-year anniversary ceremony, commemorative lecture, and banquet were held in the city of Hokuto in Yamanashi Prefecture on September 26, with nearly 160 participants in attendance. Along with a 30th anniversary commemorative publication, a movie showing the past 30 years of history at the observatory was produced.

An international symposium, "New Trends in Radio Astronomy in the ALMA Era: The 30th Anniversary of Nobeyama Radio Observatory", was also held in Hakone from December 3 to 8.

(2) NRO Conference Workshops

- July 25–26, 2012
  30th NRO Users Meeting (representative: Daisuke Iono)
- August 1–4, 2012
  42nd Summer School for Young Researchers on Astronomy and Astrophysics 2012 (representative: Masato Yasumi)
- September 6–8, 2012
  Workshop on the Milky Way Galaxy in 2012: large-scale surveys and the latest image of our Galaxy (representative: Toshihiro Handa)
- December 10–12, 2012
  Star Formation 2012 (representative: Fumitaka Nakamura)
- March 29, 2013
  Nobeyama Legacy Project Mini-Workshop (representative: Aya Higuchi)

(3) Part-time Research Staff Transfers

- Researchers
  Yoshito Shimajiri: Le Centre CEA de Saclay (Saclay Nuclear Research Center)
  Hiroko Shinnaga: Specially-Appointed Associate Professor, NAOJ Chile Observatory
- Research Supporters
  Tomohisa Yonezu
  Max Curran

3. Nobeyama Solar Radio Observatory

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

According to the latest investigation the radioheliographs exhibit few problems, despite now having been in operation for 21 years since 1992. They have had utilization rates over 99% for the past 10 years, offering consistent high quality data of for open use. The radio polarimeter has also offered well-calibrated data over extended periods. 2013 is expected to feature the maximum of the 24th solar activity cycle, but the level of activity is extremely low compared to past maximums with few large sunspots or flares.

2. PR Activities

The observatory engaged in PR activities in tandem with a series of solar events that occurred during the summer: an annular solar eclipse on the morning of May 22 and the transit of Venus across the Sun on June 6. Modified software to allow for synthesis even using solar images with significant eclipse was prepared, and images were transmitted in quasi-real-time during the annular eclipse. Although the observatory was not open to

the public due to the early morning occurrence of the eclipse, TV station cameras filmed the event from within the observation room for broadcast on the afternoon and evening news.

A paper was published comparing radio butterfly diagrams using 20 years of data from the radioheliograph with magnetic observation data from the United States and suggested that solar activity is currently waning. A press conference about the paper was held on May 31. Reporters from nine newspapers and news agencies attended, and articles were subsequently carried in various newspapers. There is an extremely high level of public interest in the solar activity decrease. During the autumn astronomical conference a press conference was held about a paper comparing these radio butterfly diagrams with solar wind butterfly diagrams form observations at the Solar-Terrestrial Environment Laboratory of Nagoya University and discussing the relationship between the Sun and interplanetary space. A report was made to the press in tandem with the conference.

3. International Symposium

Hosting an international symposium was the largest undertaking this year at the Nobeyama Solar Radio Observatory. For four days from November 20 to 23, at Nagoya University's Symposion Hall, 20 years of radioheliograph results were presented and future activities were discussed under the theme "Solar Physics with Radio Observations: Twenty years of Nobeyama Radioheliograph and Beyond." There were 32 participants from 10 overseas countries and 31 from within Japan, 14 review lectures, 19 oral reports of research results, and 27 poster reports. There were five sessions – S1: Particle acceleration and oscillations in solar flares; S2: Prominence eruptions and interplanetary disturbances; S3: Quiet sun, active regions and global solar activity; S4: Current and next generation instruments; and S5: Future directions of solar radio astronomy and roles of NoRH – showing the wide array of fields within solar physics in which data from the Nobeyama radioheliographs is put to use. The research results presented will be published in a PASJ special edition, in addition to the reviews and such being published as conference proceedings.

4. Continuing Radioheliograph Operation

The ongoing decrease in solar activity and the resultant manifest effects on interplanetary space and the upper atmosphere of the Earth have led to a reexamination of long-term solar observational data. Combining data from the Nobeyama radio polarimeter with observations from Nagoya University's Research Institute of Atmospherics, there is a total of 61 years of data, and a calibration method has been firmly established, making this data extremely valuable. The performance of the radioheliographs has been maintained over 20 years, preserving image data quality and allowing for stable data calibration. The demand for continued operation from researchers around the world has grown especially keen following the recognition that brightening in the polar regions of the Sun are extremely important as indexes of polar area activity.

Based on requests from researchers around the world, the chairmen of the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP), 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 NINS and the Director General of NAOJ to continue radioheliograph operation from FY 2015 onward. A panel discussion on the matter was held during Session 5 of the international symposium mentioned above, "Future directions of solar radio astronomy and roles of NoRH," and a proposal was made that Nagoya University take the lead in continuing radioheliograph operations from FY 2015 onward with assistance from NAOJ and partners from overseas.

Domestically, the Astronomy and Astrophysics Subcommittee of Science Council of Japan is currently discussing the matter in the context of future plans in various fields. The radioheliograph operation may be continued as part of the inter-university "Next-Generation Heliospheric Environment Variation Observation Network Plan" proposed for the solar sciences.

5. Open Use and Consortium Activities

All observed data is released to the public, and is used in studies by researchers around the world, as well as for PR activities. Open use is also supported by a consortium of university users in Japan. A solar research symposium titled "Solar Research of Activity Maximums: Laying the Ground for New Directions in Solar Research" was held at Rikkyo University from February 20 to 22 with cooperation from solar-related organizations in Japan, and reports on activities and research results were presented.

Two PhD students from Russia's Scientific Research Institute of Radio Physics (S. Kuznetsov and A. Morgachev) stayed for one month and one PhD student from Brazil's INPE/DAS (T.S.N. Pinto) for a total of six months to work on their doctoral theses as participants from overseas. There were a number of other visitors as well.

Following the update of the computer system at the Astronomy Data Center in Mitaka, data from the Nobeyama Solar Radio Observatory can now be analyzed at Mitaka.

6. Other

Five undergraduate students visited for one week and took part in research as part of a research internship program at Shinshu University. On the high school level, students from Hakuyo High School in Kanagawa and Komagane Technical High School in Nagano participated in the SPP Program, where they took part in lectures and workshops.

Kazumasa Iwai joined the Observatory as a new member of research staff. Postdoctoral Researcher V. Reznikova finished her term at the end of June.

4. Solar Observatory

The Solar Observatory primarily engages in the operation of the 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 (the photosphere, chromosphere, corona, and solar wind) and active phenomena (sunspots, faculae, prominences, and flares). The observatory performs regular observations using observational instruments such as the Solar Flare Telescope (SFT), and is also engaged in the development of new observational instruments and expeditions for total solar eclipses. Regular observations of sunspots and flares have been continued for extended periods, and the resulting data is provided to researchers.

1. Observational Facilities in Mitaka

(1) Magnetic Field Observation

The SFT, which has been the main instrument of the observatory in the Mitaka campus, had continued to observe active region photospheric vector magnetic fields and H-alpha flares since its completion, but it is now engaging in regular observation using an infrared Stokes polarimeter [Grant-in-Aid for Scientific Research, foundation A (representative: Sakurai, FY 2005–2008)]. Whereas previous magnetic field observations covered part of the solar surface, this instrument performs full-disk polarimetric observation to obtain high-accuracy vector magnetic field information in order to shed light upon the origins of solar activity cycle. This polarimeter is equipped with a 15 cm infrared lens, and performs slit scanning 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 the constant acquisition of unprecedented infrared polarization data for the photosphere and chromosphere of the entire solar disk.

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

Sunspot observations, which have been continuously performed since 1929, are currently conducted via automatic detection of sunspots on digital images taken with a 10 cm refractor and a 2k x 2k pixel CCD camera equipped in the new sunspot telescope. Observations in 2012 were conducted for 258 days from January to December.

Although full-disk solar image data is a widely needed resource in the astrophysics/geophysics community, some of these synoptic instruments are not very new. 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 the tracking of active phenomena and a broad dynamic range by a combination of multiple exposure times. This enabled to observe active phenomena such as flares and prominence eruptions, as the solar activity increases. Regular imaging observation of the G-band and continuous emissions using the SFT has also begun.

The regular observational data described above, including real-time images, is available on the webpage for the Solar Observatory.

Using a Grant-in-Aid for Scientific Research (representative: Hanaoka; FY 2011–2014), production of a spectrograph system in order to perform long-term, full-disk observation, including more quantitative velocity and magnetic field observations, is ongoing. Other existing equipment is maintained to allow for everyday observation, as well as experimental use.

(3) Other

A total solar eclipse occurred in November 2012 in the southern hemisphere, including Australia, and a photometric observation of the white corona was performed.

2. Opening of Data Archives to Public

The Solar Observatory has made nearly 3.8 TB of data publicly available online, including not only data from the current observations of white light, H-alpha, and magnetic fields, but also data for nearly 100 years of various types of solar observations. The various phenomena occurring in the solar-terrestrial environment must be studied both in terms of sudden, short-term events (space weather) and in terms of gradual changes that take over years or decades (space climate). The observatory will continue to contribute providing fundamental data to this research. In particular, the observatory possesses nearly 100 years' worth of accumulated records, including continuum images, Ca II K-line images, and H-alpha images, recorded on films, photographic plates, and hand-written sketches, which have been made available to the public after being digitized and organized. As some of the oldest solar activity records in the world, these materials are expected to contribute greatly to research. The observatory's track record of long-term solar observation and data publication were highly acclaimed, leading to the 2012 NAOJ Director General's Prize being awarded to the "Solar Observatory / Long-Term Continuous Solar Observation and Database Creation Team" at a ceremony held on February 28, 2013.

Data publicized via the website had previously been stored on a server belong to the Solar Observatory, but was transferred to the Astronomy Data Center following the integration of their data servers. The same data is stored at multiple locations in the data center, serving as a backup in case of disaster.

3. Other Activities / Personnel Transfers

In FY 2012, two events related to the Sun widely attracted public attention - the annular solar eclipse on May 21 and the transit of Venus on June 8. Both the events were supposed to be seen from an extensive area including the Mitaka campus; thus,

imaging was performed using the Solar Observatory's telescopes (although inclement weather unfortunately led to almost entirely cloudy conditions during the transit of Venus), and the taken images were distributed by the Public Relations Center in real-time via internet. In addition, the staff of the Solar Observatory responded to requests for interviews, which increased before and after the events.

Observations of the solar corona at the Norikura Solar Observatory ceased in 2009, and the facility was transferred to NINS, but the NOGIS coronagraph, which allows for advanced observations such as coronal velocity field measurements, is currently being transferred to the Yunnan Astronomical Observatory in China so that observation can continue at a suitable location. This year, the entire coronagraph including the refurbished telescope tube was brought to the Norikura Solar Observatory, where good results were obtained in test observations. Chinese staff visited Japan to undergo training in using the device, and made preparations to transport the coronagraph to China.

A research conference, doubling as the annual users meeting, is held jointly with other organizations. This year, the conference was combined with the solar research symposium, "Solar Research of Activity Maximums: Laying the Ground for New Directions in Solar Research", held at Rikkyo University from February 20 to 22, 2013 and with the Cosmic Radiation Symposium by ISAS.

Joint research projects are also being conducted with universities with an eye toward future instrument development and education. Undergraduate students took part in a "Cutting Edge Solar Research Experience Tour" of solar-related research facilities. When representatives from Peru visited Kyoto University this year, the current status and future developments of the Japan-Peru collaborative solar observations continued since 2004 were discussed, and the support from the Solar Observatory is scheduled to continue.

Fundamental solar data acquired by the Solar Observatory has often been used in pictures in textbooks and the like. With the attention surrounding the decrease and subsequent increase in the solar activity besides the above-mentioned annular solar eclipse, the observatory actively responded to more than 20 applications for image usage or interviews in FY 2012. One study workshop was also accepted as part of the Science Partnership Program.

The following transfers of research experts took place. Tomoko Kawate replaced a staff member who departed last year, but transferred to Kyoto University in October, after which Satoshi Morita joined. Takehiko Arai departed upon the completion of his term.

5. Okayama

The Okayama Astrophysical Observatory serves as the observing and research base for optical and infrared astronomy in Japan, and pursues primarily the open use of the 188 cm reflector among university researchers around the country. Joint research and development projects are also conducted with universities, which contributes to strengthening their capability of astronomy research. Concurrently, the location and observational environment of the observatory is utilized to engage in unique research activities.

Roughly 210–230 nights are allocated to the open use of the 188 cm telescope every year. The observatory maintains and operates the instruments and provides observer support (observation support, support for travel expenses, accommodation, living expenses, etc.) The observatory also engages in renovating the common-use observing instruments to improve the performances, developing new common-use instruments, and supporting brought-in instruments from other organizations.

Joint projects being conducted with universities include Kyoto University's New Technology 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 Okayama Astrophysical Observatory are involved in the "Optical and Infrared Synergetic Telescopes for Education and Research (OISTER)" program, which has been functioning since 2011. International collaborative studies focusing on the search for exoplanetary systems are also being conducted with researchers from China, South Korea, Turkey, and Russia. The observatory also offers technical support to overseas observatories upon request to take part in international cooperation.

Currently, as our own research activity, a project is ongoing that converts the 91 cm telescope into an ultra-wide-field near-infrared camera (OAO-WFC) for a comprehensive survey of infrared-variable objects in the galactic plane. Another project is also running in which the 188 cm telescope is going to be refurbished to improve dramatically its planet searching capabilities. This is supported by a Grant-in-Aid for Scientific Research (Basic Research (A), FY 2011-2016).

The personnel breakdown as of March 2013 was six full-time staffs (including one associate professor, one assistant professor, two chief research engineers, one research engineer, and one associate professor/chief clerk (concurrent posts)), twelve contracted staffs (including two special contract employees, two postdoctoral fellows, three research supporters, three administrative supporters, and two operational supporters), and one temporary staff member.

1. Open Use

(1) Overview

122 nights were allotted for open use in the first semester

(January to June) and 109 nights for the second semester (July to December) of 2012, and a call for observing proposals was made for each semester. Submitted proposals were reviewed by the Okayama Program Subcommittee, and a total of two project observation proposals and 19 general observation proposals were accepted. Open-use observation generally proceeded without incident.

(2) Facility Maintenance/Management

In order to maintain the observing efficiency, regular works including mirror aluminization (June), optical axis alignment, instrument maintenance (June to July), and telescope oiling (September) were done for the 188 cm telescope and related facilities. Regular cleanings were also done for the 188 cm primary and other smaller mirrors roughly every one-and-a-half months. These maintenance and upkeep works and observing instrument exchanges were safely performed, with no accidents or incidents whatsoever. A limited number of telescope mirrors from other organizations are accepted for aluminization during the period in June. Participants in the aluminization work from these organizations were given NAOJ-mandated safety and hygiene training as necessary. The quadrennial replacement of the wire ropes for the slit door of the 188 cm telescope dome was performed in September. Other facility maintenance efforts included repairing the slit door guide rails (June), mending damaged exterior panels, preventing rain leakage through the louvers, renewing power and ground lines, and engaging in everyday inspections.

(3) Conferences

The Program Subcommittee met on June 7 and February 27 to review the proposals submitted to the open time of the 188 cm telescope for the second semester of CY 2012 and the first semester of CY 2013, respectively, and fixed the observing programs. The Okayama Users Meeting (23rd Optical/Infrared Users Meeting) was held at the NAOJ Mitaka campus on August 7 and 8. Reports were made on the current state of the observatory, research results based on data obtained at the observatory, and short-term plans. In particular, the impacts of the refurbishment of the 188 cm telescope, under the support of Grant-in-Aid for Scientific Research begun last fiscal year, including a significant reduction of the period of common use for the first semester of CY 2013 were explained to get users' understanding. Also discussed were the Kyoto University's new technology telescope plan, operations of other optical/infrared observational facilities (including the Higashi-Hiroshima Observatory), and cooperation of small- and mid-size telescopes.

(4) Observation/Research Results

Stars were the primary objects observed in the common use period for 2012. Others including Solar System objects and galaxies were also observed in several subjects during the year. The primary observational subjects were searching for exoplanets via precise radial velocity measurement, elemental abundance analyses of stars via high-dispersion spectroscopic observation, and the observation of exoplanet transits via precise near-infrared differential photometry, which prospered rapidly in recent years. 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 and published in refereed journals (for individual results, see the proceedings of the users meetings and other relevant conferences and the reports presented at the bi-annual meetings of the astronomical society of Japan).

2. Developing Open-Use Observing Instruments

(1) HIDES (High-Dispersion Echelle Spectrograph)

HIDES is a cross-dispersed high-dispersion echelle spectrograph made for open use. Two fiber links have been developed to improve its observing sensitivity. Test observations in 2010 show that the high-efficiency fiber link providing a reciprocal resolution of ~50,000 can afford a throughput that is nearly one magnitude better than before and a high precision for radial velocity measurement (~2 m/s) that is comparable to the one available with the Coudé light path. A paper describing the instrument was published in a refereed journal in February 2013. The fiber link was made available to the open use with shared-risk condition in 2011, and has been fully open for common-use since January 2012. Its use is steadily increasing. Meanwhile, the other fiber-link with a resolution of nearly 100,000 is approaching completion, with test observations having been performed in April and December 2012. Preliminary results show a dramatic increase in throughput of far more than one magnitude over that available with the Coudé light path.

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

ISLE provides imaging and low- and mid-dispersion spectroscopic functionalities in the near-infrared for open use. All the functionalities have been available for the Project Observations at OAO since the second observing semester of 2011. ISLE is the only instrument that offers opportunities of near-infrared spectroscopy in East Asia and is characterized by its best-global low-noise readout (less than 10 electrons). The high precision of relative photometry (at a milli-magnitude level) achieved by ISLE has also greatly increased the demand of observing time for exoplanet transits. In FY 2012, hybrid automatic tracking that analyzes images of acquired objects in real-time and performs offset correction was added to the existing auto-guide function to further improve relative photometric precision.

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

The instrument was made available for open use as a PI-type instrument in FY 2008, and its steady operation has been continuing since then. The CCD output linearity, which had been an issue to be dealt with, was improved in FY 2009, which relaxed particularly the limitations on imaging and spectroscopic observations of bright objects with KOOLS. The guiding software has been improved to implement non-sidereal tracking that allows for long-time integration on Solar System objects.

The number of newly proposed monitoring programs over multiple years increased significantly in the semesters of 2012.

3. Joint Research with Universities

(1) Gamma Ray Burst Optical Afterglow Follow-up Project

Optical follow-up observations of gamma-ray bursts (GRB) are being conducted in cooperation with the Tokyo Institute of Technology's Kawai Laboratory. During FY 2012 the automatic observation scheduler performed observations on nearly every possible night, and 25 gamma ray bursts were observed, with optical afterglows being successfully detected in four. Observation results were reported as 15 GCN circulars. Monitoring of cataclysmic variables, Mira variables, and exoplanet transits were concurrently performed while the telescope was waiting for GRB to happen. A refereed paper was published based on multicolor photometric observations of SU UMa-type dwarf nova.

(2) Kyoto University New Technology Telescope Project

A cooperative implementation framework for the 3.8m New Technology Telescope Project being spearheaded by Kyoto University has been established as part of the future plans for the Okayama Astrophysical Observatory. A part of developmental testing of a main mirror control system was conducted with Kyoto University in FY 2012, and it was confirmed that the actuator and other control mechanisms met the required specifications. Technical investigations of the telescope and dome, including those mentioned above, were conducted through regularly scheduled technical meetings.

(3) East Asian Planet Search Network

Telescope time secured at a 2.16m telescope in China, a 1.8m telescope in South Korea, a 1.5m telescope in Turkey, and the 1.88m telescope at the Observatory was shared to continue searching for exoplanetary systems around G-type giant stars. One exoplanet candidate was found through the cooperation with South Korea in FY 2012, and a refereed paper was published to report the detection.

(4) Optical and Infrared Synergetic Telescopes for Education and Research

In FY 2012, two new universities joined this project which began in FY 2011, for a total of nine participating universities in Japan along with the NAOJ, further strengthening the network. The Okayama Astrophysical Observatory has provided its 188 cm telescope, 50cm telescope, and 91cm telescope for the project, and has taken an active role in leading the project along with the Office of International Relations. A proposal system was introduced for ToO observation this year, and five objects were observed, including a super-Chandrasekhar supernova candidate, that was successfully observed from initial brightening via multicolor observation, and a blazar object; with a total of 69 nights' worth of observation for the project as a whole. The observatory also took an active role in establishing the framework for cooperative observation and in realizing actual observations. A refereed paper using part of this cooperative network including the 50cm telescope was accepted.

4. Unique Research Projects

(1) Searching for distant GRBs and galactic plane variables via the ultra-wide-field infrared camera

The 91cm telescope has been converted into an infrared telescope with an ultra-wide field of view of one square degree and is used to identify infrared counterparts for objects such as distant GRBs and gravitational wave sources. Meanwhile, a project is also underway to engage in a comprehensive search for variable stars in the galactic plane. DIA analysis to detect new variable objects was successfully performed for K-band images of the galactic plane obtained during test observation the previous year, yielding the prospect of meeting the initial goals. In order to obtain good-quality images across the entire field of view, precise optical axis measurements were performed and it was confirmed that actual adjustments are possible within the tolerance for optical axis adjustment given by the optical design. The exterior of the dome building was coated with painting using the research environment maintenance budget, and the rotating part of the dome and its drive system were also repaired.

(2) Automation of exoplanetary system searches

Supported by a Grant-in-Aid for Scientific Research (Basic Research (A), "Automation of the search for extra-solar planetary systems," PI: Hideyuki Izumiura, 2011–2016), a project is underway that refurbishes the 188 cm telescope and its dome. The project is to increase the speed, precision, and reliability of the telescope, facilitate automation of observation, and further expand the search for exoplanetary systems. The driving and control systems of the 188cm telescope were updated in the fourth quarter of this year, and the performances were found to meet the required specifications. The dome control system was concurrently updated in March, increasing the reliability of actuation control.

5. PR / Awareness Promotion Activities

The 188cm telescope and its dome are open to the public year round, which provides the window view of the telescope from the visitor's room. The observatory welcomed 15,677 visitors in FY 2012. A special open-house event was jointly held by the Okayama Astronomical Museum, the Asakuchi City Board of Education, and the observatory, with support from the Yakage Town Board of Education, to host 607 visitors on August 25 (Sat). An audience of nearly 100 gathered in the dome to listen to a special lecture entitled "Is There Another Earth? The Search for Exoplanets," given by the Associate Professor Bun'ei Sato at the Graduate School of the Tokyo Institute of Technology. Special stargazing parties were co-hosted by the Okayama Astronomical Museum and the observatory on May 26 (Sat) and October 13 (Sat), with 210 attendees in total selected by lottery from a total of 1,029 applicants. The transit of Venus across the Sun on June 6 (Wed) was broadcasted live on the internet to 33,836 viewers. A lecture was held in Okayama City

on July 7 (Sat) as part of the nation-wide Tanabata Lecture activity, with an audience of around 90. Nearly 80 astronomy-related questions from the public were made irregularly to the observatory and they were answered appropriately. The 4D2U screening jointly operated by the Okayama Astronomical Museum and the observatory welcomed 5,626 visitors. Elven tours inside the observatory were invited to give local elementary school students from Asakuchi and Yakage opportunities to learn about the observatory and astronomy. The observatory also accepted eight requests for speakers from local boards of education and community centers. One speaker was provided to the "Fureai (Friendly) Astronomy" activity promoted by NAOJ.

6. Subaru Telescope

The Subaru Telescope engages in open-use observations using the Subaru Telescope (an 8.2 m large optical/infrared telescope) at the top of Mt. 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.

Repair of the telescope peripheral devices and some of the observational instruments which had been affected by a coolant leak from the prime focus unit for visible light in the previous year was completed in FY 2012, and open-use observations were conducted using the eight existing open-use instruments. The SEEDS project using a high-contrast coronagraph (HiCIAO) started in FY 2009 and FastSound using the Fiber Multi-Object Spectrograph (FMOS) started in FY 2011 were continued as strategic projects. As a new open-use instrument, initial test observations of the ultra-wide-field camera called Hyper Suprime-Cam (HSC) were performed. Preparations are underway to make the HSC available for open use in FY 2013.

The open-use period for FY 2012 was the four months starting April 1 in period S12A (which began on February 1, 2012), the full six months of period S12B starting on August 1, as well as two months in period S13A (which began February 1, 2013). Open-use related statistics in this report will be limited to S12A and S12B.

1. Subaru Telescope Staff

As of the end of FY 2012, the Subaru Telescope Project had dedicated staff consisting of 18 dedicated research/teaching staff members (including four stationed at Mitaka), five technical staff members, three administration staff members, four research experts (at Mitaka), seven postdoctoral fellows (at Mitaka), two research supporters (at Mitaka), two JSPS fellows (one stationed at Mitaka), and six administrative supporters (at Mitaka), and concurrently-serving staff including seven research/teaching staff members (at Mitaka) and two technical staff members (at Mitaka).

The project also has 68 local staff members dispatched from the Research Corporation of the University of Hawaii (RCUH) including scientific assistants; engineers in charge of software and observational equipment; technicians for facilities, machinery, vehicles, and laboratories; telescope/equipment operators; secretaries; librarians; administrative staff; researchers employed via a Grant-in-Aid for Scientific Research; and graduate students. These staff members work together for operations of telescope, observational instruments, and observational facilities as well as open-use observations, research and development, PR, and educational activities.

2. Main Observational Results

The following important research results using the Subaru Telescope's observations were published in papers in FY 2012.

(1) In early Universe studies, observation using the wide-field visible light camera (Suprime-Cam) of the Subaru Telescope discovered the most distant galaxy ($z = 7.215$) ever recorded in the 750-million-year-old early Universe (12.91 billion years ago). The most distant protocluster in the Universe to date was also discovered at 12.72 billion years ago ($z = 6$).

(2) In studies of the peak galactic evolution epoch, Subaru Telescope's new FMOS was used to perform the world's largest-scale systematic near-infrared spectrographic survey of star-forming galaxies (nearly 300) on the Universe roughly nine billion light years distant ($z \sim 1.4$), shedding light on the time evolution of the relationship between the mass of a galaxy and its heavy element content, i.e., the real chemical evolution of galaxies. Imaging observation using the wide-field near-infrared camera MOIRCS and its installed narrow-band filters discovered a number of protoclusters in which star-forming galaxies were presumed to be clumping and rapidly growing.

(3) In supernova research, polarization observation using the Subaru Telescope's FOCAS revealed that the supernova explosion that occurs at the end of the lifespan of a massive star has a bumpy three-dimensional structure, yielding clues to the mechanism of such explosions, which has long been a mystery.

(4) In protoplanetary disk observations, using the cutting edge observational instrument HiCIAO installed on the Subaru Telescope, the world's clearest and most detailed image of the structure of a protoplanetary disk was successfully obtained, resulting in the discovery of small spiral-shaped structures within the disk and large gaps thought to have been formed by gravitational effects from newly created planets.

3. Open Use

A call for open-use proposals is put out every half-year. The offered periods were from February 1 to July 31 (S12A) for the first half and from August 1 to January 31 (S12B) for the second half. Applications were accepted at the NAOJ Mitaka

campus. The Subaru Time Allocation Committee, under the NAOJ Advisory Committee for Optical and Infrared Astronomy, referred to referee evaluations from inside and outside Japan to examine and determine which proposed topics to accept. 48 proposals (77.5 nights) were accepted for S12A [out of 114 submissions (312 nights)] and 39 proposals (63 nights) for S12B [out of 132 submissions (350 nights)]. Service program observations consisting of short-term projects were also performed. Of the abovementioned proposals accepted for open use in S12A and S12B (excluding UH time), 18 (12 in S12A and six in S12B) were conducted by foreign PIs. The total number of respondents, including joint researchers, was 1,363 belonging to Japanese organizations and 632 belonging to overseas organizations. The total numbers for staff for accepted projects were 510 from Japan and 253 from overseas. Hyper Suprime-Cam test observations were partially canceled, and there were periods in which the secondary mirror could not be exchanged due to equipment malfunctions; thus, an additional call for proposals was issued along with a reassignment of backup programs sorted by the Time Allocation Committee. There were 93 additional submissions (192 nights), of which nine (11.5 nights) were accepted.

There were a total of 373 open-use observers (including 38 from overseas) during S12A and S12B. Calls for observation proposals, the examination of submissions, procedures for dispatching researchers from Japan, and travel expense compensation were handled by NAOJ Mitaka. Observation schedules, accommodations for researchers in Hawai`i, transport, and observational support were handled by the Subaru Telescope. Excluding weather-related factors, an average 95.1% observable time rate was obtained during S12A and S12B, including the time for University of Hawai`i. The downtime consisted of roughly 0.8% due to equipment problems, 0.4% due to communication system problems, and 3.7% due to telescope problems.

Remote observation from the Hilo base facility, which began in the latter half of FY 2012, was performed for one night each during S12A and S12B. Service observations were performed for 19.85 nights. Observation hours were exchanged with the Gemini telescopes and the Keck telescopes in order to make effective use of the resources of the telescope group on Mt. Mauna Kea, with nine nights in S12A and 3.5 nights in S12B exchanged with Gemini, and two nights in S12A and four nights in S12B with Keck.

4. Telescope Maintenance and Performance Improvement

Primary telescope functions were maintained from the previous year, but there was a period during which the top unit could not be exchanged due to a malfunction in the top unit exchanger. The utmost effort was expended on repair work. The following work was also performed.

- Repairs and adjustments were completed for part of the equipment affected by the coolant leak which happened the previous year. Preparation is underway to complete the rest of the repairs when access becomes possible during re-deposition of the main mirror.
- Work continues from last year to introduce the ultra-wide-field prime-focus camera (HSC). Along with performance evaluations of the observational instrument itself, telescope top unit installation and basic functions such as pointing analysis and mirror analysis were confirmed.
- The performance and operational efficiency of the telescope were further upgraded, while the telescope control equipment, which is more than 10 years old, was updated and repaired. The telescope control computers TCSMCU and TCFRCU (PF) were updated. The shutters of the optical system of both Nasmyth focuses (Auto Guider/ Shack-Hartmann systems) were overhauled. Some equipments such as the image rotator of the visible Nasmyth focus, the electrical system for the main shutter, and the chiller, had malfunctioning due to aging and they were repaired. Temporary fix was performed on the hoses around the Cassegrain focus, which interfered with the rotation of the instrument rotator. Replacement of aging internal wirings, including those within the rotator, and hoses is scheduled for next year.

Along with the foregoing, daily maintenance work has been continued. Steps were taken to accommodate the insertion of a "leap second" in June. The lateral guide rollers, which keep the wheels of the dome in place, were adjusted.

5. Observational Instrument Operation and Development

In FY 2012 repairs were completed on the prime focus camera (Suprime-Cam) and the Faint Object Camera and Spectrograph (FOCAS), for which operation had been suspended due to the effects of the coolant leak the previous year. All eight open-use instruments were put into operation. [The others include the High Dispersion Spectrograph (HDS), the Infrared Camera and Spectrograph (IRCS), the Cooled Mid-Infrared Camera and spectrograph (COMICS), the Multi-Object Infrared Camera and Spectrograph (MOIRCS), the Fiber-Multi-Object Spectrograph (FMOS), and the Laser Guide Star Adaptive Optics (AO188/LGS) system.] A multi-object fiber unit for HDS was developed as an upgrade of the existing equipment. Development towards replacement of MOIRCS detectors and the introduction of an Integral Field Unit (IFU) is also underway.

For PI-type instruments, the HiCIAO high-contrast coronagraphic imager and the Kyoto3DII visible integral field spectrograph were used in open-use observations. Continuing from last year, HiCIAO was used as the primary device in the strategic observational project SEEDS with successful results. Combined testing of Kyoto3DII with AO188/LGS was completed, allowing for observations at high spatial resolution in the visible light.

Another coronagraph unit (SCExAO), enabling even higher spatial resolution and contrast in combination with AO188 and HiCIAO, is currently under development at the Subaru Telescope. A technique for suppressing quasi-static speckle noise was successfully demonstrated using actual astronomical

objects in FY 2012. The introduction of a unit which performs ultra-high-order wavefront correction is scheduled for FY 2013 or later. An apparatus for performing near-infrared integral field spectroscopic observation at high spatial resolution in combination with AO188 and SCExAO (CHARIS) and a near-infrared spectrograph (IRD) yielding high wavelength stability are also being developed. Design reviews of them have been conducted. These devices promise further developments in exoplanet research.

Development of an ultra-wide-field prime-focus camera, the Hyper Suprime-Cam (HSC), as a next-generation open use device is underway. Its engineering first light was carried out in FY 2012, and it was confirmed that the desired stellar images could be obtained. Test observation using actual astronomical objects is underway for the start of open-use operation in FY 2013.

Development is underway for an ultra-wide field multi-object Prime Focus Spectrograph (PFS) for installation on the Subaru Telescope as the next main instrument of the Subaru Telescope following the HSC. Following the conceptual design review performed the previous year, a preliminary design review (PDR) was performed in FY 2012, and approval was received to enter the next design phase. The PFS project has a large budget requirement and is a complex international cooperation involving multiple countries; thus, review is scheduled for FY 2013 from the viewpoint of NAOJ project management.

Along with the HSC and PFS, another major Subaru Telescope project underway is the Ground-Layer Adaptive Optics (GLAO) project. The project goals are the development of the GLAO system, in which atmospheric variations only in layers near the ground are measured and corrected using an adaptive secondary mirror, thereby yielding improvements in star images over a field of view of more than 15 arc minutes, and a new wide-field near-infrared imager/spectrograph to take advantage of these improvements; as well as the operation as a major instrument for the Subaru Telescope in the 2020s, when TMT observations are to begin. An investigative report into next-generation wide-field adaptive optics for the Subaru Telescope was compiled in FY 2012. Opinions from the community are also gathered at the Subaru Users Meetings and the like, and work is underway to define device specifications in preparation for the conceptual design review scheduled for FY 2013.

6. Computer Systems/Software

This year, the third generation computer system, which had been in operation since February 2008, was updated to a new system, and the fourth generation computer system began operation starting February 2013. In the fourth generation system, the mail system is outsourced and a high-speed data analysis server was introduced in order to improve data analysis performance. A virtual machine group capable of being used in various observatory projects was also introduced.

The data archives have been in full operation with the support of the archivists in Hawai`i and Mitaka based on the operational support agreements, but it has now been over 10 years since the data archive system used up until now was put into operation. Thus, a new replacement system was developed and put into public test operations starting in FY 2011. This new system has just been installed in the fourth generation computer system and put into operation. On the summit of Mauna Kea, the core network was updated as a part of the fourth computer system.

An HSC onsite system has gradually been put into place starting from FY 2010 to quickly process the massive amounts of image data generated by Hyper Suprime-Cam (HSC), which went into operation this year, and instantly returning processing results to observers. This year, the HSC software team installed analysis software, and proceeded with the preparations for HSC test observations.

Support for the Subaru Telescope users, including data archive operations and remote observation monitoring support, continues to be conducted at Mitaka. The proposal submission system is also being continuously upgraded, including smooth operation of the web-based submission system.

7. University / Graduate School Education

The number of research/teaching staff members posted concurrently in Hawai`i from the Graduate University for Advanced Studies (Sokendai) increased by two to a total of nine members. Three graduate students were accepted at the Subaru Telescope on a long-term basis in FY 2012, one of which was a graduate student in the Graduate University for Advanced Studies. Educational activities for graduate students were also held at Mitaka in cooperation with the Division of Optical and Infrared Astronomy. Seven graduate students across Japan obtained degrees as the result of research performed using the Subaru Telescope, two of whom belonged to the NAOJ's optical/infrared group.

Educational activities for graduate and undergraduate students held around Japan include the “Subaru Spring School” (May) and “Autumn School” (December) held at Mitaka in which data analysis workshops are given, as well as the Subaru Observation Experience Program (October–November) for undergraduate students around the country, and the Subaru Observation Workshop (October) for the Graduate University for Advanced Studies.

Subaru Seminars are also held once or twice per month at the Subaru Telescope (in English), where participants in open use projects, visitors, and Subaru Telescope staff report their latest research results.

8. PR / Awareness Promotion Activities

A major social responsibility of the Subaru Telescope is to respond to the high levels of interest in astronomical research from the general public. The Public Information and Outreach (PIO) Office has been established in order to contribute to short- and long-term project success and engages in three basic types of activities. Particular care is taken in engaging with the local population, as their understanding of the activities being conducted at the Subaru Telescope is a key factor in their acceptance of these and next-generation projects.

The first pillar of the PIO Office's activities 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 and observatory activities. The PIO Office releases information publically through press release and the like. This year, 36 press releases (17 in Japanese, 19 in English) and webpages were prepared for the releases. Also, 86 articles (40 in Japanese, 46 in English) featuring topics such as instrumental development, observatory activities, and news items were put up on the website. As appropriate, the office approaches the media in Japan or locally in Hawai`i, or contacts networks worldwide via the mailing service of the American Astronomical Society. Apart from conventional dissemination via the website, the PIO Office also utilizes social media such as Twitter and Facebook, and has also begun working on video distribution via YouTube, etc. The PIO handles requests for interviews (two in Japanese and three in English) and questions from the media, educational organizations, science museums, and the like, and also handles the granting of English requests to use images (11 cases).

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 public tour program, for which reservations could be made online, sets aside 140 days a year for visitors, during which there were 1,134 visitors on 113 days. Including 122 specially arranged tours, there was a grand total of 1,638 visitors. Many visitors came to the observatory for the transit of Venus in June.

The Hilo Office facility offers not only facility tours, but also lectures and occupational mentoring by staff members. Researchers provide guidance to visiting students for presenting their research. This year, there were 38 tours and a total of 542 visitors.

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. There were 92 lectures and classes given at the Hilo Office facility of the Subaru Telescope and other local organizations, four lecture visits to Japan and other locations outside Hawai`i, and 17 remote courses. Local school visits included 56 special intensive courses over one week with assistance from the Mauna Kea Astronomical Outreach Committee. Outreach to more than 1,220 students was successfully made.

There were no special open house events, but the exhibitions, demonstrations, and explanations were given at annual events jointly organized by the observatories Mauna Kea. The Observatory staff had the chance to interact with more than 1,000 people, such as local citizens and families.

7. Center for Computational Astrophysics

1. Overview

Center for Computational Astrophysics (CfCA) carries out the management of a group of open use simulation computers centered around a general-purpose supercomputer and special-purpose computers for gravitational N-body problems; implementation of new systems; operational research and development; and promotions to improve the visibility of astronomical numerical simulation and their results. Operation of the supercomputer system introduced at the end of FY 2007 was continued in FY 2012. Open use operations also continued for the special-purpose computers for gravitational N-body problems GRAPE-6, GRAPE-7, and GRAPE-DR; the small-scale computational PC cluster; and the mid-scale computational PC cluster. As the operational term for the current supercomputer system, which began operation in 2008, was supposed to expire in March 2013, additional work of this year was focused on the implementation of a new system.

2. Open Use

(1) Computer systems

Operation of the open use computer system, "Astronomical Simulation System," which began in April 2008, was continued. A Cray XT4 scalar parallel computer, with a theoretical peak performance of approximately 27 TFops, and an NEC SX-9 vector parallel computer, having a theoretical peak performance of approximately 2 TFlops, form the core of the system. This yields a roughly 60-fold performance improvement over the previous computer system, which was built on a Fujitsu VPP5000 and was in operation until FY 2007. Also in operation along with the XT4 and SX-9 are the GRAPE special-purpose computers for gravitational n-body problems as well as other PC cluster platforms for executing small- or mid-scale calculations; an accompanying large-scale file server and an analysis server group for processing calculation results data; and network equipment for overseeing the entire computer system. This equipment forms the core for numerical simulation research by numerical astronomical researchers not only throughout Japan, but throughout the world. It continues to serves as a "telescope for theoretical astronomy" in both name and practice. A screening system-based computational resource allocation method has been adopted for the XT4, SX-9, GRAPE, and a small-scale PC cluster. Their usage, application, and acceptance statuses for FY 2012 are as shown below. A survey was conducted in FY 2012 about the status of refereed papers in English published in FY 2011 based on research using CfCA's open-use computer system, with the conclusion that 77 papers

were published.

The current Astronomical Simulation System, which began its operation in April 2008, will cease the operation on the last day of March 2013. Thus, the final stages of work to introduce a next-generation supercomputer system were performed in FY 2012. As the result of the bidding held in October 2012, a contract was awarded to Cray Japan Inc. and a supercomputer system called Cray XC30 will go into operation starting FY 2013. Due to various political circumstances, the main supercomputer had to be installed at the Mizusawa VLBI Observatory, and the work to install the system was performed up until the end of FY 2012 with assistance from the Mizusawa VLBI Observatory. Concurrently, the work was performed to update the peripheral file servers and analysis servers constituting peripherals, the GRAPE system, and other PC clusters which are independent from the supercomputer.

* Cray XT4
Operational status
- Annual operating hours: 8620.0
- Annual core utilization rate: 90.8%
Users
- Category A: 16 in first half-year, 16 in second half-year
- Category B: 43 in first half-year, 44 in second half-year
- Category C: 5 in first half-year, 8 in second half-year
- Category MD: 8 in first half-year, 11 in second half-year

* NEC SX-9
Operational status
- Annual operating hours: 8653.0
- Annual CPU utilization rate: 96.9%
Users
- Category A: 19 in first half-year, 19 in second half-year
- Category C: 1 in first half-year, 1 in second half-year
- Category MD: 3 in first half-year, 3 in second half-year

* Special-purpose computers for gravitational N-body problems (GRAPE)
Users
- Category A: 5 in first half-year, 5 in second half-year
- Category B: 8 in first half-year, 9 in second half-year
- Category C: 2 in first half-year, 1 in second half-year

* General-purpose PC system
Operational status
- Annual operating hours: 8701.5
- Annual job utilization rate: 71.5%
Total users: 35 (year-round)

(2) Tutorials and Users' Meeting

The following tutorials were held as part of education and promotion activities targeting the open-use computer system users in order to foster the next generation of young researchers.

* IDL Seminar
August 28-29, 2012; 8 participants

* AVS Seminar
August 30, 2012; 7 participants

* Midwinter School on N-body Simulation
January 21-23, 2013; 8 participants

The annual users' meeting was held as a forum for directly exchanging information with users. The numerous participants had a lively discussion.

* Users' Meeting
December 11-12, 2012; 61 participants

3. Research Results

(1) Special-Purpose Computer Project

The purpose of this project is to engage in hardware and software development, improvement, and maintenance to promote the effective open use of the special-purpose computer for gravitational N-body problems: GRAPE (MUV system.) The following primary activities were performed in FY 2012.

* The Start of Full GRAPE-DR Operation and an Increase in the Number of Nodes
Full operation of GRAPE-DR commenced in FY 2012. The number of GRAPE-DR nodes was increased from 12 to 16.

* Hosting of N-body Simulation School
The winter school on N-body simulation was held in January 2012.

(2) 4D2U Project

Two movies "Formation and Evolution of Dark Matter Halos" and "Central Engine of Supernova Explosion I" were produced and made available online. "Zindaiji3", an improved version of the N-body simulation visualization tool "Zindaiji", was developed and released. Development also continued on the volume data visualization tool "Oosawa" and the 4-Dimensional digital universe viewer "Mitaka".

4. PR Activities / Publishing Support

The CfCA announcement mailing list is under operation to provide news and information to users of the open-use computer system. It sends out announcements to subscribers. The CfCA News is also regularly issued in an effort to ensure that the users obtain all the information about the computer system. We also continues to offer a subsidy application system for publishing papers in order to promote the publication and dissemination of research results obtained using the computers run by the center. This includes five grants that were approved in FY 2011 and paid for in FY 2012 (approx. ¥640,000), and six grants that were approved and paid for in FY 2012 (approx. ¥370,000).

The 4D2U Dome Theater provided regular screenings twice a month and special screenings for occasional group visits in collaboration with the Public Relations Center. The flat-screen

mobile 4D2U system was used in research facility open house events. The 4D2U project supports the "Fureai Astronomy" program by offering explanations of astronomy using 4D2U contents with a non-3D system.

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 between three organizations, Center for Computational Sciences (CCS) of the University of Tsukuba, the High Energy Accelerator Research Organization (KEK), and NAOJ, providing active support for fundamental scientific research using computers. CfCA forms the core of NAOJ's contribution to JICFuS. In particular, the institute engages primarily in computer-aided theoretical research into fundamental physics in the fields of elementary particles, atomic nuclei, and astrophysics. A goal of the institute is to promote fundamental research based on computational fundamental science in order to engage in interdisciplinary research into elementary particles, atomic nuclei, and astrophysics. A major characteristic of the institute is its ability not just as a single organization, but with the cooperation of its three member organizations and their partner organizations to provide detailed and rigorous support to researchers currently engaged in, or planning to engage in, computational fundamental scientific research. Another important mission of the institute is to provide researchers around Japan with advice regarding efficient supercomputer use and the development of novel algorithms for meeting research goals from the perspective of computer specialists.

In FY 2012, the Center hired Takaaki Takeda, Hiroyuki Takahashi, and Tomoya Takiwaki as Project Assistant Professors to aid in implementing research plans. Takeda used his numerical simulations in the field of planetary science as a launching pad for visualization and imaging work focusing on large-scale simulation data. He is also currently working on visualization, imaging, and creating visualization tools for numerical measurement data in fields outside of astronomy as well. He took an active role in developing the "Mitaka" tool for presenting cutting-edge scientific results in an easily understood format. Takahashi is engaged in code development for a plasma simulation to find first principle solutions in relativistic radiation magnetohydrodynamics (MHD), as well as active research into important topics of plasma astrophysics such as magnetohydrodynamic reconnection process, the derivation of a self-similar solution having shockwaves between expanding loops accompanying magnetor flares and ambient gases, and quantitative evaluation of the magnetic diffusion effect arising from wave-particle interactions within neutron stars. The three-dimensional simulation of core-collapse supernova explosions being conducted by Takiwaki was selected as a representative user project of the K supercomputer in the fields of elementary particles, atomic nuclei, and astrophysics, and calculations are currently being executed. The evolution of stars and the supernovae that follow them holds the key to the elemental synthesis that is the origin of life on Earth. There is more than 80 years of research into the mechanism behind these explosions. The results generated by K are expected to greatly contribute to solving this problem.

Professor Kohji Tomisaka of the NAOJ is a participant in the bimonthly JICFuS steering committee meetings, where he engages in deliberations on spurring computational science-based developments in astrophysics research through discussion with other committee members specializing in atomic nuclei and elementary particles.

(2) HPCI Consortium

As a participant in the government-led High-Performance Computing Infrastructure (HPCI) project since its planning stage which began in FY 2010, the center is engaged in the promotion of the HPC research field in Japan, centered on use of the national supercomputer "K" (Note: although the center is involved with the JICFuS-led HPCI Strategic Program Field 5, 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 its associate member (able to state views and obtain information but lacks voting rights as well as the obligation to pay membership fees) and is observing the overall trends of the Consortium. A number of conferences and working groups were held this year to discuss a next-generation national supercomputing framework. At present, a plan to replace a set of "multiple large-scale systems serving as the second layer" as well as "a top-level national systems like K" within five or six years is under discussion, and is already at the stage where it is eligible for MEXT approval. Continuing discussion is underway towards an official response to the government with a proposal for the next generation of K equipment to be put into operation by FY 2018 at the latest. It is theoretically possible that NAOJ will becoming the center of next-generation high-performance computing after K.

6. Contract Staff Changes

The following contracted employees were hired in FY 2012.

(Research Expert)	Shoichi Oshino
(Postdoctoral Fellow)	Akihiro Suzuki
(Research Associate)	Shigeru Wakita, Jin Matsumoto
(Admin Associate)	Yuko Kimura

The following contracted employees were transferred in FY 2012.

(Research Expert)	Akitoshi Oshima, Hirotaka Nakayama
(Research Associate)	Shigeru Wakita, Yumi Iwashita, Jin Matsumoto, Hiroshi Oda
(Admin Associate)	Ibuki Kawamoto

8. Hinode Science Center

The scientific satellite HINODE is an artificial satellite that was launched on September 23, 2006, by ISAS division of JAXA, as Japan's third solar observational satellite following Hinotori (1981) and Yohkoh (1991). NAOJ is implementing of this satellite project through the exchange of joint research-related memoranda with 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 phenomena occurring in the solar atmosphere. HINODE is equipped with three telescopes – the Solar Optical Telescope (SOT), the X-Ray Telescope (XRT), and the Extreme-Ultraviolet Imaging Spectrometer (EIS) – and engages in simultaneous observations of the detailed magnetic fields and velocity fields on the surface of the photosphere, and the brightness and velocity fields of the chromosphere and corona. The onboard telescopes were developed as part of a wide-ranging international collaboration with assistance from ISAS/JAXA. The SOT was developed mainly by NAOJ, and the Focal Plane Package (FPP) by 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) for the focal plane camera. The EIS is the result of an even broader international cooperation: the structure and electrical system were developed by STFC and University College London; the optics system was developed by NASA and NRL; and the University of Oslo in Norway assisted with the terrestrial testing equipment and Quick Look system. NAOJ participates in and promotes the EIS/satellite interface, satellite testing, and launch experiments. The NAOJ serves as the hub for collecting and analyzing data acquired by the satellite post-launch.

The Hinode Science Working Group (SWG), composed of representatives from the international team, offers scientific operation and data analysis support. Four members of the Hinode Science Center (Tsuneta, chairman; Sakurai, project scientist; Suematsu, SOT; Watanabe, EIS) belong to the 15-member group, which includes two members from the European Space Agency (ESA). Science Schedule Coordinators have been assigned in order to effectively utilize the open use observation system. Many of the Japanese coordinators (Watanabe, Chairman, EIS; Sekii, SOT) are NAOJ staff. FY 2012 marks the sixth year since the satellite's launch. Extremely good evaluations were received from the senior review-level evaluation committees held at the various aerospace organizations, primarily in FY 2010. These made it possible for the satellite to continue operating at its current level for the next few years. Deliberations on the next-generation solar observational satellite project "Solar-C" continue, and a project proposal is currently being formulated.

1. The HINODE Satellite: Onboard Telescopes and Scientific Operation

The SOT is a telescope for obtaining photospheric magnetic field vectors via polarization observations of absorption lines. The SOT is capable of continuously observing at the diffraction limit (spatial resolution: 0.2–0.3 arc seconds) with an effective aperture of 50 cm without atmospheric seeing. The SOT's focal plane package consists of three types of optics systems and imaging functions to maintain the desired performance. Operational modifications have maintained field of view robustness even in the Narrowband Filter Imager, in which image distortion was found in part of the initial field of view.

The XRT is capable of capturing the solar corona and plasma via soft X-rays. The telescope has inherited the grazing-incidence optics system and has improved spatial resolution. Its wavelength characteristics have been improved to allow for observation of the solar corona and plasma over a broader temperature range. Resolution of nearly one arc second has also been achieved. Temporal variations in spectral characteristics due to surface contamination on the detector can now be corrected for, and analysis via spectral performance is possible.

The EIS obtains temperatures, densities, and velocities for the chromosphere, transition region, corona, and plasma via spectral observation of extreme ultraviolet emission lines. The instrument allows for spectroscopy and imaging at multiple wavelengths via the operation of slits and slots. Its purpose is to investigate how energy is conveyed starting from its generation in the photosphere until its dissipation in the corona via observations covering the chromosphere, corona and the transition region located between the photosphere and the corona.

A Mission Data Processor (MDP) is installed in order to manage observations via the three telescopes and acquire data. Coordinated observation using the three telescopes is vital to achieve the scientific goals of the HINODE satellite, and the MDP plays a vital role in overseeing this. In particular for the XRT, the exposure time adjustment, observation zone selection, and flare detection mechanism functions are handled by the MDP, requiring close coordination with the telescope.

Data from the HINODE satellite is primarily downlinked at Norway's Svalsat station with help from the Kagoshima station (USC) and the ESA, allowing for data acquisition for every orbit. Scientific operation was again performed in FY 2012 via S-band data reception. The S-band reception frequency was increased with help from the ESA and NASA, allowing normal, stable scientific operation to be continued.

Obtained data is collected at ISAS/JAXA, converted to FITS format, and provided to researchers around the world as Level-0 data in a form close to raw data. Staff and students belonging to the Hinode Science Center took part in satellite operation for a total of 221 days (50 days of which were for contracted work) in FY 2012, and contribution rates to the scientific operation of the Hinode Science Center were 14.3% (domestic) and 25.6% (overall). Instantaneous publication of all data acquired by HINODE, which began on May 27, 2007, has subsequently been continuously and stably implemented by the Hinode Science

Center (HSC).

Calls for "Hinode Operation Plans" (HOPs), soliciting proposals for collaborative observation with other satellites and terrestrial observational equipment promotes joint observations with solar researchers around the world. A total of 230 HOP applications have been received as of March 2013. In particular, core HOPs proposed by scientific equipment team members are refined over multiple implementations, and systematic observation is performed, yielding results that can be extended to the studies on solar activity cycles.

2. HINODE Satellite Data Analysis

The NAOJ Hinode Science Center (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 facilitate access to Hinode observational data and provide impetus for collaborative research between researchers inside Japan and abroad, by providing an environment for analyzing Hinode observational data to researchers in Japan and overseas to maximize the scientific outputs yielded by the HINODE satellite, and by distributing analyzed data and constructing a data search system.

The HSC also works to raise awareness of the relationship between solar research and everyday life using the latest observational data, and to raise public awareness of the importance of solar research through its educational and public outreach (E/PO) activities. E/PO-related activities for FY 2012 included press releases; web releases; appearances and interviews on television programs and in magazine articles; and providing materials to publicize scientific results.

HSC staff members and students published 15 refereed papers related to Hinode in FY 2012, for a total of 209 as of the end of March 2013. An overall total of 644 refereed papers regarding Hinode have been published. Publications continue at a pace of nearly 100 refereed papers per year even six and a half years after launch.

3. Deliberations on the Solar-C Project

The Solar-C Planning Office (Head: Hara) functions as a sub-project. A working group (Chaired by Tsuneta until December 2012; Vice Chairs: Sakao (ISAS/JAXA), Shimizu (ISAS/JAXA), and Watanabe —Chair starting December 2012) has been established under the Steering Committee for Space Science at ISAS/JAXA.

Two plans for the next solar observational satellite project, Solar-C, were simultaneously considered (see the Solar-C Interim Report on Mission Concept). Last year, the priority of these plans was debated, and, after considering their scientific significance as well as technical maturation, the scientific technological heritage within Japan, and international division of responsibilities and estimate costs for each, the mission selected for Solar-C was plan B, i.e., the high-resolution spectroscopic mission "Seeking to Understand the Overall Physical Processes in the Photosphere, Chromosphere, and Corona via Systematic Observation of the Solar Atmosphere with Increaced Capabilities of High-Resolution Imaging and Spectroscopy."

Concurrently, the general goals and international task shares with scientifically synergistic solar missions of NASA and ESA were clarified. Within Japan, development continued for a large telescope assembly, spacecraft system, and a focus adjustment mechanism, a focal plane instrument for an optical telescope, and a highly reliable actuation mechanism capable of frequent operation. Investigation and experimentation into high-precision spectro-polarimetric observations in the UV range is also underway. The development of a photon-counting X-ray telescope continues.

Solar and Space Physics: A Science for a Technological Society (a decadal survey in the field of heliophysics) was published by the U.S. National Research Council in August 2012. The survey rates Japan as the "most reliable partner," mentions the Solar-C project 35 times in the text, and proposes that Japan and the United States "form a Science and Technology Definition Team for Solar-C as soon as possible."

4. Other Activities

In FY2012, the center had three postdoctoral fellows (two through the framework of the center, one through JSPS), with one leaving at the end of August.

Hinode Science Meetings for Japanese and international solar researchers continue to be held to promote heliophysical research using the HINODE scientific satellite. The sixth conference was held in St. Andrews in the U.K. from August 14th through the 17th, 2012.

Apart from the abovementioned activities, Hinode Science Center research and educational staff have been invited to or have participated in numerous solar-related international symposia, where they have spoken regarding scientific observation results. Researchers from overseas have also been accepted to engage in collaborative research. Long-term (one month or more) visitors to the center from overseas for FY 2012 are shown in the table below.

Name	Organization (Country)
Choudhury, Arnab R.	Indian Institute of Science (India)
Judge, Phillip	National Center for Atmospheric Research (U.S.)

Table 1. Long-term Visitors.

9. NAOJ Chile Observatory

The Japanese ALMA Project Office, which was organized for the purpose of the construction of the ALMA telescope, was reorganized as the Chile Observatory in order to more robustly promote scientific observation using the ALMA telescope. The ALMA Project is a plan to construct a gigantic radio telescope for receiving millimeter and submillimeter waves by commissioning 66 high-precision parabolic antennas in the 5,000 m-altitude Atacama highlands in Northern Chile. This international collaborative project is a partnership between East Asia (represented by Japan), Europe, and North America (represented by the United States.) ALMA is projected to have an observational resolution nearly ten times better than that of the Subaru Telescope or the Hubble Space Telescope. Early scientific observation with ALMA began in FY 2011 using a partial number of antennas, and shifted to full operation starting FY 2012. This report will discuss the progress of the construction project in Japan and overall, the progress of the scientific observations, and education/public outreach activities. The ASTE telescope is a single-dish 10 m submillimeter telescope installed in the Atacama highlands. It is operated to make headway into the Southern Hemisphere submillimeter observations in preparation for the ALMA era. The ASTE telescope had been in operation at the Nobeyama Radio Observatory until FY 2011, and was moved to the Chile Observatory in FY 2012 in order to have an organic function with the ALMA telescope. This report will also discuss the progress of the ASTE telescope.

1. ALMA Project Progress

(1) Development/Manufacturing of the Atacama Compact Array (ACA, Izayoi)

FY 2012 marks the ninth year of the ALMA construction project in Japan. The Atacama Compact Array (ACA, Izayoi) is a high-precision antenna array made up of four 12 m antennas and twelve 7 m antennas. Onsite assembly of all telescopes was completed by FY 2011. A performance evaluation test of 7 m telescope #12 was finished in September 2012, which marked the completion of the handover of all sixteen antennas developed by Japan to the joint ALMA Observatory. By the end of FY 2012, all of the 12 m antennas and eleven of the 7 m antennas were installed on the Array Operations Site (AOS) at the 5,000 m altitude, and some of them have been made available for use in scientific observation.

(2) Development/Manufacturing of Receiver Cartridge

Production of the Band 4, Band 8, and Band 10 receiver cartridges continues. In August 2012, an interferometry test was successfully performed using the Band 4 receivers installed in two of the 7 m antennas located at the AOS. An interferometry test using the Band 8 receivers installed in three of the 7 m antennas was successfully performed in September 2012. The first spectrum using the Band 10 receiver was successfully acquired in November 2012.

(3) Progress of the Joint ALMA Project

The Cycle 0 preliminary scientific observations, which began in September 2011, ended in January 2013, and Cycle 1 full observations began. Test observations also proceeded apace with scientific observation, with test observation at a baseline of 1,966 m and polarized test observation using the ACA antenna and the ACA correlator being performed in April 2012. On March 13, 2013, the ALMA inauguration ceremony was held at the Operations Support Facility (OSF) inviting Chilean President Piñera and numerous other guests. At this ceremony the transition to full observation was celebrated and announced in Chile and worldwide. The ceremony was covered by nearly 150 reporters from around the world, and was a major global news item. Japanese media coverage of the event will be discussed in section 4. Scientific observation during Cycle 0 and Cycle 1 will be discussed in detail in the next section.

2. ALMA Open Use and Scientific Observation

Initial open use observations using ALMA were performed from September 30, 2011 to January 1, 2013 as ALMA Early Science Cycle 0. Now completed, ALMA consists of 66 parabolic antennas. Preliminary open use using only a partial number of the antennas is called “Early Science” operation. In Cycle 0, interferometric observations were performed using sixteen of the 12 m antennas, with a maximum baseline of 400 m and four usable receiver frequency bands (3, 6, 7, and 9), allowing for mosaic observations of up to 50 fields of view. In Cycle 0, a research group led by Tohru Nagao of Kyoto University detected nitrogen emission lines in a distant galaxy using ALMA and revealed that chemical evolution of the Universe had progressed considerably, even in galaxies only 1.4 billion years after the Big Bang.

An open call for the second round of open use observations was issued for Cycle 1. In Cycle 1, an open call was made for interferometric observations using thirty-two 12 m antennas and ACA observations (interferometric observations using nine 7 m antennas and single-dish observations using two 12 m antennas), with a maximum baseline of 1 km and four usable receiver frequency bands (3, 6, 7, and 9), allowing for mosaic observation of up to 150 fields of view. The deadline for observation proposals was 01:00 JST on July 13, 2012. A total of 1,131 proposals were submitted. Among them, 211.5 proposals were from East Asia (0.5 was from a proposal from Taiwan being split 50/50 between East Asia and North America). Scientific evaluation of the observation proposals was conducted on October 1 through 5, 2012 at the Joint ALMA Observatory (JAO) in Santiago, Chile. Proposals were reviewed by 78 examiners, 17 of whom were from East Asia. Of the 1,131 observation proposals, 197 were designated as “highest priority.” Of these 197 proposals, 50 (25.4%) were from East Asia, and

the proportion of scheduled observation time occupied by East Asian projects was 21.5%. Full-fledged science operations for Cycle 1 began in January 2013.

Concurrently, the JAO made public the data taken from scientific evaluation observations, which were carried out to evaluate the feasibility prior to open use observations, and papers were published based on the newly obtained data. Daniel Espada and colleagues at NAOJ analyzed ALMA observation data of the Antennae Galaxies, identified a molecular cloud arm formed by tidal forces in colliding galaxies, and discovered an apparent increase of an order of magnitude in star formation efficiency therein. This paper was the first paper in Japan based on the results from ALMA. Tomoya Hirota and colleagues at NAOJ investigated ALMA observational data from a molecular cloud in Orion, and detected a 232 GHz vibrationally excited water maser emission line in a star-forming region for the first time. This discovery is highly significant as a new star-forming region probe.

3. Educational Activities / Internship Acceptances

The Chile Observatory held a graduate school guidance session on May 12, 2012. The session was attended by eight university students, who listened to talks by teachers and met with current graduate students.

4. Public Outreach Activities

In May 2012, NAOJ ALMA participated in the Japanese Geoscience Union Meeting by setting up an exhibit booth for one week. In November 2012, an NAOJ speech session was held at the Science Agora, where a speech about the ALMA telescope was given. In December 2012, NAOJ ALMA held an academic conference inviting Max Planck Institute for Astrophysics Director Eiichiro Komatsu, Joint ALMA Observatory Director Thijs de Graauw, and ALMA Board member Ewine van Dishoeck. A total of 23 speeches and science cafes for the general public were held in FY 2012, making widely known the current status of ALMA through dialogs with numerous visitors and raising interest in ALMA and its results.

63 news articles and 8 press releases were published on the project website. A mail magazine (approx. 2,500 subscribers) is also published monthly. Up-to-the-minute information is released via the project Twitter account (@ALMA_Japan), which had nearly 9,400 followers as of the end of FY 2012.

Nearly 70 articles have been published in newspapers and magazines reporting the start of science results from the early science observations. In addition to these, there was wide media coverage at the times of the start of full operation in January 2013 and the inauguration ceremony held in March with the visit of seven Japanese media companies to Chile. The events were featured on NHK TV News 7, Fuji Television FNN Super News, FNN Speak, and in numerous newspapers. Kyodo News and the Asahi Shimbun subsequently carried series and major articles written by reporters who visited Chile in their science sections, which effectively attracted continuing interest after the event.

As part of the construction film making project being continued since FY 2003, a video was produced in FY 2012 showing a 7 m antenna being transported to Chile and scientific evaluation observation being performed onsite. The assembly of the receiver performance evaluation equipment at the Operations Support Facility (OSF) and the inauguration ceremony held in March 2013 were also filmed.

The series “Bienvenido a ALMA,” in which ALMA staff introduce their work, is being continued from last year in the NAOJ newsletter. The June 2012 issue carried a special feature on ALMA consisting of photographs of the observation site in Chile and interviews with members of the Joint ALMA Observatory. A special website based on the series was also set up.

5. International Collaboration (Committees, etc.)

Various committees are frequently held for international collaboration in the ALMA project. Two meetings of the ALMA Board and three meetings of the ALMA Scientific Advisory Committee were held in FY 2012, as well as monthly teleconferences for both. The ALMA Annual External Review met over the course of a week in October 2012. The ALMA East Asian Scientific Advisory Committee also held monthly teleconferences. More frequent meetings and teleconferences are held for individual areas of concern in order to maintain close communication in implementing the international project.

6. Workshops and Town Meetings

- June 7, 2012: Kyoto University
  ALMA Cycle 1 Town Meeting
- June 12, 2012: Nagoya University
  ALMA Cycle 1 Town Meeting
- June 13, 2012: Tohoku University
  ALMA Cycle 1 Town Meeting
- June 18, 2012: NAOJ Mitaka
  ALMA Cycle 1 Town Meeting
- June 28, 2012: Osaka Prefecture University
  ALMA Cycle 1 Town Meeting
- June 29, 2012: Kagoshima University
  ALMA Cycle 1 Town Meeting
- October 20–22, 2012: NAOJ Mitaka
  ALMA User Meeting 2012

7. Research Staff Changes

(1) Hired

Eiji Akiyama, Postdoctoral Fellow

(2) Departed/Transferred

Yasutaka Kurono, Postdoctoral Fellow, transferred to the Joint ALMA Observatory as JAO Fellow

8. Main Visitors

March 13, 2013: 65 East Asian visitors to the Opening Ceremony in Chile
MEXT: Senior Vice Minister Teru Fukui and three others
Embassy of Japan in Chile: Ambassador Hidenori Murakami and two others
Academic experts: 21
NINS: President Katsuhiko Sato and three others
NAOJ: Director General Masahiko Hayashi and 18 others
Taiwan: ASIAA Director Paul Ho and three others
South Korea: KASI President Pilho Park and one other
Contractors: 8

9. Progress of ASTE Telescope

The ASTE Telescope has been operated in order to promote full-fledged submillimeter astronomical research in the Southern Hemisphere, as well as to advance the development and verification of observational equipment and methods supporting this research. With the construction of ALMA entering its final stages, and early science observations successfully starting, the primary goal of ASTE Telescope operation will be to provide observational corroboration in order to strengthen ALMA observation proposals. In order to open the doors to the astronomy community, an operations system was constructed this year to enable full-fledged open use observations using the ASTE Telescope

10. TAMA Project Office

1. Project Overview and Progress

The TAMA (Gravitational Wave Antenna) Project Office is engaged in research and development of observation technologies to make gravitational wave astronomy a reality. The greatest task for FY 2012 was the promotion of the construction of KAGRA, a 3 km-baseline large-scale underground laser interferometer, at Kamioka in Gifu Prefecture. The plan is being spearheaded by the University of Tokyo Institute for Cosmic Ray Research (ICRR), KEK, and NAOJ, with assistance from numerous research organizations in Japan and overseas. The design of KAGRA is based on previous experience and results from TAMA300, the 300 m-baseline laser interferometer in the Mitaka campus. Development and evaluation of the vibration-isolation and optics systems were conducted in FY 2012.

Along with the development and construction of KAGRA, the office is also engaged in research into methods for analyzing the obtained data and theoretical research into the general relativity and gravitational wave sources. With a long-term view toward the development of gravitational wave astronomy, the office is also collaborating with the Advanced Technology Center (ATC) and other universities and organizations to develop cutting-edge technologies such as quantum optical methods for increasing the sensitivity of KAGRA or the space-based gravitational wave detectors DECIGO/DPF.

(1) KAGRA Project Implementation

Staff from the project office participated as leaders or key members in the numerous subgroups central to KAGRA construction planning. They played a leading role in designing the primary components, discussing and formulating detailed specifications for ordering equipment, and conducting prototype performance evaluations.

- Vacuum component design and manufacture: KAGRA's vacuum system will be the largest ultra-high vacuum system in Japan. The necessary pressure is 2×10^{-7} Pa, requiring suitable pipe interior surface treatments and heating/degassing treatments. The manufacturing of the total 6 km of vacuum ducts, comprised of about 500 unit ducts, was completed in FY 2012. The basic design for the room temperature vacuum chambers was also completed.
- Vibration isolation system design and prototype manufacturing: The Office is responsible for the design, prototyping, and manufacture of all vibration isolation systems. In FY 2012, a prototype pre-isolator was produced; its properties were measured and control tests were performed; and six actual units were manufactured. Preparations were also made for room temperature vibration isolation system general prototype testing at NAOJ.
- Design/development of auxiliary optics system: The project office is in charge of the design and manufacturing of various optical systems collectively referred to as the auxiliary optics. A conceptual design for an anti-scattering system including the design/location of baffles and beam dumps was completed. Development of several large baffles is continuing with cooperation from the ATC. Design studies and prototyping were carried out. Requirements for optical levers for the angular control of optical elements suspended from the vibration isolation system and for a wide-aperture beam profiler for rapidly measuring the modes of Gaussian beams over 20 cm in diameter were decided. Prototype tests and performance evaluation of them were performed.
- Development of high-reflectivity, low-loss mirrors: KAGRA requires high-quality mirrors in terms of surface shape, surface roughness, and optical loss in order to resonate high laser power inside the interferometer. For this reason, construction of a system for evaluating the primary mirrors of the interferometer is underway. To evaluate the thin-film properties of the optical elements, measurements of two-dimensional scattering distribution, scattering intensity distribution, reflectivity, transmission, loss, were performed as well as dark-field microscopy-based surface state measurements. Research focused in particular on scattering from thin films, where mirror performance is well documented. As a result, the initial

scattering loss of up to 200 ppm observed at the beginning of thin film development was lowered to less than 20 ppm. This loss value indicates high performance compared to the loss exhibited by currently available thin films.

- Auxiliary lock system control design: Lock acquisition involving bringing variables such as the the resonance cavity length from an uncontrolled state to the operating configuration is vital in operating the KAGRA interferometer. Therefore in addition to the main laser beam (wavelength: 1064 nm) for observing gravitational waves, an auxiliary lock system for pre-controlling the 3 km cavity length via an incident laser beam having a frequency-doubled wavelength of 532 nm has also been introduced. In FY 2012, detailed designs were made for a control system for this auxiliary lock system. The results show that it was possible to lock the cavity length with narrow resonant linewidth of less than 33 pm.
- KAGRA interferometer diagnostic system development: Irregular noise arising from noise generated within the interferometer and sudden interference changes due to geological vibration or the like prevents KAGRA from attaining its maximum sensitivity, making it difficult to distinguish them from gravitational wave signals. KAGRA is equipped with as many as 10,000 auxiliary channels and environmental monitors, which are analyzed to identify and remove noise sources in order to obtain high gravitational wave detection efficiency. A digital control system identical to that introduced in KAGRA was installed in TAMA300; interferometer diagnostic system development was conducted; a prototype version of the system was installed in the prototype interferometer CLIO at the Kamioka site; and test operation was performed for one week. Joint research was also conducted with the Korean Gravitational Wave Group (KGWG) into a method of performing multivariate analysis on multiple environmental monitors and gravitational wave channels in order to distinguish gravitational wave signals from telescope-generated irregular noise.

(2) Gravitational wave exploration data analysis, theoretical research

KAGRA is expected to be the first instrument to detect gravitational waves and serve part of an international gravitational wave observational network along with LIGO and VIRGO. Along with the observation of electromagnetic waves which carrying information about astronomical phenomena and the energy surrounding them and elementary particles such as neutrinos which carry information about elementary processes, gravitational wave observations will enable the direct observation of space-time variations carrying information about the origins of astronomical phenomena. Observation via these various means is expected to allow for multi-messenger observations for a multifaceted understanding of astronomical phenomena. NAOJ is expected to be a central organization for such observation.

- Radio transient and gravitational wave: Under a collaborative framework with the members of the Nasu Pulsar Observatory and Yamaguchi University, NAOJ continued to play a central role in a joint Nasu Pulsar Observatory/LIGO analysis of radio transients detected at the Nasu Observatory, which could possibly be radio afterglows from binary neutron star mergers. The construction of an observational framework for radio transients with diverse time domain parameters via a partnership between the radio telescopes of Yamaguchi University and NICT, the Japanese VLBI network, the Nasu Pulsar Observatory, and gravitational wave telescopes including KAGRA was also discussed.
- Neutrino observation and gravitational waves: A working group for multi-messenger observation of low-energy neutrinos and gravitational waves was formed by LIGO, Virgo, and KAGRA, with NAOJ to participate as a central member on the KAGRA side.
- X-ray observation and gravitational waves: Multi-messenger observations using RXTE and LIGO were continued from last year. This year, a collaborative framework was constructed with Duncan Galloway of the University of Melbourne, Ed Morgan of MIT, and Chris Messenger of Cardiff University, and joint research on the results of RXTE data analysis was conducted.
- Eliminating fake events: The high rate of false events for gravitational wave candidates is one of the greatest concerns when performing multi-messenger observations. In order to address this, development was conducted to incorporate false signal-removing veto analysis into the interferometer diagnostic systems. The development was performed on the digital system used in developing the KAGRA interferometer diagnostic system.
- Construction of a data grid system for gravitational wave data analysis: A data grid is a component of the data analysis that will be necessary in the future to perform multi-messenger observation using telescopes around the world. As a foundation for this, a small-scale data grid for analyzing observational data was introduced, and development of a data analysis environment for the data grid began.

(3) Advanced technology development: The space-based gravitational wave detector DECIGO/DPF

DECIGO is a space-based gravitational wave detector aiming to be launched around 2027. By enabling the observation of gravitational waves near 0.1 Hz, which are difficult to observe using terrestrial gravitational wave telescopes, DECIGO will observe binary star mergers at cosmological distances, gravitational waves from the early universe, etc. As an extreme gravitational wave detector, DECIGO shows promise to be a rich source of scientific results and shed light on the birth and evolution of the Universe. Once gravitational waves have first been detected by terrestrial gravitational wave telescopes such as KAGRA and the field of gravitational wave astronomy has been established, the next step will naturally be to develop space telescopes to expand the field. Thus, fundamental research and development in this area with an eye to the future is vital. The roadmap for the DECIGO Project involves launching the small scientific satellite DECIGO Pathfinder (DPF) as an initial pathfinder satellite. Fundamental development research for its satellite systems and payload is underway.

- DPF satellite system planning: The mission of the DPF was discussed. Drag-free control and orbital satellite attitude stabilization were evaluated. As a result, the viability of the mission sequence from initial introduction into orbit until the achievement of an observation state was confirmed. The viability of the satellite shape, mass balance, etc., for achieving passive stabilization of satellite attitude was also confirmed.
- Specific design for interferometer module: The interferometer module constitutes the DPF's central observational device. It consists of two test masses serving as inertial system references and their housings; an input optics system; and subsystems for numerous other auxiliary devices. Development of these was continued from the previous year, and structure planning and prototype production were conducted using the sizes and shapes projected for actual installation on the satellite.
- Development of DPF optical system: When introducing light from a stabilized laser into the interferometer of the DPF, mode matching is necessary. Light reflecting from the interferometer must also be guided to a photodetector, and information on changes in baseline length and test mass angle variations must be obtained. Out of consideration for stability, a monolithic optical system featuring optical elements attached to a glass substrate is used for this optical system. Design and production of a monolithic optical system having the predicted shape and configuration of the flight equipment were conducted up until last year. In FY 2012, the operation of a fixed-mirror interferometer was successfully confirmed using this optical system.
- Test mass module development: Because the test masses serve as inertial references during gravity and gravitational wave observation, the modules are provided with various functions, such as an electrostatic sensor-actuator, a launch lock/clamp release, and a static discharging system. Testing of the principles behind a contactless retaining system using these sensors and actuators was completed last year. BBM design/production and operational testing using terrestrial testing equipment were performed in FY 2012. As a result, control of two of the degrees of freedom of one test mass was successfully performed.
- Test mass module drop test: The test mass module is designed to operate in zero-gravity. To that end, a free-fall test system for evaluating overall performance in zero-gravity is being constructed. In FY 2012, a conceptual design and parts were planned. Data acquisition systems and a drop facility with a release mechanism and a drop module with built-in power source and signal processing were largely completed. Future plans include installing the test mass module and performing control experiments in zero-gravity.

(4) Advanced technology development: Next-generation technology for increasing KAGRA sensitivity, etc.

Once KAGRA and other second generation of interferometer-based gravitational wave telescopes achieve the first successful gravitational wave detection and gravitational wave astronomy has been established, the range of observational targets will be broadened by increasing telescope sensitivity and by observing other frequency bands. The TAMA Project Office also aims to engage in basic R&D and seminal research to this end, obtain research results, foster personnel, and expand the research field.

- Precise quantum efficiency measurement experiments: Interferometer-based gravitational wave detectors are ultimately limited by quantum noise. Quantum noise includes radiation pressure noise and shot noise. The reduction of these forms of noise will present a major challenge for future gravitational wave detector development. In particular, photodetectors having high levels (approx. 99%) of quantum efficiency and devices capable of measuring detection efficiency with 1% uncertainty will be necessary. To that end, a novel ultra-lightweight (20 mg) power meter was developed, and it was proven that power measurements with 1% uncertainty (i.e., precise quantum efficiency measurement) are possible.
- Theoretical research into quantum measurement: Gravitational wave observations call for a degree of precision that may, in extreme cases, run up against the quantum limit in quantum theory. Research was conducted to explore the application of concepts from quantum information theory and quantum measurement theory, which have witnessed continued development in recent years, to gravitational wave measurement apparatus. In particular, research into the application of a method called "weak measurement" to gravitational wave measurement apparatus was conducted in FY 2012.
- Developing a torsion-bar antenna (TOBA) gravitational wave telescope: Development is underway for a novel torsion-bar antenna (TOBA) gravitational wave telescope capable of observing gravitational waves at 0.1 Hz and in other low-frequency bands where ordinary laser interferometer-based gravitational wave telescopes, like KAGRA, have difficulty. A small prototype telescope using an approximately 20 cm-long bar-shaped test mass has already been developed, and has yielded the highest level of sensitivity to this frequency band in the world. In FY 2012, further development of a mid-scale, lower temperature telescope was conducted and the conceptual design was completed.
- Theoretical research into general-relativistic higher-order gauge-invariant perturbation theory and its applications: A theoretical framework for the paper "General formulation of general-relativistic higher-order gauge-invariant perturbation theory" has been developed further in an attempt to apply this general theory to problems such as the nonlinear effects of primordial fluctuations in the Universe; the problem of gravitational wave radiation reactions in black holes; relativistic perturbations in neutron stars and other strong gravity fields and the instability thereof; gravitational waves emitted from binary star systems due to post-Minkowski expansion; and the relationship between higher-order gauge invariance and observed levels in experimentation and observation. In FY 2012, a paper suggesting the possibility that the "General formulation of general-relativistic higher-order gauge-invariant perturbation" is applicable to areas other than

cosmological perturbation theory was completed.

2. Educational Activities, Internships

Tomotada Akutsu
- April – September 2012: "Fluid and Collective Motion Models," Department of Advanced Sciences, Faculty of Science and Engineering, Hosei University

Naoko Ohishi
- December 7, 2012: Science seminar, Japan Women's University

Kazuhiro Agatsuma
- March 19, 2012: JSPS-sponsored Science Dialogue at Tokyo Metropolitan High School of Science and Technology (see http://www.jsps.go.jp/english/e-plaza/e-sdialogue/)

3. PR Activities

Project staff works to increase understanding and awareness of gravitational wave research through tours of the TAMA300. Up-to-date information on gravitational wave research can be found on the project homepage.

Tomotada Akutsu
- May 19, 2012: Special Public Lecture at Graduate University for Advanced Studies
- November 17, 2012: Class at Asahi Culture Center Yokohama

4. Hosted Research Conferences

Kouji Nakamura, Kazuhiro Hayama
- February 20–23, 2013: KAGRA Data Analysis School at NAOJ

60 participants, 3 guest lecturers, tour of TAMA300 held

5. Obtained external grants other than Grants-in-Aid for Scientific Research (industry-university collaboration expenses, etc.)

Masaki Ando: JAXA small scientific satellite strategic development expenses
Tomotada Akutsu: Basic development and testing expenses for JAXA-mounted equipment

6. Part-time Staff Transfers

March 2013 onward: Kazuhiro Hayama, Special Appointment Assistant Professor, Osaka City University

11. TMT Project Office

The TMT Project Office started as the ELT Project Office established in April 2005 to build a next-generation extremely large optical/infrared telescope, and was renamed to its current name in FY 2010 upon entering into a partnership with the TMT project. As at the end of FY 2012, the eighth year of the office, a full time staff consisting three professors, two associate professors, one chief research engineer, one specially-appointed senior specialist, one project research fellow, and one administrative support, as well as three associate professors and two assistant professors with concurrent appointments worked to strengthen the organization.

1. TMT Project Developments Inside and Outside of Japan

The NAOJ TMT Project Office members participated in

Figure 1: TMT Board meeting held in Tokyo (October 2012).

TMT board meetings, science advisory committees, and external advisory panel reviews held quarterly in Pasadena. Members from Pasadena also visited NAOJ on 22 occasions to attend various meetings. TV and telephone conferences were held as necessary in order to discuss the project as a whole and the specifics of the Japanese business plan.

In June 2012, a request for verification of core construction technologies for extremely large telescopes was submitted via NINS as a budgetary request for FY 2013. In July, the TMT project was examined by the "Working Group for the Implementation of Large-Scale Academic Research Projects" of MEXT's Council for Science and Technology, and recommended for implementation.

India's Minister of External Affairs announced his country's participation in the TMT in June 2012 during strategic talks between the United States and India. In March 2013, in response to a TMT plan submitted to a call for proposals by United States' National Science Foundation (NSF), NSF formally announced the awarding of funding over the next five years to investigate the possibility of participation by NSF in the TMT project.

The 36th TMT Board Meeting was held in Tokyo in October 2012 (Fig. 1). This was the first time the Board of the international TMT project met outside of the United States and was followed by a Board meeting in New Delhi in January 2013.

In regards to the problem of providing benefits for up-front investment which had been under discussion for several years without an agreement being reached, a request to McKinsey and Company for third-party consultation resulted in the arguments made by Japan and other international partners being largely granted.

In August 2012, a group which included legal counsels from each project partner began discussion for drafting the overall agreement documents, the articles of incorporation for the TMT International Observatory, the bylaws for the articles, and other documents which need to be prepared prior to the beginning of construction.

In February 2013, partial manufacturing costs of the mirror blanks for the segmented primary mirror were approved in the supplementary budget for FY 2012. Provisions were made in the FY 2013 budget for a part of the cost for the aspherical surface grinding of the segmented mirror to be included as the initial budget for construction. These provisions for the international effort to start construction scheduled in 2014 led Japan to take a leading role in the international collaboration.

2. Research Conferences and Lectures in Japan

Information regarding the progress of the TMT project is disseminated on the TMT Project Office website, and was distributed in issues 32 to 36 of the TMT Newsletter. The project office also created both Japanese and English-language pamphlets, and worked to raise public awareness of the project through events such as an NAOJ-hosted public lecture held at the Hitotsubashi Auditorium in October and a symposium on Inter-University Research Institutes held at Tokyo International Forum in November. A 1/100 scale movable model of the telescope was also made to increase understanding of the telescope project (Fig. 2).

Figure 2: Display of a model of the TMT (MEXT entrance hall).

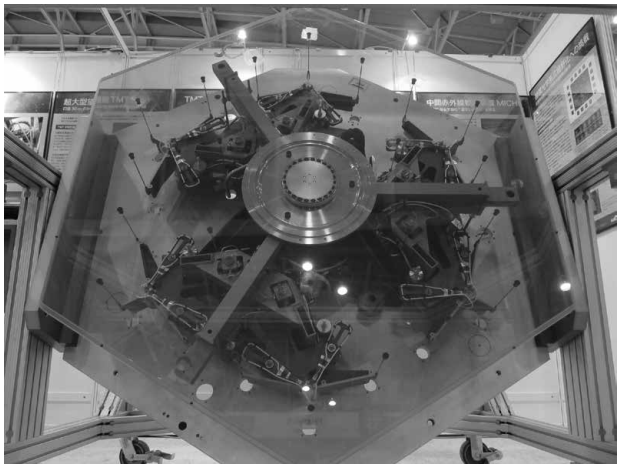
Figure 3: Prototype of the segmented primary mirror.

Club TMT, composed primarily of museum curators, was formed in November to begin organized planning of programs and lectures introducing the TMT project at science museums and planetariums around the country. The TMT Project Office offered assistance in the form of information and guest lecturers. Following the decision to erect a plaque in Hawai`i with the names of donors to the TMT project, nearly 1,700 applications to donate were received, with total donations reaching 17 million yen.

3. Work to Detail the Japanese Business Plan

Japan's specific contributions to the project were discussed, focusing on the telescope structure, the primary mirror segment blanks, grinding of the primary mirror, and the observational instruments.

Regarding the structure of the telescope, the conceptual design of the telescope was developed based on the detailed studies of the design, fabrication, and installation experience of the Subaru Telescope. Basic performances are improved

by enhancing pointing/tracking capabilities and modifying the secondary mirror support mechanism. Original design concepts for the primary mirror cleaning mechanism, the primary mirror segment handling system, and the seismic isolation mechanism were discussed. The specific processes of pre-shipping test assembly in Japan and on-site installation and adjustment needed were identified. Methods for achieving more reliable performance were also discussed. The boundaries for the division of responsibilities in areas shared with other project participant countries, such as the enclosure, foundation, secondary mirror, and tertiary mirror, were also defined more clearly.

To verify the optical and thermal properties of the TMT main mirror material, a prototype mirror blank was tested jointly by Japan and the United States.

During the fabrication of TMT's mirror segment, existing facilities in Japan were effectively utilized to finish polishing of a full-sized, extremely low-expansion glass blank having a 1.44 m diameter into the type 82 aspheric surface, corresponding to the outermost segment. Measurements for a single unit — a segment installed in its support mechanisms — were completed (Fig. 3). Further process improvements are necessary for mass production, and plans for technological development for that purpose were investigated.

As for the instruments, a plan is being discussed for NAOJ to fabricate the IRIS imaging system of the first generation TMT observational instrument. In addition, the feasibility of fabricating the WFOS camera system and proposals for second generation instruments were discussed by multiple teams participating from domestic universities.

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 galactic bulge (20° × 10° around the center of the galaxy) and perform infrared (Kw-band: 1.5–2.5 microns) measurement of annual parallax, proper motions, and celestial coordinates of the stars at a high accuracy of 1/100,000 arcsecond (10 microarcseconds) in order to determine with high reliability the distance and transverse velocity of stars within approximately 10 kpc from Earth in the surveyed direction. Nearly one million stars can be measured with high precision (relative error of annual parallax necessary to accurately determine the distance to better than 10%) in the galactic bulge. By using observational data to construct a phase space distribution of gravitational matter, astrometric surveys of the bulge forming the core of the Milky Way promise 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,.

Two projects (ultra-small-size and small-size) in order to progressively build up scientific results and accumulate the necessary technical knowledge and experience are being implemented prior to the JASMINE project, which is a mid-sized scientific satellite. The Nano-JASMINE micro-satellite project (primary mirror aperture: 5 cm) is currently being implemented in order to test part of the technologies for JASMINE. Despite its small aperture, the satellite is capable of a level of observational precision comparable to the Hipparcos satellite, and the combination of observational data from Nano-JASMINE and the Hipparcos Catalogue is expected to improve proper motion and annual parallax precision. The satellite is scheduled for launch around December 2014. Also underway is a project to launch a small-size version (primary mirror aperture: 30 cm) of JASMINE around a target date of 2018. The satellite will engage in observations of only a limited area around the bulge and certain specific astronomical objects. This small-size version has a goal of obtaining advanced scientific results at an early stage. The mid-size JASMINE satellite (main aperture: approx. 80 cm) for surveying the entire bulge is targeted for launch in the 2020s. Internationally, Japan shares responsibilities with ESA by engaging in infrared observation in the direction of the galactic center, while they perform visible-light observation of the entire sky at a precision of 10 microarcseconds (the Gaia Project).

(2) Primary Progress for FY 2012

1) Organization of the Office

The JASMINE Project Office is composed of four full-time staff, seven staff members holding other posts, two postdoctoral fellows, one research supporter, one technical supporter, and two graduate students. The Office is also the grateful recipient of significant cooperation from organizations such as NAOJ's TAMA Project Office; Kyoto University's Graduate School of Science; JAXA's Systems Engineering (SE) Office, Aerospace Research and Development Directorate (ARD), and ISAS; the University of Tokyo's School of Engineering; the Tokyo University of Marine Science and Technology; and the University of Tsukuba.

2) Progress of Nano-JASMINE Project

The Nano-JASMINE Project will engage in actual space observation using an ultra-small satellite in order to make Japan's first foray into space astrometry; to accumulate technical experience in the onboard data acquisition and the like that will be conducted in the upcoming JASMINE project; and to achieve scientific results like information on the structure of the galaxy near the Solar System.

The satellite is scheduled to be launched from a Brazilian launch site operated by Alcântara Cyclone Space using a Cyclone-4 rocket built by Ukrainian rocket developer Yuzhnoye. The launch has been pushed back due to delays in the construction of the Alcântara Space Center launch site in Brazil; at present, launching is scheduled for the end of 2014. The launch rocket has already been prepared, and work on adjusting the rocket/satellite interface is proceeding apace. Assembly of the Flight Model (FM) that will actually be launched into space was completed in FY 2011, but the extra time yielded by the launch delay is being utilized to perform additional testing of the FM in order to further ensure project success. Maintenance of the satellite was also performed. Work to establish terrestrial communication stations involved in the operation of the satellite was continued, and one month of training simulating actual operation (in the initial phase) was performed in order to identify and address problems.

Development of algorithms and software necessary to determine astrometric information at the necessary level of precision from raw observational data also proceeded apace. In particular, a method for determining the centers of stellar images at high precision while taking into account error factors affecting the shapes of stars was developed as part of a graduate student thesis. International cooperation with the data analysis team for Gaia, which involves observational and analytical methods similar to those of Nano-JASMINE, also proceeded without interruption. A Japanese working group (lead by Ryoichi Nishi, Niigata University) for investigating the scientific results obtained by Nano-JASMINE also continued its activities.

3) Planning/Development of Small-JASMINE Project

The goal of the Small-JASMINE Project is to use a telescope with a three-mirror optical system, having a primary mirror aperture of 30 cm to perform infrared (Hw band: 1.1–1.7 μm) astrometric observations and measure annular parallax at a precision of 10–70 microarcseconds and proper motions (transverse angular velocity across the celestial sphere) at 10–70 microarcseconds/year in the direction of a few square degrees area near 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 movement of stars 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 at high frequency. This will enable revolutionary breakthroughs in astronomy including the structure and history of the formation of the galactic bulge; the co-evolution of the galactic bulge and the supermassive black hole at the center of the galaxy; the orbital elements of X-ray binary stars; the physics of fixed stars, star formation, and planetary systems; as well as in basic physics including gravitational lensing. This data will allow for the compilation of a more significant catalogue when combined with data from Earth based observations of the line-of-sight velocities and chemical compositions of stars in the bulge. Focused conceptual planning and design of the Small-JASMINE satellite system and detailed planning of the subsystems for vital elements of the Small-JASMINE satellite, such as thermal structure, attitude control, and orbit, began in November 2008 with cooperation from nearly ten engineers (from JAXA's SE Office, ARD, and ISAS).

Against this background, conceptual planning and design; technical testing; international project partnerships; and scientific discussion by a Science Working Group (led by Masayuki Umemura of the University of Tsukuba) composed of volunteers from diverse fields in Japan were conducted in FY 2012 toward a goal of submitting a mission proposal to the call for small-size scientific satellite mission proposals originally scheduled by JAXA/ISAS for FY 2012. (The ISAS call for mission proposals was not held in FY 2012, and is expected to be held in FY 2013.) The Science Working Group hosted a workshop in FY 2012 as well, and discussed the scientific results expected from Small-JASMINE.

Investigation of the satellite system design to determine if the satellite as a whole will be capable of achieving the target astrometric precision has been performed in-house as well as by the manufacturer since FY 2009. Following the results of the investigations performed in FY 2011, research and development in FY 2012 focused on vital issues in the mission unit (including the satellite system design study and proving tests) that still need to be addressed prior to submitting the mission proposal, as well as detailed planning of the interface with the bus unit. As a result, the plans for orbit/attitude; the thermal environment of the observational equipment; telescope pointing stability; power systems; mass and center of gravity; and communications systems were revised to successfully meet design specification requirements. As a result of investigation into the bus unit interface, specifications were successfully developed so the mission can be completed without the need for additional modification requirements to the standard bus. It was also confirmed that there were no major problems in the cost estimate for the mission unit. Prospective measures for dealing with stray light and outgassing were also raised. In this way, headway was made on preparations for the mission proposal.

International partnerships have also been formed with multiple overseas groups engaging in terrestrial high-dispersion spectroscopic observation in order to determine the line-of-sight velocities and chemical compositions for bulge stars with the aim of gaining a further understanding of the galactic bulge. In particular, a proposal was received from the PI of the United States' APOGEE Project, Steven Majewski (University of Virginia), to jointly submit a proposal for the APOGEE-2 project to equip a telescope in the southern hemisphere suitable for bulge observation with a high-dispersion spectroscope identical to that used in APOGEE and engage in bulge observations. This resulted in a joint proposal submission. JASMINE Project members also participated in APOGEE team meetings. It was decided to further deepen the partnership between the two projects for the sake of future breakthroughs in our understanding of the galactic bulge. As a result, a memorandum was exchanged between the APOGEE-2 team, the SDSS-IV Collaboration, and Small-JASMINE in order to strengthen

international partnerships and establish scientific goals related to the galactic bulge. In this way, Small-JASMINE has obtained international support and concrete assistance, and international cooperation in scientific development is being advanced.

13. Extrasolar Planet Detection Project Office

The Extrasolar Planet Detection Project Office cooperates with researchers interested in exoplanet science at universities around the country, centered around the NAOJ to promotes the general development of technologies for observing exoplanets and their formation as well as to organize exoplanet related observation, The office engages in the development of observational equipment, the promotion of research, mission planning, and research and development of basic shared technologies. The project office also spearheads international cooperative efforts related to exoplanets. Specifically, the research and development conducted by the office focuses on the following five core areas:

(1) The development, maintenance, and operation of the HiCIAO high-contrast instrument for directly observing exoplanets with the Subaru Telescope, as well as the implementation of the related Strategic Explorations of Exoplanets and Disks with Subaru (SEEDS) survey.

(2) Development of the next novel observation instrument (IRD: the InfraRed Doppler Instrument) for detecting terrestrial exoplanets with the Subaru Telescope.

(3) Technical planning of the TMT/SEIT instrument for directly observing terrestrial planets and the mission JPTF, as well as relevant international cooperation.

(4) Implementation of the next-generation infrared astronomy satellite SPICA and related exoplanet science investigations.

(5) Research the interstellar medium and the formation of stars and planets via wide-field imaging polarimetric observation using the IRSF telescope in South Africa.

The Office staff for FY 2012 consisted of four full-time staff members, five staff members holding other posts, and six full-time postdoctoral fellows. There were 26 refereed Western-language papers, 12 non-refereed Western-language papers, 32 Western-language reports (speeches at international conferences, etc.), two non-refereed Japanese-language reports, one Japanese-language report in the form of a book or publication, and 56 Japanese-language reports at academic conferences and the like.

1. Development of the next observational instrument for exoplanet research for the Subaru Telescope and implementation of observational research using the same

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

Development was completed for the modular high-contrast instrument HiCIAO, which is equipped with a coronagraph and simultaneous differential imaging technologies (featuring different polarizations, wavelengths, and angles) for directly observing exoplanets and the circumstellar discs in which they form using the 8.2 m Subaru Telescope. Design and fabrication began in FY 2004. Test observations were completed in FY 2009, and SEEDS (Strategic Explorations of Exoplanets and Disks with Subaru), the first strategic project using Subaru, was begun in October 2009 with cooperation from nearly 100 researchers across Japan and the world. Observations are continuing smoothly.

(2) Infrared Doppler Instrument (IRD)

Development is underway into a high-dispersion infrared spectrometer having a line-of-sight velocity precision of approximately 1 m/s in order to create an infrared Doppler instrument for detecting habitable terrestrial planets around M-type and other low-mass stars. The budget for the project is based on a specially implemented research project (led by Motohide Tamura) funded by a Grant-in-Aid for Scientific Research for FY 2010–2014. The final design of the optical system; fabrication of high-dispersion optical elements; planning for a 4096×4096 pixel infrared detector; laboratory evaluation of the optical system components; fiber selection experiments for guiding light from astronomical objects and comb light; and optical frequency comb generation experiments were conducted. The Science Working Group also engaged in investigations of planets around M-type stars.

2. Technical planning of space mission and next-generation observational apparatus for extremely large terrestrial telescopes for the direct observation of terrestrial planets, and international cooperation efforts

(1) Japanese Terrestrial Planet Finder (JTPF)

The scientific goal of this mission project is to directly observe terrestrial planets and search for signs of life. Along with the planning of Japanese missions, the possibility of international cooperative missions is also being explored. Fundamental experiments continued with performance testing at the JPL test bed with collaborators. A paper on the SPICES Mission was published. In addition, the TESS Mission, in which project staff members are participating, was selected for the NASA Discovery Mission.

(2) Second Earth Imager for TMT (SEIT)

Technical and scientific planning of the new SEIT observational apparatus to enable the detection of terrestrial planets using the 30 m next-generation extremely large terrestrial telescope, TMT, was continued. A proof-of-concept optical system for the SEIT observational method was constructed, and

verification experiments were performed.

3. Observation instrument and scientific implementation for next-generation infrared astronomical satellite SPICA

The office has been involved in the scientific planning of a high-contrast observation instrument for SPICA, the 3.2 m single-mirror (not deployable segmented mirror) telescope with high sensitivity, which has been led by JAXA since the beginning of the mission project. The project seeks to engage in imaging and spectroscopy of planets located at comparatively large distances from their primary stars.

4. Research/Educational/Outreach Activities

Research was conducted into exoplanets and the discs in which they form, as well as related fields including rogue planets, brown dwarfs, star/planet formation, and fixed stars. A total of 25 refereed scientific papers were published. In particular, 11 papers were published on the Strategic Explorations of Exoplanets and Disks with Subaru (SEEDS) project. Notable results include the direct imaging of a giant planet around the star Kappa Andromedae by HiCIAO; the discovery of gaps (PDS 70 and USco J1604) via high-resolution observation of protoplanetary discs also by HiCIAO; as well as the discovery of small spiral arm structures (MWC 758 and SAO 206462). The disc structures of the latter two both exhibited signs of the presence of planets (Fig. 1). Other major results include the detailed modeling of transitional discs photographed by HiCIAO; investigation into the possibility of detecting oxygen emission lines in near-infrared wavelengths as biomarkers via terrestrial telescopes; observations in order to detect giant planets around M-type stars; the cataloguing of isolated planetary-mass objects by the SONYC Project; the discovery of a companion star for the retrograde planet in the HAT-P-7 system; discoveries regarding the circular polarization and homochirality of the NGC 6334 region using the SIRPOL infrared polarimeter; and research into brown dwarfs and star formation by the UKIDSS/VVV Project. The SEEDS strategic observational project using the Subaru Telescope proceeded smoothly this year. Theoretical research and research via transit and Doppler methods were also conducted.

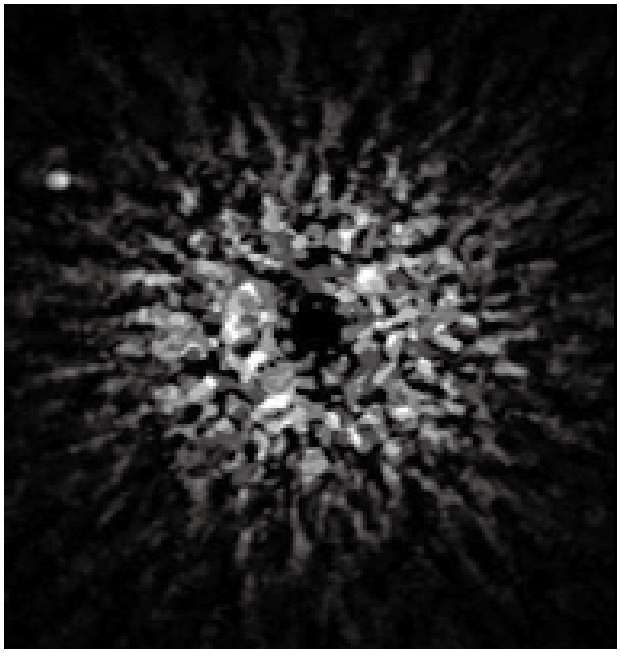

Figure 1: HiCIAO image discovering an exoplanet circling Kappa Andromedae. The object is believed to be a planet 13 times the mass of Jupiter located at a distance of 55AU from the B-type star.

Research guidance was given to 15 graduate students engaged in exoplanet research and related R&D. Numerous lectures and publications for the general public on exoplanets, discs, and general astronomy were implemented, and a total of six press releases were issued.

14. RISE (Research of Interior Structure and Evolution) Project Office

1. Lunar Explorer Kaguya (SELENE)

(1) Publication of Kaguya Data

Data from the RISE lunar exploration project on the topography and the free-air gravitational field, as well as processed data for Bouguer gravity anomalies and crust thickness, were made available to the public on the NAOJ website starting July 2010. Gravitational field and topographical data are constantly updated. Data can be accessed at the following addresses:
(Japanese) http://www.miz.nao.ac.jp/rise-pub/
(English) http://www.miz.nao.ac.jp/rise-pub/en

(2) Research into the Internal Structure of the Moon using Kaguya Data

The model of the lunar gravitational field was expanded to a spherical harmonic degree and order up to 150 by incorporating VLBI phase delay data and simultaneously adding low-altitude orbit tracking data from the NASA Lunar Prospector. Co-analysis of lunar topographic data obtained by the LALT laser altimeter and lunar topographic data obtained by the LOLA laser altimeter on the NASA Lunar Reconnaissance Orbiter (LRO) was conducted. The relationship between lunar crust thickness and mare basalt distribution was investigated, confirming that there are differences in the maximum crust thickness where mare basalts can erupt on the near and far sides of the moon, as well as significant differences between the Feldspathic Highland Terrane (FHT) and the South-Pole Aitken Basin (SPA) on the far side of the moon.

2. Future Lunar/Planetary Exploration Projects

(1) High-Precision VLBI Observation of Lunar Gravitation

Building on the results from the Kaguya mission, planning of the onboard equipment, including lander, for the next lunar exploration project SELENE-2 is underway. The deep structure of the Moon, especially core size, density, physical state, and composition, are invaluable elements in exploring the origins and evolution of the Moon. Limiting values for these parameters can be obtained from the low-order elements J2 and C22 of the lunar gravitational field and the tidal Love number k2.

Thus, a new mission to measure the lunar gravitational field has been proposed for SELENE-2 in order to improve, in particular, the precision of low-order gravitational field coefficients and k2. Specifically, VLBI radio sources will be installed in a lunar orbiter and a survival module to be set up on the lunar surface, and the gravitational field will be measured via same-beam VLBI observation. Whereas the trajectories of two small satellites were simultaneously determined in the Kaguya project, one radio source will be immobilized on the lunar surface and used as a reference to determine the trajectory of the other radio source (the orbiter) in the SELENE-2 project. The path of the orbiter satellite will be selected so that the elongation between the radio sources constantly satisfies same-beam conditions, thus allowing for the acquisition of large amounts of high-precision VLBI observational data in order to efficiently improve low-order gravitational field coefficients and k2.

Investigations focused on the following points in FY 2012.

i) Internal structure limitability

In order to more clearly define the scientific goals of SELENE-2, the extent to which the interior structure of the Moon could be constrained by combining geodesic data and moonquake data was investigated. An error evaluation was conducted for the radius and density of the core for a scenario in which moonquake data for Tycho is acquired by SELENE-2 in addition to the moonquake data from the Apollo mission and geodesic data precision is improved in the VLBI mission. Results indicated that a precision of roughly 10% could be expected for both radius and density. Next, a method of actually combining geodesic data and moonquake data to perform a Bayesian estimate of the interior structure was developed, and the abovementioned results were tested. Results indicated that the core radius could be determined at roughly 10% precision using a simple three-layered model, even if there were uncertainties regarding the structure of the crust.

ii) Antenna heat resistance

A patch antenna on a Macor substrate was selected for an antenna usable in lunar surface temperature conditions (−200°C − +120°C) as a tradeoff between formats, materials, etc. Thermal shock testing of a Macor substrate was performed using liquid nitrogen, confirming that the unit was capable of independently withstanding lunar surface temperature conditions. Electrical properties analysis was also performed, confirming that performance requirements were met in lunar surface temperature conditions.

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

Same-beam S-band VLBI observation had been considered as the primary method for differential VLBI observation between the orbiter and the lander in the SELENE-2 project. But to achieve more precise dual-beam S/X band VLBI observations joint research was begun with the Mizusawa VLBI Observatory using a Grant-in-Aid for Scientific Research, Category A (Researching Lunar/Planetary Interior Structures via Explorer VLBI Observation: Size, State, and Origins of Metal Cores). Whereas the elongation between the orbiter and the lander is between 0° and a maximum of 0.6° in SELENE-2, observations at elongations of less than about 0.3° are difficult in methods involving receivers installed in two stages, as in the conventional VERA dual-beam system; thus, it was decided to adopt a phased array method allowing for observation at smaller elongations. Conceptual planning was conducted using a self-complementary array antenna, a VIVALDI antenna, and the like as candidates.

(2) Studying the structure of the lunar interior via lunar laser ranging

The distance between the Moon and the Earth can be accurately measured by transmitting a laser from a telescope on Earth to laser retroreflectors left on the lunar surface by the U.S. Apollo Project and Soviet lunar exploration projects and observing the reflected photons, thereby allowing lunar orbit variations to be investigated.

Due to the lack of reflectors in the southern hemisphere of the lunar surface and the time difference between the two ends of reflector arrays generated by libration, the level of precision has hitherto been insufficient to determine fine 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 variations.

Investigations focused on the following points in FY 2012.

i) Retroreflecting mirror

ZPF (Nihon Ceratec), Clearceram-Z EX (Ohara), and monocrystalline silicon were selected as candidate materials for the retroreflecting mirror to be installed on the lunar surface out of consideration of their linear expansion coefficient, thermal diffusivity, Young's modulus, and density. Iwate University, NICT, Hitotsubashi University, and others analyzed mirror deformation due to temperature changes and gravity on the lunar surface and the resulting degradation of optical properties. Chubu University, the Chiba Institute of Technology, NICT, and the manufacturer jointly discussed grinding methods for the case of a single-piece mirror, bonding methods in the case of a laminated mirror, methods of precisely determining interplanar angles, and a gimbal for orienting the reflector in the direction of Earth.

ii) Terrestrial ranging station tests

In order to enable lunar laser ranging, an experimental ranging to an Earth-orbit satellite equipped with a reflecting

mirror was conducted jointly with NICT using a version of the NICT Koganei satellite laser ranging (SLR) system that had been modified for lunar observation.

(3) Study of the structure of the lunar interior using the ILOM telescope

Research is underway to install a small PZT telescope (ILOM: In situ Lunar Orientation Measurement) on the lunar surface and perform high-precision observation of variations in the rotational movement of the Moon in order to limit the internal structure of the Moon. Because measurement can be conducted independent of lunar orbital components, this small telescope is capable of detecting miniscule variations in the rotation of the Moon, making it possible to determine if the lunar core is molten.

Planning, development, and testing focused on the following points in FY 2012.

i) Development of diffractive lens

It has been practically confirmed that the use of a diffractive lens for a lunar surface telescope presents no problems for analysis or element testing, and construction of a prototype objective lens for actual performance evaluation was begun. Chubu University's Suzuki Laboratory, which specializes in precision machining, was requested for assistance in fabricating the body of the diffractive lens. Planning for the overall design, fabrication, and evaluation of the objective lens was also begun with the manufacturer.

ii) Telescope performance evaluation

Telescope performance was evaluated jointly with Iwate University using a terrestrial observational model and an artificial light source. In particular, various shapes of mercury pools were fabricated and compared in order to evaluate the effects of vibrations in the mercury pool used as a horizontal reference plane. At present, a copper mercury pool 0.5 mm deep by 84 mm diameter is most resistant to the effects of vibration.

(4) Hayabusa 2 LIDAR

The LIDAR scheduled to be carried by the Hayabusa 2 asteroid explorer slated for launch in 2014 is an instrument using laser ranging to estimate asteroid shape and gravitational fields. The Chiba Institute of Technology and the University of Aizu are also participating in its design based on the previous experience with the Kaguya project. Investigation is underway for science promotion and a hardware testing plan for science maturation. The project is planned to make scientific contributions in gravity (object mass) determination and photometry.

Efforts focused on the following points in FY 2012.

i) A new dust observation mode was developed and included as a scientific observational mode. Prior to this, investigations into dust flux, light levels, acquired data levels, and the like were performed.

ii) An algorithm for modeling asteroid shapes and an operating method for estimating gravitational fields were examined and suggested for the project.

iii) A simple data monitoring software program (QuickLook, QL) was created and telemetry packet adjustment was performed in preparation for primary engagement.

iv) Operating methods for asteroid surface albedo measurements and the precision thereof were discussed.

(5) Research into Internal Structure in Explorations of Mars

The Mars general exploration working group is making plans for landers. The RISE Group seeks to accurately measure variations in the rotation of Mars by loading radio sources onto multiple landers and using methods such as four-way Doppler and inverse VLBI. This will enable debate on the presence or lack of a molten core in Mars; the growth and shrinkage of its polar ice caps; annual variations in atmospheric movement; and the like.

(6) Other Exploration Projects

The office is continuing its activities as a co-investigator of the BepiColombo Mercury exploration project, jointly planned by the European Space Agency (ESA) and Japan and scheduled for launch in 2015. The office decided to participate, along with the Chiba Institute of Technology, in the development team for the GALA laser altimeter to be used in the ESA's JUICE mission to explore the Jovian system. The Japanese team will be responsible for the receiverunit.

3. Educational Activities/PR

The Office continues to engage in raising public awareness regarding the Kaguya project. The layout of the Office's website was updated to allow for regular posting of the latest information. The website can be viewed at http://www.miz.nao.ac.jp/rise/en.

4. Joint Research / International Cooperation

Joint research into the basic development of a lunar lander/explorer (LLR and ILOM) is being conducted with the Faculty of Engineering at Iwate University, with monthly meetings being held alternately at the Faculty of Engineering at Iwate University and NAOJ Mizusawa. This collaboration is being conducted under the Memorandum on Basic Matters Concerning Research and Development of Lunar Surface Exploration and Observational Equipment exchanged between the RISE Lunar Exploration Project and the Faculty of Engineering at Iwate University, and the two will continue to cooperate in the research and development of lunar surface exploration and observational equipment.

Data analysis and joint research into future projects is being continued with a group at China's Shanghai Astronomical Observatory, which was a collaborator in observation via the Kaguya satellite. Approval was granted in FY 2012 for a Japan/China joint seminar planned by the Japan Society for the Promotion of Science (JSPS), and a workshop doubling as a

RISE research conference was held at NAOJ Mitaka in June.

Research collaboration with a group at Russia's Kazan Federal University, which has a history of theoretical research into the structure of the lunar interior, was continued within the framework of a Japan/Russia joint research project (two years, third session) planned by JSPS that was approved from FY 2011. In FY 2011, Y. Barkin of Moscow State University spent half a year at Mizusawa as a visiting professor, and engaged in research into the construction of a new theory of lunar rotation.

Joint research was also conducted with T. Hiroi of Brown University in the United States and T. Nakamura of Tohoku University, with experiments in space weathering and measurement of meteorite reflectance being performed at Mizusawa.

15. 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 in open computer use and research infrastructure. Its activities consist of the DB/DA Project, the Network Project, the Japanese Virtual Observatory (JVO) Project, the Hyper Suprime-Cam Data Analysis Software Development Project, and works related to the computer open-use.

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. ADC has made public various types of astronomical data, 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 core of the project, the SMOKA database (http://smoka.nao.ac.jp/) which holds archive data from sources such as the Subaru Telescope; the 188 cm telescope of the Okayama Astrophysical Observatory; the 105 cm Schmidt telescope at the Kiso Observatory, University of Tokyo; the MITSuME telescope operated by Tokyo Institute of Technology (two 50 cm telescopes); and the Kanata telescope (150 cm) at the Higashi-Hiroshima Observatory of Hiroshima University, is open to the public and has yielded numerous research breakthroughs. Nearly 7.32 million frames and 39 TBytes of observational data (excluding environmental data and meteorological data) are available for viewing in SMOKA as of May 2013. In FY 2012, 21 papers based on SMOKA data were published in refereed journals, for a total of 120 published papers as of May 2013.

Efforts in FY 2012 were focused on transitional work accompanying the updating (replacement) of the computer system. Work on developing an advanced search function for SMOKA and increasing operational efficiency was continued from the previous year.

(2) Network Project

ADC operates network systems connecting its headquarters (at the Mitaka Campus) and branches distributed around Japan, as well as wide-area lines connecting regional networks. Operational highlights for FY 2012 were as follows.

1) Introduction of new information network system: A new information network system has been provided for the Mitaka, the Mizusawa, the Nobeyama, and the Okayama campuses from March 2013 onward. In particular, 40 Gbps ethernet-compatible foundamental networks have been put into operation at the Mitaka and the Mizusawa campuses.

2) Research and development of systems for the CfCA supercomputer system: The CfCA supercomputer system is distributed amongst the Mizusawa and the Mitaka campuses. The CfCA Project is collaboratively developing highly cost-efficient 40 Gbps high-speed routers and a storage cache (accelerator) for transmitting data amongst the distributed systems at high efficiency.

3) Special classes for elementary and junior high school students in earthquake-affected areas: ADC held three special classes primarily for elementary and junior high schools in affected regions via real-time links between the Subaru Telescope and the classroom. This program was offered in cooperation with both Japanese and foreign support organizations.

(3) Japanese Virtual Observatory (JVO) Project

The JVO Project is engaged in the development and operation of a portal site (http://jvo.nao.ac.jp/portal) to astronomical data from around the world, in order to promote data-intensive astronomical research.

1) Distribution of ALMA data: Distribution of ALMA science verification data via a VO interface was begun. A GUI allowing for simultaneous data searching and viewing was developed jointly with the ALMA software group.

2) Improvement of JVO Sky service functionality: We have developed a system to display data gathered from VO services around the world via a crawling system on a celestial chart and to download the data. This allows astronomers easily check

specific regions having observational data from the Subaru Telescope, ALMA, the Suzaku X-Ray Telescope, the Hubble Space Telescope, and the Chandra X-Ray Telescope and others.

3) Addition of AKARI data to LMC Survey Catalogue: We have registered to the JVO system a merged catalogue including the LMC catalogue from the IRSF telescope in South Africa, developed by Daisuke Kato of the AKARI team's.

4) JVO system refactoring: Unused portions, redundant functions, and the like were cleaned up in order to improve future code maintainability and expandability, and to prepare for a redesign of the system for easier-to-use screen transitions for JVO Portal in the future.

5) VO Tutorials: Tutorials were held on how to use the JVO Portal as well as software developed by overseas VO groups. Work on three research topics was performed using the JVO Portal and other various types of VO software.

6) Scientific research using VO: Large samples on the evolution of SMBH-containing galaxies were searched for and analyzed via VOs, yielding new discoveries regarding the evolution of SMBHs.

7) International Collaboration: Masatoshi Ohishi served as the president of IAU Commission 5 from August 2009 to August 2012, as a member of the science advisory board of Europe's VAMDC Project, and as chairman of the ICUAF, an international group that protects radio astronomical observation from radio interference, from August 2009 onward.

(4) HSC Data Analysis Software Development Project

The HSC Data Analysis Software Development Project aims to develop data analysis software for the next-generation ultra-wide field visible light camera equipped with the Subaru Telescope (HyperSuprime-Cam, HSC) as well as a database for managing and sharing analysis results.

This project, which was begun in January 2009, engages in the planning and implementation of parallelized and distributed processes; methods of correcting instrumental distortion; and methods of calibrating object position and brightness, for the sake of efficient and precise analysis of HSC data obtained with the 104 CCDs.

Operational tests during actual test observations were performed in FY 2012 with the necessary software at the Subaru Telescope's base facility immediately following observation as the on-site analysis. At present, the software is able to complete in analyzing data from all 104 CCDs in about five minutes after data acquisition. Further strategies will be sought to enable even faster processing. Meanwhile, there have been various developments in image processing. A series of data processing pipeline for mosaicing and catalogue compilation is being completed by using data obtained by HSC test observation since January 2013. The groundwork is currently being laid for achieving more complete data production while adding the necessary measuring functions.

We continue to test and develop a database for managing analyzed and processed data. A general outlook for the data processing procedure has been established via integration with the analysis software. In particular, steady progress is being made on the database registration and management of the catalogue including mosaiced images and astronomical objects detected therein.

(5) Works related to the Computer open-use

A group of rental computers forms the core of the open use in ADC. These comprise the primary responsibility of ADC as an inter-university research institute. In parallel with improving the hardware performance of the computer system, efforts were also made for astronomical application and developing data analysis software for better efficiency. The rental computer system was replaced in FY 2012, and a new rental computer system, the NAOJ Data Analysis/Archive/Publication System, went into operation on March 1, 2013.

The System is composed of a "multi-wavelength data analysis" subsystem, a "large-scale data archive", a "data publication" subsystem, a "virtual observatory" subsystem, a "solar data archive/analysis/publication" subsystem, a "Mizusawa area data analysis" subsystem, and a "expetiment-use" subsystem. Of these, the computational resources of the multi-wavelength data analysis subsystem have been enhanced to nearly five times the capabilities of the old data analysis system, and 122 users registered to the subsystem in FY 2012.

The Center also hosted and co-hosted various seminars as part of its open use efforts. 11 seminars and other events were held this year, with a total of 169 participants. Details are as follows.

Event Name (*: co-hosted)	Dates	Participants
Subaru Spring School 2012*	May 29–31, 2012	10
IDL Seminar for Beginners	June 21–22, 2012	12
FY 2012 IRAF Seminar	July 19–20, 2012	13
VO Tutorial, Autumn 2012	September 27–28, 2012	11
ALMA CASA Tutorial*	November 22, 2012	55
IDL Seminar on FITS Data Analysis	November 27–28, 2012	9
Asian Winter School on Exoplanets*	December 3–5, 2012	21
Subaru Autumn School (FMOS) 2012*	December 11–12, 2012	9
Midwinter School on N-body Simulation*	January 21–23, 2013	8
FY 2012 SQL Seminar	February 26–March 1, 2013	16
VO Tutorial, Spring 2013	March 25–26, 2013	5

3. Other Activities

As part of PR activities, 90 issues of "Information from ADC," from issue No. 235 to No. 324, were published in FY 2012. These were distributed via email and on the Web.

16. Advanced Technology Center

1. Overview of the Organization and Activities of the Advanced Technology Center (ATC)

Development of Hyper Suprime-Cam (HSC) which had been designated an area for focused development was completed, and test installation on the Subaru Telescope began. Fabrication of the ALMA receivers is proceeding apace, and the final stages of parts machining have been entered in the Mechanical Engineering Shop. Fabrication of all three receiver bands is targeted for completion in FY 2013.

Meanwhile, established as an organization dedicated to instrument development for NAOJ projects, leading edge development continued for the IRIS observational apparatus for the next-generation extremely large Thirty Meter Telescope (TMT) and for gravitational wave-related development focusing on the KAGRA project. Technical staff involved in structural design were reassigned, technical staff capable of optical design were hired, and experimental space was secured.

In the activities related to Advisory Committee for Advanced Technology, the "Recommendations of the Advisory Committee for Advanced Technology" which had been an object of concern from the previous year was completed, and submitted to the Director General of the NAOJ in September. Firstly, the document discusses the importance of autonomous development of instruments for TMT, KAGRA, and the like. Also discussed is the necessity of drawing upon previous instrumentation development experience with the aim of establishing the ATC as a center for international development in the future, as well as the necessity of the personnel reinforcement that will be essential to this end. Meetings of the Advisory Committee for Advanced Technology were held in September and March this fiscal year. The Director General was asked for feedback, based on which the Advisory Committee discussed and studied specific strategies for transitioning to a framework for supporting the development of TMT and KAGRA. Discussions are ongoing.

In other activities, brochures about the Advanced Technology Center were completely overhauled to more impressively convey the details of the areas of focused development supporting NAOJ projects and the development of advanced technology contributing to future projects. These materials were utilized for promotional purposes at the IAU General Assembly held in Beijing.

The 23rd International Symposium on Space Terahertz Technology co-hosted by the NAOJ, the Advanced Technology Center, and JAXA/ISAS on April 2–4, 2012, at the National Center of Sciences was the first time the event was held in Asia. There 87 participants from Western countries and 52 from Japan discussed ALMA, SPICA, and other terahertz technologies.

2. Workshops and Development Support Facilities

(1) Mechanical Engineering Shop

The goal of the Mechanical Engineering Shop (ME Shop) is to engage in the entire process of creating experimental and observational instruments, from design to fabrication and shape measurements.

A new full-time technician joining the Shop following an intra-Observatory transfer was assigned to the design department to enhance design strength.

The design department is engaged in projects such as the structural design of the primary parts for the auxiliary optics system of the KAGRA gravitational wave telescope, and the detailed design of a lens mount for the optical framework of the IRIS focal plane instrument for TMT.

Fabrication of mass produced parts for the ALMA receiver is proceeding according to schedule. The shop is engaged in HSC development support as well as responding to project requests from both within and outside the observatory. Some of the major requested projects completed by the Shop include thermal radiation shielding parts for SIMS (University of Tokyo), a mechanical deformable mirror (JAXA/ISAS), a concentric cone mirror (Underwater Technology Research Center at the Institute of Industrial Science of the University of Tokyo), and a small format slicing mirror (University of Tokyo, SPICA Project).

In the field of ultra-precision machining, the shop engaged in collaborative research and development with external organizations and worked on project requests. Joint research and development efforts included the development of an ultra-precise milling process using a monocrystalline diamond tool with the Mechanical Engineering Center of the High Energy Accelerator Research Organization (KEK), and the successful development of optimal mirror surface machining conditions for an X-band accelerator tube disc. A project involving the grinding of aspherical lenses of magnesium fluoride (MgF2) using a monocrystalline diamond bit was continued from last year with the Institute for Molecular Science and Nagoya University. Follow up investigation into machining conditions for practical applications is also underway. In prototype manufacturing of the radio camera lens array being developed in the ATC, ultra-precise cutting of the antireflective film newly applied to the surface of the array was successfully performed, achieving a film pressure error of $\pm 3\mu$m.

Technical exchange with the Mechanical Engineering Center at KEK has been conducted for the past two years as part of the shop's technical collaborations with external research organizations. The "Technical Conference on the Introduction of a Five-Axis Control Machining Center" was held this year by technicians experienced in the field of machining to exchange information and specialized technical expertise.

The ME Shop accepted 105 manufacturing and repairs requests last year. Including four carried over from the previous year there was a total of 109, of which 93 were completed, and 16 were carried over into FY 2013. 10 projects involved the use of external organizations. The numbers of requests received in FY 2012 were as follows. (Numbers in parentheses indicate projects carried over to FY 2013.)

Carryover from previous year	4
Advanced Technology Center	15 (6)
Subaru Telescope	3 (1)
HSC	2
TMT	4 (1)
JASMINE Project Office	2
Okayama Astrophysical Observatory	1
Extrasolar Planet Detection Project	13 (1)
Solar Observatory	4 (1)
Hinode	3
SOLAR-C/CLASP	11 (1)
ALMA	22 (3)
RISE	2
Nobeyama Observatory	1
Division of Radio Astronomy	1
KAGRA	1
TAMA Project Office	5
Public Relations Center	1
Astronomy Data Center	1 (1)
Center for Computation Astrophysics	2
Administration Department	1
External organizations	10
Institute of Astronomy, University of Tokyo	5 (1)
Institute of Industrial Science, University of Tokyo	2
JAXA/ISAS	2
Osaka University	1
Total	109 (16)

(2) Optical Shop

A. Usual Operation and Maintenance

- Measurement equipment maintenance (day-to-day inspection, etc.)
- Measurement-related consultations (69)
- Repair/upgrading of facilities (adding buffer tank to LEGEX 910 compressor, PC upgrade for UV-3100 PC, ZYGO interferometer maintenance, etc.)

B. Shared use of measurement equipment

April 2012 – March 2013 (including use in joint research projects)

- Instances of measurement equipment usage: 400
  Itemized: within ATC: 131
  ALMA-related: 14
  NAOJ and Institute of Astronomy of University of Tokyo: 162
  Non-NAOJ: 93
- Use of LEGEX 910 large three-dimensional observational apparatus: 58
  The equipment was constantly used throughout the year, for a total of 75 days of utilization.
  Itemized: ALMA and HSC: 51 (used by measurers of each group)
  Requests to the Optical Shop for measurement: 7

(3) Space Chamber Shop

This workshop provides support for the shared use of the vacuum chamber, clean room, and other facilities belonging to the Advanced Technology Center. The primary results of shared use efforts include tests for the CLASP sounding rocket experiment performed by the UVSOR synchrotron facility using the ATC vacuum chamber. Also various vacuum experiments were performed as part of the next solar observation satellite SOLAR-C project. Additionally, using a temperature control apparatus featuring the newly-installed mechanical freezer, low-temperature motor tests for the filter exchange mechanism of the WISH (Wide-field Imaging Surveyor for High-Redshift) satellite, and temperature-cycling tests of mirror materials for the RISE lunar and planetary exploration project were conducted. The vacuum chamber had almost daily use by open use researchers in out-gassing measurement experiments and the like.

(4) Facility Service Unit

In building and facility-related news, air conditioning equipment and lighting were refurbished in the Instrument Development Building (South). The air conditioning capabilities of the aging equipment of the 18-year-old building had declined, and the office area air conditioning equipment was renovated. With this renovation, the air conditioning equipment for this entire building was fully refurbished because Lab room air conditioning equipment had already been renovated in FY 2011. Repairs were also performed on aging light fixtures in part of the office areas, which had exhibited increasing levels of lighting problems. The new lighting features LEDs, which are quite bright at nearly twice the brightness of fluorescent lights. Refurbishment of the remaining lighting is scheduled for FY 2013.

In building-related news, rain leaks occurred simultaneously in three different lab rooms due to degradation of the waterproof sheeting on the roof of the Instrument Development Building (South). There was widespread damage in the waterproof sheeting due to degradation, leading to high levels of indoor rain leakage; thankfully, no lab equipment was damaged. Inspection of the waterproof sheeting performed following the leaks revealed damage at numerous locations around the same building, leading to widespread replacement of the sheeting. A number of damaged locations were also discovered around the Instrument Development Building (North), and partial repairs were performed.

Legally mandated inspections of 0.5 ton and heavier crane equipment are performed annually. Since load testing of three-ton and heavier crane equipment is also mandated, the testing for the 4.8 ton crane was performed so as to coincide with the annual inspection performed in November 2012. Load testing must be performed every two years before the certification expiration date; the next test is scheduled for November 2014.

The cold evaporator (CE) must also be inspected annually. Despite 18 years having passed since its installation in 1994, the evaporator exhibits no anomalies and continues to be used without incident. Primary management duties include legally

mandated day-to-day inspection and operational management of the buildings, electrical equipment, and CE equipment; as well as diverse other duties including the management of clean rooms, clean room external air conditioning equipment, private power generator equipment; operation of the Electrical Shop; chemical substance management; and the disposal of used chemicals.

In peripheral equipment-related news, the mirror of the heliostat on the roof of the Instrument Development Building (North) was re-plated. The heliostat has been used in performance testing of the on-board visible light telescope of the HINODE solar observation satellite and small observational instrument testing since its start of operation in 2003. But the surface of the mirror coating had severely degraded due to harsh outdoor conditions, and was re-plated in January 2013.

Two lab rooms in the Instrument Development Building (South) were assigned to the TAMA and KAGRA projects, which falls under the rubric of advanced technology development in the ATC, and equipment was installed in the large-area lab room. A clean booth (class 1) was installed in another lab room, and equipment installation work is underway towards actual operation. The lab room with the clean booth had been used for the evaluation testing of HSC, and clean-up was performed after HSC was shipped to the Subaru Telescope. The Advanced Technology Center has a limited numbers of lab rooms, and projects are accepted according to availability. Lab capacity continues to be near maximum since FY 2011, and is assigned to users and operated as available.

Mutsumi Yokota, who had been in charge of facilities management for years, retired in March 2013. His long years of service in operating and maintaining the facilities are greatly appreciated.

3. Project Support

Two calls for open use projects were held last year; resulting in Advanced Technology Center equipment being used for 8 joint research and development projects and 26 cases of facilities usage. Results reports are available at the homepage of the Advanced Technology Center.

4 Areas of Focused Development

(1) ALMA SIS Element Development

The furnishing of Band 4 and Band 8 receiver equipment satisfying ALMA specs was continued from the previous year. The necessary numbers of devices are being manufactured for the production of receivers up to December 2013 and the subsequent maintenance of these receivers.

A new SIS element manufacturing apparatus was delivered at the end of October 2012, and work to bring the apparatus online is underway. After apparatus performance confirmation operation and device prototype testing have been performed, the apparatus is scheduled for use primarily in manufacturing band-10 receiver SIS elements.

(2) ALMA Band 4

A Band 4 cartridge Manufacturing Readiness Review (MRR) was held on June 6, 2012, with review committee members in attendance from North America, Europe, Chile, and Taiwan. As a result, it has been confirmed that the testing and assembly equipment necessary for mass production are ready, and that there are no problems in receiver performance or the quality control system. However, difficulties in attaining a polarization efficiency of 99.5% or higher led to a revision to specifications being approved. The target of at least three units per month for post-MRR mass production has been met. Manufacturing of the mixer elements, for which the sputtering apparatus was changed following the Great East Japan Earthquake, is also proceeding apace. Close partnership with the SIS group will be necessary in order to secure a sufficient number of mixer elements, including spares.

(3) ALMA Band 8

Band 8 (385–500 GHz) cartridge receivers were produced at a pace of three units per month. A total of 53 spec-compliant units were delivered to the Joint ALMA Office (JAO) by the end of April 2013. Complete sets of parts including cooled optical blocks for 73 units were procured for shipment from the ATC's ME shop. Assembly, testing, and delivery of the remaining receivers are scheduled for FY 2013.

(4) ALMA Band 10

A Band 10 cartridge MRR was held on June 6, 2012, with review committee members in attendance from North America, Europe, Chile, and Taiwan. As a result, it has been confirmed that the testing and assembly equipment necessary for mass production are ready, and that there are no problems in receiver performance or the quality control system. However, a change in specifications regarding the requirement of a noise performance of 80% for the RF band at 230K or less was approved out of consideration for scientific impact and mass production schedule. Despite a roughly four month delay in the delivery of parts (multipliers) necessary for receiver production from NRAO in the United States, manufacturing of Unit 36 was completed by the target of the end of March 2013. NICT is scheduled to continue supplying high-quality NbTiN thin films in order to manufacture the mixer elements for all of the 73 units being shipped.

(5) HSC Development

This is a project to make full use of the advantages of the Subaru Telescope by developing and producing a camera prime focus camera having an ultra-wide-field (Hyper Suprime-Cam, HSC) which is not possible with previous giant telescopes, and to use this new instrument to engage in the imaging and exploration of an ultra-wide area of at least 1,000 square degrees. Nearly 200 million galaxies are estimated to be present in the area to be explored. Systematic morphological deformation caused by (weak) gravitational lensing will be detected via morphological analysis of these galaxies in order to determine the total mass (including dark matter) between distant

galaxies and the Earth and create a mass distribution map. The following milestones were attained in FY 2012.

- Primary test observations were performed in August 2012 to confirm the functioning of all systems.
- An observation proposal requesting 300 observation nights was submitted in October in cooperation with 166 joint researchers, and accepted in May 2013 following examination.
- Secondary test observations were performed in January 2013 to confirm the performance of all systems. Image forming performance at better than 0.5 arcseconds for the entire field of view was confirmed, as per design. Compared to the roughly 1 arcsecond performance reported for the project's direct competitor, the U.S. Department of Energy's Dark Energy Camera project, this represents a major advantage on the part of the HSC, as image forming performance is the key to signal detection.
- Constant progress is being made in data management system (analytics and database) development, and performance and reliability evaluations are scheduled to be conducted based on live data obtained from future test observations.

(6) TMT Observational Instrument Development

Development of the imaging system for IRIS, the first observational instrument for the next-generation extremely large Thirty Meter Telescope (TMT), began in FY 2011. IRIS development is currently in the basic design phase. The following prototype tests for component technologies were performed this year primarily by members of the ME Shop.

- Design, production, and performance evaluation of a vacuum container for ultra-precise pinhole grid measurements
- Measurement using an ultra-precise pinhole grid prototype at -30°C.
- Combination analysis and bonding testing of lens materials, adhesives, and metals for a bonded lens mount
- Conceptual design, prototype production, and testing of a low temperature drive system.

A measurement precision of 250 nm and a reproducibility of 40 nm were achieved at -30°C in ultra-precise pinhole grid prototype measurements. In bonded lens mount analysis and testing, a usable combination of adhesives and metals was discovered for the lens material to be actually used in the IRIS imaging system.

Development of basic technologies is also underway towards the goal of developing a visible integral field spectrograph as a promising candidate for an upgrade to the first generation observational instrument of TMT. This year, an integral field unit capable of being incorporated into the FOCAS visible light imaging spectroscopic instrument being utilized by the Subaru Telescope was developed.

(7) Gravitational Wave Telescope Development

Following a request from the Director of the University of Tokyo's Institute for Cosmic Ray Research, the primary host organization of the large-scale cryogenic gravitational wave telescope KAGRA, to the co-host organization NAOJ, the ATC will develop various types of optical systems for installation in KAGRA.

This area was designated for focused development at the ATC starting in the summer of 2012.

Development efforts this year focused on various types of baffles to suppress stray light in the KAGRA interferometer unit. Five types of baffle were developed, with the largest having a diameter of 800 mm. Four types will be installed in two 3 km arms of KAGRA, which are especially sensitive and vital in converting gravitational wave signals to light signals. The baffle arrays are scheduled for installation at suitable intervals in the arms in the following order starting from the main mirrors: wide-angle scattering baffle, a cryoduct shield, and a narrow-angle scattering baffle. Working together, these baffles are designed to keep stray light-induced noise under 1/100 of the total design noise level.

The noise contribution of stray light in an interferometer-type gravitational wave telescope is generally determined by the product of baffle vibration, baffle stray light absorption, the level of recombination of secondary scattered stray light not absorbed by the baffle into the main optical axis of the interferometer, and the like. Thus, attention must be paid not only to baffle absorption and scattering levels, but also to its mechanical structure. Mechanical design and assembly methods were therefore discussed in connection to mechanical baffle design with cooperation from the ATC's ME Shop. Optical design was planned primarily based on ray tracing simulations performed with assistance from external optical systems corporations.

A narrow-angle scattering baffle for installation in the 3 km arms of KAGRA was designed, and a prototype unit was produced. The baffle array was designed based on optical simulations. The array layout was optimized, successfully enabling the number of baffles to be reduced to less than half of the number in the initial design, and contributing to a considerable reduction in the overall costs of the KAGRA project.

A clean booth for assembling and testing optical components for installation in KAGRA was also installed in Multipurpose Laboratory 3 at the ATC. An ISO class 1 clean level has been achieved during stable operation.

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

Development of a torsion-bar antenna (TOBA) was conducted towards the goal of observing gravitational waves at lower frequencies than those observed by KAGRA and other large laser interferometer gravitational wave telescopes. At present, the greatest sensitivity in the 0.1 Hz frequency band reported in the world has been attained. Research and development is underway in order to improve sensitivity.

Development was also conducted for the main interferometer unit and a signal acquisition system for the DECIGO Pathfinder (DPF), a milestone satellite for the DECIGO space gravitational wave antenna project. Efforts were focused primarily on the design and production of the interferometer module (BBM) in the gravitational wave sensor unit. Interferometer operation

was confirmed by assembling an interferometer unit using a monolithic incident optical system of the same size as in the optical system actually being launched, a light source of the same wavelength, and a mirror of the same curvature and diameter.

5. Advanced Technology Development

(1) Radio Camera Development

Development of a Microwave Kinetic Inductance Detector (MKID) camera proceeded for the sake of observing B-mode polarization in the cosmic microwave background (CMB). A prototype 102-pixel sub-millimeter camera was built, and beam patterns and noise were evaluated. A detailed design for a 700-pixel millimeter camera and a conceptual design for a 2,000-pixel sub-millimeter camera were developed.

The MKID detects photons with frequencies at or above the superconducting gap. In order to control the gap frequency, a laminated Al/Nb MKID utilizing the superconducting proximity effect was developed, with a resonator quality factor of 106 being achieved. A design and a prototype for a cooled optical system for a multi-element camera were created in order to perform wide-field observations. An antireflective coating for a silicone lens array was developed. After two types of epoxy resins were mixed and applied, the array was successfully cut to optimal thickness.

Development was conducted into a superconducting sub-millimeter camera using a sub-millimeter band SIS photon detector and a gallium-arsenic semiconductor super-low-temperature circuit. Evaluation of the readout characteristics using an SIS photon detector integrating amplifier and the optimization of operating conditions for a 32-channel readout module were continued from the previous year.

(2) Space Optics

Activities to observe astronomical bodies from outer space using rockets and artificial satellites are being conducted for the sake of future space projects. In FY 2012, fundamental development towards the implementation of the CLASP rocket test project and the WISH and SOLAR-C satellite projects was conducted. As part of the WISH project, which involves observations in the near-infrared wavelength band, drive tests were performed for a low-temperature motor for the filter exchange mechanism. As part of the CLASP project, which seeks to perform magnetic field observation of the chromosphere and transitional region of the Sun via hydrogen Lyman-alpha lines, observational instruments and a calibration test apparatus were developed in preparation for flight tests in FY 2015.

In FY 2012, a prototype optical element and a measurement system developed at ATC were brought to the Institute for Molecular Science. Evaluation testing was performed on the optical element via synchrotron radiation. In addition, using ATC resources, the capabilities and durability in mechanical environmental tests were confirmed for the slit unit and the produced slit-jaw optical system components of the CLASP polarization spectrometer. Also the rotational uniformity was confirmed for the rotating wave plate drive mechanism currently being developed for use in flight. Activities related to the next solar observation satellite SOLAR-C project included optical performance evaluation of the optical fiber bundles used in the optical integral field unit (IFU) for the polarization spectrometer, and the acquisition of basic data for contamination management technologies for optical telescopes under UV irradiation.

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

A low-noise readout IC necessary for near-infrared image sensors and CMOS image sensors for use in astronomical observation was designed, and a prototype was created and evaluated. Results showed low noise levels of 70μV readout noise (equivalent to 11 electrons in the prototype IC) and 35μV (6 electrons) in quadruple sampling. The pixel circuit of this readout IC is expected to be applied to future Japanese-produced near-infrared image sensors and visible light CMOS image sensors for astronomical observation.

In readout electronics-related efforts, an analog circuit compatible with multichannel CMOS image sensors was developed. Development of a digital circuit unit continued at NAOJ. A conceptual design for MESSIA 6, the successor to the data acquisition systems used in the Subaru Telescope and numerous other observational apparatus, was developed and proposed to the community.

17. Public Relations Center

1. Overview

The goals of the center are to spread knowledge and raise the awareness of the general public, about not only the activities of the NAOJ but of scientific advances in the field of astronomy in general; to announce the discovery of new astronomical objects; and to provide ephemeris and other types of astronomical information directly connected to our daily lives, such as sunrise and sunset times. The center is composed of the Public Relations Office, the Outreach and Education Office, the Ephemeris Computation Office, the Archive Office, the Library, the Publications Office, the Science Culture Promotion Unit, and the General Affairs Office. The activities of each office will be reported hereafter.

2. Personnel

Center staff in FY 2012 consisted of Center Director Toshio Fukushima, two professors, one associate professor, two assistant professors (one holding another post concurrently), four research engineers, one senior engineer, one engineer, one chief of the library, one specially-appointed senior specialist, two research experts, 19 PR and outreach staff members, two research supporters, and three administrative supporters.

As of April 1, 2012, PR and outreach staff members Takuya Okawa and Sei'ichiro Naito are assigned to the Public Relations Office; PR/outreach staff member Kuninori Iwashiro are assigned to the Publications Office, and PR/outreach staff member Naoyo Mikami and administrative supporter Keiko Yoshitomi are assigned to the Science Culture Promotion Unit. Specially-appointed senior specialist Sarah Reed joined the Public Relations Office on September 1. PR/outreach staff member Satomi Natsugari joined on January 1, 2013. PR/outreach staff member Yukie Baba joined on February 12. Research assistant Makiko Nakane was transferred to the Astronomy Data Center, and PR/outreach staff members Masao Nakagiri, Yoshiro Yamada, and Masato Namikawa and administrative assistant Keiko Yoshitomi left on March 31, 2013.

3. Public Relations Office Activities

Via press conferences and web releases, the Public Relations Office actively worked to promote and raise awareness of scientific developments yielded by the various projects being conducted by the NAOJ, including the Chile Observatory, the Subaru Telescope, the Hinode Science Center, the Extrasolar Planet Detection Project, and the Nobeyama Radio Observatory, as well as the results of joint research projects being conducted with other universities and research organizations. In cooperation with the Outreach and Education Office, the 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 valuable new tools in sharing information.

(1) Answering Questions from the General Public

The Office responded to 9,973 telephone inquiries (Table 1) and 152 letters, 90 of which were official documents, from the media, governmental offices, and the general public. The Office also received 447 (Table 2) inquiries via the Internet.

(2) Multimedia-Based Information Sharing

The Office runs the NAOJ website (http://www.nao.ac.jp/en/), through which it releases information via the Internet. Website hits are shown in Table 3.

Issues 74 to 102 of the NAOJ E-mail News were issued, in which major news items were announced in headline format with links to detail pages. The mail magazine distribution service introduced in December 2011 is provided on regular basis. Efforts were made to increase the efficiency and speed of subscriber registration. 24 semimonthly editions of the Astronomy Information Telephone Service voice news service were also issued.

	Solar info	Lunar info	Ephemeris info	Time	Solar System	Universe	Astronomy	Other	Total
April – June	1450	207	47	23	668	123	215	1201	3934
July – September	229	164	105	19	386	162	220	828	2113
October – December	358	200	59	12	413	135	177	640	1994
January – March	254	103	65	10	460	120	155	765	1932
Total	2291	674	276	64	1927	540	767	3434	9973

Table 1: Telephone inquiries to the Public Relations Office of the NAOJ Public Relations Center (April 2012 – March 2013).

	Solar info	Lunar info	Ephemeris info	Time	Solar System	Universe	Astronomy	Other	Total
April – June	8	7	4	2	37	7	64	31	160
July – September	8	3	1	1	12	12	25	28	90
October – December	9	3	4	1	27	14	20	17	95
January – March	3	4	6	1	17	16	36	19	102
Total	28	17	15	5	93	49	145	95	447

Table 2: Internet inquiries to the Public Relations Office of the NAOJ Public Relations Center (April 2012 – March 2013).

Month	Hits	Month	Hits	Month	Hits
April 2012	468,312	August 2012	549,814	December 2012	646,116
May 2012	1,069,389	September 2012	421,321	January 2013	508,491
June 2012	606,672	October 2012	584,870	February 2013	486,463
July 2012	419,447	November 2012	468,856	March 2013	960,486
Total: 7,190,237					

Table 3: Monthly numbers of hits on the website of the Public Relations Office of the NAOJ's Public Relations Center (April 2012 – March 2013).

December 26, 2012	Spiral Structure of Disk May Reveal Planets
April 13, 2012	ALMA Reveals Workings of Nearby Planetary System
May 1, 2012	Subaru-Led Team Discovers a Rare Stellar Disk of Quartz Dust
June 25 25, 2012	Multiple Mergers Generate Ultraluminous Infrared Galaxy
June 21, 2012	ALMA Reveals Constituent of a Galaxy at 12.4 Billion Light-Years Away
August 3, 2012	Subaru Telescope Reveals 3D Structure of Supernovae
August 29, 2012	Result from ALMA: Building blocks of life found around young star
October 1, 2012	Discovery of an Ancient Celestial City Undergoing Rapid Growth: A Young Protocluster of Active Star-Forming Galaxies
September 4, 2012	Discovery of the "Pigtail" Molecular Cloud
September 13, 2012	Hyper Suprime-Cam Ushers in a New Era of Observational Astronomy
September 28, 2012	Radio Interferometer Measure the Edge of a Black Hole
October 17, 2012	Surprising Spiral Structure Spotted by ALMA – New observations reveal the secrets of a dying star
October 25, 2012	ALMA discovers the new tool to explore baby stars: a new water maser emission in the Orion Nebula
November 12, 2012	Discovery of a Giant Gap in the Disk of a Sun-like Star
November 28, 2012	Dust Grains Highlight the Path to Planet Formation
January 7, 2013	ALMA Sheds Light on Planet-Forming Gas Streams – Tantalising signs of flows feeding gas-guzzling giant planets
January 25, 2013	The Origin and Maintenance of a Retrograde Exoplanet
January 31, 2013	Progress of the Solar Pole Reversal Confirmed by the Solar Observation Satellite Hinode (Japanese Only)
February 8, 2013	Direct Infrared Image of an Arm in Disk Demonstrates Transition to Planet Formation
March 6, 2013	Soccer Balls in Interstellar Space
March 14, 2013	ALMA Rewrites History of Universe's Stellar Baby Boom

Table 4: Web Releases.

April 19, 2012	Polar Field Reversal as observed with Hinode
April 24, 2012	Subaru Telescope Discovers the Most Distant Protocluster of Galaxies
May 31, 2012	Nobeyama Radioheliograph Reveals Global Activity of the Sun
June 4, 2012	Discovery of the Most Distant Galaxy in the Cosmic Dawn
July 20, 2012	'Seeds' of Massive Black Holes Found at the Center of the Milky Way Galaxy
October 2, 2012	Mass of Dark Matter Revealed by Precise Measurements of the Galaxy
October 9, 2012	Current Status of TMT Project and Joint Board Meeting Held in Tokyo (Japanese Only)
February 19, 2013	3-D Observations of the Outflow from an Active Galactic Nucleus

Table 5: Press Conferences.

Information on the status of various NAOJ projects; facility open house events and regular observation sessions at the Mitaka Campus; and personnel openings have been shared via the Public Relations Center's account on the Twitter social networking service since October 2010. The account had nearly 25,000 followers as of the end of March 2013.

(3) Publicizing Developments

Over the course of the year 29 releases were issued (up from 17 the previous year).

As the 17th event of the Astronomy Lecture for Science Journalists series, an astronomy lecture for journalists was held on the topic of annular eclipses for general journalists as well as for science reporters, the 18th lecture, held on the topic of solar activity and the environment on Earth, was an interdisciplinary discussion of the results from the solar observation satellite HINODE and past research into solar activity and atmospheric changes on Earth. Starting with the 18th lecture, lectures were streamed over the web to journalists only. The lectures were also recorded for later viewing not only by journalists who couldn't participate on the day of the event, but also for attending journalists wishing to review the material.

(4) Activities as PR Center for the NAOJ

The Office hosted an exhibition booth at the General Assembly of the International Astronomical Union held in

Beijing as part of its activities as the NAOJ's PR Center. The booth panels were designed using mobile pop-up display tools, yielding the highest acclaim for the exhibition booth thus far. Original notebooks and pamphlet folders featuring the same illustrations as the booth panels were produced to make a stronger impression for the NAOJ. The office also assisted the Advanced Technology Center and JASMINE Project Office in overhauling their selection of pamphlets and leaflets for the General Assembly of the IAU.

The office provided support in preparing and running lectures for the general public planned by the NAOJ projects. In particular, setting up forms for accepting pre-registration requests online and creating lists of the applicants have become standard practice for the Public Relations Office. The lectures held in December were the first simultaneously interpreted lectures for the general public held by the Office.

(5) Emergency Responses

The Public Relations Office served as the NAOJ liaison in handling media inquiries and communicating with next-of-kin and relatives regarding a criminal incident to which a Japanese NAOJ staff member fell victim on May 7, 2012, while stationed in Chile.

4. Outreach and Education Office Activities

(1) Facility Open House Events

As in previous years, regular semimonthly screenings (the day before the second Saturday, fourth the Saturday) were held at the 4D2U Dome Theater in FY 2012, with reservations being taken in advance. A total of 23 screenings were held, with 1,809 attendees. A total of 50 group events were also held for 1,556 visitors, as well as 36 other tours and events held for 299 visitors, for a total of 109 events and 3,664 visitors viewing 4D2U movies.

Annual observation sessions featuring the 50 cm public telescope were also held on the same days as Dome Theater screenings regardless of weather conditions. Starting this year, observations shifted to an advance reservation / limited capacity (300) basis, with 23 observations being held for 4,725 audience members this year. The Summer Vacation Junior Star Gazing Party (no application necessary) were also held on July 26 (Thurs) and July 27 (Fri) during the summer break for elementary school, junior high school, and high school students. Weather conditions were favorable on both days, and 577 visitors (270 on the 26th, 307 on the 27th) attended.

17,111 visitors attended the regular open house events held at Mitaka during FY 2012. There were a total of 147 group tours, including workplace visits, consisting of 6,671 visitors in FY 2012, as well as 479 interviews.

Guided tours of Mitaka began in June 2011 as part of the Archive Office's work and open house events. The guided tours were operated on an advance reservation / limited capacity basis of 20 participants per tour, with tours of registered tangible cultural properties being held on the first Tuesday and second Sunday; and tours of important cultural properties and geodesy-related sites being held on the third Tuesday and fourth Sunday. This year's tours welcomed 510 participants to great acclaim.

The Public Relations Center participated as the secretariat for the Mitaka Open House Day, a special public event held in the Mitaka area, under the guidance of the operating committee. 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 (SOKENDAI) on October 26 (Fri) and October 27 (Sat), the event featured "The Life of a Star: From Baby Star to Supernova" as a main topic. Weather was favorable on both days, and turnout was good, with a total of 4,431 visitors (651 on the 26th and 3,780 on the 27th) over two days.

(2) Education and Outreach Activities

The Office distributed 100,000 copies of the pamphlet (four A4-size color pages) on how to safely observe solar eclipses jointly with the Publications Office as part of its efforts to raise awareness of methods to safely observe the annular eclipse that occurred on May 21, 2012. As part of its efforts to provide information and safety advice to schools around the country, the Office distributed the pamphlet, a DVD produced by the Science Culture Promotion Unit, and a pair of foldable solar observation safety glasses with the Spring 2012 issue of Science Window (published at the beginning of April 2012) in cooperation with the Science Communication Headquarters at the Japan Science and Technology Agency. The Outreach and Education Office was also a member of the Japan Astronomy Council's 2012 Annular Eclipse Japan Committee, where it assisted in holding press conferences and in producing educational resources for schools on how to safely observe the solar eclipse on May 21 (Mon), 2012.

The "Star Week: Getting to Know the Starry Sky" event was held over the first week of August, as in previous years. Astronomy related facilities of 102 participating organizations took part in 175 collaborative events.

The "Astronomy for Beginners" events hosted every year with the Tamarokuto Science Center were held twice, on September 23 (Sun) and March 10 (Sun). The visitors' area, screenings at the 4D2U Theater, and astronomical observation sessions, with a total of 100 visitors participating were also held to high acclaim.

Three astronomical phenomena campaigns begun in FY 2004 and bidirectional information-sharing events were hosted: "Perseid Meteors 2012" in August 2012 (1,089 reports), "Geminids Meteors 2012" in December 2012 (2,655 reports), and "Let's Go Out and Find the Comet PANSTARRS" held during March–April 2013 (2,042 reports).

Responsibility for the "Fureai (Friendly) Astronomy" project, implemented by the Graduate Education Support Office since FY 2010 with funding from the Astronomy Promotion Fund, was transferred to the Public Relations Center this year. Events were hosted at 35 elementary schools and eight junior high schools, for a total of 43 schools around the country. Applications were accepted during the period from

late September to early March FY 2012, with a total of 3,866 participants in attendance. 38 NAOJ staff members participated as speakers. As part of support activities for earthquake-affected areas, the office collaborated with the Astronomy Data Center and the Subaru Telescope in hosting the "Special Class: Experiencing the Stars and Space Up-Close" via remote teaching on May 25, 2012, at Furukawa Junior High School in the city of Osaki in Miyagi Prefecture, on January 29, 2013 and at Iide Junior High School in the town of Iide in Yamagata Prefecture, and on February 21 at Kinto Elementary School in the city of Koriyama in Fukushima Prefecture.

The Eighth Workshop for Popularizing Cutting Edge Astronomy was held at the Subaru Telescope from September 8 (Sun) through 15 (Sat) focusing on the Subaru Telescope, with a total of 35 researchers and education/outreach-related participants in attendance. The Club TMT group for promoting the TMT Project was formed on October 29, primarily of science museum staff members taking part in the workshop. A webpage and numerous videos introducing the TMT Project were produced. The Public Relations Center supports the activities of Club TMT.

As an offshoot of the Galileoscope project conducted as part of the international Cornerstone Projects held for the International Year of Astronomy 2009, the "You are Galileo!" project planned by the Japanese committee for the International Year of Astronomy 2009 has been continued even after FY 2010 in collaboration with the Office of International Relations. In FY 2012, lectures, telescope construction workshops, and observation sessions were also held in Thailand's Udon Thani, Chiang Mai, Songkhla, Chachoengsao, and Nakhon Ratchasima provinces during November and December 2012 with Official Development Assistance Grants for UNESCO Activities from MEXT and the cooperation of the National Astronomical Research Institute of Thailand. Over 400 teachers and undergraduate students in education attended. There were also five workshops supported by a total of nearly 100 staff members from universities and the like. 360 assembled telescope and tripod sets and five 8 cm equatorial refracting telescopes were also provided for local use.

Makali'i, an image analysis software Makali'i developed for the sake of utilizing FITS data obtained in research observation performed using the Subaru Telescope and other apparatus for astronomical education and outreach, has been distributed in Japan and overseas via Internet. The number of registrations includes 1,656 in English and 6,348 in Japanese for a total of 8,004 (as of March 31, 2013). The "One for Every Household: Diagram of Our Universe 2007" poster created and produced in 2007 was also revised with cooperation from related external organizations, and the "One for Every Household: Diagram of Our Universe 2013" poster (A1 size, A2 size; Japanese and English reversible poster) was distributed in Japan and overseas.

(3) Community Activities

In FY 2012, a total of 37,187 visitors were welcomed at the "Mitaka Picture Book House in the Astronomical Observatory Forest" 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 (a lot of 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 traditional and modern Tanabata celebrations, moon-viewing parties, and other events at the Mitaka Picture Book House in the Astronomical Observatory Forest in cooperation with staff from Mitaka City Hall and local volunteers.

The Astronomy Pub event held at Mitaka Network University has been hosted by the NPO Mitaka Network University Promotion Organization since FY 2009. It is held in the evening on the third Saturday of every month, except August, with 20 citizens in attendance. The Office assisted in the "Star Sommelier Mitaka" astronomical guide training course hosted by Mitaka Network University via telescope operation workshops and the like.

5. Ephemeris Computation Office Activities

The Ephemeris Computation Office estimates calendar-related phenomena such as the apparent positions of the Sun, Moon, and stars on the basis of the internationally adopted standard calendar, and publishes the "Calendar and Ephemeris" as part of the compilation of almanacs that is one of the NAOJ's raisons d'être.

(1) The Office published the 2013 edition of the Calendar and Ephemeris, the 2013 version of the calendrical section of the Rika Nenpyo, and the 2014 edition of the Reki Yoko (posted in the official gazette on February 1, 2013).

(2) Special editions about the annular eclipse, transit of Venus, The lunar occultation of Venus, and the first sunrise of the year were hosted at the office's website (http://eco.mtk.nao.ac.jp/koyomi/index.html.en) and received just shy of 500,000 hits in a single day on the days of the annular eclipse and the first sunrise of the year in particular. An English-language version of the Calendar and Ephemeris became available online. As in previous years, the "Sky Viewer" page displayed the radiant points of the Perseids and Geminids in collaboration with the campaigns. As a result, there were more than 34 million hits in FY 2012, and improvements continue.

(3) The Japan Association for Calendars and Culture Promotion hosted its second General Meeting and a Calendar Presentation Ceremony. The office took part in the Japan Weather Association's Word of the Season selection committee and attended the discussion of potential words of the season and other related events.

(4) Using selections from the NAOJ's valuable collection of Chinese/Japanese-language books cooperation with the Library, the office hosted the 46th Selection of Seasonal Words for Poets and the 47th exhibit, this time about 17th-century astronomer

Harumi (Shunkai) Shibukawa and the novel Tenchi Meisatsu depicting his life. These exhibits can also be viewed at the Library's Rare Book website (http://library.nao.ac.jp/kichou/open/index.html Japanese Only).

The October edition of the NAOJ News also featured a special on "The Calendars of Japan."

(5) Five staff members (three full-time, two part-time) took turns handling reports of new astronomical objects and the like submitted to the NAOJ. A total of 21 reports of new object discoveries, requests for confirmation, and other reports were submitted this year. Of these, ten were for new stars or supernovae, two were for comets or comet-shaped objects, six were for luminous objects, and three were questions regarding astronomical phenomena.

Amidst the many false alarms attributed to known supernovae, asteroids, comets, ghost images of bright stars, and the like, a report of a new star received in August was submitted via NAOJ to the IAU Central Bureau for Astronomical Telegrams, and the reporter was recognized as the discoverer of Nova Monocerotis 2012.

6. Archive Office Activities

In its fifth year of activities this year, the office engaged in the collection and organization of historically important observational data and measurement equipment, not only from Mitaka but also from other areas and organizations external to the NAOJ in order to prevent their loss; worked to improve the methods and environments to display these materials; and engaged in preparatory discussions on the founding principles and organization of the NAOJ Museum (tentative name).

A symposium on the concept of the NAOJ Museum was held at NAOJ Mitaka on November 3 and 4, with 60 participants in attendance. A subcommittee for developing the concept of the NAOJ Museum was also established under the Advisory Special Committee for Public Relations, and met three times during the year. As a result, the conclusion was reached that it was still too early to proceed with the original concept, and a decision was made to create a new project, starting in FY 2013, for another concept of NAOJ Museum showcasing past, present, and future developments in astronomy with a focus on exhibits and explanations of the latest developments in astronomy. It was therefore decided to dissolve the Archive Office, starting in FY 2013, to create a new Museum Project Office merging the current Office with the facility open house section of the Outreach and Education Office.

Function restoration work was also performed on the Solar Tower Telescope as part of the third annual NINS President's discretionary budget. The dome rotation, opening/closing mechanism, and coelostat operation mechanism were restored, allowing sunlight to be admitted.

7. Library Activities

Along with its normal work in collecting and organizing academic journals and books focused on astronomy for viewing by students and researchers inside and outside the NAOJ, the Library released digital data for its collection of rare documents in FY 2012. The Library also engaged in inspections of its collection and compiled a catalog and resources data.

The numbers and types of documents and journals in the collections of the Mitaka Library and the various observatories, as well as the publication status of ongoing NAOJ publications, are published in organizational books and publications.

8. Publications Office Activities

The Office continued its activities in planning, editing, and printing in-house publications for PR and outreach. Periodicals published this year were as follows.

- NAOJ Pamphlet (Japanese)
- NAOJ Pamphlet (English)
- NAOJ News, Nos. 225–236 (April 2012 – March 2013)
- Annual Report of NAOJ Vol. 24, Fiscal 2011 (Japanese)
- Annual Report of NAOJ Vol. 14, Fiscal 2011 (English)
- NAOJ Gazette Vol. 14, Nos. 3, 4; Vol. 15, Nos. 1, 2

The contents of the NAOJ News were further enriched in FY 2012. In particular, NAOJ project PR support was expanded by building on the results achieved by experiments in FY 2011 organizing editorial content according to themes such as research and educational activities attempted in FY 2011. One example was the June issue with a special feature on the ALMA Telescope (part 2). It contained more than double the normal page count at 36 pages and focused on interviews with staff members. The material from this special edition and part 1 featured in the March issue were later combined and published on the website of the Chile Observatory under the title "ALMA-Jin." The office plans to continue producing integrated and fundamental articles in close partnership with the NAOJ's various projects so that articles from the NAOJ News can be shared and more widely utilized as PR content resources for NAOJ projects.

Apart from periodical publications, the office compiled the "Subaru" image collection, and produced the 2012 NAOJ SUBARU Telescope Calendar (eighth edition since 2005). The office also provided support in creating posters for the Mitaka Open House Day event, as in previous years.

In an effort to digitize published content, Japanese-language NAOJ pamphlets were digitized, and a digitized digest of Western-language NAOJ pamphlets was created for the General Assembly of the IAU. Future plans include the organization and preparation of existing article resources as digital content; and the enhancement of information distribution capability via booklets and increased telecommunications lines.

As part of general astronomy outreach-related activities, various pieces of PR- and outreach-related information on the annular eclipse in May were compiled, distributed, and printed. The movie Tenchi Meisatsu released in September features 17th-century astronomer and NAOJ forerunner Harumi (Shunkai) Shibukawa as the main characters, and the Office produced a

variety of content as part of the tie-in project “Let's Find the North Star” campaign.

The Office also performed observational imaging and image processing to create high-quality public images of astronomical phenomena subjected to widespread public attention, such as the annular eclipse of May 21, 2012, the passage of the asteroid 2012 DA14 near the Earth on February 16, 2013, and the PANSTARRS comet which increased in brightness during March 2013. These images are published on the NAOJ website.

Continuing from FY 2011, the office offered planning and production advice and oversight for Japan Post’s special stamp Constellations Series No.3 (Spring Edition) and No.4 (Winter Edition). The office also designed a commemorative stamp “Mitaka: Home Town of NAOJ” introducing the Mitaka Campus.

Continuing from FY 2011, the office engaged in creating worksheets for the Thai edition of the “You are Galileo!” project being conducted as a program to support overseas astronomical education.

9. Science Culture Promotion Unit

(1) Fourth Tokyo International Science Festival

The Fourth Tokyo International Science Festival (TUSF) was held from September 8 (Sat) to October 8 (Mon). During this period, 134 events were hosted by 66 members around the greater Tokyo area, and over 30,000 visitors were welcomed. This regional science festival was conceived by the NAOJ in order to build community ties with local residents through the appreciation of science and technology. The Fourth TISF Executive Committee to implement the festival was formed by the NAOJ along with staff members from the British Council, the Japan Science Foundation, Tokyo University of Science, Mitaka City Hall, and the NPO Mitaka Network University Promotion Organization. The event was co-hosted by NAOJ, with the Science Culture Promotion Unit acting as the secretariat for the Fourth TISF.

(2) Third International Festival of Scientific Visualization

The Third International Festival of Scientific Visualization was held from August 1 (Wed) to September 30 (Sun) in collaboration with over 100 partner organizations and groups. During this period, screenings of scientific movies and stamp rallies were held at 54 facilities around Japan, including science museums, planetariums, and theaters, with 1,008,597 visitors participating. A Science Film Cafe and Workshop (Science Museum, Tokyo) and a Dome Festa (Sofia-Sakai) were held as the core events. These events were organized and hosted by the Organizing Committee for the Third International Festival of Scientific Visualization. The event was co-hosted by NAOJ, with the Public Relations Center acting as secretariat. The event was backed by MEXT, JAXA, and the Japan Planetarium Association, and it was a partner event for the Japan International Contents Festival 2012 (CoFesta 2012) hosted by METI.

(3) Other

NAOJ partnered with related local organizations, universities, and research institutes to establish a joint company and an alumni association called “Mitaka Association of Science and Culture” (unincorporated) for students who completed the courses of the Unit in order to promote the digital content production industry, create employment opportunities, and establish a center for fostering personnel for community revitalization efforts. This established the groundwork for video incubation efforts from FY 2013 onwards. Semimonthly 4D2U public screenings were also held in partnership with the Outreach and Education Office and the Center for Computational Astrophysics.

18. Division of Optical and Infrared Astronomy

1. Overview

Projects overseen by the Division of Optical and Infrared Astronomy include the Okayama Astrophysical Observatory and the Subaru Telescope (C Projects); the TMT Project Office and the TAMA Project Office (B Projects); and the JASMINE Project Office and Extrasolar Planet Detection Project Office (A Projects). The Division moves personnel to research locations suitable for their individual projects via personnel exchanges, and serves the basic role of facilitating and invigorating projects and individual research. Along with engaging in seminal observational and developmental researches, the Division expands upon these to launchnew projects as necessary. The Division also actively engages in graduate education efforts in order to foster the next generation of personnel. These activities are based on the concept, developed at the time when the Subaru Telescope was constructed, of the Division as a center for personnel exchange between the Subaru Telescope engaging the open use and universities and research institutes in Japan focusing on developmental research into new instruments and observational research.

Almost all NAOJ members in optical- and infrared-related fields belong to the Division of Optical and Infrared Astronomy, and primarily work in the Division or on A, B, or C Projects. Division members also work as affiliates on other projects apart from their primary work. The research divisions and the various projects carry equal weight in organizational terms. The primary staff of the Division of Optical and Infrared Astronomy in FY 2012 consisted of one professor, one associate professor, four assistant professors, and two JSPS research fellows.

The research divisions handle educational, research and administrative activities for all research division and project activities apart from TAMA and JASMINE Projects. The Division of Optical and Infrared Astronomy as a whole maintains and operates mailing lists and research environment facilities, such as web servers, for various optical- and infrared-related projects (the Subaru Telescope, TMT, the Extrasolar Planet Detection, TAMA, and JASMINE).

The following report will focus on the details of research projects constituting the main work of the Division of Optical and Infrared Astronomy and support activities for 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; the structures around late-type stars; and the search for exoplanets. Research was conducted on star formation activity in the Virgo Cluster and the ionization of gas ejected from galaxies. Results were released for the quantitative analysis of crosstalk in the Subaru prime focus camera (Suprime-Cam), which had been conducted since last year. The search for exoplanets via direct imaging methods continued. The division also engaged in research on astronomical phenomena based on old calendars and documents; the automatic identification of active galactic nucleus using astronomical archive data and astronomical databases; and statistical research on galactic shapes and SEDs. As part of research using astronomical archive data, quantitative comparison research on photometric zero-points between the publicly available SDF/SXDF catalogs and the SDSS catalog was also performed.

(2) International Cooperative Observational Research

The Division also engages in international collaborative research with overseas researchers. Research on LINERs was conducted along with Korean researchers. The Division also worked with the National Astronomical Observatory of China in the search for construction sites for a telescope in western Tibet.

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.

The division is also engaged in developing data processing software for the Hyper Suprime-Cam (HSC) currently under development. In data archive-related activities, the division is a participant in the file system utilization technology working group of the Society of Scientific Systems, where it works on overcoming the difficulties associated with increased storage capacity and researches more efficient methods of storage utilization.

4. Operational Support for the Subaru Telescope

The Division of Optical and Infrared Astronomy offers support for the open use of the Subaru Telescope. The division is involved in the open calls forproposals; program selection; the management of open use related travel expenses ; the operation of the Subaru Data Analysis System (located on the first floor of the Subaru Building of the Mitaka Campus and operated with cooperation from the Astronomy Data Center); Subaru-related PR and outreach activities; the hosting of Subaru Spring/Autumn Schools (co-hosted by the Division of Optical and Infrared Astronomy, the Subaru Telescope, and the Astronomy Data Center); and cooperation in planning Observing class usingthe Subaru Telescope. In addition to renewing rental agreements for computational equipment for the Observatory as a whole, the

division worked closely with the Data Center to reorganize the equipment layout in the Archive Office on the first floor of the Subaru Building.

The division engaged in the management and operation of the printers and rented multifunction photocopiers in the Subaru Building, the teleconferencing systems on the second and third floors, and the sub-networks. The division operated a data backup server for the Subaru Office as part of its research environment maintenance efforts. The division also replaced the aging printers and installed new ones.

5. Next-Generation Large-Scale Project Planning

The division is engaged in planning projects such as the Thirty Meter Telescope (TMT), the JASMINE series, and the JTPF as optical- and infrared-related large-scale projects serving as successors to the Subaru Telescope project. A framework for collaboration between ISAS and NAOJ also needs to be established.

In astronomical database-related activities, the division cooperated with KEK, which handles large amounts of data, to establish a research group for the next generation of large-scale discs and computer systems with an eye toward creating archives five to ten years in the future for the next observation instruments for the Subaru Telescope and for the TMT. They are also engaged in both archive hardware and software planning for ten years in the future.

6. PR/Outreach Activities, Discovery of New Astronomical Objects

The division cooperates with the Public Relations Center to support PR and outreach activities, such as the publication of Subaru Telescope research results (including through press conferences), and works to discover new astronomical objects. The division was an active participant in a special public event held at Mitaka (Mitaka Open House Day), where it provided mini-lectures and exhibits and planned projects appealing to elementary and junior high school students, such as magnet puzzles. The division also cooperated in open house days at the Okayama Astrophysical Observatory.

7. Educational Activities

The division accepted 33 graduate students from the Graduate University for Advanced Studies (SOKENDAI), the University of Tokyo, the Tokyo University of Agriculture and Technology, Nihon University, and other organizations. Division staff actively contributed to seminars and self-directed studies.

The division participated in the “Fureai Astronomy” project for encouraging an appreciation of and an interest in astronomy in elementary and junior high school students. The division sent guest lecturers to 11 elementary and junior high schools around the country.

19. Division of Radio Astronomy

The Division of Radio Astronomy oversees the Nobeyama Radio Observatory, the Mizusawa VLBI Observatory, the RISE Lunar Exploration Project, and ALMA project in Japan. Members of these projects are also members of the Division of Radio Astronomy. The Division of Radio Astronomy coordinates radio astronomy research while working in cooperation between these radio-related projects. See the respective project reports for details on the results of these projects.

Keywords for specific research themes engaged by the division include the Big Bang; the early Universe; galaxy formation; black holes; galactic dynamics; star formation; planetary system formation; planets and satellites; the Moon; and the evolution of cosmic matter as well as the origins of life during the process of the evolution of cosmic matter as an ultimate theme. The division promotes research into these topics and mysteries of the Universe via invisible radio waves. See project reports and research highlights for details on advances made in these various fields of research.

The Radio Astronomy Frequency Subcommittee was also established in the Division of Radio Astronomy in order to find measures for protection against electrical equipment-generated artificial radio interference, which is a major obstacle to radio astronomical observation.

1. Radio Astronomy Frequency Subcommittee

The mission of the Radio Astronomy Frequency Subcommittee is to protect the environment for radio astronomy observation. It was Karl Jansky of the United States who first accidentally discovered radio waves emitted by astronomical objects in 1932. Since then, dramatic advances have been made in the methods for observing astronomical objects by radio waves, showing us a view of the Universe different from that observed at visible wavelengths by eyes. Just as optical pollution from artificial light sources is an obstacle to optical observation, artificial radio interference generated by the electronic devices that surround us is a major obstacle in radio-based observation.

Recent years have seen breathtaking advances in wireless communication technologies. Mobile phones and wireless LANs have become an integral part of our day-to-day lives. Television broadcasts, which constitute an important source of information in our daily lives, are also undergoing further development via digitization. As such, the demand for the limited radio band resources is certainly expanding, therefore the efficiency of bands utilization needs to be improved, due to the usefulness for their possible applications. Further efforts to maintain the “sky” in which radio astronomy observations can be performed are therefore imperative.

(1) Role and Organization

The role of the Radio Astronomy Frequency Subcommittee is to protect radio astronomy observations from artificial radio waves that might affect it, and to raise awareness of the importance of its protection activities. Radio astronomy is a "quiet" endeavor that does not involve the emission of radio waves, and thus does not inhibit other wireless communications efforts. Therefore, active effort is necessary in order to obtain widespread understanding and support of the need to protect this field. The Subcommittee has taken opportunities to engage in explanatory sessions on the subject of radio astronomy with the Ministry of Internal Affairs and Communications (MIC) and Regional Bureaus of Telecommunications in order to solicit an appreciation of the importance of protecting the field.

The balancing of the field of radio astronomy with other fields and activities involving the application of radio waves is overseen by MIC within Japan, and by the ITU Radiocommunication Sector (ITU-R) of the International Telecommunication Union, a specialized agency of the United Nations, internationally. As part of activities for FY 2012, the Subcommittee took an active part in managing these activities as a representative of the Japanese radio astronomy community (the community of radio astronomy researchers within Japan).

The subcommittee is made up of members from NAOJ, as well as from universities and research organizations within Japan.

(2) Current Challenges

The Radio Astronomy Frequency Subcommittee is currently engaged in overcoming the following interference-related problems.

- Generation and increase of wireless activity due to natural disasters: Since the Great East Japan Earthquake, there has been an increase in radio interference due to new activity in response to the aftereffects of natural disasters.
- Development and expansion of new radio applications: Ultra-wide-band (UWB) technology utilizes low-level, wide-frequency bandwidths, and its wireless licenses have been exempted due to its low emission power level.
- Repurposing of vacant frequencies arising from the new effective use of radio waves: The digitization of TV broadcasts has led to vacant frequencies being assigned to portable phones and the like.

The effect of interference arising from such radio applications (wireless activity) varies widely depending upon the frequency band. Fortunately, radio astronomy observations have been given priority in a number of frequency bands by the Radio Regulations (RR) of the ITU. However, when radio wave application bandwidths and radio astronomy bandwidths have the same priority level, discussion is necessary for the sake of co-existence. Extremely faint radio waves from distant astronomical objects must be detected in radio astronomy observation. Even extremely faint extraneous terrestrial radio waves can greatly affect radio astronomy observations.

Sources of interference that must be addressed are the 23 GHz CATV wireless system for emergency broadcast (which affects ammonia observation), 21 GHz next-generation new satellite broadcasts (which affect water maser observations), 1.6 GHz emergency satellite mobile phones (which affect the observation of pulsars and the like), a number of new UWB wireless applications, and high-speed power line communication (PLC) which affects decameter-band observation. These sources are increasing in number every year.

(3) International Activities

The ITU's Radio Regulations (RR), which determines the assignment of radio frequencies to wireless applications, are revised once every three to four years by the World Radiocommunication Conference (WRC). Most recently, WRC-12 was held in February 2012. The frequency bands protected in the name of radio astronomy observation are listed in the RR. Numerous preparatory conferences necessary for the revision of the RR in preparation for the upcoming WRC-15 are held every year in Geneva. Discussions relevant to the Radio Astronomy Frequency Subcommittee include the WP7D (radio astronomy) meeting and the WP1A (frequency management) meeting. The subcommittee has participated in numerous international meetings as a representative of Japanese radio astronomy. The subcommittee has also participated in every meeting for the Asia/Pacific Region (APG meeting) in preparation for WRC-15, contributing to opinion formation in the Asia region. In FY 2012, the subcommittee engaged in the protection of radio astronomy frequency bands via participation in the ITU-R WP7D meeting held in Geneva in June, APG meeting held in Vietnam in September, and various other conferences.

(4) Activities in Japan

The activities of the Radio Astronomy Frequency Subcommittee in Japan can be broadly divided into two groups: participating in committees hosted by MIC, and participating in negotiations regarding radio interference sources directly or indirectly concerning MIC. Negotiations regarding interference sources are a major characteristic of the subcommittee's activities in Japan.

The majority of the committees hosted by MIC are domestic conferences corresponding to the abovementioned international conferences, and serve to develop Japan's policies regarding the international conferences. Other conferences hosted by MIC include councils on radio application technology implemented by MIC as part of its policy, and negotiations with radio interference sources mediated by MIC. Negotiations directly affecting the protection of radio astronomy observations have been conducted concurrently in order to respond to the interference problems discussed in section (2) above.

A few examples of the interference problems discussed in section (2) are as follows. One new advent of UWB wireless applications is for determining positions to understand the flow of materials at manufacturing and distribution sites. The UWB frequency band induces interference in VLBI geodetic observation regularly detecting tectonic plate movement. Although this band is not protected by the RR, it is vital from the

perspective of predicting earthquakes, and is the object of special consideration by the MIC. For 24 GHz automobile radars, work was underway to determine the distance observatories must be isolated and to legally mandate automatic radar switch-off functions. The 79 GHz high-resolution automobile radars currently under development are expected to be accepted much widely. The effect of interference from these radars upon the 45 m radio telescope at the Nobeyama Radio Observatory, which seeks to observe molecular lines of deuterium and other elements in dark nebulae, is a matter of concern. On the other hand, given that automobile radars are deeply related to human life, negotiations have been conducted in order to obtain an agreement from both sides.

When CATV cables are severed due to natural disasters, on one hand emergency connections are made using 23 GHz band wireless transmissions. On the other hand, due to red shift caused by cosmic expansion, the 23 GHz CATV band begin to include important ammonia molecule emission lines, which originally locate in a radio observation band protected by the RR. In addition, satellite mobile phones are useful as supplement for terrestrial mobile phones during disasters. The MIC took a role as mediator in discussions regarding interference from satellite phones using geosynchronous and orbiting satellites, and a usage condition agreement was concluded between the parties creating and affected by the interference (radio astronomy constituting the latter) while bearing in mind the importance of satellite phones during natural disasters.

A new radio wave application is underway pursuing for 21 GHz-band next-generation satellite broadcasting (16 times the resolution of current HDTV picture quality). This band is near the 22 GHz radio astronomy band (an important band for water vapor observation), and the effects thereof are the causes for concern. Power line communication (PLC) utilizing home power lines affects radio astronomy observations in low-frequency band up to 30 MHz. A petition not to introduce PLC with undue haste was submitted to the Minister of Internal Affairs and Communications with cooperation from the Astronomical Society of Japan and the Society of Geomagnetism and Earth, Planetary and Space Sciences. Press conferences were held in order to achieve broad public awareness of the relevant facts.

In activities separate from such negotiations, support for requests to protect the reception facilities for radio telescopes belonging to the radio astronomy community constitutes an important part of the subcommittee's work.

20. Division of Solar and Plasma Astrophysics

The Division of Solar and Plasma Astrophysics is home to research and teaching staff belonging to projects at the Solar Observatory, the Hinode Science Center, and the Nobeyama Solar Radio Observatory, and engages in solar physics research in close association with these projects. All division staff members concurrently belonged to anyone of above or other projects this year as well, with no dedicated staff members.

The division conducts both theoretical and observational research into the inner structure of the Sun; as well as the photosphere, chromosphere, corona, solar winds and other parts of the Sun's external atmosphere; and the various phenomena and activity 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 use of magnetohydrodynamics as a common means for exploring cosmic jets and phenomena occurring in stars similar to the Sun. Observational research had focused on work to begin observations from space from early on and to continue with the development of the HINODE scientific satellite, which is currently in orbit and in scientific operation. Research is also underway in the field of ground-based observation to develop new technologies for solar flare telescopes. The division engages in sustained long-term observations of steady phenomena such as sunspots, flares, and the corona. The division works with related overseas organizations to exchange data and release publications.

1. Integrated Solar Physics Research

We have already entered the age of integrated observational (from space and the ground) and theoretical studies of solar physics. A framework for stable steady operation of the HINODE mission has been established. The high acclaim for the scientific results obtained in reviews conducted in FY 2010 by space agencies around the world has led to commitments from all of these organizations to continue operating HINODE until FY 2013/14. The division supported the sixth Hinode Science Meeting (Hinode-6) held in St. Andrews in the United Kingdom on August 14–17, 2012.

2. Educational Activities

In FY 2012, two students from the University of Tokyo and two students from the Graduate University for Advanced Studies (SOKENDAI) had division faculty members as their research advisors. The division also supported research activities not directly related to the projects of the division's staff and students, such as participation in international research conferences and observation in Japan and abroad. The division also partnered with Kyoto University and Nagoya University with support from various NAOJ projects to plan and conduct a tour for undergraduate students to visit solar-related research organizations and experience the front lines of solar physics research.

3. International Cooperation

The HINODEmission is an international project involving cooperation from NASA in the United States, STFC in the United Kingdom, ESA in Europe, and NSC in Norway. Meetings of the Hinode Science Working Group (HSWG, chaired by Tsuneta) are regularly held in order to obtain scientific results from the project, and to discuss a framework for international cooperation and shared use in the scientific operation of the satellite. All data obtained by HINODE continues to be made available to the public instantly. In order to maximize the outputs of HINODE observations, the Science Schedule Coordinators (SSCs: NAOJ staff members Sekii, Watanabe) hold monthly telephone conferences in order to solicit observational projects (HINODE Operation Plans, "HOPs") using the scientific equipment on HINODE from solar researchers around the world, as well as joint observational projects with other solar observation satellites and terrestrial observation instruments.

21. Division of Theoretical Astronomy

1. Overview

From the early Universe to galaxies, stars, planetary formation, compact object activity, and astrophysical plasma phenomena, the division engages in theoretical research into the formation/evolution processes, dynamics, and physical states of matter of various hierarchical structures of the Universe. The research conducted by the division spans a variety of distinctive fields, including joint observational astronomy projects involving the Subaru Telescope, ALMA, the Nobeyama radio telescope, and observational satellites for various wavelengths; joint interdisciplinary projects involving closely related fields such as plasma physics, particle/nuclear physics, and geophysics; and computer simulation projects utilizing NAOJ supercomputers and the dedicated computer group of the Division of Theoretical Astronomy.

The Division of Theoretical Astronomy offers a superb research environment as a base for astronomical and astrophysical projects conducted inside Japan and overseas. It has accepted a wide range of both Japanese and international researchers as guest faculty members who actively engage in various research projects with the Division's full-time, associate, assistant, and project assistant professors, NAOJ postdoctoral fellows, JSPS fellows, and graduate students from the Graduate University for Advanced Studies (SOKENDAI) and the University of Tokyo. The Division of Theoretical Astronomy plays a central role in hosting international meetings and domestic cross disciplinary research conferences for the fields of observational astronomy and experimental physics as well as theoretical astronomy. The division leads research activities in a variety of fields. In particular, the division has fostered research developments as an influential research center for young researchers, and actively engages in personnel exchanges with universities and research institutes.

2. Current Staff and Transfers

In FY 2012, the dedicated staff of the Division of Theoretical Astronomy included two professors, two associate professors, and four assistant professors, as well as one affiliate professor and one affiliate assistance professor whose primary work focused on the Center for Computation Astrophysics. In addition to research and educational staff, Division staff included two project assistant professors, six NAOJ postdoctoral fellows, one JSPS fellow, and one administrative supporter supporting the various research and educational staff mentioned above. Assistant Professor Kei Kotake left at the end of March for a position as associate professor at Fukuoka University.

3. Research Results

Research results in the form of published papers and the like are listed in Section IV: Publications, Presentations. Results published or presented by members of the Division of Theoretical Astronomy were as listed below. Categories in which there were fewer than ten publications have been omitted.

Refereed Publications: 58
Conference Proceedings: 45
Conference Presentations: 96

Many of these achievements can be seen among the Scientific Highlights at the beginning of the volume. Scientific highlights in which Division of Theoretical Astronomy members took a leading role are listed here.

- Three-Dimensional Structure of Supernovae Studied by Spectropolarimetric Observations (Masaomi Tanaka et al.)
- Infrared Observations of "Middle-Aged" Supernovae Filling the Gap between Supernovae and Supernova Remnants (Masaomi Tanaka et al.)
- Spacecraft Observation of a Central Engine of Magnetic Reconnection (Seiji Zenitani et al.)
- Effects of Power Law Primordial Magnetic Field on Big Bang Nucleosynthesis (Dai Yamazaki, Motohiko Kusakabe)
- 3D Dissipation Mechanism in Fast Magnetic Reconnection (Keizo Fujimoto)
- Substellar-Mass Condensations in Prestellar Cores (Fumitaka Nakamura et al.)
- Astrophysical Impact of New β-decay Half-lives on γ-process Nucleosynthesis (Toshitaka Kajino, Toshio Suzuki, et al.)
- Solution to Big-Bang Nucleosynthesis in Hybrid Axion Dark

Matter Model (Toshitaka Kajino et al.)
- Supernova-, Solar- and Reactor-Neutrino Detection and Precise Theoretical Calculation of Neutrino Capture Cross Section on ^{13}C (Toshio Suzuki, Toshitaka Kajino et al.)
- Exploring the Neutrino Mass Hierarchy Probability with Meteoritic Supernova Material, ν-Process Nucleosynthesis, and θ_{13} Mixing (Toshitaka Kajino et al.)
- High-Lying Excited States in Gamow Teller Strength and Their Roles on Neutrino Reactions (Toshitaka Kajino et al.)
- Neutrino Induced Reactions Related to the ν-Process Nucleosynthesis of ^{92}Nb and ^{98}Tc (Toshitaka Kajino et al.)
- Early Galactic Chemical Evolution and γ-Process Nucleosynthesis in Black-Hole Forming Supernovae (Michael Famiano, Toshitaka Kajino et al.)
- Pulsar Kick Induced by Asymmetric Emission of Supernova Neutrinos (Toshitaka Kajino et al.)

4. Educational Activities

The activities of research and educational staff members as part-time lecturers at universities and graduate schools are summarized in Section III: Organizations. Lecture subjects are listed here by way of supplementation.

Kajino: Graduate University for Advanced Studies (Fundamentals of Theoretical Astronomy), Gakushuin University (Science of Time, Space, and Matter; Fundamentals of Physics), Japan Women's University (Modern Physics), Jissen Women's University (Astrophysics), Meiji University (Nuclear Physics)
Kudoh: University of Electro-Communications (Space and Earth Science)
Kokubo: National Graduate Institute for Policy Studies (The Earth in Space), University of Tokyo (Planetary Science)
Nakamura: University of Tokyo (Special Lecture in Astronomy III), Osaka Prefecture University (Special Lecture in Physical Sciences), Hokkaido University (Special Lecture in Space Sciences 1), Ibaraki University (Cosmic Evolution), Chiba University (Special Lecture in Computational Physics III)
Hamana: Tokyo University of Agriculture and Technology (Geology)
Hori: Kanagawa University (Introduction to Astronomy)

Kudoh used the Summer Student 2012 Program of the Graduate University for Advanced Studies as an opportunity to allow undergraduate students to visit actual research sites. Educational activities (events and locations) targeting elementary, junior high school, and high school students are listed below.

Ohsuga: Akitakko Global Vision – Cosmopolitans of the Future (Nikaho Municipal Hirasawa Elementary School)
Kajino: Lectures at Super Science High Schools (Kanagawa Prefectural Yokosuka High School)
Kudoh: Fureai Astronomy (Niigata Municipal Masago Elementary School)
Kokubo: Lectures at Super Science High Schools (Ishikawa Prefectural Kanazawa Izumigaoka High School, Tokyo Metropolitan Hibiya High School)
Hori: Fureai Astronomy (Osaka Hirakata Municipal Sugahara-Higashi Elementary School)

5. PR and Outreach Activities

Research and educational staff members of the Division of Theoretical Astronomy contributed to wide-scale PR and outreach activities via lectures for the general public. The following is a summary of these activities. Ohsuga gave an intensive course on black holes for complete beginners at the Asahi Culture Center in Nakanoshima. Kokubo gave lectures on a variety of topics related to the Solar System at Asahi Culture Centers (Shinjuku, Yokohama, Kyoto); Ikebukuro Community College; the Roppongi Tenmon Club; Newton; the Iwate Galaxy Festival; the Science café; the NHK Culture Center; lecture meeting on K Computer in Tokyo; lecture meeting at the Research Center for Space and Cosmic Evolution at Ehime University; Star Island 2012; and the Kavli IPMU public lecture "Challenge for the Mystery of the Universe." Tanaka gave a lecture on supernova explosions at the Asahi Culture Center (Yokohama). Hori gave lectures on "The Countless Stars in the Universe," "Planetary Science Night II," and "Fun with Planetary Science" as part of the Marunouchi Uchu-juku's "Kotowari noWakusei" event.

6. International Cooperation

Continuing from the previous year, Kajino was a member of the editorial board for the UK Institute of Physics' Journal of Physics, a member of the review panel for the European Science Foundation's EuroGENESIS Project, and an international examiner for the Science, Council of Canadian Science Foundation. Kokubo continued as an Organizing Committee member of the IAU's Extrasolar Planets Commission.

7. Awards

Ohsuga received the PASJ Excellent Paper Award 2012 from the Astronomical Society of Japan for the paper "Global Radiation-Magnetohydrodynamic Simulations of Black-Hole Accretion Flow and Outflow: Unified Model of Three States" (K. Ohsuga, S. Mineshige, M. Mori, Y. Kato 2009, Vol. 61, L7–L11), as well as the 28th Kodansha Scientific Publication Award in 2012 for Zero kara wakaru burakku hohru [Black Holes for Complete Beginners], Kodansha Blue Backs book series. Kokubo was selected by the National Institute of Science and Technology Policy as a 2012 NISTEP Researcher.

8. Main Visitors from Overseas

To fulfill its role as a center of excellence in Japan for theoretical studies in astronomy, The Division of Theoretical

Astronomy accepts numerous visitors engaging in joint research projects from overseas via Grants-in-Aid for Scientific Research, government subsidies for operating expenses, the budget for the observatory guests, and so forth. The following is a list of the main visitors.

Balantekin, Akif B. (University of Wisconsin-Madison, United States)
Boyd, Richard N. (Lawrence Livermore National Laboratory, University of California, United States)
Chen, Huei-Ru (National Tsing Hua University, Taiwan)
Cheoun, Myung-Ki (Soongsil University, South Korea)
Choi, Ki-Seok (Soongsil University, South Korea)
Deliduman, Cemsinan (Mimar Sinan Fine Arts University, Turkey)
Deliduman, Yamac (Mimar Sinan Fine Arts University, Turkey)
Famiano, Michael (Western Michigan University, United States)
Hacar, Alvaro (University of Vienna, Austria)
Jingqi, Miao (University of Kent, United Kingdom)
Kauffmann, Jens (California Institute of Technology, United States)
Latter, Henrik (University of Cambridge, United Kingdom)
Mathews, Grant J. (University of Notre Dame, United States)
Ogilvie, Gordon (University of Cambridge, United Kingdom)
Philippe, Andre (Saclay Nuclear Research Centre, France)
Ryu, Chung-Yeol (Hanyang University, South Korea)
Shantanu, Basu (University of Western Ontario, Canada)
So, Woon-Young Kangwon National University, South Korea)
Thushara, Pillai (California Institute of Technology, United States)
Yong, David (Australian National University, Australia)

22. Office of International Relations

For the sake of distinctive international research cooperation across the NAOJ as a whole, and to promote autonomous research activities by researchers, the Office of International Relations engages in planning and implementing strategies and support efforts to provide a strong foundation for expanded internationalization. The Office of International Relations engages in various activities such as supporting international collaborative projects; serving as a point of contact for interaction with overseas astronomical research organizations; gathering and providing information on international activities; offering support for hosting international research conferences, workshops, and seminars; providing support for visiting foreign researchers and students; and assisting in international partnerships involving Japanese research organizations.

1. International Collaborative Project Support

The office gathers and provides information necessary for organized independent implementation of international research collaborations; serves as a liaison for international activities; supports and joins international agreements; and accumulates know-how. By discussing and investigating individual cases through agreements and contracts with overseas universities and research organizations, the office gathers, accumulates, and provides information regarding questions such as: what points must be considered and what sorts of solutions exist. The office also offers advice and consulting services and answers questions regarding individual projects.

In FY 2012, the office cooperated with the Outreach and Education Office of the Public Relations Center to support the activities of the "You are Galileo!" project in Thailand, implemented with Official Development Assistance Grants for UNESCO Activities from MEXT.

The office also worked on agreements and memoranda for international collaboration, and handled import/export security control issues relating to joint research projects.

2. Contact Point for Overseas Astronomical Research Organizations

The annual directorate meeting the four member organizations of the East Asian Core Observatories Association (EACOA), – the National Astronomical Observatories of China (NAOC), the National Astronomical Observatory of Japan (NAOJ), the Korea Astronomy and Space Science Institute (KASI), and the Academia Sinica Institute of Astronomy and Astrophysics (ASIAA) in Taiwan – was held on August 20, 2012, at NAOC in Beijing. The office also issued a public call for EACOA postdoctoral fellowship program 2013. In addition, the office co-hosted the EACOA Site Survey Workshop (April 3–4, 2012, at NAOC in Beijing) for astronomical observation in the East Asia region.

The office planned and implemented an exhibit introducing NAOJ research activities and achievements at the 28th General Assembly of the IAU held in Beijing on August 19–31, 2012.

The Office engaged in procedures to publicly seek and employ Public Outreach Coordinators from around the world on the basis of the agreement between NAOJ and IAU to establish an IAU Office for Public Outreach at NAOJ. The Office 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 in Hosting International Research Conferences, Workshops, and Seminars

The office offers support for the planning and implementation of international research conferences,

workshops, and seminars hosted or supported by NAOJ. The office also offers consultation and answers questions regarding administrative problems and responses. If requested, the office offers advice on the appropriate organizations or individuals to contact, coordinates between organizations, and gathers relevant information.

This year, the office offered support in hosting an international conference "New Trends in Radio Astronomy in the ALMA Era? The 30th Anniversary of Nobeyama Radio Observatory" held on December 3–8, 2012 at Hakone.

4. Support for Hosting Foreign Researchers and Students

The office enhanced its framework for offering organizational support for research, education and living arrangements for foreign researchers and exchange students. The office offered consultation on visas, other procedures and matters related to life in Japan to help ensure a pleasant experience for foreign researchers and exchange students, as well as information on daily life.

5. Assistance in International Partnerships Involving Japanese Research Organizations

The office assists in international partnerships involving universities and other educational and research organizations in Japan, as well as coordinating with the International Strategy Headquarters and the International Cooperation Office at NINS regarding international collaborations.

The office oversaw the project Optical and Infrared Synergetic Telescopes for Education and Research (OISTER) begun in FY 2011 with the Okayama Astrophysical Observatory, the Ishigakijima Astronomical Observatory, and seven Japanese universities. The office offered support in authoring an agreement for Saitama University and the University of Hyogo to join the project.

The office collaborated with the International Cooperation Office at NINS to support planning a workshop for support staff for international joint research, creating a manual for hosting foreign researchers, and hosting English-language master seminars at various NINS organizations. The office also cooperated with the Administrative Bureau at NINS to dispatch two members of NINS office staff to the Subaru Telescope for overseas training.