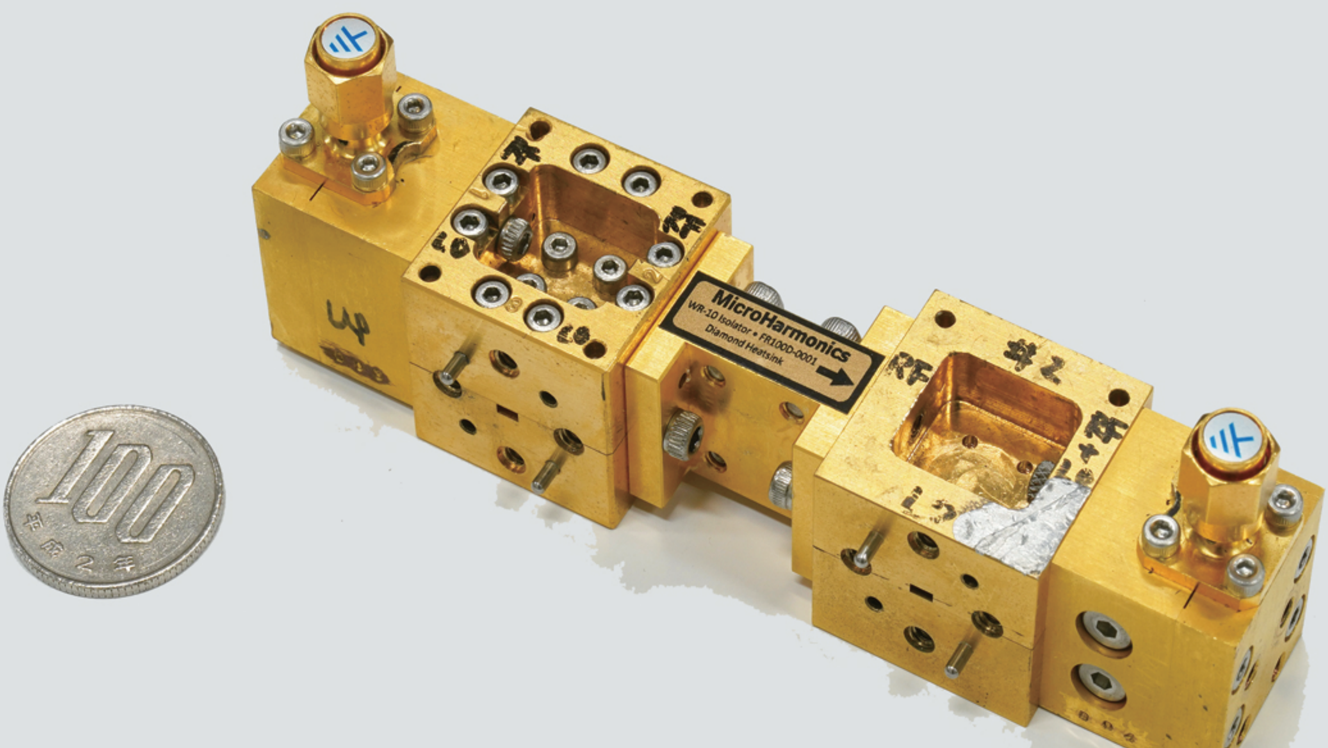
PRINT ISSN 1346-1192
ONLINE ISSN 2436-7214

Annual Report of the National Astronomical Observatory of Japan

Volume 25 Fiscal 2022



Cover Caption

A superconducting microwave amplifier developed by NAOJ. It is an amplifier based on a completely new principle that combines two SIS mixers (frequency converters) used in receivers on radio telescopes. Further research into miniaturizing and integrating superconducting circuits will contribute to the realization of multi-pixel radio cameras and large-scale quantum computers.

Credit: NAOJ

Postscript

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PREFACE

Fiscal Year 2022 (FY 2022), like Fiscal Year 2021, continued to feel the effects of the novel coronavirus, and we maintained a hybrid style of online and face-to-face for various aspects of our endeavors. I am confident that the National Astronomical Observatory of Japan (NAOJ) can strongly promote its activities in this new era by embracing a hybrid workstyle, not just as a decision forced by the need to prevent infection, but as a new paradigm that takes the best parts of both to create an efficient and effective working style.

One of the highlights in the world of astronomy in 2022 was that the James Webb Space Telescope (JWST) launched on December 25, 2021 began science observations, and reported mind-boggling results one after another. On July 11, 2022 (local time) United States President Joe Biden unveiled the first image of a distant galaxy cluster taken by JWST, demonstrating the United States of America's commitment to continue to lead the next generation of astronomy. In addition to the release of the beautiful, high-resolution infrared images, with the first detection of carbon dioxide in the atmosphere of an extrasolar planet and the detection of a galaxy candidate in the Universe over 13.5 billion years ago, JWST can truly be said to be living up to the expectations that it will deliver results stretching from the Milky Way Galaxy back to the earliest days of the Universe. Science proposals are being accepted from all over the world, including many proposals in which Japanese researchers, particularly young researchers, are playing leading roles. We expect strong synergy between JWST and Japan's leading observation facilities including the Subaru Telescope and ALMA.

New instruments which will show us new views of the Universe have been developed for NAOJ telescopes. The Prime Focus Spectrograph (PFS), which can deliver simultaneous spectral observations of up to about 2,400 celestial objects, using the approximately 2,400 fibers arrayed across the wide field of view offered by the Subaru Telescope, conducted engineering observations in September 2022 where it successfully obtained the spectra for the light from many stars at the same time, achieving engineering first light. This is an important milestone in the Subaru Telescope 2.0 project launched in FY 2022 to upgrade the capabilities of the Subaru Telescope. Test observations to confirm instrument performance have followed, led by KAVLI IPMU at the University of Tokyo, making progress towards PFS's ultimate goal of "revealing the true nature of dark energy through spectral observations of numerous galaxies."
In addition to "Subaru Telescope 2.0" the upgrade plan for ALMA, "ALMA 2.0" will start in FY 2023. Various development work is continuing in hopes of achieving the 3 major stated science goals of understanding the formation process of planetary systems on scales equivalent to the size of Earth's orbit; understanding the nature of organic material in the formation process of planetary system, and pinpointing the beginning of nucleosynthesis in the Universe.

This development has potential applications beyond the realm of astronomy research. A research team in the Advanced Technology Center (ATC) demonstrated a novel microwave amplifier based on completely new principles by coupling together superconducting SIS mixers from ALMA. This opens the possibility for significant reductions in size and power consumption compared to previous microwave amplifiers. It can be expected that this result will contribute to the actualization of authentic quantum supercomputers requiring many amplifiers.

The Industry Liaison Office was launched in order to give back to society though the development of technologies like this at NAOJ. One example is the lecture for journalist about "Technology Development in NAOJ and Collaboration with Industry" conducted in collaboration with the Public Relations Center together with a tour of ATC in December of 2022. FY 2022 also saw the realization of academic consultation and joint research, contracted research, and contracted projects with private companies. The Industry Liaison Office plans to further extend its reach by hosting exhibits at conferences and by courting the media.

As always, NAOJ produced many research results in FY 2022. In the strategic program utilizing the Subaru Telescope's Infrared Doppler instrument (IRD), an extrasolar "Super Earth" with a mass 4 times that of the Earth was discovered around a low temperature star. The elucidation of the types of planets that can be found around low temperature stars, which account for three-quarters of the stars in the Milky Way Galaxy, provides fodder for the discussion of the possibility of life in environments very different from what is found on Earth. An artificial intelligence (AI) trained on simulation results from the supercomputer "ATERUI II" analyzed observational data for real galaxies and successfully measured the cosmic parameters (physical constants which govern the properties of the Universe) with high precision. As AI is proving its usefulness in various aspects of society, the application of AI to astronomy dealing with Big Data is also advancing.

A worldclass result contributed in data analysis by Japanese researchers, the imaging the supermassive black hole "Tau A*" (pronounced Tau A Star) at the center of the Milky Way Galaxy, had large impact on society. This is a result of the "Event Horizon Telescope" which creates a global scale telescope by combining data taken by 8 radio telescopes at 6 locations, first and foremost ALMA operated by NAOJ together with international partners.

One of the bases of research like this is the Division of Science, which had its first international review since its founding where its research activities combining theory and research were praised. Further developments are expected through activities occurring across the traditional boundaries between NAOJ projects and beyond the Division of Science, such as regularly held joint seminars and calls for researcher positions conducted together with Projects including Subaru Telescope and ALMA. Observational results on extrasolar planets, cosmic parameters, and black holes are all themes that provide important hints about the appearance and structure of the Universe in which we live and provide a basis to think about our own roots. These are themes which NAOJ needs to pursue.

Here I would like to summarize the status of NAOJ's various projects in FY 2022.

New observational instruments have been introduced sequentially at the Subaru Telescope since it started observations in 1999, maintaining its high level of international competitiveness. There were 192 refereed papers in FY 2022. This is at the highest world level for a single 8-10 m class ground-based optical/infrared telescope. This happens against a backdrop where researchers unaffiliated with NAOJ are actively using the data releases from the ultra-wide field of view prime focus camera Hyper Suprime-Cam (HSC) to write papers.

On the other hand, the mechanical components of the telescope and dome continue to age. Since 2018, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) has been providing a budget for countermeasures against the aging of the equipment. In FY 2022, the telescope drive mechanism, which is vital to the operation of the telescope, was repaired and the dome air conditioning system was renewed.

“Subaru Telescope 2.0” was accepted as a Large-scale Academic Frontiers Project in FY 2022 and integration and assembly is continuing for the facility instrument PFS. The Ground Layer Adaptive Optics (GLAO) to improve the resolution over a wide field of view, which is required for another facility instrument, the Ultra-wide Laser Tomographic Imager and MOS with AO for Transcendent Exploration (ULTIMATE), has passed the preliminary design review and has now moved on to the detailed design phase.

It has been decided to conduct synergetic observations between the Subaru Telescope and Roman Space Telescope (scheduled for launch in 2026). Now we are fleshing out the plan together with the United States National Aeronautics and Space Administration (NASA) and Institute of Space and Astronautical Science (ISAS) of the Japan Aerospace Exploration Agency (JAXA). Also, in preparation for cooperative research with the Euclid space telescope of the European Space Agency (ESA) and the American Rubin Observatory, a framework for collaboration is being erected based on discussions with the astronomy community.

ALMA started its 10th open-use observation cycle, Cycle 9, from October 2022. A record-setting 1,769 observation proposals were received from all over the world. At the end of October, ALMA observatory in Chile suffered a cyberattack on its computer systems, forcing the suspension of astronomical observations. But through the dedicated efforts of everyone involved, open-use observations resumed in mid-December. The number of scientific papers published based on ALMA data reached 3,238 during the eleven-and-a-half-years ending with FY 2022. Japan continues to do well, in terms of primary authors, we had the second largest number of papers, following the United States of America.

New instrument development and production is proceeding under the framework for collaboration in East Asia being led by NAOJ. The Band 1 receivers (observational bandwidth 35-50 GHz) led by the Institute of Astronomy and Astrophysics, Academia Sinica (ASIAA) and the new spectrometer led by the Korea Astronomy and Space Science Institute (KASI) for the Atacama Compact Array (ACA/Morita Array) will be offered for open-use observations starting with Cycle 10 in October 2023. Corrugated horns developed and manufactured using a 3D metal printer in ATC are installed in the Band 1 receivers.

Preparation for the “ALMA 2.0” plan aiming for performance improvements including angular resolution two times better than ALMA, continued with the project transition evaluation and preliminary review for the Large-scale Academic Frontiers Projects of the Council for Science and Technology, Subdivision on Technology, Subcommittee on Research Environment conducted in 2022. The preliminary review found that “this plan needs to be actively pursued, and work should start as soon as possible,” thus the ALMA 2.0 plan will start from FY 2023.

Construction of TMT, an extremely large telescope with a 30 m diameter being advanced through international collaboration, is on hold due to opposition movements in Hawai`i. NAOJ in cooperation with TMT International Observatory (TIO) is pursuing a direct dialog with local residents and education support to foster a relationship of mutual trust. The Mauna Kea Stewardship and Oversight Authority (MKSOA) with participation by Native Hawaiian representatives was established in 2022, for the first time creating a mechanism to reflect the opinions of indigenous people in the management of the operation and construction of telescopes on Maunakea. Also, to achieve the reduction in the number of telescopes desired by the Native Hawaiians, progress is being made on the decommissioning of the 10.4 m diameter Caltech Submillimeter Observatory (CSO) and decommissioning preparations for the University of Hawai`i educational telescope Hoku Kea. The situation in Hawai`i is improving thanks to these efforts.

The preliminary design review by the United States National Science Foundation (NSF), which is vital for securing the TMT construction budget, was held and deemed TMT ready to proceed to the Final Design Phase. The high level of engineering for the telescope main structure for which Japan is responsible and the outreach efforts in Hawai’i led by NAOJ members were both highly evaluated. In these ways, the TMT plan is advancing both at the local level in Hawai`i and the US federal government level. In Japan, while continuing to minimize budgetary expenditures, preparation is proceeding with the Japanese community for the manufacturing of Japan’s work share, including a Production Readiness Review of the main telescope structure conducted by TIO.

KAGRA, the Large-scale Cryogenic Gravitational Wave Telescope, developed through collaboration between the Institute for Cosmic Ray Research of the University of Tokyo, NAOJ, and the High Energy Accelerator Research Organization KEK, has completed upgrades to participate in the fourth international gravitational observing run O4 scheduled to start from May 2023. The Power-Recycled Fabry-Perot Michelson interferometer can now be stably locked for over 2 hours. NAOJ contributes to various aspects of KAGRA including interferometer commissioning, noise hunting, and calibration. The sapphire mirrors developed in collaboration with KASI in Korea and ASIAA in Taiwan are scheduled to be installed in KAGRA before the O5 run. In addition, the KAGRA satellite control room established in Mitaka Campus in FY 2021 has increased work efficiency and reduced costs.

At Nobeyama Radio Observatory, while a new policy of charging for observation time has been implemented from FY 2022, observational research is still being actively conducted as before. Through the use of artificial intelligence (AI) the distances to interstellar molecular clouds have been determined from observational data, creating the first 3D map of molecular gas distribution in the Milky Way Galaxy.

At Mizusawa VLBI Observatory, collaborative observation programs have started in addition to open use of the East Asian VLBI Network (EAVN). Results are being produced, such as a scenario to explain the detailed velocity structure of the M87 jet revealed by Japan-Korea VLBI observations. Additionally, efforts to diversify in funding sources are ongoing, including crowd funding and the employment of project assistant professors through cooperation with a media company.

The Okayama Branch of Subaru Telescope facilitates the open use of Kyoto University’s 3.8-m Seimei Telescope, contributing to the creation of scientific results. Under the leadership of Tokyo Institute of Technology, the Branch's 188-cm Reflector Telescope was used as a dedicated extrasolar planet survey telescope. Since FY 2018, the city of Asakuchi has used it to offer paid chartered telescope time and stargazing parties. A problem developed in the dome slit in September 2022, and investigations towards recovery are underway.

Ishigakijima Astronomical Observatory, taking advantage of the wide observable area of the sky thanks to being located at the southern tip of Japan, is using the 105 cm aperture "Murikabushi Telescope" to study Solar System bodies and transient celestial phenomena. Starting from FY 2022 a paid admission system was implemented to increase safety and security of the guests and improve employee working conditions.

In the Optical and Infrared Synergetic Telescopes for Education and Research (OISTER), 9 domestic universities run 1 m class optical/infrared telescopes arrayed across Japan and overseas to conduct follow-up observations of transient phenomena. In Japanese VLBI Network (JVN) activities, 30 m class radio telescopes operated by 6 domestic universities are combined to form a VLBI observation network, and mazer monitor observations led by Ibaraki University continue to detect accretion bursts.

The East Asian Observatory (EAO), with its 5 members of Japan, China, the Republic of Korea, Taiwan, and Thailand, continues to operate the James Clerk Maxwell Telescope (JCMT).

The SOLAR-C satellite plan to conduct high-spatial resolution spectroscopy in the extreme ultraviolet is making steady progress. It passed the JAXA Mission Definition Review in July 2022, moving to the pre-project phase, and in December completed the System Requirement Review. The international SUNRISE-3 balloon experiment, which was to conduct high angular resolution polarimetry using a 1-m aperture optical telescope, launched in July 2022, but was unable to collect observational data due to a malfunction in the gondola. A re-flight is planned for the summer of 2024. Development is underway at NAOJ for flight models for a high-speed CMOS camera for soft X-rays and an X-ray collimator for the NASA FOXSI-4 sounding-rocket experiment. Aiming for a launch in spring of 2024, FOXSI-4 will conduct solar X-ray spectroscopy with focusing optics.

The lunar and planetary exploration RISE Project, as the Geodesy Science Strategy Team (GSST) for the Martian Moons eXploration (MMX) sample return mission, worked together with the Centre National d'Etudes Spatiales (CNES) in France to develop orbit/gravity field estimation software. The surface evolution and interior structure research of the asteroid Ryugu cultivated by Hayabusa2 is now being expanded towards observations of the Martain satellite Phobos.

In ATC, evaluation tests are underway for a prototype for use in satellites based on an InGaAs infrared imaging sensors developed for terrestrial use. Good results, including high sensitivity, have been obtained. A 2k × 2k multielement prototype has been completed, and is scheduled to be evaluated in FY 2023 in cooperation with the JASMINE Project. This sensor will be installed on JAXA's JASMINE infrared astrometry satellite.

Work to expand the ATC microfabrication cleanroom is underway, laying a foundation for accelerated progress on research and development for applications including ALMA 2.0 and quantum computers. From the perspective of economic security, we have established a management system for superconducting devices and various device manufacturing equipment, including a newly constructed secure storage area for sensitive items with security in mind.

Also, a framework is being developed for the application of ultra-low power consumption cooled amplifiers and isolators developed for radio telescopes to error-tolerant quantum computers and the repurposing of adaptive optics technology, which was developed to compensate for atmospheric fluctuations in order to capture clear images of celestial objects, for application in biological microscopy or satellite to ground communications. In order to make the technology in ATC relevant to society beyond the limits of astronomy, preparation is proceeding within the center to launch the "Social Implementation Program."

In the Astronomy Data Center, the renewal of the large-scale archive and multi-wavelength data analysis system has been postponed due to a semiconductor shortage. The Japanese Virtual Observatory (JVO) released a VO interface for the JAXA infrared astronomy satellite AKARI data catalog.

In the Public Relations Center, the live coverage internet broadcast of the total lunar eclipse and occultation of Uranus which occurred on November 8, 2022 attracted much attention with approximately 1.85 million views, over 2 million if you include views of the archive video. In parallel with online information dissemination like this, face to face events such as Mitaka Campus Special Open House Day and Regular Stargazing Parties using the 50-cm Telescope for Public Outreach are helping to forge a hybrid approach of in-person and online activities. By offering the genuine experience of in-person communication and the accessibility of online content, we are pursuing an outreach and education strategy catering to the different needs of different segments of society.

The 2,969 refereed papers published during 2018~2022 by members of NAOJ have had an international collaboration rate of 81.8 %; also, 17.3 % of the papers have made it into the Top10% of papers published worldwide in terms of citations and 3.6 % have made it into the Top1% (according to InCites as of August 2023). While as of August 1, 2023, Japanese members account for only 5.5 % of the total members of the International Astronomical Union (with 689 Japanese members, approximately 27 % the number of United States members), Japan achieved a 9.1 % world share in the number of papers published in space science during 2022 with 1,590 papers. This is Japan's highest world share among the 22 fields of study, surpassing physics (6.6 % with 7,748 papers). As of April 1, 2023, women account for 10.2 % of NAOJ researchers (including Research and Academic Staff and specially appointed teachers) compared to 10.5 % in the previous fiscal year.

In addition, the newly created Graduate Education Office can conduct systematic graduate student education and human resource development, and can also act as a window for communication with other institutes. The "NAOJ Future Planning Symposium 2022: How to decide and promote future plans" (December 7, 8 @ Mitaka Campus) was held based on discussions by the NAOJ Scientific Advisory Committee. Here researchers from inside and outside of NAOJ had a lively exchange of opinions.

This concludes my overview of NAOJ's activities in FY 2022. More details can be found in the full report. I look forward to your continued cooperation and support.

Saku Tsuneta

I Scientific Highlights

(April 2022 – March 2023)

Spectral Evolution of 596 Scheila and Dark Asteroids Induced by Space Weathering over a Decade

HASEGAWA, Sunao[1], DeMEO, Francesca E.[2], MARSSET, Michaël2/3, HANUS, Josef[4], AVDELLIDOU, Chrysa[5], DELBO, Marco[5], BUS, Schelte J.[6], HANAYAMA, Hidekazu[7], HORIUCHI, Takashi[8], TAKIR, Driss[9], JEHIN, Emmanuël[10], FERRAIS, Marin[11], GEEM, Jooyeon[12], IM, Myungshin[12], SEO, Jinguk[12], BACH, Yoonsoo P.[12], JIN, Sunho[12], ISHIGURO, Masateru[12], KURODA, Daisuke[13], Binzel, Richard P.[2], NAKAMURA, Akiko M.[14], YANG, Bin[15], VERNAZZA, Pierre[11]

1: Japan Aerospace Exploration Agency, 2: MIT, 3: European Southern Observatory (ESO), 4: Charles University, 5: Observatoire de la Côte d'Azur, 6: University of Hawaii, 7: NAOJ, 8: University of Tokyo, 9: NASA Johnson Space Center, 10: Universite de Liege, 11: Laboratoire d'Astrophysique de Marseille, 12: Seoul National University, 13: Japan Spaceguard Association, 14: Kobe University, 15: Universidad Diego Portales

The surface of airless bodies like asteroids in our Solar System are known to be affected by space weathering. Experiments simulating space weathering are essential for studying the effects of this process on meteorite samples, but the problem is that the time spent to reproduce space weathering in these experiments is billions of times shorter than the actual phenomenon. The T-type asteroid 596 Scheila underwent a collision with a few-tens-of-meters impactor in December 2010 [1,2] and its surface was covered with fresh material [3]. A decade later, there is an opportunity to study how the surface layer of this asteroid is being altered by space weathering after the impact. To do so, we performed visible spectrophotometric and near-infrared spectroscopic observations of 596 Scheila [4]. The acquired spectrum is consistent with those observed shortly after the 2010 impact event within the observational uncertainty range This indicates that the surface color of dark asteroids is not noticeably changed by space weathering over a 10-year period (Fig. 1). Our study is the first to investigate color changes due to space weathering on an actual asteroid surface in our Solar System (Fig. 2). Considering that fresh layers are regularly created on asteroid surfaces by collisions, we suggest a genetic link between D/T-type and dark (low albedo) X-complex asteroids and very red objects such as 269 Justitia, 732 Tjilaki (and 203 Pompeja). New observations show that 203 Pompeja has a X-type-like surface, with some local surface areas exhibiting a very red spectrum.

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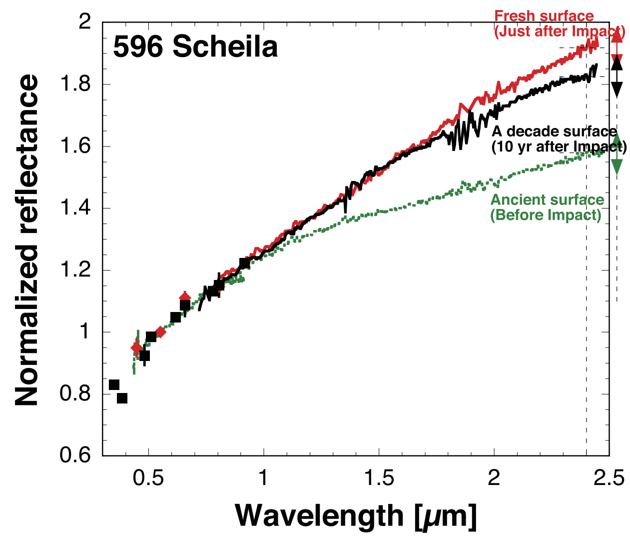

Figure 1: Spectra of the asteroid 596 Scheila

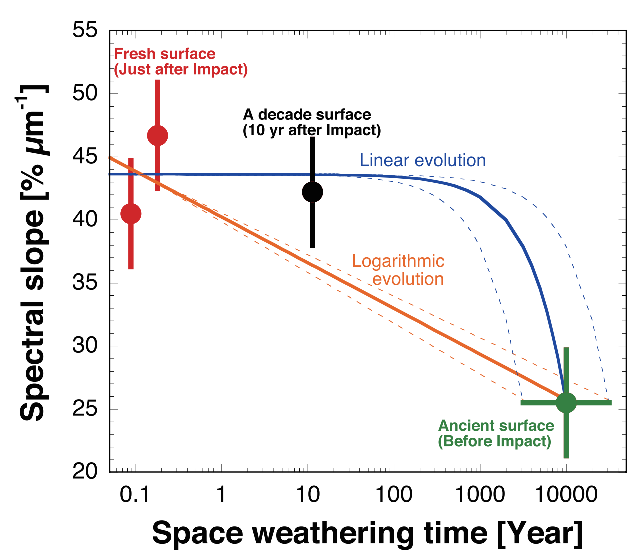

Figure 2: Spectral slope for 596 Scheila against space weathering time.

Over Seven Decades of Solar Microwave Data Obtained with Toyokawa and Nobeyama Radio Polarimeters

SHIMOJO, Masumi[1/2], IWAI, Kazumasa[3]

1: NAOJ, 2: SOKENDAI, 3: ISEE, Nagoya University

In Japan, we have a long history of observing total solar microwave fluxes. It was started in May 1951 with 3.75 GHz at Research Institute of Atmospherics, Nagoya University, then the monitoring observations were started with 1 GHz started in June 1957, 2 GHz started in May 1957, and 9.4 GHz started in May 1956 at Toyokawa (Figure 1). In Nobeyama Solar Radio Observatory, Tokyo Astronomical Observatory, the monitoring observations with higher frequencies (17, 35, and 80 GHz) were started in the late 1970s and early 1980s. These monitoring observations are being continued at the Nobeyama Campus, NAOJ until now (Figure 1).

Figure 1: Upper panel: Toyokawa Radio Polarimeters (behind. The antennas in front are the 8-element solar grating array. Courtesy of the family of H. Tanaka) Lower panel: Nobeyama Radio Polarimeters.

We summarized the history of the Toyokawa and Nobeyama Radio Polarimeters, especially the instrument history after the 1, 2, 3.75, and 9.4 GHz antennas were moved from Toyokawa to Nobeyama, and explained the details of the solar microwave database (Figures 2&3) provided by the Solar Data Archive System (SDAS) operated by the Astronomy Data Center and Solar Science Observatory, NAOJ.

The long-term solar microwave database is useful for understanding not only the long-term variation of the solar activity but also the microwave emission from late-type stars.

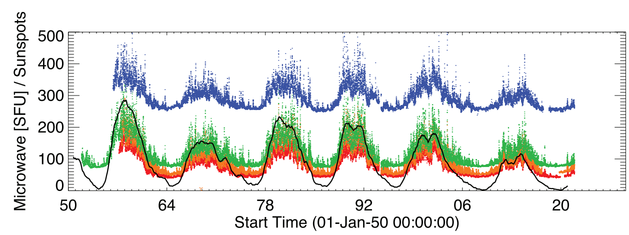

Figure 2: Variations in total solar microwave fluxes over 70 years. Red: 1 GHz, orange: 2 GHz, green: 3.75 GHz, blue: 9.4 GHz, and black: Sunspot number.

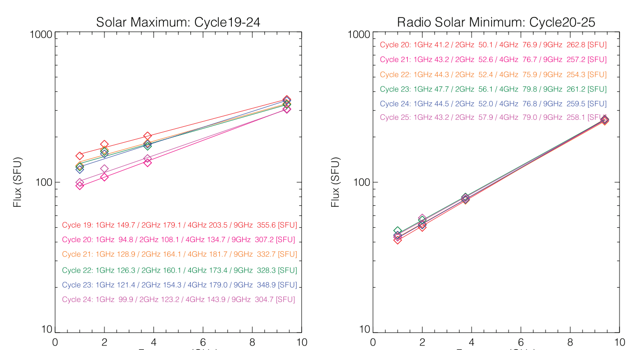

Figure 3: Solar microwave spectra at solar maxima and minima. Left panel: solar maxima, and right panel: solar minima. Colors indicate solar cycles.

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Survival of Terrestrial N_2-O_2 Atmospheres in Violent XUV Environments by Efficient Atomic Line Radiative Cooling

NAKAYAMA, Akifumi[1/2], IKOMA, Masahiro[2/3/4], TERADA, Naoki[5]

1: Rikkyo University, 2: The University of Tokyo, 3: NAOJ, 4: SOKENDAI, 5: Tohoku University

Observational efforts have recently been made to find potentially habitable planets around M dwarfs, including a radial velocity survey with Subaru-IRD. In maintaining planetary habitability, meanwhile, atmospheres are known to have a crucial role. Around M dwarfs and young Sun-like stars, planets receiving the same insolation as the present-day Earth does are exposed to intense stellar X-ray and extreme-ultraviolet (XUV) radiation. A fundamental question, then, arises whether the present Earth's atmosphere could survive in such harsh XUV environments. Previous theoretical studies suggest that the stellar XUV irradiation is intense enough to remove atmospheres like the present-day Earth's one completely on short timescales [1].

In this study [2], we develop a new upper-atmosphere model and re-examine the thermal and hydrodynamic response of the thermospheric structure of an Earth-like N_2-O_2 atmosphere on an Earth-mass planet to increase in XUV irradiation. The model includes newly the effects of radiative cooling via electronic transitions in the atoms (or atomic line cooling), in addition to thermo- and photo-chemistry, thermal and chemical diffusion, adiabatic cooling, absorption of stellar IR radiation, and molecular IR radiative cooling, which previous models already took into account. As shown in Figure 1, we have found that the atomic line cooling dominates over the hydrodynamic effect at XUV irradiation levels higher than several times the present Earth's level. As a consequence, the atmosphere's structure is kept almost hydrostatic, and its escape remains sluggish even at XUV irradiation levels even up to thousand times the present Earth's one.

The estimated lifetime of the 1~bar N_2-O_2 atmosphere is shown as a function of the XUV irradiation level in Figure 2. Our estimates for the Jeans escape rates of N_2-O_2 atmospheres suggest that the 1-bar atmospheres survive in early active phases of Sun-like stars except for rapid rotators. Even around rapidly rotating Sun-like stars and M dwarfs, the N_2-O_2 atmospheres of several bars could avoid a significant thermal loss on timescales of Gyr. Those results give new insights into the habitability of terrestrial exoplanets and the Earth's climate history.

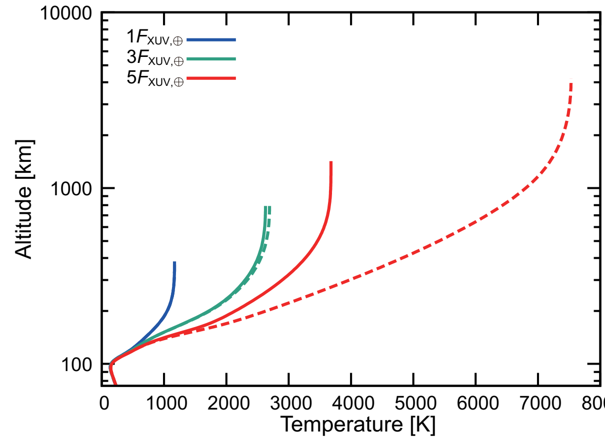

Figure 1: Effects of atomic line cooling on the upper-atmospheric structure. Temperature profiles simulated with (solid lines) and without (dashed lines) atomic line cooling are shown for three different XUV irradiation levels, one times (blue), three times (green), and five times (red) the present-day Earth's one, $F_{XUV,\oplus}$.

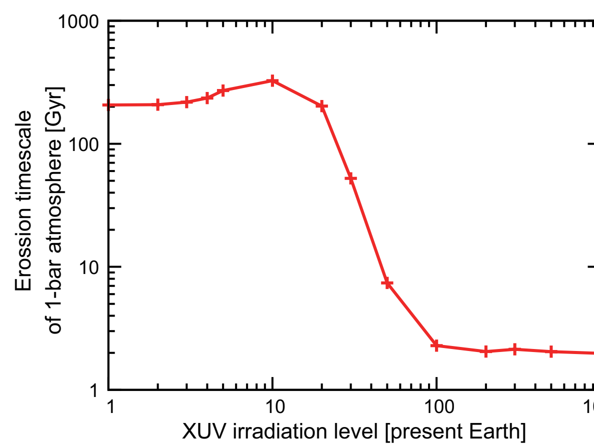

Figure 2: Estimated lifetime of the 1 bar N_2-O_2 Earth-like atmosphere. We have estimated the lifetime, dividing the mass of present Earth's atmosphere by the mass-loss rate calculated from our model for each XUV irradiation flux.

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Narrow Fe-Kα Reverberation Mapping Unveils the Deactivated Broad-Line Region in a Changing-Look Active Galactic Nucleus

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Active Galactic Nuclei (AGN) are luminous compact object powered by mass accretion onto supermassive black holes (SMBH). The primary X-ray and UV/optical continua (from the central X-ray corona and accretion disk, respectively) irradiate surrounding gas/dust clouds that produce secondary emission such as emission lines and dust thermal emission. In the X-ray band, the most prominent emission line feature commonly observed in AGNs is the Fe-Kα fluorescence line at 6.4 keV. Due to the observational difficulty of precisely measuring the narrow (~ 1000–2000 km/s) Fe-Kα line profile with existing X-ray satellites (e.g., [1,2]), it is still under debate where this prominent emission line is originated from.

Since the AGN emission shows flux variability on time scales of days-to-years, we can expect new observational constraints on the spatial extent of the Fe-Kα emission region to be obtained from the temporal information. To this end, we performed multi-epoch X-ray and optical observations targeting for a Seyfert galaxy NGC 3516 in 2013-2015 with *Suzaku* and Japanese ground-based telescopes in the OISTER framework ([3,4]). The X-ray and optical *B*-band light curves, along with the archival *Swift* X-ray continuum data points, are shown in Figure 1.

NGC 3516 showed large flux variations both in the X-ray and optical bands over the observing period (NGC 3516 is a Changing-Look AGN; [5]), that enabled us to measure the time lags between light curves of the X-ray corona continuum, optical accretion disk continuum, and the Fe-Kα emission line; the optical-to-X-ray continuum lag was $2.0^{+0.7}_{-0.6}$ days, and the Fe-Kα line-to-X-ray continuum lag was $10.1^{+5.8}_{-5.6}$ days. This is the second detection of the 6.4 keV Fe-Kα lag in AGNs after the marginal detection in a Seyfert galaxy NGC 4151 ([6]). The measured time lags are consistent with the 'lamp-post picture' in that the variable X-ray corona emission drives the flux variations of the disk optical continuum ($R_{\rm disk}$ ~ 2 lt-days) and Fe-Kα ($R_{\text{Fe-K}\alpha}$ ~ 10 lt-days).

The inferred size of the Fe-Kα emission region coincides with that of the broad-line region (BLR). Future multi-epoch high-resolution X-ray spectroscopy with *XRISM* will enable us to further constrain the Fe-Kα emission region and its relation to the BLR utilizing both the temporal and precise line profile information.

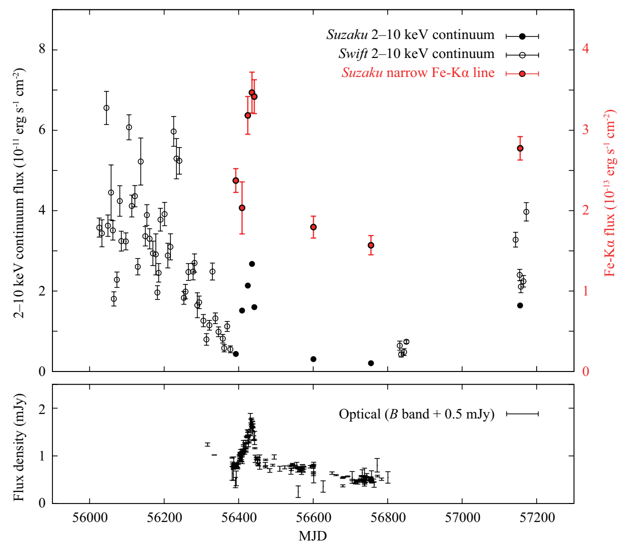

Figure 1: The X-ray and optical light curves of NGC 3516 ([4]). Top: *Suzaku*/XIS and *Swift*/XRT X-ray 2–10 keV continuum (black) and *Suzaku*/XIS Fe-Kα emission line (red). Bottom: optical *B*-band accretion disk continuum.

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Millimeter Methanol Emission in the High-mass Star-forming Region G24.33+0.14

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Maser Monitoring Organization (M2O)

We have been conducting monitoring observations of astronomical maser sources under international collaboration with Maser Monitoring Organization (M2O; https://www.masermonitoring.org). One of the purposes of the M2O is to detect sudden increase of the maser emission (maser flares) by a global network of radio telescopes.

In the course of the M2O monitoring, a flare of the 6.7 GHz methanol (CH_3OH) maser was observed toward the high-mass star-forming region G24.33+0.14 (7.2 kpc from the Sun) in September 2019 using the Torun 32-m radio telescope in Poland [1]. G24.33+0.14 experienced a similar flare in 2010–2012, suggesting repeating/periodic flare activity with an 8-year interval. As reported for some of the methanol maser flare events, it could be triggered by an episodic mass accretion event (accretion burst) in a high-mass protostar.

Using the Atacama Large Millimeter/submillimeter Array (ALMA) in the Director's Discretionary Time (DDT), we carried out a Target-of-Opportunity (ToO) observations of the millimeter continuum and molecular lines toward G24.33+0.14 in mid-September 2019 (ALMA Cycle 6), 20 days after the onset of the maser flare [2]. Combined with the ALMA data taken in the pre-flare phase in August 2016 (ALMA Cycle 3), we investigated possible variability of the millimeter emission in G24.33+0.14.

In G24.33+0.14, we identified a massive (~60 $M_\odot$) and compact (~2000 au) millimeter core C1 associated with the 6.7 GHz methanol masers. The continuum flux density of C1 showed a marginal increase in Cycle 6 with a flux ratio (Cycle 6/Cycle 3) of 1.16 ± 0.01, which is comparable to the absolute flux calibration uncertainty of 10 %. Other than methanol, we also compared the 26 molecular line emission identified in G24.33+0.14 between Cycle 3 and Cycle 6, and found almost the same flux ratios as that of the continuum emission, with an average and standard deviation of 1.12 ± 0.15. On the other hand, we found that 8 identified methanol lines including a torsionally excited transition and a ^{13}C isotopologue showed a slightly larger flux increase with the average ratio of 1.23 ± 0.13 (Figure 1). Furthermore, the methanol lines at higher excitation states tend to have larger flux increases. If this systematic trend of the flux increase in the methanol lines is significant, it would suggest radiative heating in the central part of the continuum source C1 due to an episodic accretion event.

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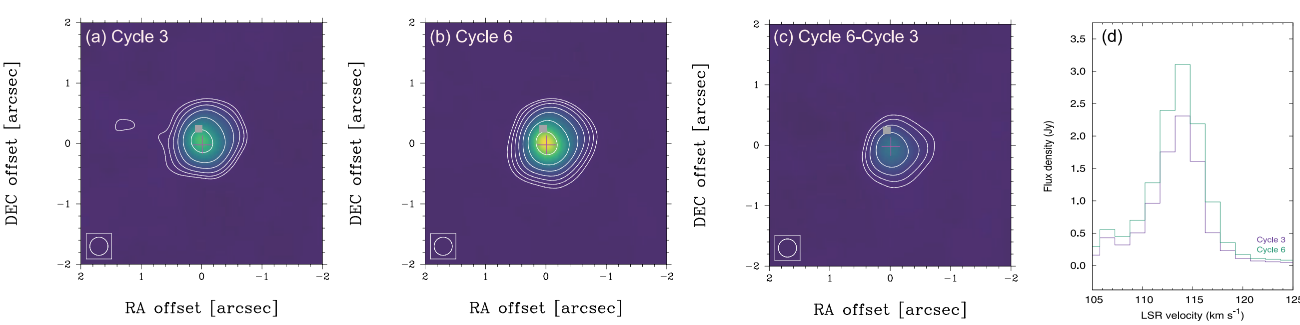

Figure 1: (a) Moment 0 map of the CH_3OH 229.589 GHz (15_4-16_3 E) line for the Cycle 3 data. Contour levels are 4, 8, 16, ..., times the rms noise level of 18.7 mJy beam^{-1} km s^{-1}. A magenta cross and gray square indicate positions of the continuum peak C1 and the 6.7 GHz methanol maser flare, respectively. (b) Same as (a) but for the Cycle 6 data. The rms noise level is 13.4 mJy beam^{-1} km s^{-1}. (c) Differential image of the moment 0 maps between Cycle 3 and Cycle 6. The rms noise level is 23.5 mJy beam^{-1} km s^{-1}. (d) Spectra of the 229.589 GHz methanol line in Cycle 3 and Cycle 6.

The Resolved Feature at the Center of M87 Found from EHT Public Data

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We report the result of our independent image reconstruction of the M87 from the public data of the Event Horizon Telescope Collaboration (EHTC). Our result is different from the image published by the EHTC. Our analysis shows that (a) the structure at 230 GHz is consistent with those of lower-frequency very long baseline interferometry observations, (b) the jet structure is evident at 230 GHz extending from the core to a few milliarcsecond, although the intensity rapidly decreases along the axis, and (c) the "unresolved core" is resolved into three bright features presumably showing an initial jet with a wide opening angle of ~ 70°.

The EHTC ring image had un-reasonable features, such as the jets not being visible, the maximum brightness temperature being too low, the flux density not being reproduced, and obtaining a ring with the same diameter as the spacing between the main beam and the first sidelobes seen in the structure of the point spread function.

On the other hand, our image shows that (d) the image reproduces the higher brightness temperature (~ 10^{11} K) and comparable flux density as that indicated by the observed data (~ 1 Jy), and that (e) comparing the amount of residuals between the data and the reconstructed image, our results show smaller residuals about 1/2 to 1/3 times than those of the EHTC ring image. Therefore, our resulting images (central core-knot structure and elongated jet structure) are more reliable.

We also investigated why the EHTC ring image was acquired. The ring-like structures of the EHTC can be created not only from the public data but also from the simulated data of a point image and noise. Also, the rings are very sensitive to the field-of-view (FOV) size. The *u*-*v* coverage of EHT for M87 lacks ~ 40 μas fringe spacings. Combining with a very narrow FOV, it created the ~ 40 μas ring structure. One more to note is that the EHTC performed simulations searching for appropriate imaging parameters, but there are deficiencies. Because the EHTC's simulations only take into account the reproduction of the input image models, and not those of the input noise models, their optimal parameters can enhance the effects of sampling bias and produce artifacts such as the ~ 40 μas ring structure, rather than reproducing the correct image.

We conclude that the absence of the jet and the presence of the ring in the EHTC result are both artifacts owing to the narrow FOV setting and the *u*-*v* data sampling bias effect of the EHT array 2017.

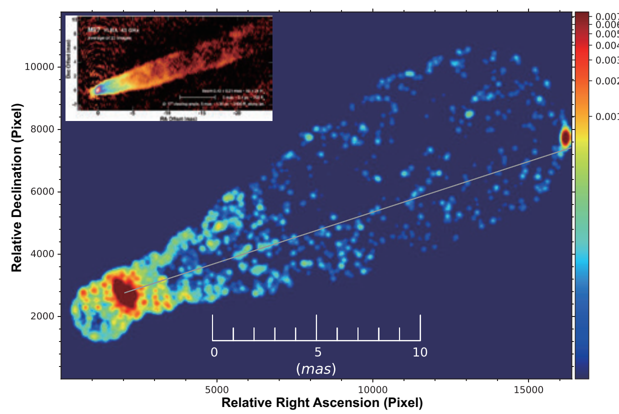

Figure 1: Image reconstructed from public data of EHT 2017 observations of M87, revealing a jet structure missed in the EHTC analysis. The inset is an averaged image of M87 from VLBA 43 GHz observations added for comparison.

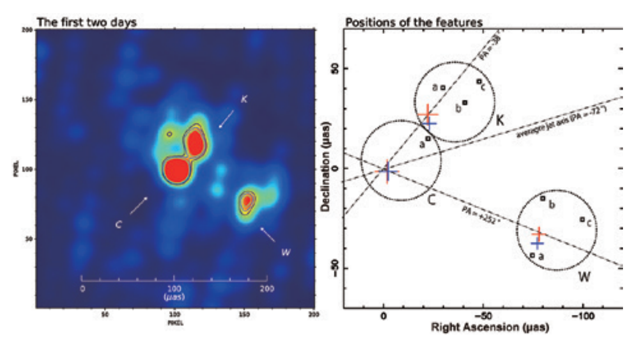

Figure 2: Core (C) and knots (K, W) structure found at the center of M87. The directions of the C-K and C-W lines are the same as those of the ridges found in the 43 GHz observations. The axis of the average jet direction bisects the angle KCW.

Reference

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Automated Sunspot Detection as an Alternative to Visual Observations

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Sunspot numbers present the variation in solar activity for more than 400 years, and it is important to continue the derivation of the sunspot number. The sunspot number counts are still based on hand-drawn sketches obtained by visual observations. Therefore, automated detection of sunspots on digital white-light images, which enables objective sunspot counting with small manpower, is required.

For this reason, NAOJ changed the sunspot counting method from hand-drawn visual observation to automated sunspot detection based on digital images in 1998 [1]. However, the quality of images is not very high, and detections of false spots and missed detections of true spots often occur. Therefore, we have started higher-quality imaging observation with the Solar Flare Telescope at Mitaka and developed another method of which the performance is comparable to that of visual observations [2]. An example of the results of the automated detection is shown in Figure 1.

To identify small spots correctly, the quiet-disk component of the Sun, which is used as a reference to identify sunspots using a threshold, is derived accurately. This threshold is determined using an adaptive method to process images obtained under various conditions. To eliminate the seeing effect, our method can process multiple images taken within a short time.

We applied the developed method to digital images captured by three different observers (the Solar Flare Telescope, Kawaguchi Science Museum, and an amateur observer Mr. S. Morita) and compared the detection results with those of visual observations by Specola Solare Ticinese and Kwasan Observatory of Kyoto University. Figure 2(a) presents the number of sunspots detected by these observations during 2021. Because they show significant scatter, the monthly-mean ratios of the number of sunspots with respect to that of the Solar Flare Telescope are shown in Figure 2(b). The numbers of sunspots detected on the digital images are between two visual observations. We conclude that the proposed sunspot detection method has a similar performance to that of visual observation. This method can process data taken with various instruments, and therefore, it can be widely used by public observatories and amateurs as well as professional observatories as an alternative to hand-drawn visual observation for sunspot counting.

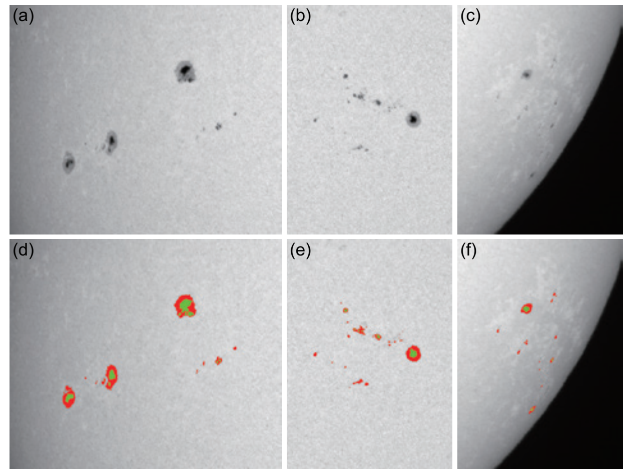

Figure 1: Sunspot detection results for some portions in a white-light image on 2014 February 28 taken with the Solar Flare Telescope. Resutls of sunspot detection for regions shown in panels (a)–(c) are presented in panels (d)–(f). Penumbrae and umbrae are indicated with red and green patches, respectively.

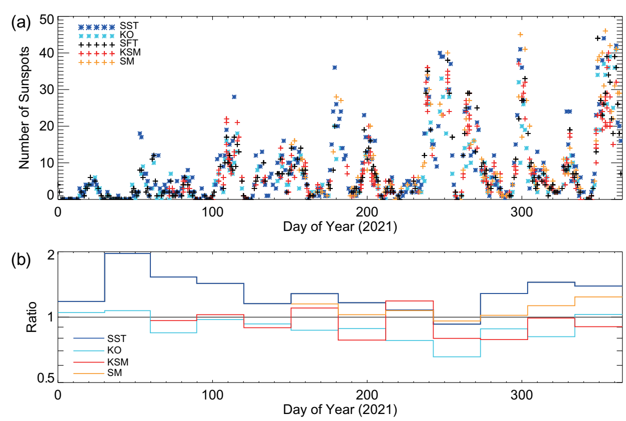

Figure 2: Comparison of detection results based on digital white-light images and visual observations for 2021. (a) Daily number of sunspots obtained by automated detection for data taken by the Solar Flare Telescoe (SFT), Kawaguchi Science Museum (KSM), and Mr. S. Morita (SM) and those by Specola Solare Ticinese (SST) and Kwasan Observatory (KO) visual observations. (b) Ratio of the number of sunspots detected with KSM, SM, SST, and KO observations to those by the SFT each month.

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Optical IFU Observations of GOALS Sample with KOOLS-IFU on Seimei Telescope: Initial Results of Nine U/LIRGs at $z < 0.04$

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Galaxy mergers are one of the key phenomena for understanding the co-evolution of galaxies and supermassive black holes (SMBHs). To understand how galaxy mergers affect SMBHs and their host galaxies, spatially resolved observations with IFU are essential. In particular, ultra/luminous infrared galaxies (U/LIRGs) with $L_{\mathrm{IR}} > 10^{11} L_{\odot}$ show disturbed features in their optical images and are thought to be an important population to study the relationship between galaxy mergers and co-evolution, even from the theoretical point of view. We have performed IFU observations of U/LIRGs using the KOOLS-IFU on the Seimei Telescope. The targets were selected from 245 U/LIRGs from the Great Observatories All-sky LIRG Survey (GOALS; [1]). We picked up a few U/LIRGs from each of the five galaxy merger stages visually classified from IRAC/Spitzer images in [2] and nine objects selected as targets and observed during 2019–2020.

We have successfully detected various emission lines for star-forming galaxies (SFGs) and/or active galactic nuclei (AGNs) (e.g., Hα, Hβ, [O III]$\lambda\lambda$4959,5007, [N II]$\lambda\lambda$6549,6583, [S II]$\lambda\lambda$6716,6731). This allowed for creating 2D intensity maps of these emission lines and BPT diagrams (AGN/SFG diagnostics using emission line ratios: e.g., [3] (Figure 1). We employed a value by combining velocity shift and the velocity dispersion of the broad component of [O III] line (σ_0) as an indicator of the strength of the AGN-driven outflow. We investigated how σ_0 depends on the distance from the galactic center and the merger stage. We found that AGN outflows become stronger (1) towards the galactic center and (2) as a sequence of merging stages (Figure 2), suggesting that galaxy mergers could induce AGN-driven outflows [4].

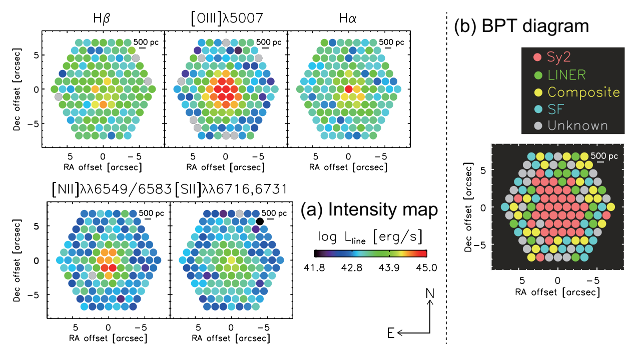

Figure 1: (a) Intensity maps and (b) 2D BPT diagram for NGC 7674.

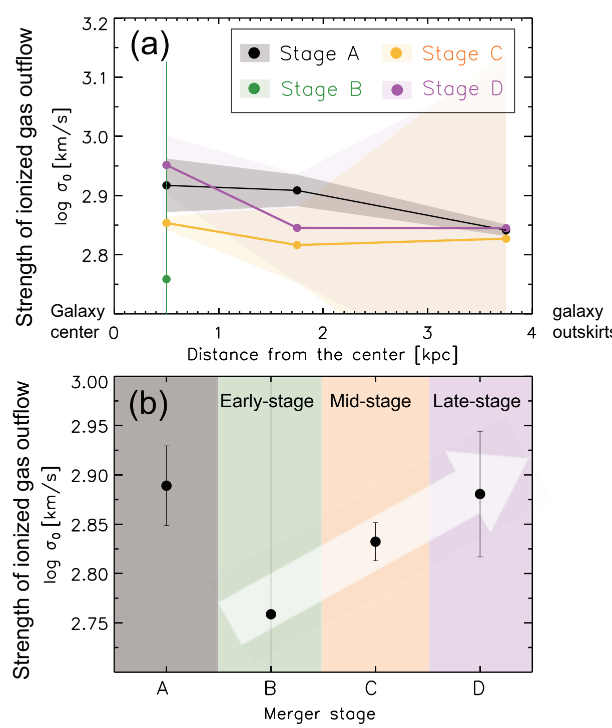

Figure 2: Dependence of an indicator of the strength of ionized gas outflow (σ_0) estimated from [O III] emission line profiles on (a) distance from the galactic center and (b) galaxy merger stage.

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Exploring Cosmic Dawn and Epoch of Reionization with 21 cm Line

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After the Big Bang, there was a period in the universe when there were no stars or galaxies. This is called the Dark Ages. Then the first stars and galaxies formed in the universe, and the Cosmic dawn began. Ultraviolet photons emitted from these first objects ionized the intergalactic medium (IGM). This epoch is called the epoch of reionization (EoR) [1]. Through the observation of galaxies at high redshift such as the James Webb Space Telescope (JWST), galaxies have already been found in the EoR [2]. The ionization state of the IGM in the middle to late stage of EoR is gradually being revealed. However, to better understand the EoR and the cosmic dawn, it is more effective to study the IGM more directly, combined with observing galaxies.

To study these periods, we focus on the 21 cm line signal. The 21 cm line is emitted from neutral hydrogen atoms due to the hyperfine structure, which corresponds to the transition between two energy levels of neutral hydrogen atoms. The 21 cm signal can be expressed by

$$\delta T_{\rm b}(\mathbf{x},z) \approx 27 x_{\rm HI}(\mathbf{x},z)\left[1+\delta_m(\mathbf{x},z)\right] \times \left[1-\frac{T_\gamma(z)}{T_{\rm S}(\mathbf{x},z)}\right]\left[1+\frac{1}{H(z)}\frac{dv_\parallel}{dr_\parallel}\right]^{-1} \times \left(\frac{1+z}{10}\frac{0.15}{\Omega_m h^2}\right)^{\frac{1}{2}}\left(\frac{\Omega_{\rm b}h^2}{0.023}\right)[\mathrm{mK}]. \quad (1)$$

The 21 cm line signal contains useful information such as the neutral fraction of the IGM, $x_{\rm HI}$, the spin temperature, $T_{\rm S}$, and cosmological parameters.

We review the current progress of the cosmic dawn and EoR studies, with a focus on the use of the 21 cm line signal in our paper [3]. The review paper is divided into six sections. In section 1, we introduce the various topics of the high-z universe and provide an overview of our study. In section 2, we review the essential physics of the 21 cm line, including what physical mechanism determines the 21 cm line signal. In section 3, we focus on astrophysics that affects the 21 cm line signal, with a particular emphasis on the impact of the first stars on the 21 cm signal. Section 4 reviews how astrophysical information can be statistically extracted from the 21 cm line signal. In section 5, we introduce the synergy of the 21 cm line with extract more information about EoR. Finally, in section 6, we review the current status of radio interferometers related to studying cosmic dawn and EoR using the 21 cm line signal.

Currently, radio telescopes such as MWA, LOFAR, and HERA, which are designed to observe the 21 cm line, are in operation and have already begun to constrain the 21 cm line power spectrum, although they have not detected it [4]. In addition, the Square Kilometer Array (SKA) is planned to begin the observation in the near future, and construction has already begun [5]. It is expected that the research on the EoR and the cosmic dawn using the 21 cm line will become increasingly active, and this review paper is expected to be useful for a comprehensive understanding of EoR and cosmic dawn studies using the 21 cm line. It is also useful as a reference for those interested in entering the 21 cm line research.

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ALMA Lensing Cluster Survey: Properties of Millimeter Galaxies Hosting X-ray Detected Active Galactic Nuclei

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1: Kyoto University, 2: The University of Tokyo, 3: RIKEN, 4: NAOJ, 5: Academia Sinica Institute of Astronomy and Astrophysics, 6: Ehime University, 7: Cosmic Dawn Center, 8: University of Copenhagen, 9: Nagoya University, 10: Universidad de Granada, 11: Facultad de Ciencias, 12: University of Arizona, 13: Technical University of Denmark, 14: University of Groningen, 15: Purple Mountain Observatory and Key Laboratory for Radio Astronomy

The averaged growth rate of galaxies and SMBHs reached a peak at $z = 1–3$, which is often referred to as "cosmic noon". Thus, galaxies hosting active galactic nuclei (AGNs) at these epochs are a key population to reveal the mechanisms of galaxy-SMBH co-evolution. Submillimeter and X-ray observations are powerful tools to study this population. This is because infrared radiation from star-formation activity at these redshifts is observed in millimeter bansd (submillimeter galaxies; SMGs), while X-ray observations can detect the obscured AGNs. Utilizing ALMA in cycle-6, our team has performed an extensive survey with ALMA, called the ALMA Lensing Cluster Survey (ALCS; Project ID: 2018.1.00035. L; PI: K. Kohno). This survey covers 134 arcmin^2 and detects 180 secure sources at $z \sim 0.5–6$ with a flux limit of ~0.2 mJy at 1.2 mm [1]. Here we report the multi-wavelength properties of millimeter galaxies hosting X-ray detected AGN in the ALCS sample.

Chandra observed the ALCS fields on multiple occasions since 1999. We processed all the data obtained by 2017, and performed source detection. Then, We cross-matched the *Chandra*-detected sources with the ALMA source list. We found three X-ray counterparts in the cluster fields of Abell370, MACSJ0416.1–2403, and MACS0329.7–0211, where the total exposure times of the *Chandra* observations are 96.3 ks, 328 ks, and 77.5 ks, respectively. The source names are A370-ID110, M0416-ID117, and M0329-ID11, and the redshifts are 1.06 (spec-z), 2.09 (spec-z), and 2.84 (photo-z); hereafter we refer to these X-ray AGNs as "ALCS-XAGNs".

First, we perform an X-ray spectrum analysis. We fit the observed X-ray spectra with a simple absorbed power-law model. We find that M0416-ID117 and M0329-ID11 are not significantly absorbed ($\log N_{\rm H}/{\rm cm}^{-2} < 23$), while A370-ID110 shows signs of moderate absorption ($\log N_{\rm H}/{\rm cm}^{-2} \sim 23.5$). This suggests that the former are type-1 AGNs and the latter is a type-2 AGN. After that, we perform SED modelling of X-ray to millimeter photometries with CIGALE [2]. We find that all the X-ray AGNs are classified as ultra-luminous infrared galaxies (ULIRGs; $\log L_{\rm IR}/L_\odot > 12$) and show high star-forming rates (SFR $\gtrsim 100\, M_\odot$ yr^{-1}).

Figure 1 plots de-absorbed X-ray luminosity versus SFR. For comparison, we plots other ALMA and *Chandra* selected AGN samples (i.e., X-ray detected AGNs in ALESS, UDF, ASAGAO, and AS2UDS) at $z = 1–3$. We also plots the X-ray selected broad line AGNs at $z = 1.18–1.68$ in the SXDF as a sample with a different selection method. We find that ALCS-XAGNs show higher X-ray luminosities (~ mass-accretion rates) than other ALMA selected X-ray AGN samples. We also confirm that ALCS-XAGNs show higher SFRs than a purely X-ray-selected AGN sample. This can be explained by the selection bias, showing that a wide and deep survey with ALMA, combined with medium-depth X-ray data, can efficiently detect intense growth stage of both galaxies and SMBHs in high-redshift universe. According to the merger-driven evolutionary scenario, the galaxies and SMBHs "co-evolve" during major mergers being deeply embedded by gas and dust, and then evolved to the AGN dominant phase with quenched SFRs by AGN feedback. If this scenario is applicable, our sources may correspond to the transition stage where the merging has finished, but the star formation is not yet quenched.

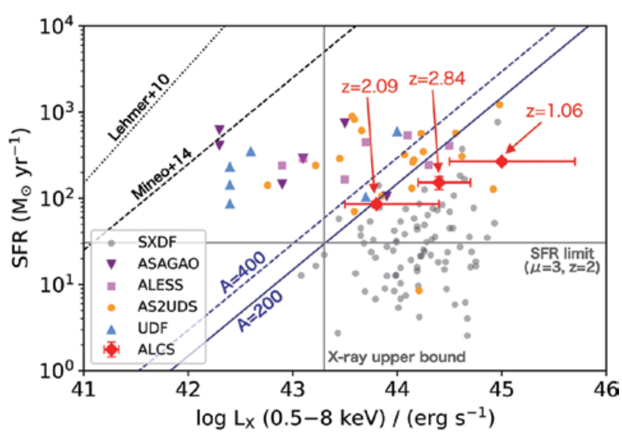

Figure 1: de-absorbed X-ray luminosities versus SFRs. The solid and dashed blue lines represent the relation of galaxy-SMBH simultaneous evolution.

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WISE/NEOWISE Multiepoch Imaging of the Potentially Geminid-related Asteroids: (3200) Phaethon, 2005 UD, and 1999 YC

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(NAOJ)

MASIERO, Joseph R.
(Caltech/IPAC)

Recently, the large-scale structure in the distant universe has been explored through the distribution of various galaxy populations. On the other hand, it is not necessarilWe study space-based thermal infrared observations of the presumably Geminid-associated asteroids: (3200) Phaethon, 2005 UD, and 1999 YC using Wide-field Infrared Survey Explorer/Near-Earth Object WISE. WISE, the full sky survey simultaneously obtained the infrared data at the four infrared wavelength bands 3.4micron (W1), 4.6micron (W2), 12micron (W3), and 22micron (W4) in 2010. The NEOWISE survey started in December 2013 and is ongoing project taking the shorter two-bands at W1 and W2.

Here, we note the primary candidate Phaethon. Phaethon seems to be dynamically associated with the Geminid meteoroid stream. The Geminid meteoroid stream consists of near millimeter-scale or larger solid particles, up to tens of centimeters, as measured by radar and lunar impact flushes. The notable orbital feature of both is the small perihelion distance, q=0.14 au, where repeatedly exposed to intense thermal process which possibly causes the Phaethon's recurrent activity.

Spectroscopic measurements of sodium (Na) content of the Geminid meteors have been utilized for studying the thermal processes on Phaethon. The Geminids exhibit the extreme variety in their Na content, from depletion (free) of the Na abundance to near solar-like values. The thermal desorption of Na is unlikely to occur for the Geminid stream phase even at q=0.14 au. It takes too long timescale to sublimate Na compared to the stream age. Therefore the Na-loss observed in the Geminids must have originated from the thermal process of the parent, Phaethon [1].

The WISE/NEOWISE multiple observing epochs of the infrared data provide with information about where in the orbit the object is along with the limits, as we might expect a strong variation in production at different points in the orbit. Another motivation is to find an activity mechanism far from perihelion, which is different from thermal-driven. This study provides a groundwork for JAXA DESTINY$^+$, which is planning to flyby at a distance of 500 km from Phaethon in 2028.

We find no strong variation in the production rate at different epochs, and find no dependency on the location of the object in the orbit at the time of observation. No evidence of lasting mass loss found in the W1 image. The maximum dust production rate is 2 kg s^{-1}, suggesting no strong dependency on heliocentric distance at 1.0–2.3 au. We find neither dust trail (Geminid stream) from Phaethon nor co-moving objects in the W3 and W4 images at the heliocentric distance of 2.3 au. The upper limit to the optical depth along the trail direction is 7 × 10^{-9}. Correspondingly, during the DESTINY$^+$ flyby phase (at 500 km distance), a few 500micron-sized particles are to be encountered by the dust analyzer. Those moderately large particles might be the Gemindis, insensitive to the radiation pressure sweeping. On the other hand, when DESTINY$^+$ passes at 50,000 km distance from Phaethon, several 10micron-sized particles are to be captured by the instrument [2].

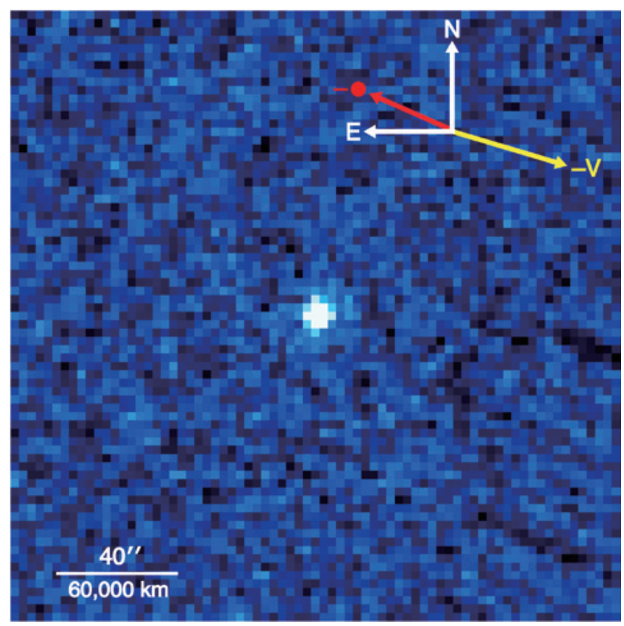

Figure 1: Composite W3-band image of Phaethon in 17.6 s integration (2 × 8.8s) taken by WISE on UT 2010 January 7. The frame size is 200″ × 200″.

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Comparison of Size Distributions between L_4 and L_5 Jupiter Trojans

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Jupiter Trojans (JTs) are asteroid swarms liberating around the L_4 and L_5 Lagrangian points of Jupiter. They can provide clues for elucidating the formation process of the solar system, thus NASA is currently conducting a spacecraft mission for flyby exploration of several JTs [1]. As for their origin, models of their capture by Jupiter into the current Trojan region when giant planets experienced orbital instability seem to be promising, but further studies are desirable. One of the clues to clarify their origin is the size-frequency distribution (object diameter vs. number) of the L_4 and L_5 swarms. In the case of capture due to orbital instability, as mentioned above, the shape of both size distributions is expected to be the same, otherwise different effects should be involved. Although this should be examined by observational studies, it was difficult because a sample of small (km-sized) L_5 JTs was very limited. A previous studies showed that the L_4 and L_5 swarms may have different size distributions, however, the number of the detected objects were insufficient so that the measurement accuracy was not very high.

We therefore performed a survey observation over ~15 deg^2 of sky in the Jupiter L_5 region using Hyper Suprime-Cam (HSC) mounted on the Subaru Telescope. As a result of our data analysis similar to the previous studies for L_4 JTs with HSC [2], we detected 189 L_5 JT objects from the survey data with a detection limit of 24.1 mag in the *r* band which corresponds to ~2 km of diameter assuming a geometric albedo of 0.05. We found that the size distribution derived from the unbiased sample consisting of 87 objects in the diameter range of ~2–10 km can be approximated by a single-slope power law with an index for the differential absolute magnitude distribution of $\alpha = 0.37 \pm 0.01$, which well coincides with that of L_4 JTs [3].

By combining our results with the size distribution of known L_5 JTs, we also found that the shapes of the size distributions of L_4 and L_5 JTs agree well with each other over the entire size range of ~2–100 km (see Figure 1). The ratio of the total number of asteroids larger than 2 km in diameter between the two swarms was figured out at $N_{L4}/N_{L5} = 1.40 \pm 0.15$. The total number of all JTs larger than 1 km in diameter is estimated to be 2.6×10^5, which is one digit smaller than that of main-belt asteroids in the same size range (~2×10^6 [4]).

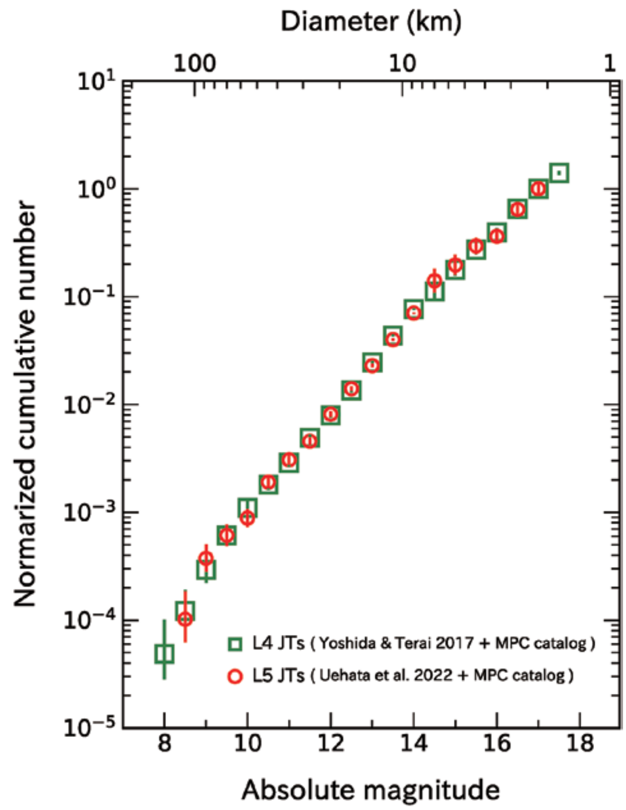

Figure 1: Size frequency distributions of L_4 (squares) and L_5 (circles) swarms of Jupiter Trojans combining the measurement results by Subaru/HSC observations [2,3] with known asteroids taken from the Minor Planet Center catalog, which were normalized by absolute magnitude of 17.0 mag corresponding to 2 km in diameter assuming a geometric albedo of 0.05.

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Mass Function of a Young Cluster in a Low-metallicity Environment. Sh 2-209

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The outer part of spiral galaxies, such as our own Galaxy, and dwarf irregular galaxies are known to have low metallicity (~ −1 dex) and to be in a different environment than the solar neighborhood. Among them, the outer Galaxy is closest, making them the only environment suitable for observational studies of individual stars spatially resolved, as is the case in the solar neighborhood. We have already observed about 10 young star-forming clusters in the outer Galaxy using the Subaru Telescope in the near-infrared wavelength range. However, because the number of stars in these targets has not been sufficient ($N_{\rm stars}$ ~ 100), the initial mass function has not been derived with high accuracy.

In this study, we performed near-infrared imaging observations of a star-forming region Sh 2-209 in a low-metal abundance environment ([O/H] = −0.5 dex) using the Subaru Telescope MOIRCS (Figure 1), and identified two star-forming clusters in S209. We developed a code for fitting a model luminosity function with three parameters, the initial mass function, age, and distance, and fitted the observed clusters to the luminosity function (Figure 2). The results confirm that i) the distance obtained from the fitting is consistent with those obtained with Gaia EDR3 based on parallaxes (2.5 kpc). This is close enough to enable us to resolve cluster members clearly (≃1000 au separation) down to a mass-detection limit of ≃0.1 $M_\odot$, with individual cluster scales (~1 pc). ii) The initial mass function has a slightly flat high-mass slopes (Γ ≃ −1.0) compared to the Salpeter slope (Γ = −1.35), which is generally obtained in the solar neighborhood. iii) On the other hand, the peak mass of the initial mass function is suggested to be slightly smaller (≃0.1 $M_\odot$) compared to the masses usually seen in the solar neighborhood (~0.3 $M_\odot$). In particular, because the S209 main cluster is a star-forming cluster with a larger number of members (~1500) than the numbers in regions previously studied in such environments, it is possible for the first time to derive the IMF in a low-metallicity environment with high accuracy over the wide mass range 0.1–20 $M_\odot$ [1].

Figure 1: NIR color image for S209.

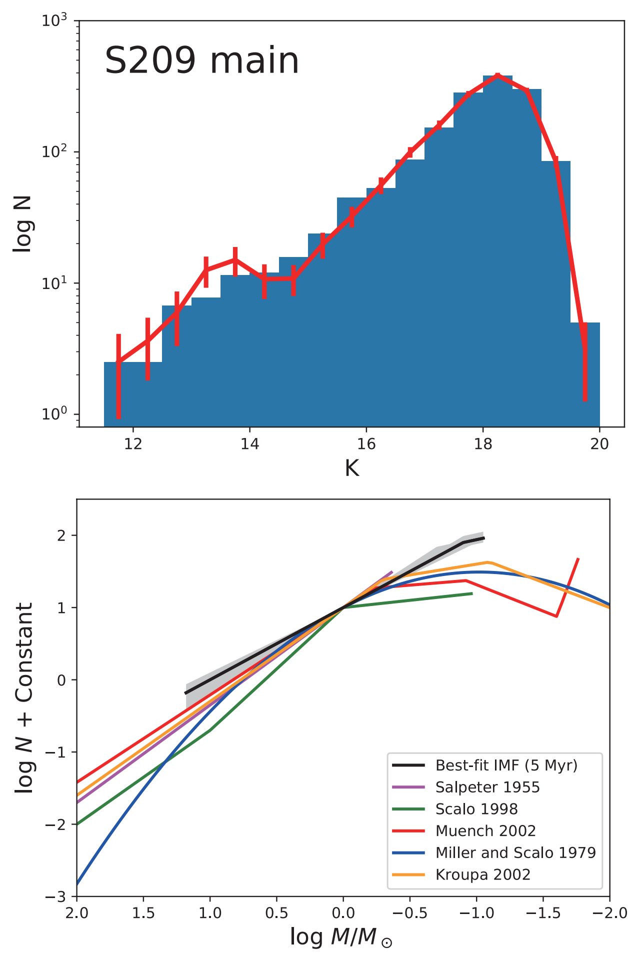

Figure 2: The obtained KLF and IMF for the S209 cluster. Left: Obtained cluster KLF (blue histogram) and model KLF for the best-fit IMF (red). Right: Best-fit IMF (black line) and IMFs previously obtained in the field nearby star clusters (colored lines).

Reference

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Configuration of Probe Tones for MKID Readout with Frequency Sweeping Scheme

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We are developing detector arrays using microwave kinetic inductance detectors (MKIDs) for astronomical observations in the 100-GHz band and a readout system for MKID arrays [1] with frequency sweeping scheme [2]. Probe tones in this scheme are generated and acquired by a frequency sweep probe (FSP) which is a digital fast Fourier transform spectrometer (FFTS) while the probe tones are converted and modulated by an intermediate frequency (IF) section. Since the values of the resonance frequencies change under different photon backgrounds, an appropriate method to configure the probe tones is essential to preserve the dynamic of the detected signals. We considered a general IF section which is a cascade of up/down converter pairs and found that its characteristics can be described with the base band, the target band, the sign of probe tone order, and the sign of frequency sweep direction [3]. We implemented an algorithm to make a list of tone frequencies from a list of resonance frequencies given (Figure 1). Using this configuring method, we assembled IF sections for an antenna-coupled MKID array and for a LEKID array [4] and set up a prototype FSP. The resonance frequencies of the antenna-coupled MKIDs and the LEKIDs are at 4.6–5.1 GHz and 0.6–1.0 GHz, respectively, and their spectra were obtained successfully as shown in Figure 2 and Figure 3. The method enables us to configure the readout system for both types of arrays.

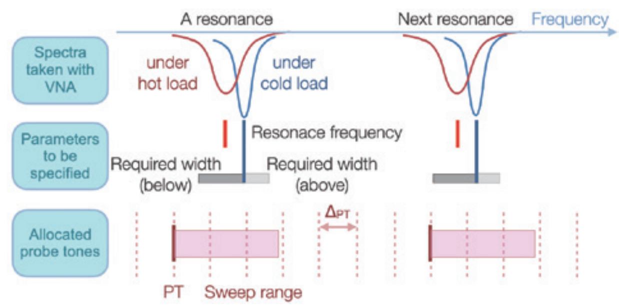

Figure 1: Configuring probe tone in the resonator band.

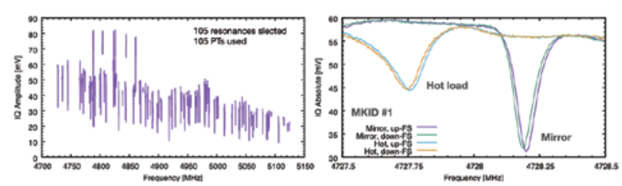

Figure 2: Obtained spectra of antenna-coupled MKID array. *Left*) Whole resonator band. The number of PTs is 105 to cover 105 selected resonances. The ranges of two PTs overlap at 23 PTs. *Right*) Spectra of the pixel with the lowest resonance frequency.

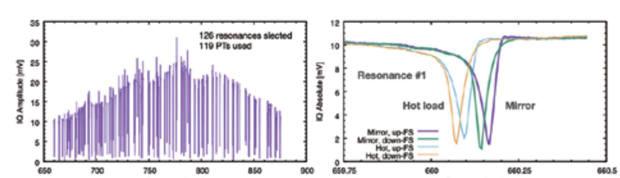

Figure 3: Obtained spectra of LEKID array. *Left*) Whole resonator band. The number of PTs is 119 to cover 126 selected resonances. The ranges of two PTs overlap at 24 PTs. *Right*) Spectra of the pixel with the lowest resonance frequency.

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Correlation Polarimeter for Millimeter-Wave Wavefront Sensing

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The mirror surface measurement is of great importance for next-generation radio telescopes with a large single dish for millimeter- and submillimeter-wave astronomy. The main cause of mirror deformation is the wind load to the primary mirror whose time scale is typically 10^{-1} s to 1 s [1]. Wavefront sensing in millimeter-wave is necessary to realize adaptive optics which can compensate for mirror deformation with short time scales. One proposed solution is aperture-plane interferometry, which places a transmitter array on the primary mirror [1]. Another proposed way of wavefront sensing is the radio point diffraction interferometer (RPDI) [2]. To measure the field distribution of a beam, we propose a new type of correlation polarimeter array based on phase-shifting interferometry [3]. We are developing a correlation polarimeter easy to fabricate a large-format array. The polarimeter is implemented as a superconducting film on a silicon wafer, which employs a dual-polarization twin-slot antenna, a delay circuit composed of coplanar waveguide (CPW), and microwave kinetic inductance detectors (MKIDs), as shown in Figure 1. We developed a pixel design for 100 GHz, made electromagnetic simulations of the components (Figure 2, and are preparing for trial production.

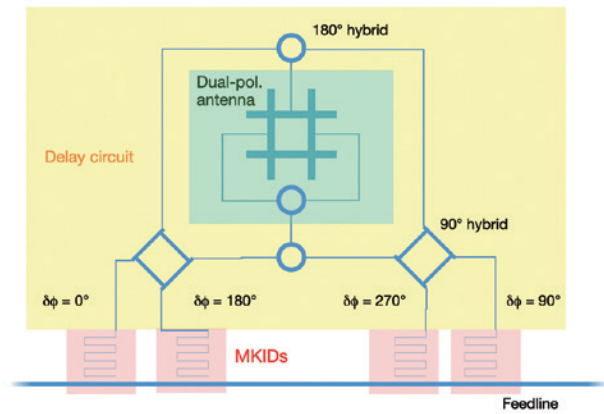

Figure 1: Schematic of a correlation polarimeter pixel. The input ports of the delay circuit are named as Port 1 and Port 2. The output ports of the delay circuit are named as Port 3, Port 4, Port 5, and Port 6.

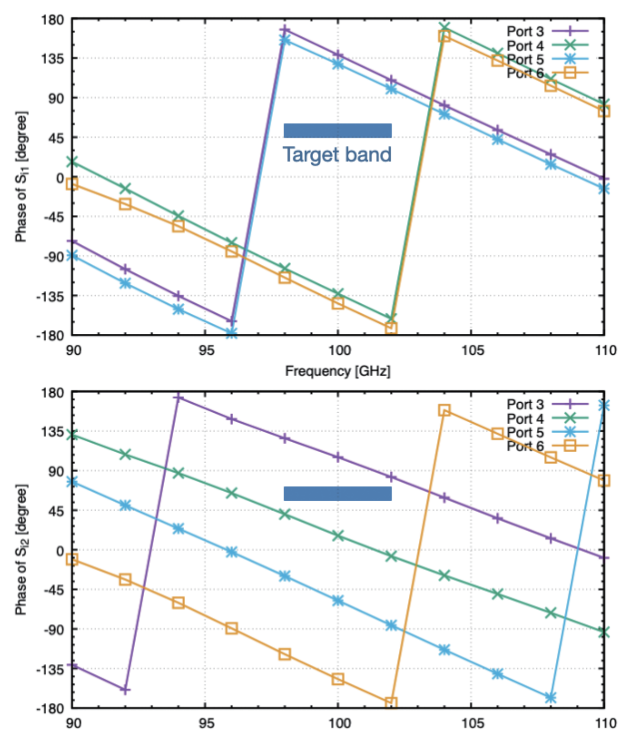

Figure 2: Simulation result of phase shift induced by the delay circuit. (*Top*) From Port 1. (*Bottom*) From Port 2.

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uGMRT Observation of CIZA J1358.9-4750 : Discovery of a New Diffuse Radio Source

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Galaxy clusters grow through merger events and accretion from the large scale structure of the universe. Radio relics and halos, which would be made by shock waves and turbulence of merging event, have been discovered previously. Recently, a radio bridge, which is the expected structure within a galaxy cluster pair and not been detected in GHz band previously, have been detected in early-stage merging galaxy clusters called Abell 399/401. Although, there are theoretical challenges that cannot be explained by simple Fermi acceleration alone in order to form these radio structures.

CIZA J1358.9-4750 (CIZA1359) is thought to be one of the early-stage merging galaxy clusterscite [1]. This source is located at (RA, Dec) = ($13^h58^m40^s$, $-47^d46^m00^s$) (J2000), and there is no diffuse radio structure, such as a radio bridge, in and around the cluster from previous radio observations [2]. Therefore, in this study, observations were made with the upgraded Giant Metrewave Radio Telescope (uGMRT) to probe the diffuse radio emissions associated with CIZA1359.

We used the Source Peeling and Atmospheric Modeling (SPAM) [3] and applied direction-dependent calibration (DDC) [4]. Figure 1 shows the distribution of the radio intensity with the uGMRT. The orange labels from M to W were added for the new sources detected in this study.

The largest radio structure around CIZA1359 in the uGMRT data is a source U. Since the radio source U contains several radio compact sources, these compact sources were subtracted and the flux density was measured. As a result, the integrated flux density of the radio source U is 24.04 ± 2.48 mJy, which is significantly larger than zero with the error. The radio source U is in the between two sub-structures of ICM shown and is consistent with the location of the northern shock wave [5]. The structure is well aligned with the shock front, and four galaxies are found within the source U. The radio energy is 2.40×10^{24} W Hz^{-1}, which is consistent with the value expected from the X-ray luminosity of CIZA1359. Also, the estimated magnetic field strength is 2.1 μG, which is also consistent with previous studies [6].

In summary, we suggest that the radio source U is a structure made by re-accelerating seed electrons with shock waves from galaxy cluster merging event. Our result is considered to be the first detection of radio emission originating from shock waves in early stage merging galaxy cluster.

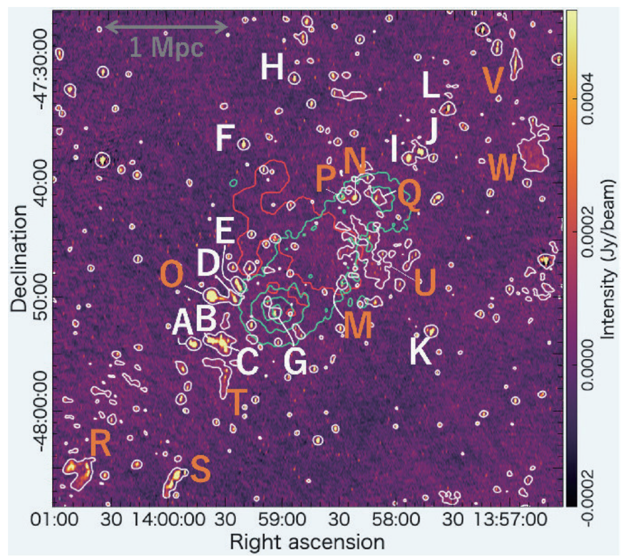

Figure 1: Broadband uGMRT radio intensity distribution of CIZA1359. The background image shows the total intensity distribution with a center frequency of 400 MHz and a bandwidth of 200 MHz. The resolution is 14.″8 × 5.″2 and is indicated by the ellipse at the lower left of the figure. The white line shows the intensity distribution of 0.4 mJy beam^{-1} when smoothed at 25 arcsec resolution. The green line shows the X-ray surface brightness distribution of Suzaku [1]. The red line indicates the high-temperature region above 6 keV estimated by XMM-Newton [5].

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Extreme Nature of Four Blue-excess Dust-obscured Galaxies Revealed by Optical Spectroscopy

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In Noboriguchi et al. (2022) [1], we reported optical spectroscopic observations of four blue-excess dust-obscured galaxies (BluDOGs) identified by the Subaru Hyper Suprime-Cam. BluDOGs are a subclass of dust-obscured galaxies (DOGs; defined with the extremely red color $(i - [22])_{\rm AB} \geq 7.0$; [2]), showing a significant flux excess in the optical g and r bands over the power-law fits to the fluxes at the longer wavelengths ([3]). Noboriguchi et al. (2019) [3] suggested that BluDOGs with such blue excess may be in the blowing-out phase involved in the gas-rich major-merger scenario ([4]). However, the detailed properties of BluDOGs are not well understood because of the lack of spectroscopic information.

We executed the optical spectroscopic observations for four BluDOGs by using Subaru/FOCAS and VLT/FORS2. The obtained spectra show broad emission lines with extremely large equivalent widths, and a blue wing in the C IV line profile (Figure 1). The averaged rest-frame equivalent widths of the C IV lines are 160 ± 33 Å, ~7 times higher than the average of a typical type 1 quasar (23.8 ± 0.1 Å: [5]). Such strong C IV lines significantly affect the broadband magnitudes, which are partly the origin of the blue excess seen in the spectral energy distribution of BluDOGs. The estimated supermassive black hole (SMBH) masses ($M_{\rm BH}$) are $1.1 \times 10^8 < M_{\rm BH}/M_\odot < 5.5 \times 10^8$ (Figure 2). The inferred Eddington ratios ($\lambda_{\rm Edd}$) of the BluDOGs are higher than 1 ($1.1 < \lambda_{\rm Edd} < 3.8$), suggesting that the BluDOGs are in a rapidly evolving phase of supermassive black holes.

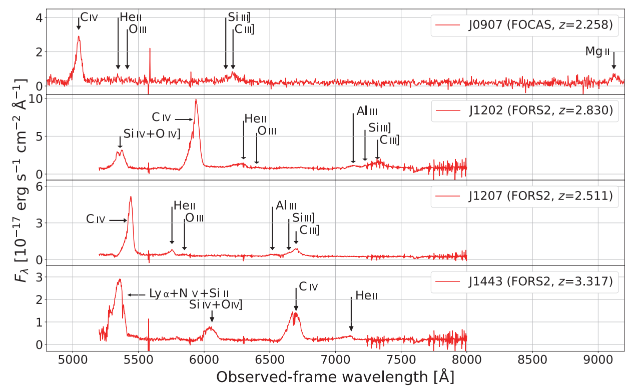

Figure 1: Reduced spectra of the BluDOGs. The spectra are for J0907, J1202, J1207, and J1443 from the top to bottom. Detected lines are marked by arrows and labels.

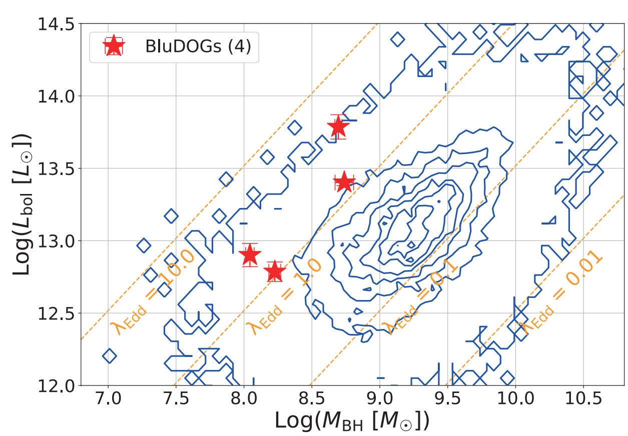

Figure 2: Diagram of SMBH mass vs. bolometric luminosity. The filled-red stars and blue contour denote the BluDOGs and SDSS quasars ([6]), respectively. The orange-dashed lines represent a constant Eddington ratio of $\lambda_{\rm Edd}$ = 0.01, 0.1, 1.0, and 10.0.

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The Coherent Differential Imaging on Speckle Area Nulling (CDI-SAN) Method for High-contrast Imaging under Speckle Variation

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Searching for biosignatures in the spectrum of reflected light from exoplanets is one of the goals of future large telescope projects. The contrast of the exoplanet to the host star in reflected light is $10^{-8} \sim 10^{-10}$. In ground-based telescopes and space telescopes with insufficient temperature control, speckle noise brighter than planets remains and changes, being limited planet detection by the seckle noise even after post-processing. The coherent differential imaging on speckle area nulling (CDI-SAN) method is an observation algorithm and post-processing method that detect a faint exoplanet lying beneath residual speckles of a host star [1].

The SAN method is a kind of real-time dark-hole control method that does not use a model. The speckle electric field (E_s) of all pixels in the region of interest is calculated using the intensities of the five types of focused images expressed by equation (1) obtained by adding five types of modulated wavefronts with the deformable mirror, respectively, and is reduced by modifyig the wavefront [2].

$$\begin{cases} I_0 = |E_s|^2 + I_p \\ I_1^+ = |E_s + \Delta E_1|^2 + I_p \\ I_1^- = |E_s - \Delta E_1|^2 + I_p \\ I_2^+ = |E_s + \Delta E_2|^2 + I_p \\ I_2^- = |E_s - \Delta E_2|^2 + I_p \end{cases} \quad (1)$$

However, the higher the contrast, the longer the exposure time, and if the speckle fluctuates during that time, the reduction of Es stops and the real-time contrast setteles there.

Therefore, in the CDI-SAN method, data is acquired for a long period of time while repeating five types of modulation wavefront addition and focus image acquisition by the SAN method at a higher speed than the speckle variation. As shown in Eq. (2), we separate the planetary light (I_p) from the stellar light with a contrast close to the photon noise limit under appropriate conditions by using the integral of the focal image intensity and the integral of the squared difference.

$$I_{p1} = \langle I_0 \rangle - \frac{\langle (I_1^+ - I_1^-)^2 \rangle}{8\left(\langle I_1^+ \rangle + \langle I_1^- \rangle - 2\langle I_0 \rangle\right)} - \frac{\langle (I_2^+ - I_2^-)^2 \rangle}{8\left(\langle I_2^+ \rangle + \langle I_2^- \rangle - 2\langle I_0 \rangle\right)}, \quad (2)$$

Figure 1 shows the results of a numerical simulation that showed an improvement in contrast from data obtained by measuring two sets of five intensities within the timescale of speckle change, and repeating this measurement one million times. Here hidden pseudo-planets appeared. Assuming that the time scale of speckle change is 36 ms, the exposure time for one image is 3.6 ms, which is the accumulated data for 10 hours. When the initial intensity is 10^{-4}, planets at 1/1000 of the speckle level can be detected. The method has potential implementation in current and future large telescopes on the ground and in space.

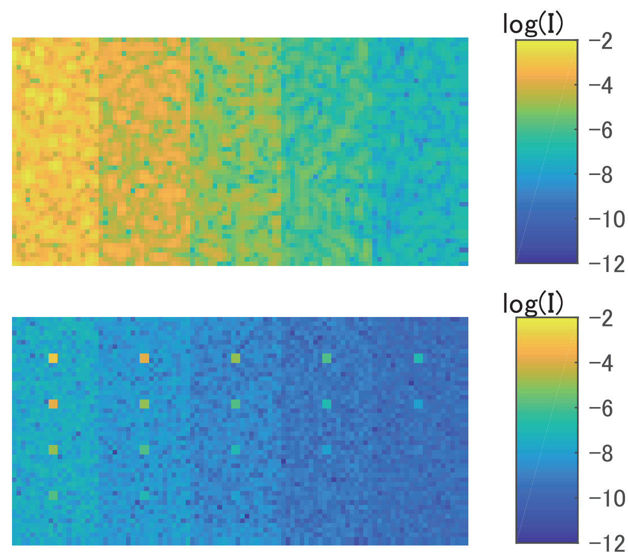

Figure 1: Contrast improvement effect by numerical simulation of CDI-SAN. (Top) Assumed speckle level. From the left zone, the average intensities were 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6}, and 10^{-7}. (Bottom) Image after processing 2 million sets of data. Hidden pseudoplanets are 1x, 1/10th, 1/100th, 1/1000th of the speckle level at each zone, from top to bottom.

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Passive Spiral Galaxies Deeply Captured by Subaru Hyper Suprime-Cam

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The fundamental relations between galaxy morphology and physical properties have been extensively studied over the past decades, and modern astronomy is still at the stage of trying to fit the remaining missing pieces. In this context, this study focused on an “anemic” spiral galaxy with deep learning, which is a unique population but is of great scientific importance. We hereafter overview the importance of anemic spiral galaxies for a comprehensive understanding of galaxy evolution and the results obtained in this study [1]. Anemic spiral galaxies are a generic term for spiral galaxies with little or no star formation. In general, spiral galaxies are rich in gas, the fuel for star formation, which plays a role in forming their spiral arms and hence are representative of “star-forming galaxies”. However, when this fuel tank is lost for some reason, star formation ceases and there is a period of time when the spiral arms are present even though no star formation is taking place. Spiral galaxies in such a special state are called anemic spiral galaxies. Anemic spirals are essential for understanding how spiral galaxies lose their spiral structure as they reach the end of their activity. Still, they are extremely difficult to survey statistically because only a few percent of all bright galaxies exist. This study focused on this problem and conducted a statistical survey of anemic spiral galaxies using high-quality big data from the Subaru telescope and deep learning classification.

This study used high-quality images of 55k bright nearby galaxies with redshifts of 0.01–0.3 taken by Subaru Hyper Suprime-Cam, which have been spectroscopically confirmed and for which detailed physical information is available from multi-wavelength data. We classified the spiral galaxies using deep learning. Then we used the physical information from the multi-wavelength data to obtain a sample of more than 1k non-star-forming anemic spiral galaxies for the first time. Figure 1 shows the evolution of the color and morphology of selected spiral galaxies concerning star formation activity, and Figure 2 compares normal and anemic spiral galaxies, showing that anemic spiral galaxies are composed entirely of old stars (orange), from the center to the spiral arms, and spiral arms look smooth. In fact, through this study, we found that the bulge structure and properties of these anemic spirals are much closer to those of early-type galaxies than spiral galaxies, despite the presence of spiral arms. Furthermore, once a sufficient number of anemic spiral samples were obtained, we tested if there were any peculiarities in the distribution of anemic spirals around galaxy clusters with few spiral galaxies in the center. We found that anemic spiral galaxies are more than 10 times (40 percent) more common in the outer regions of clusters than usual. This result strongly supports the ram pressure stripping scenario of the loss of spiral structure.

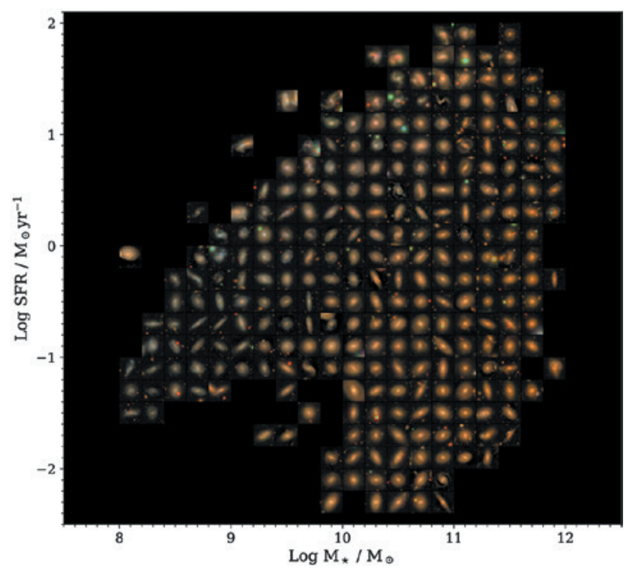

Figure 1: Color and morphology of spiral galaxies at different SFRs–stellar masses [1].

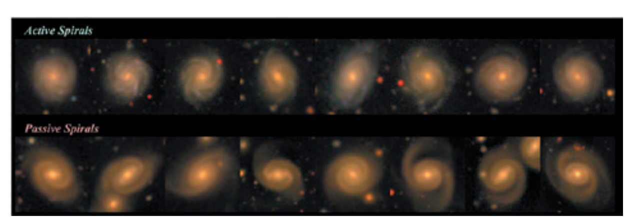

Figure 2: Examples of normal spiral galaxies (upper panel) and anemic spiral galaxies (lower panel).

Reference

[1] Shimakawa, R., et al.: 2022, *PASJ*, **74**, 612

Discovery of the Monster Supercluster in the Universe at $z = 0.6$

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The universe is a complex, large-scale structure of galaxy clusters, filaments, and voids. Clusters of galaxies are known as the largest self-gravitating systems in the universe. However, there is a huge structure called a galaxy supercluster, which is composed of more clusters of galaxies. While superclusters extend over about 100 Mpc, their definition itself is still unclear, and many questions remain as to their true nature, what is going on inside them, and whether they are different from ordinary clusters of galaxies. Milky Way and local galaxy groups are part of a supercluster called the Virgo supercluster, and together with other nearby clusters and superclusters, they form the giant Laniakea supercluster. In other words, many issues related to these superclusters are inseparable from understanding the formation of the nearby universe that surrounds us.

This project aims to discover a large number of distant superclusters and voids in the universe and to study the environmental dependence of galaxies on large scales by analyzing multicolor data covering about 1000 square degrees obtained by the Subaru Hyper Suprime-Cam. In this study, as part of this project, we performed (1) dark matter mapping by weak gravitational lensing analysis and (2) derivation and comparison of stellar mass density maps obtained by SED fitting for the most promising candidate supercluster at $z = 0.55$ from the candidates selected in previous work [1].

As a result, we succeeded in detecting a large-scale weak gravitational lensing signal centered on three dense dark matter regions at a scale of 70 Mpc around the target (we named this object the King Ghidorah supercluster). In addition to the density excess of dark matter, the King Ghidorah supercluster is composed of at least 19 clusters of galaxies (Figure 1). This is the largest supercluster ever reported in the same period. This is the first time that such a wide range of density excesses has been observed in both the dark matter and stellar mass distributions at $z > 0.5$ [2].

Furthermore, we performed a direct comparison of the overdensity analysis on mock data from cosmological simulations as well as observational data. The results suggest that the King Ghidorah supercluster has a total dark matter mass of about 10^{16} times the mass of the Sun. On top of that, two more giant structures equivalent to superclusters were identified just outside of this supercluster, suggesting that this supercluster and its surrounding region may grow into a supermassive structure like the Laniakea supercluster, the largest in the nearby universe, in the future.

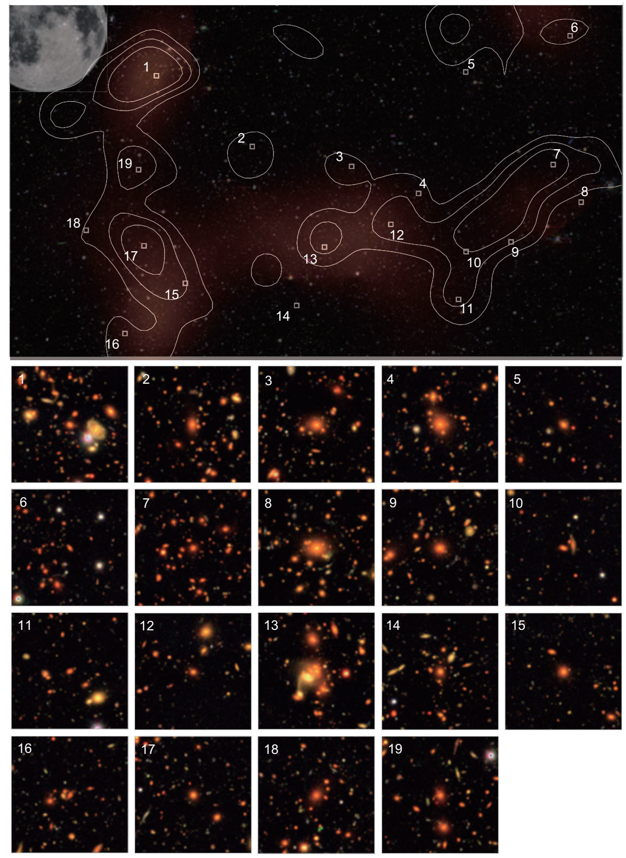

Figure 1: Three-color composite image of a supercluster region. The white contours in the upper image show the galaxy density distribution, and the light red-filled area shows the dark matter density distribution. The numbers appended on the image indicate the location of the red clusters associated with the supercluster [3], and their respective extended regions are shown in the lower panels. The full moon in the upper left panel is the apparent size of the full moon, corresponding to the supercluster region (see also the web release in the Subaru Telescope website).

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[3] Oguri, M., et al.: 2018, *PASJ*, **70**, S20.

An Empirical Method for Mitigating an Excess Up-scattering Mass Bias on the Weak Lensing Mass Estimates for Shear-selected Cluster Samples

HAMANA, Takashi
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An excess up-scattering mass bias on a weak lensing cluster mass estimate is a statistical bias that an observed weak lensing mass of a cluster of galaxies is, in a statistical sense, larger than its true mass because of a higher chance of up-scattering than that of down-scattering due to random noises in a weak lensing cluster shear profile. This non-symmetric scattering probability is caused by a monotonically decreasing cluster mass function with increasing mass. We examine this bias in weak lensing shear-selected clusters, and present an empirical method for mitigating it [1]. In so doing, we perform the standard weak lensing mass estimate of realistic mock clusters generated using the super-computer system, XC50, at Center for Computational Astrophysics, NAOJ, and find that the weak lensing mass estimate based on the standard chi-square analysis gives a statistically correct confidence intervals, but resulting best-fitting masses are biased high on average. Our correction method uses the framework of the standard Bayesian statistics with the prior of the probability distribution of the cluster mass and concentration parameter from recent empirical models. We test our correction method using mock weak lensing clusters, and find that the method works well with resulting corrected. We applied the correction method to weak lensing shear-selected cluster samples from Hyper Suprime-Cam survey S16A and S19A data, and present bias-corrected weak lensing cluster masses.

Reference

[1] Hamana, T.: 2023, *PASJ*, **75**, 14.

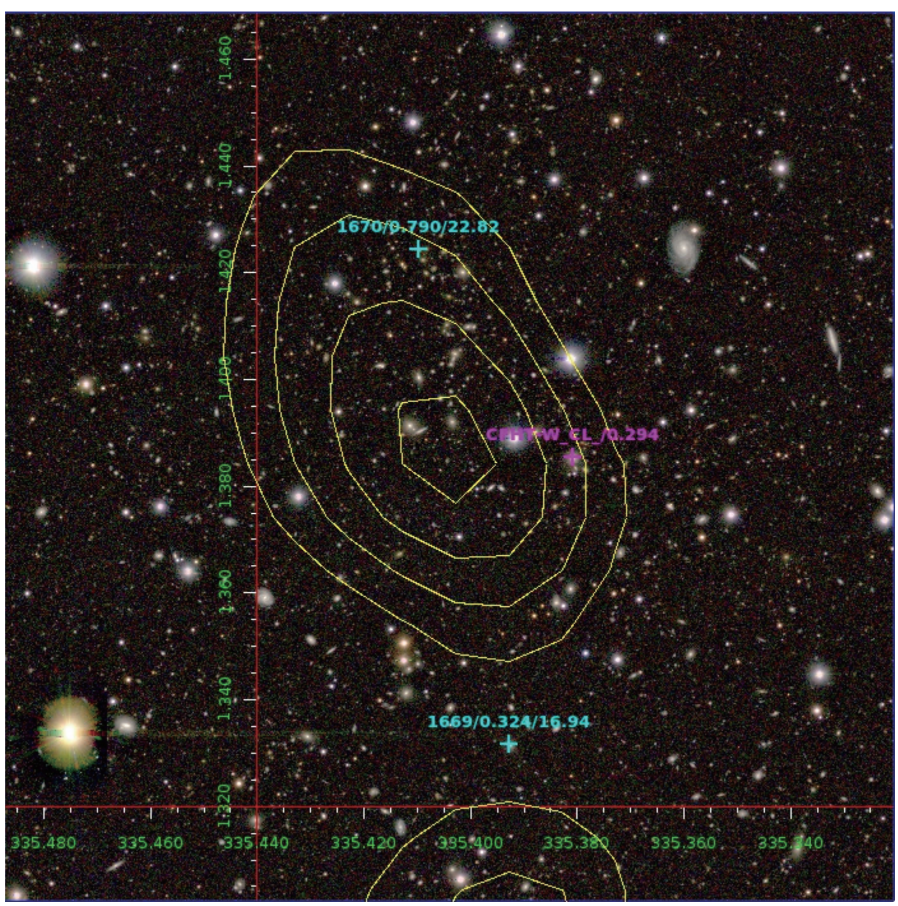

Figure 1: A weak lensing shear-selected cluster of galaxies from HSC survey S16A data. Shown is a 10 arcmin-side riz composite image, the yellow contour shows the weak lensing Signal-to-Noise ratio (the contour lines start from $SN = 2$ with the interval of 1), and the plus marks show the position of known clusters.

A Tale of a Tail: A Tidally-Disrupting Ultra-Diffuse Galaxy in the M81 Group

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Ultra-diffuse galaxies (UDGs) are distinguished by their low central surface brightnesses and large sizes. A commonly-used definition is that they have effective radii $R_{\mathrm{eff}} \geq 1.5$ kpc and central surface brightnesses fainter than $\mu_g(0) \geq 24$ mag arcsec^{-2} [1]. Although systems with these properties have been known to exist for decades, there has been a recent resurgence in interest in them due to the sheer abundance of such objects being discovered in modern deep imaging surveys [2]. They appear particularly common in dense environments [1], but are also found in low density groups and in the field [3].

Several explanations for the origin of UDGs have appeared in the literature, such as, they may be rapidly rotating normal dwarf galaxies, resulting in a very extended profile for their stellar mass. Or, their large sizes may result from tidal stripping and heating experienced through interactions with massive neighbouring galaxies. Other possible scenarios are that they are puffed-up dwarf galaxies that have experienced gas loss due to star formation-driven outflows or that they are 'failed' galaxies that did not manage to build-up their expected stellar mass. Ram-pressure stripping may play a further role in transforming gas-rich blue UDGs into red ones. While it is likely that the present-day UDG population results from a variety of these formation channels, the question of which is the dominant channel remains open.

We investigate the deep map of resolved red giant branch stars constructed using data from our Subaru Hyper Suprime-Cam survey of the M81 Group [4] and discover a giant tidal tail of stars associated with F8D1, the closest known example of an UDG (see Figure 1). F8D1 sits in a region of the sky heavily contaminated by Galactic cirrus and has been poorly studied since its discovery two decades ago. It has an average surface brightness of $\mu_g \sim 32$ mag arcsec^{-2} and can be traced for over a degree on the sky (60 kpc at the distance of F8D1) with our current imagery. We revisit the main body properties of F8D1 using deep multiband imagery acquired with MegaCam on CFHT and measure effective radii of 1.7–1.9 kpc, central surface brightnesses of 24.7–25.7 mag and a stellar mass of ~$7 \times 10^7 M_\odot$. Assuming a symmetric feature on the other side of the galaxy, we calculate that 30–36 % of F8D1's present-day luminosity is contained in the tail. We argue that the most likely origin of F8D1's disruption is a recent close passage to M81, which would have stripped its gas and quenched its star formation.

As the only UDG that is close enough to allow studies at extremely low surface brightness, and the first to be unambiguously linked to tidal stripping, our results for F8D1 are of particular importance. It leaves open the possibility that many other UDGs could be the result of similar processes, with the most telling signatures of this lurking below current detection limits.

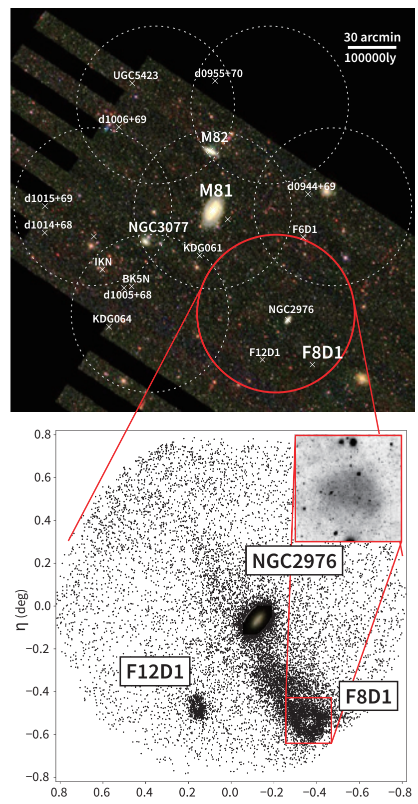

Figure 1: Top: Our M81 Group Survey footprint (seven HSC pointings) overlaid on an SDSS image. Each HSC pointing has a diameter of 1.5 deg and the known galaxies within this area are marked. The red circle indicates the pointing containing F8D1, which is the focus of this paper. Bottom: The RGB star count density across our HSC pointing. A giant tidal stream can be seen emanating from F8D1, which is located at the south-western edge. A DSS image of NGC 2976 is superposed for scale and the hollow centres of the galaxies indicate regions where the pipeline failed to return photometry.

References

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Discovery of an Earth-sized Planet around an M5 Dwarf Star at 22 pc

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1: NAOJ, 2: Astrobiology Center, 3: California Institute of Technology, 4: University of Cologne, 5: DLR, 6: University of Tokyo, 7: University of Turin, 8: Princeton University, 9: George Mason University, 10: Tokyo Institute of Technology, 11: University of Texas, 12: Karl Schwarzschild Observatory, 13: Aarhus University, 14: Chalmers University of Technology, 15: University of Chicago, 16: IAC, 17: Wesleyan University, 18: University College London

Recently, a number of exoplanets have been discovered around M dwarfs, which are much less massive and cooler than the Sun. Transiting planets around very low-mass stars are particularly important since their small radii make the transits deeper, which allows us to better characterize small-sized exoplanets. However, the number of "nearby" M dwarfs hosting transiting planets, which are amenable to future atmospheric characterization is very limited at this point; for instance, there are only ≈ 30 M dwarfs within 30 pc from the Earth, which are known to host transiting planets (most of which are relatively massive "early-M" dwarfs)[1].

In order to find more low-mass planets that are suitable for future atmospheric characterization by e.g., 30m-class telescopes, we have led an effort to detect and validate transiting planets around M dwarfs. We analyzed public data delivered by the Kepler spacecraft's secondary mission, known as "K2" [1], and identified a transiting-planet candidate around EPIC211414619 (Figure 1), an M5 dwarf star at 22 pc from the Earth. Since planet candidates reported by space-based transit surveys often include false positives, mostly originating from eclipsing binaries, we conducted follow-up observations for EPIC211414619 using ground-based telescopes. As a result of performing high-contrast imaging with IRCS and high-resolution spectroscopy with IRD, both mounted on the Subaru telescope, we ruled out false positive scenarios for EPIC211414619, and confirmed that the candidate is a *bona fide* planet with an orbital period of 4.02 days, which is now named "K2-415b". The host star, K2-415, was also observed by the Transiting Exoplanet Survey Satellite (TESS) in 2021, and by analyzing both light curves provided by K2 and TESS missions, we measured the radius of K2-415b as 1.015±0.051 $R_\oplus$. Based on the radial-velocity measurements by Subaru/IRD, we also obtained an upper limit of 7.5 $M_\oplus$ (at 95 % confidence) for the mass of K2-415b [2].

At 22 pc, K2-415 is one of the closest M dwarfs known to host an Earth-sized transiting planet; it is currently the closest planet-hosting star from the Earth identified by the Kepler spacecraft. K2-415 is also one of the lowest-mass (coolest) stars with known transiting planets. The only M dwarfs cooler than K2-415, hosting Earth-like transiting planets, are TRAPPIST-1 (12 pc), LP 791-18 (26 pc), LHS 1140 (15 pc), and Kepler-42 (40 pc). Moreover, as of today, there are only ten transiting-planet (of any size) hosting stars cooler than K2-415, seven of which are more distant stars than K2-415. Given its proximity (thus brightness) and small size of the host star, K2-415b is a very unique target for future atmospheric characterization.

1 https://exoplanetarchive.ipac.caltech.edu/index.html

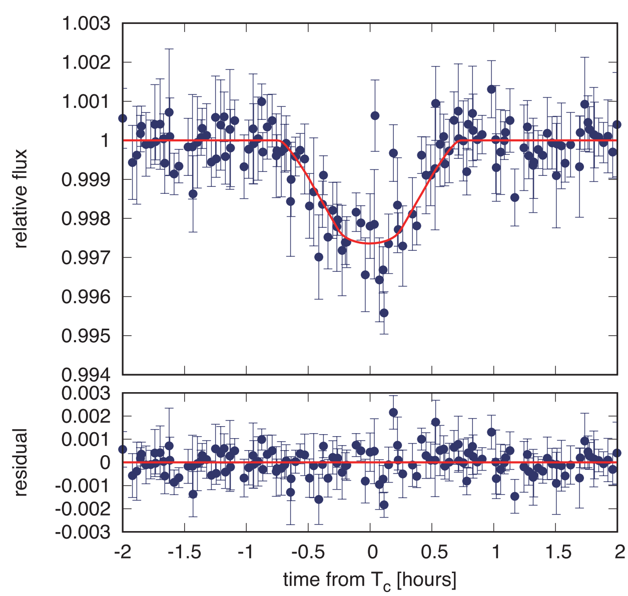

Figure 1: Light curve of EPIC211414619 (K2-415) around the planetary transit obtained by the K2 mission. It is folded with K2-415b's period (4.02 days). The red solid line indicates the best-fit theoretical model of the transit.

References

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A Wide and Deep Exploration of Radio Galaxies with Subaru HSC (WERGS). VII. Redshift Evolution of Radio Galaxy Environments at $z = 0.3-1.4$

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1: NAOJ, 2: Kanagawa University, 3: Ehime University, 4: Tohoku University, 5: MPE, 6: Kyoto University, 7: ASIAA, 8: Onomichi City University, 9: Kure College, 10: NSF's NOIRLab, 11: Shinshu University

In this study [1], we have examined the redshift evolution of density environments around 2,163 radio galaxies with the stellar masses of $\sim 10^9$–$10^{12}\,M_\odot$ between redshifts of $z = 0.3$–1.4, based on the Hyper Suprime-Cam Subaru Strategic Program (HSC-SSP) and Faint Images of the Radio Sky at Twenty-cm (FIRST). We use the k-nearest neighbor method to measure the local galaxy number density around our radio galaxy sample. We find that the overdensities of the radio galaxies are weakly but significantly anti-correlated with redshift. This is consistent with the known result that the relative abundance of less-massive radio galaxies increases with redshift [2], because less-massive radio galaxies reside in relatively low density regions. Massive radio galaxies with stellar mass of $M_* > 10^{11}\,M_\odot$ are found in high density environments compared with the control sample galaxies with radio-non-detection and matched-stellar-mass. Less-massive radio galaxies with $M_* < 10^{11}\,M_\odot$ reside in average density environments. The fraction of the radio galaxies associated with the neighbors within a typical major merger scale, < 70 kpc, is higher than (comparable to) that of the control galaxies at $M_* > 10^{11}\,M_\odot$ ($M_* < 10^{11}\,M_\odot$). We also find that the local densities around the radio galaxies are anti-correlated with the radio luminosities and black hole mass accretion rates at fixed stellar mass. These findings suggest that massive radio galaxies have matured through galaxy mergers in the past, and have supermassive black holes whose mass accretion almost ceased at $z > 1.4$, while less-massive radio galaxies undergo active accretion just at this epoch, as they have avoided such merger events.

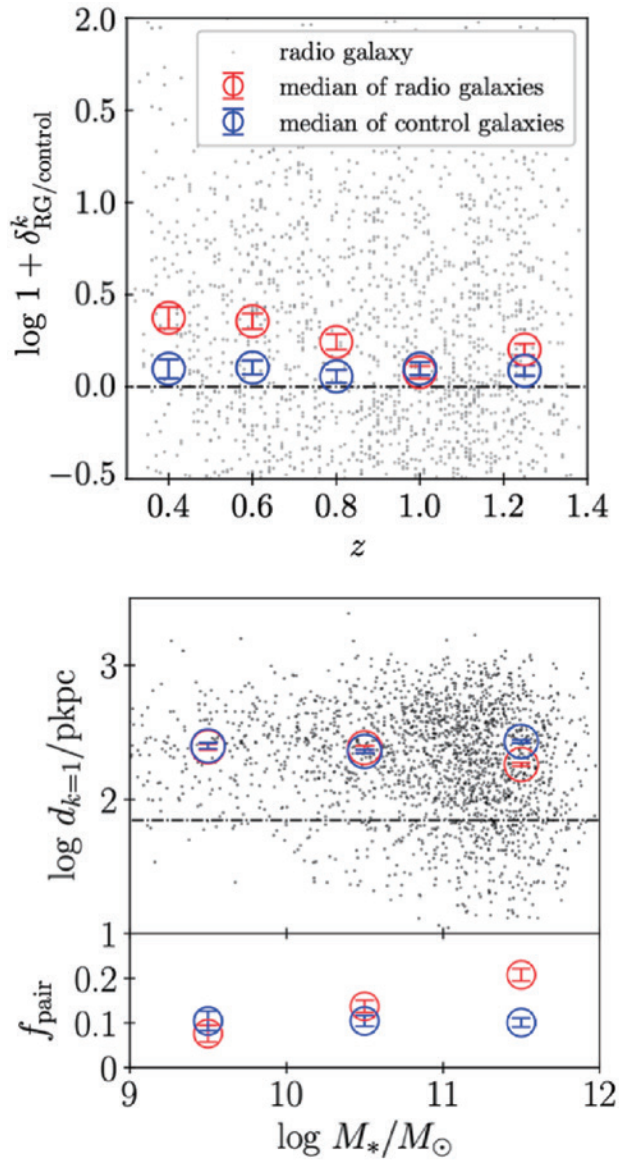

Figure 1: (upper panel) The overdensities around the radio galaxies (black points) as a function of redshifts. The red and blue open circles indicate the median of the overdensities of the radio and control galaxies, respectively. The black dashed line shows the average density. (lower panel) The projected distances from the radio galaxies and control galaxies to the nearest neighbors ($d_k = 1$) and their pair fractions ($f_{\rm pair}$) as a function of stellar mass.

References

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A Wide and Deep Exploration of Radio Galaxies with Subaru HSC (WERGS). IX. The Most Overdense Region at $z \sim 5$ Inhabited by a Massive Radio Galaxy

UCHIYAMA, Hisakazu[1/2], YAMASHITA, Takuji[1/3], NAGAO, Tohru[3], ONO, Yoshiaki[4], TOSHIKAWA, Jun[5], ICHIKAWA, Kohei[6/7], KAWAKATU, Nozomu[8], KAJISAWA, Masaru[3], TOBA, Yoshiki[1/9/10/3], MATSUOKA, Yoshiki[3], KUBO, Mariko[6], IMANISHI, Masatoshi[1/11], ITO, Kei[12], KAWAGUCHI, Toshihiro[13], LEE, Chien-Hsiu[14], SAITO, Tomoki[15]

1: NAOJ, 2: Kanagawa University, 3: Ehime University, 4: ICRR, 5: Bath University, 6: Tohoku University, 7: MPE, 8: Kure College, 9: Kyoto University, 10: ASIAA, 11: SOKENDAI, 12: Tokyo University, 13: Onomichi City University, 14: NSF's NOIRLab, 15: Hyogo University

In this study [1], we have revealed that a high-z radio galaxy (HzRG) at $z = 4.72$, HSC J083913.17+011308.1 (HSC J0839+0113) [2], associates with the most overdense region, by using the data of the Hyper Suprime-Cam Subaru Strategic Program (HSC-SSP) and Faint Images of the Radio Sky at Twenty-cm (FIRST).

We use an r-dropout Lyman break galaxy (LBG) sample from the HSC-SSP data to measure the overdensities around the HzRG. As a result, we find that HSC J0839+0113 resides in the outskirt of an overdense region identified by the r-dropout galaxies at a 4.7σ significance level (upper panel of Figure 1). The projected distance between HSC J0839+0113 and the peak position of the overdense region is 0.4 physical Mpc which is shorter than the typical protocluster radius in this epoch. According to the extended Press Schechter and the light cone models, the HSC J0839+0113-hosted overdense region is expected to evolve into a halo $> 10^{14} M_{\odot}$ at $z = 0$ with a high probability of $> 80\%$. These findings suggest that HSC J0839+0113 is associated with a protocluster. The HSC J0839+0113 rich-system is the most overdense region of LBGs among the known protoclusters with LBGs in the same cosmic epoch. We also find that there are no r-dropout galaxies with blue color of i-$z \lesssim 0.3$ in the HSC J0839+0113 overdense region (lower panel of Figure 1). This result implies that the HSC J0839+0113 overdense region predominantly includes galaxies with an old stellar population and/or large amounts of dust.

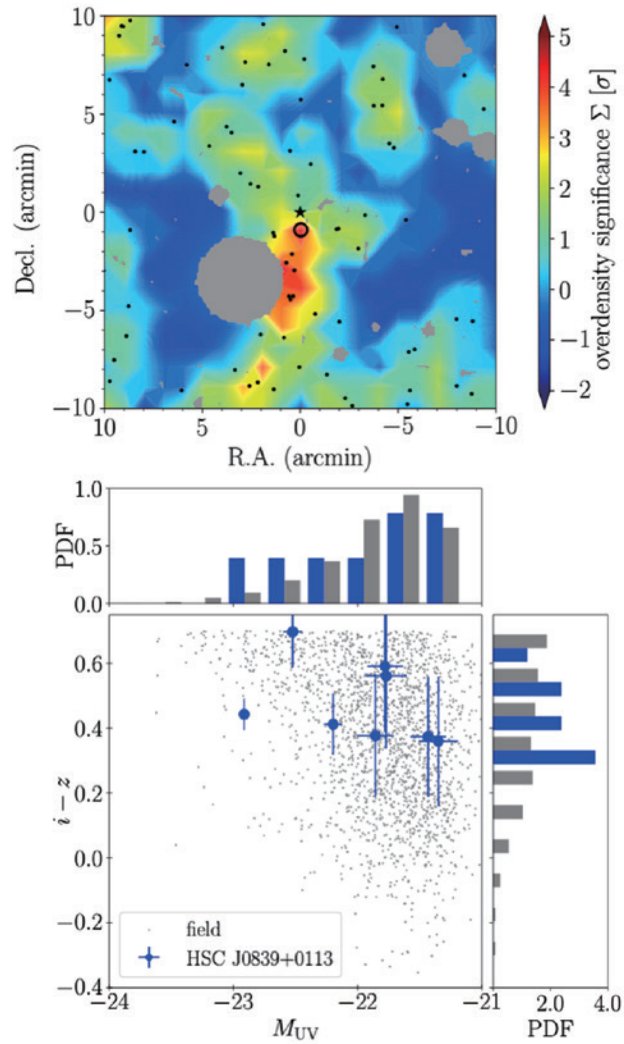

Figure 1: (upper panel) The overdensity significance map around HSC J0839+0113 (black star). The peak position is indicated by the black open circle. The black dots denote the r-dropout galaxies. The gray shades indicate the masked regions. (lower panel) The UV absolute magnitudes and i-z colors of the r-dropout galaxies in the HSC J0839+0113 field (blue) and general fields (gray).

References

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Spectroscopic Characterization of Young Stars Showing Irregular Dimmings to Unveil Their Mechanisms

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Among young stellar objects, there is a population called “dippers” that exhibit episodic or quasi-periodic dimming in their light curves. The photometric variability is attributed to a shadow by circumstellar materials, but the detailed mechanisms are not yet fully understood. Observations of dippers can provide important clues for studying planet formation processes by revealing the region close to the star in protoplanetary disks.

In this study [1], we observed four newly discovered dippers from the Transiting Exoplanet Survey Satellite (TESS) data [2]. We confirmed that all of the targets exhibit the Hα emission line in the spectra observed using the High-Dispersion Spectrograph (HDS) installed on the Subaru telescope (Figure 1). This emission line indicates ongoing accretion of materials onto the surface of a star from a protoplanetary disk. We were able to estimate the accretion in more detail from the line profiles [3]. In addition, additional observations conducted with other spectrographs, CAHA/CAFE and Okayama/HIDES, revealed variability in the Hα line profiles for two targets. The appearance of blue-shifted or red-shifted absorption in the Hα emission lines indicates the presence of a disk wind or the accretion flow around a star, supporting the dimming mechanisms for each target. Based on the results, we concluded that the dips in the light curves of those dippers are attributed to a dusty disk wind or dust in an accretion-driven disk warp (Figure 2).

This study was the first to characterize these four dippers and identify the cause of their dimming, suggesting the diversity of planet-forming environments. We also discovered that one of our targets is a binary system, as indicated by the large radial velocity variations observed. Interestingly, the orbital period of this binary is almost the same as the period of the dips seen in the TESS light curve. This suggests a strong relationship between the dipper phenomenon and the binary motion. Such dippers in close binary systems have rarely been discovered so far, making this target an important sample for further investigation.

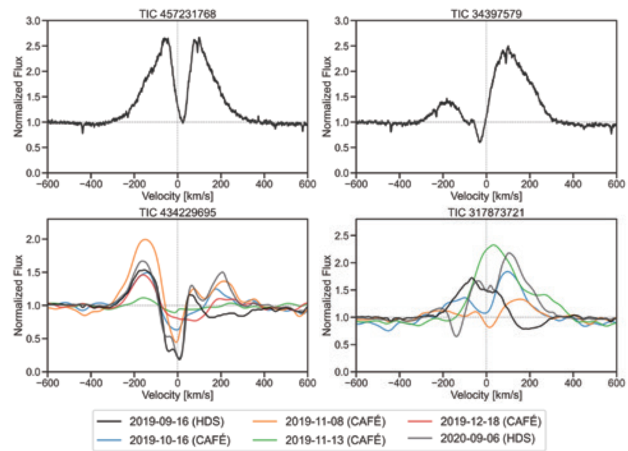

Figure 1: Observed Hα emission lines for our four targets. The vertical dashed line is at the rest wavelength (6562.8 Å).

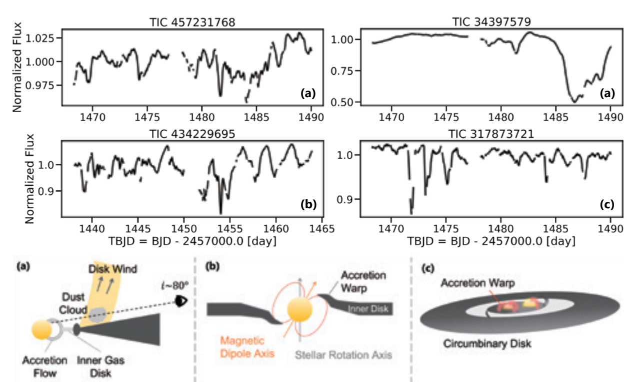

Figure 2: Upper four panels show TESS FFI light curves for our targets. The lower three images represent the plausible scenarios based on our observation.: (a) disk wind, (b) accretion warp, (c) binary and accretion warp. The labels in the light curves correspond to each scenario.

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Morpho-kinematic Modeling of the Expanding Ejecta of the Extremely Slow Nova V1280 Scorpii

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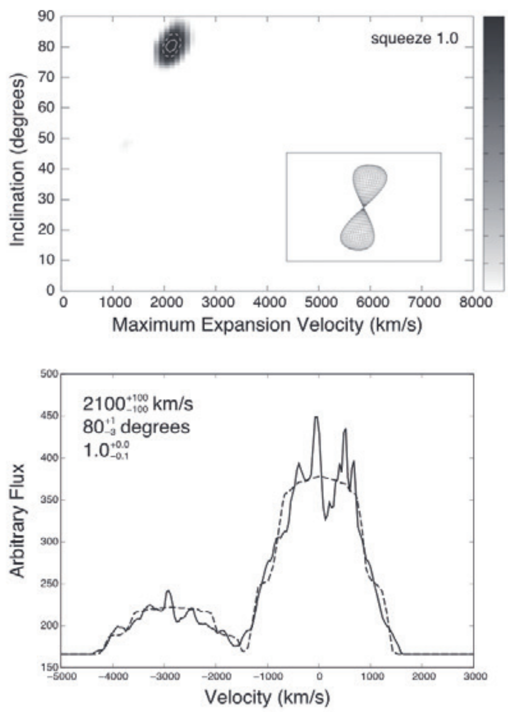

Figure 1: Top: contour plot showing goodness of fit (reduced χ^2) of model fits. Bottom: comparison between the observed ([O III] $\lambda\lambda$4959, 5007) and model spectra. The figure is taken from Fig. 5 of [2].

A classical nova is caused by a thermonuclear runaway on the surface of a white dwarf following the accretion of hydrogen-rich material from a companion star in a close binary system. However, the nova explosion model is not fully understood. Recently, γ-rays were detected during nova explosions, and an idea of collisions between slow gas ejected on the orbital plane of binary systems and fast nova ejecta has been proposed (e.g., [1]). The morphology of the ejecta, which is often not taken into account as a parameter, should be an important key to elucidating the mechanism of the explosion.

In this study [2], we analyzed high dispersion spectra of V1280 Sco taken with the Subaru Telescope's HDS between 2009 and 2019, and discussed the morphology of the nova remnant and the explosion model. V1280 Sco is a classical nova that exploded in 2007 and its evolution is extremely slow; the transition to the nebular phase occurred 50 months after the explosion. Synthetic line profile spectra were compared to the observed [O III] $\lambda\lambda$4959, 5007 and [N II] λ5755 line profiles in order to find the best-fit morphology, inclination angle, and expansion velocity of the ejected shell. We find that the observed spectra were reproduced well for high inclination angles of ~80 deg (Figure 1). A high inclination angle is consistent with the observational results showing multiple absorption lines originating from clumpy gases [3], which are produced in dense and slow equatorially focused outflows (Figure 2). Increasing the sample size of novae whose morphology is studied will be helpful in elucidating the mechanism of the nova explosion.

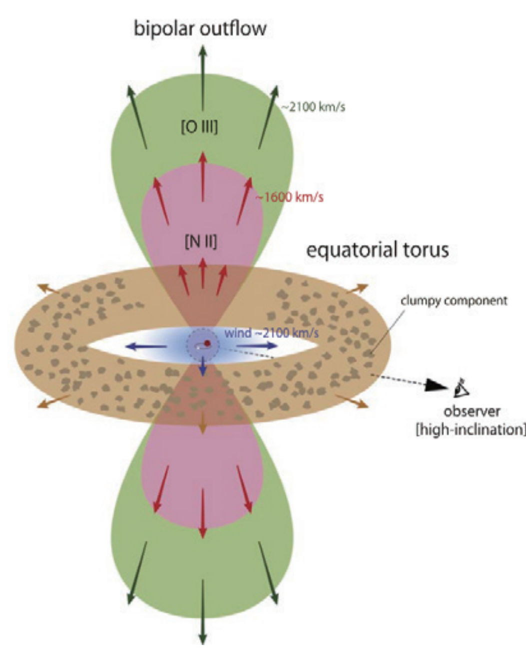

Figure 2: A schematic of V1280 Sco, illustrating fast wind ([O III] and [N II] regions) extended in the polar direction and slow clumpy absorption components ejected in the equatorial direction. The figure is taken from Fig. 8 of [2].

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Statistical Properties of Satellites of Milky Way–like Galaxies

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Although the ΛCDM model has established itself as a standard theory in modern cosmology, it is known that there are some inconsistencies between theory and observation in small-scale structures. One such problem is the discrepancy between the observed number and spatial distribution of satellite galaxies around the Milky Way (MW) and Andromeda galaxies and the simulation results based on the ΛCDM model. It is essential to clarify whether these problems related to satellite galaxies are limited to galaxies in the Local Group (LG) or whether they are universal problems in the universe in order to achieve a fair test of cosmology.

This study [1] focuses on nine galaxies with masses similar to the MW outside the LG (at a distance of approximately 20 Mpc). We observed these galaxies using Subaru/Hyper Suprime-Cam (HSC) to search for satellite galaxies. The identification of satellite galaxies followed the method used in the precursor study [2] to this study, and the candidates were narrowed down using the physical quantities of satellite galaxies estimated by model fitting to candidate objects.

Figure 1 shows some images of satellite galaxies detected in this study. A total of 93 faint satellite galaxy candidates were detected using HSC's high-sensitivity data. Figure 2a shows the luminosity function of the satellite galaxies. Compared with observations of MW and galaxies outside the LG, the average luminosity function of the nine galaxies observed in this study is consistent within a standard deviation, indicating that each galaxies have a similar number of satellite galaxies. On the other hand, we show that the projected radial distribution from the host galaxy does not indicate a centrally concentrated distribution as in the MW. It is consistent with the one expected from simulations for galaxies with similar mass to the MW (Figure 2b). We detected no indication of anisotropy in the directional distribution of satellite galaxies. These comparisons imply that the characteristics of satellite galaxies inside and outside the LG are different and that the MW may never be typical galaxies in the universe.

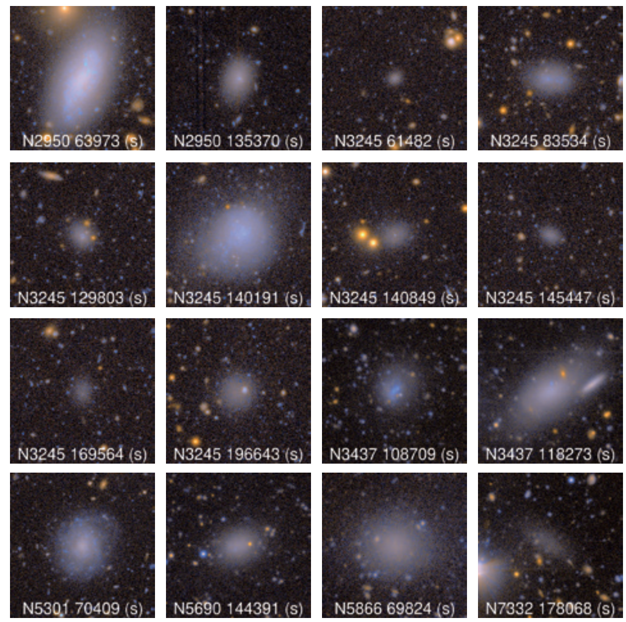
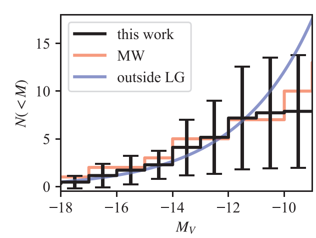
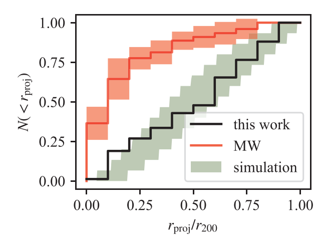


Figure 1: Some images of detected satellite galaxies.



(a) luminosity function.



(b) radial distribution.

Figure 2: Comparison with the average of satellite galaxies detected in nine galaxies. The red, blue, and green represent observation for MW [3], galaxies outside the LG [4], and simulation results for MW-like galaxies [5], respectively.

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* In NAOJ when paper was published.

First Identification of a CMB Lensing Signal Produced by 1.5 Million Galaxies at $z\sim4$: Constraints on Matter Density Fluctuations at High Redshift

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The discovery of the accelerated expansion of the universe through the observation of Type Ia supernovae in the late 1990s and the precise measurement of the cosmic microwave background (CMB) and the detection of baryonic acoustic oscillations in the 2000s have established the so-called ΛCDM standard model. Here, Λ is the cosmological constant (more generally, dark energy) that causes the cosmic acceleration, and CDM stands for cold dark matter required as a gravitational source for the formation of astronomical objects. Although the ΛCDM model can explain cosmological observations quite well, the nature of these dark components is unknown. In order to identify the dark components, it is necessary to first thoroughly examine the ΛCDM Standard Model.

In the late 2010s, it was suggested that the clumpiness of the Universe S_8 obtained from measurements of large-scale structure of the universe using weak gravitational lensing is systematically smaller than that predicted from the CMB fluctuation measurements by the Planck satellite [1]. This could be an indication of a breakdown of the ΛCDM model and is referred to as the S_8 tension.

A method for measuring the large-scale structure of the redshift $z<2$ using weak lensing has already been established, and reducing the statistical error of weak lensing signals by increasing the statistics and improving the accuracy of the S_8 measurement will be the focus of the next-generation galaxy imaging surveys, such as Legacy Survey of Space Time (LSST), Euclid Space Telescope, and Roman Space Telescope. On the other hand, a method to measure S_8 from large-scale structures at $z>2$ has not been established. A discovery that S_8 varies as a function of the redshift of the large-scale structure would suggest the existence of a theory beyond the ΛCDM Standard Model. In this study, we have developed a method to measure S_8 from large-scale structures at $z>2$ and succeeded in measuring S_8 from large-scale structures at $z\sim4$ for the first time. The details are described below.

In the measurement of large-scale structure with weak lensing, it is necessary to use tens to hundreds of millions of galaxy shapes in order to measure the slight distortion of light coming from the background galaxies. For $z>2$, weak lensing cannot be used because a sufficient number of background galaxies cannot be detected. On the other hand, light coming from CMB is also distorted by the foreground structure. Since the CMB lensing is sensitive to the structure of all redshifts from the recombination period of the universe to the present, the CMB lensing by itself cannot extract only the $z>2$ structure. Therefore, we have used cross-correlations between a large sample of distant galaxies consisting of about 1.5 million Lyman-Break galaxies detected with the Subaru Hyper Suprime-Cam (HSC) using the dropout technique [2] and the CMB lens map measured with the Planck satellite to determine the $z\sim4$, we have successfully measured the dark matter distribution around the galaxies (Figure 1) [3]. This is the first detection of the dark matter distribution around galaxies at such a high redshift in the world. In addition, S_8 was measured from the large-scale structure of $z\sim4$ by combining it with the clustering signal of the $z\sim4$ galaxies [2]. As a result, we obtained S_8 smaller than S_8 predicted from the Planck CMB measurement, but we could not conclude that the difference in S_8 was significant due to the large statistical error.

Our results are the first example of the new method for measuring S_8 from large-scale structure at $z>2$ applied to real data. We used a galaxy sample based on HSC data of about 305 square degrees, but the number of galaxies in the final HSC data is about three times larger than the sample used in this study, and LSST, Euclid Space Telescope, and Roman Space Telescope provide with us with the much more number of distant galaxies. In addition, there is already a low-noise CMB lens map by the Atacama Cosmology Telescope (ACT) and the Simons Observatory and CMB-S4 will provide a CMB lens map wich a much lower noise level. Thus, it will be possible to measure S_8 from large-scale structures at $z>2$ with higher accuracy in the future.

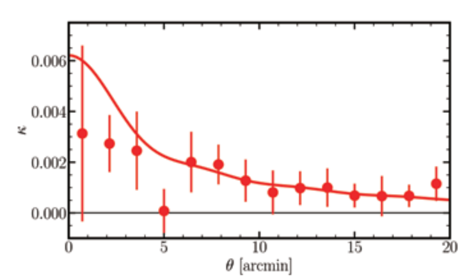

Figure 1: CMB lensing signal of a $z\sim4$ galaxy sample. The horizontal axis denotes the angular separation from the galaxies, and the vertical axis denotes the convergence field of the CMB lensing. The points with error bars denote data points and the solid line denotes the best-fit curve. This figure is adopted from [3] with modifications.

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Discovery of a Super-Earth around the M4.5 Dwarf Ross 508

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Search for exoplanets around late M-type dwarfs is one of the frontiers because of the difficulty of efficient survey using CCD cameras due to their faintness in the visible wavelength. The IRD (InfraRed Doppler instrument) is a high dispersion near-infrared spectrograph mounted on the Subaru Telescope in 2018 that enables highly accurate exoplanet searches by the Doppler method. We started the Subaru Strategic Program using IRD (IRD-SSP) in 2019 and have been conducting a systematic exoplanet search mainly targeting late M-type stars as a pioneering survey using an 8+ meter class telescope.

Ross 508 is an M4.5 main-sequence star at a distance of about 11.2 pc [1] and has been observed 102 times in a framework of IRD-SSP [2]. The spectroscopic abundance analysis [3] determined its metallicity to be [Fe/H] = −0.20. From the analysis of spectral energy distribution and photometric data, the effective temperature is estimated to be $T_{\rm eff} = 3071^{+34}_{-22}$ K and the mass is estimated to be $M_* = 0.177 \pm 0.005\,M_\odot$. The periodogram analysis of the radial-velocity (RV) variations indicates that the most significant periodicity was detected around period 10.7 days and that there is no periodicity of stellar activity that synchronizes with this period, confirming that this is not a pseudo variation of the RV but the actual motion of the star by the planet. We estimated the orbital parameters of the planet for the detected period. We found that the orbital period is 10.77 ± 0.01 days, the semi-amplitude of RV is $3.92^{+0.60}_{-0.58}$ m s^{-1}, the orbit length radius is about 0.054 au. The estimated minimum mass of the planet is approximately $4.0\,M_\oplus$ (Figure 1). Although the orbital eccentricity was not constrained by the accuracy of the RV measurements and the limited number of data, the best-fit value was $e \sim 0.33$, suggesting that the eccentricity may be high. Assuming this orbit, the mean orbital radius of the planet would be further inward than the inner boundary of the habitable zone (the distance from the central star where liquid water can exist), but the planet would enter the habitable zone near the aphelion. The detailed characterization of Ross 508 b helps understand the habitability of a super-Earth.

The discovered planet Ross 508 b is the first example of the successful detection of a super-Earth using only the near-infrared Doppler method, demonstrating that the IRD is capable of detecting planets independently while achieving the highest precision as a near-infrared Doppler method. In the future, we plan to report new planet discoveries from IRD-SSP and findings on the indicators of stellar activity, which have not yet been established in the near-infrared wavelength region.

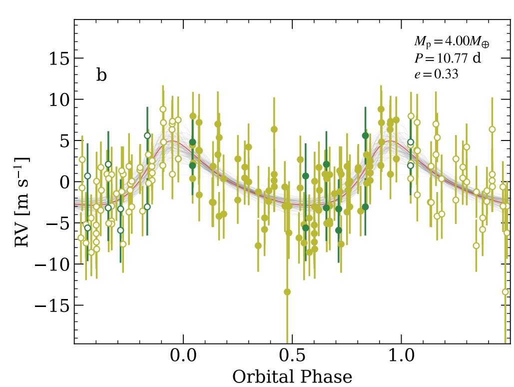

Figure 1: Phase-folded RV variations (yellow and green circles). Green circles are the same as yellow ones but obtained in 2021 August and September (See HH+2022 for details). The red line represents the best-fitting RV model. Gray lines represent 100 RV model curves randomly selected from the posterior. The white circles indicate repeated placement of the same dataset for visibility.

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Deep Near-infrared Imaging of the Faint X-ray Point Sources Constituting the Galactic Bulge X-ray Emission

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The presence of the apparently extended hard (≥ 2 keV) X-ray emission along the Galactic plane has been known since the early 1980s [1], which is called the Galactic Diffuse X-ray Emission (GDXE). The emission has an integrated luminosity of ~1×10^{38} erg s^{-1} at 2–10 keV with a spectrum described by two-temperature thermal plasma ($k_B T$~1 and 5–10 keV). A remarkable feature in the X-ray spectrum is the strong Fe K emission line complex (e.g., [2]) comprising neutral or low ionization state line at 6.4 keV (Fe I) and highly-ionized ion lines at 6.7 (Fe XXV) and 7.0 keV (Fe XXVI).

With the advent of the Chandra X-ray Observatory, a large fraction of the GDXE at the Galactic bulge (l = 0°.08, b = −1°.42; the Chandra Bulge Field or CBF, hereafter) was resolved into 2,002 faint discrete sources [3,4]. The major constituents of these sources have long been considered to be X-ray active stars and magnetic cataclysmic variables (CVs). However, recent works including our NIR imaging and spectroscopic studies argue that other populations should be more dominant [4,5]. We conducted a much deeper NIR imaging observation at the CBF to investigate this further.

We carried out a deep JHK_s imaging observation at the CBF using the MOIRCS on the Subaru telescope, reaching the limiting magnitude of ~18 mag in the J, H, and K_s bands, and identified ~50 % of the X-ray sources with NIR counterpart candidates. We classified all the X-ray sources into three groups (A, B, and C) based on their X-ray color-color diagram (Figure 1 xy-axis). Since most of the X-ray sources have poor photon statistics, we used the method based on the color quantiles developed by [6], which was also adopted in our previous work [4] (details are shown in the caption of Figure 1). We generated three-dimensional plots (Figure 1; X-ray color–color and the ratio of the X-ray to the NIR flux) to disentangle the overlap among the groups. The ratio of the X-ray flux to the NIR flux is expected to be relatively high for the binaries containing compact objects and low for stellar sources (Figure 1 z-axis). We further made a composite 0.5–8 keV spectrum of all the X-ray sources in each group and carried out spectral fittings. Then, we characterized their features based on the X-ray and NIR features of each group.

We argue that the major population of the Group A and C are, respectively, CVs (binaries containing a magnetic and non-magnetic white dwarf with a high accretion rate) and X-ray active stars. The major population of the Group B sources is presumably WD binaries with low mass accretion rates ("quiet" WD binaries). The Fe K equivalent width in the composite X-ray spectrum of the Group B sources is the largest among the three and comparable to that of the Galactic bulge X-ray emission. This leads us to speculate that there are numerous WD binaries with low mass accretion rates, which are not recognized as CVs, but are the major contributor to the apparently extended X-ray emission.

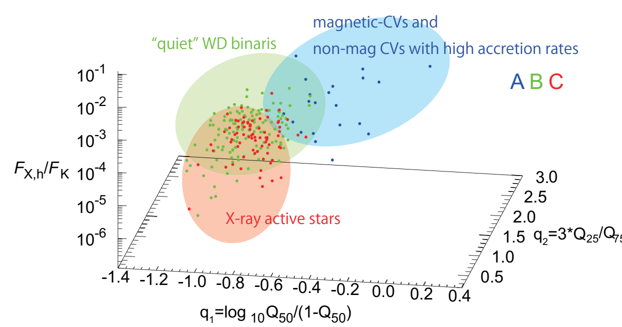

Figure 1: Three-dimensional plot of q_1, q_2, and the ratio of X-ray to NIR flux. Here, the quantile E_x (keV) is the energy below which x % of X-ray photons reside in the energy-sorted list of photons and $Q_x = \frac{E_x - E_{min}}{E_{max} - E_{min}}$, in which E_{min} and E_{max} are the lower and upper bounds of the energy (0.5 and 8 keV), respectively. The metric q_1 reflects the degree of photon spectrum being biased toward the harder (q_1 is large) or softer (q_1 is small) end, and the metric q_2 reflects the degree of photon spectrum being less (q_2 is large) or more (q_2 is small) concentrated around the peak. Different colors are used for the three groups [7].

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Direct Imaging Discovery of a Benchmark Brown Dwarf Orbiting the Hyades Accelerating F5-type Star HIP 21152 [1]

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The astrometry measurements from the Gaia space telescope can be combined with those from the Hipparcos to calculate the proper motion accelerations of nearby stars [2], which are available to predict which stars host companion objects. We used the catalog of the accelerations [2] in target selection to search for giant planet and brown dwarf (BD) companions. The selected targets were observed with SCExAO and CHARIS, extreme adaptive optics high-contrast imaging instruments of the Subaru Telescope. As a result, we discovered a BD companion around the F5-type star HIP 21152 [1]. HIP 21152 is a member of the Hyades open cluster (OC) consisting of a lot of stars as young as 750 ± 100 Myr [3,4]. We obtained four high-contrast images with the Subaru and Keck telescopes to confirm that the companion (HIP 21152B) orbits the star. We also measured radial velocity (RV) measurements of HIP 21152 using the HIDES on Okayama 188 cm telescope.

The CHARIS observations provide spectra of HIP 21152B, placing the spectral type among L/T type transition. We applied the orbit analysis software, `orvara` [5], to the data of direct imaging, RV, and the proper motion accelerations from [2]. As a result, the mass and semi-major axis of HIP 21152B was estimated to be $27.8^{+8.4}_{-5.4}$ times higher than that of Jupiter and $17.5^{+7.2}_{-3.8}$ au, respectively. The dynamical mass estimation is slightly lower than that from a mass estimation dependent on the evolutionary models of [6] and age of HIP 21152B.

The discovery of HIP 21152B corresponds to the first direct imaging of a substellar object orbiting a main-sequence star in the Hyades OC. In addition, its mass is the closest to a planetary-mass regime among all the directly-imaged BD companions whose masses have been dynamically constrained (see a sample list in [7]). Thus, HIP 21152B is a great benchmark to calibrate the techniques used to infer the properties of substellar objects, including giant planets. Our SCExAO/CHARIS survey continues to observe nearby stars having accelerations in their proper motions, enabling more discoveries of intriguing substellar companions with estimations of their dynamical masses.

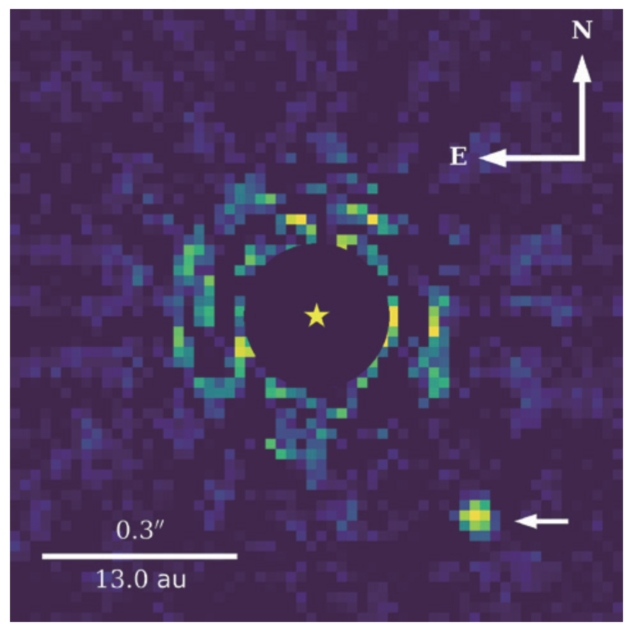

Figure 1: An image of the HIP 21152 system observed with SCExAO/CHARIS. Credit: Astrobiology center

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Demonstration of a Low-noise Microwave Amplifier Based on SIS Mixers

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The development of a large-scale array of heterodyne receivers is expected for future radio astronomy. One of the technical challenges in the array receiver development is the cryogenic low-noise amplifier operated at a physical temperature of 4 K used in the first stage of the intermediate frequency chain. The typical DC power consumption of cryogenic semiconductor-based amplifiers is about 1–10 mW, which makes it difficult to develop large-scale arrays considering the thermal load on a typical refrigerator.

We have devised a microwave low-noise amplifier based on two Superconductor-Insulator-Superconductor (SIS) mixers [1]. The first SIS mixer is used as a frequency converter to up-convert the input microwave signal to the millimeter-wave by a local oscillator (LO) source, and the subsequent SIS mixer is to down-convert the signal with the identical LO source. As a result, the input and output signals have the same frequency, and thus, this configuration can be a very simple microwave amplifier if both frequency converters provide conversion gain. It has the potential to become a versatile amplifier with power consumption in the order of μW, wide bandwidth, high gain, and low noise.

To demonstrate and characterize this superconducting amplifier concept, we configured it with two 100-GHz-band SIS mixers, two signal/LO couplers, and a millimeter-wave isolator (Figure 1). The bias voltage and current of the SIS up- and down-converters were set to the minimum noise temperature of the amplifier. As a result of characterization, low-noise performance was obtained, typically with a gain of 6–8 dB and a noise temperature of 11 K below the signal frequency of 5 GHz [2]. Using a network analyzer, we also confirmed reasonable gain linearity within the range of the measurements. Based on the breakdown of the SIS amplifier performance at a signal frequency of 1 GHz, the gain and noise temperatures of the SIS up-converter and SIS down-converter were found to operate at 2.7 dB and 4.0 K, and 6.4 dB and 7.8 K, respectively. This result indicates that the lower noise of the respective SIS converters, and the higher gain of the SIS up converter can also be expected to further improve the performance of the SIS amplifiers.

This SIS amplifier concept demonstrated in this study can be regarded as a single amplifying element like a transistor, and its microwave characteristics are comparable to those of cryogenic semiconductor devices such as High Electron Mobility Transistors. If the circuit can be integrated to be more compact, it is expected to be applied to array receivers and other array systems. In addition, we found that the concept of using two frequency mixers can work as nonreciprocal devices such as an isolator [3] and gyrator [4]. This also means that this SIS amplifier can have directivity, which recalls their realization as compact general-purpose amplification devices. This may contribute to the challenges of developing large-scale systems for radio astronomy and quantum computers.

This work was supported in part by JST Moonshot R&D Grant Number JPMJMS2067 and JSPS KAKENHI Grant Numbers JP19H02205, JP21H01134, and JP22H04955.

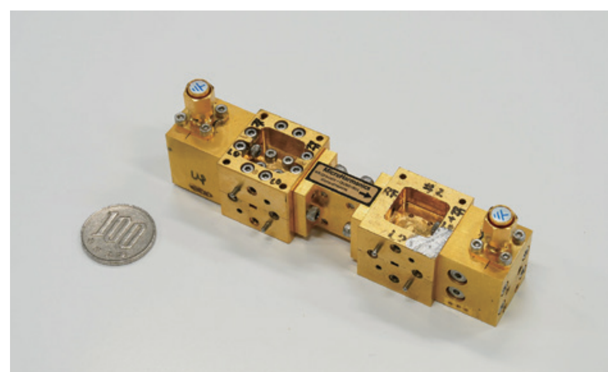

Figure 1: Photograph of the SIS-based amplifier used in this demonstration.

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II Status Reports of Research Activities

01. Mizusawa VLBI Observatory

Mizusawa VLBI Observatory operates VLBI (Very Long Baseline Interferometry) arrays to provide their machine time for open use, and conduct observational studies of Galactic structure, maser sources, active galaxy nuclei, and so on. As its main facility, the observatory operates the VERA array consisting of four 20 m radio telescopes in cooperation with Kagoshima University. KaVA (KVN and VERA Array), which combines the VERA and KVN (Korean VLBI Network) in Korea, and East Asian VLBI Network (EAVN: East Asian VLBI Network), which consists of Japanese, Chinese, and Korean radio telescopes, are being operated and opened to the international community. The observatory also operates Yamaguchi 32-m Radio Telescope and Hitachi / Takahagi 32-m radio telescopes in collaboration with Yamaguchi and Ibaraki University, respectively, contributing to research in Japanese VLBI Networks. As a member organization of the Event Horizon Telescope project, the observatory contributes to the promotion of millimeter-wave VLBI as well. The observatory also plans to participate in SKA (Square Kilometre Array) as a future project. In addition to these VLBI-related activities, the observatory plays a wide range of roles beyond astronomy, such as operation of the Esashi Earth Tide Observation Facility, which is used for research in geophysics.

1. VERA

(1) Observations and Common-Use Observations

The four stations of VERA were operated by remote control from AOC (Array Operation Center) at NAOJ Mizusawa Campus. In FY 2022, excluding EAVN common-use, 159 sessions (1459 hours) of regular VLBI observations were conducted by VERA, which is a decrease of 20 % from the previous year. The main reasons for this decrease are the extension of the maintenance period until September 2022, the suspension of operations at the Mizusawa station due to snowfall in winter, and Ishigaki-jima station has suspended operations from January 2023 due to electrical and drive system failures. For the regular scientific operation for VERA, a new observational mode “VERA Large-scale Collaborative Program (VLCOP)” has been initiated since September 2022. In FY 2022, VLBI observations carried over from FY 2021 were conducted for a total of 63 sessions (515 hours) until August 2022. After starting VLCOP in September 2022, a total of 78 observations (693 hours) were conducted via the automatic remote operation from the Mizusawa AOC. In addition, single-dish observations were carried out at the AOC and local sites. These observations were done as part of the VLCOP programs after September 2022. In the FY 2022, the observing time for the single-dish operation for all stations was 1815 hours.

As for the types of VLBI observations, regular annual parallax measurements, astrophysical observations, and geodetic observations were carried out as continuations from the previous project. Furthermore, during the period when the four stations could not operate simultaneously, observations newly adopted from the second half of this fiscal year, such as SETI-related observations, installation tests of new observation equipment and fringe tests, were carried out. In addition to these, we conducted KaVA (KVN and VERA Array) and EAVN (East Asian VLBI Network) observations, which will be described in the following sections. These VLBI data, except for KaVA and EAVN, were processed at the Mizusawa Correlation Center in NAOJ Mizusawa Campus. The correlated data were sent to each observation proposer and to persons in charge of data analyses in the case of project data and geodesy data. VERA common-use calls-for-proposals in FY 2022 were not conducted by VERA alone. This is because almost all observing modes became available in the EAVN common-use, which was released at the same time, and hence, all proposals were submitted to EAVN.

(2) Science Research

In FY 2022, Mizusawa VLBI Observatory published a total of 47 refereed journal papers for scientific achievements. Among them, 4 papers were published by the Observatory members as a PI and 2 of them were published by graduate students in the University of Tokyo as a PI. Using the facilities operated by Mizusawa VLBI Observatory, 10 papers were published to report scientific results from the East Asian VLBI Network (EAVN). These are VLBI imaging of AGNs and maser astrometry, as well as theoretical works related to the observational results and development works such as VLBI experiments between East Asia and Italy, new instruments for polarization measurements, and the multi-frequency receiving system installed on the Nobeyama 45-m telescope. As follow-up studies for the EAVN large program, two refereed journal papers were published to report maser variability and chemical properties in high-mass star-forming regions using ALMA observational data. Using radio telescopes in the Japanese VLBI Network (JVN), two papers were published to report the first FRB observation in Japan and development of an interferometer. Furthermore 16 papers were published on the AGN studies, mostly for the first imaging of the super-massive black hole at the Galactic center Sgr A*, from the international project Event Horizon Telescope (EHT) in which Mizusawa VLBI Observatory is participating. For the preparatory studies for the future project Square Kilometre Array (SKA) which is under discussion in Mizusawa VLBI Observatory, there were several refereed journal papers from the SKA precursors and pathfinders, such as two papers for the maser variability studies using the European VLBI Network (EVN), one paper each for studies on galaxy clusters from MeerKAT in South Africa, uGMRT in India, and detailed imaging of outflow of high-mass star-forming region from JVLA in US and e-MERLIN in UK through synergy with ALMA. An IAU symposium on masers (#380) was held in Kagoshima, and there were many presentations reporting VERA's results.

2. The Japanese VLBI Network (JVN)

The University VLBI Collaboration Observation projects were conducted jointly by NAOJ and six universities. We organized the radio telescopes of VERA, universities, and research institutes (JAXA/ISAS) to establish the Japanese VLBI Network (JVN). The JVN operates at three frequency bands: 6.7 GHz, 8 GHz, and 22 GHz. In FY 2022, a total of 360 hours were dedicated to VLBI observations. The primary research areas included active galactic nuclei, methanol masers, and X-ray binary systems. Additionally, Ibaraki University and Yamaguchi University each conducted over 1000 hours of single-dish observations related to JVN research.

During FY 2022, JVN focused on three research targets for time-domain VLBI astronomy: (1) (periodic) flux variations in CH_3OH masers, (2) extremely compact HII regions immediately after the onset of nuclear burning, and (3) time-domain VLBI astronomy of high-energy astrophysical events. The key baselines for these studies involved high-sensitivity telescopes larger than 30 m within JVN. One example of JVN observations in 2022 was a survey of gamma-ray emitting AGN candidates.

Throughout the year, more than 10 papers were published, including Fujisawa et al. (2022) and Tanabe et al. (2023). Among them were eight papers on the accretion burst of proto-high-mass stars which was found by the Ibaraki group, as well as two short reports. A joint research seminar called the Ibaraki-Yamaguchi Joint Seminar was held for students from these two universities. Yonekura from Ibaraki University led the development study, focusing on upgrading the VLBI observation system at the Ibaraki station through Grants-in-Aid for Scientific Research. Several students from Ibaraki and Yamaguchi Universities were under the supervision of Professor Ogawa at Osaka Metropolitan University.

3. International observations with Korea-Japan VLBI, East Asian VLBI and mm-VLBI

(1) Observations and Common Use Observations of EAVN

In FY 2022, EAVN (East Asian VLBI Network) observations, utilizing KVN and VERA Array (KaVA), Sejong 22-m in Korea, the Tianma 65-m, Sheshan 25-m, Nanshan 26-m, Kunming 40-m, Nobeyama 45-m, and Yamguchi/Hitachi/Takahagi 32-m radio telescopes, were conducted for a total of 127 observations (918 hours), including common use observation, test, and verification observations. Most of the scheduled observations were successfully conducted without any major issues despite the global COVID-19 pandemic.

EAVN open-use calls for proposals for semesters 2022B and 2023A were released in June and November of 2022, respectively. In total, 26 proposals requesting a total time of 876 hours were submitted from Japan, Korea, China, Italy, Spain, Thailand, and Chile. Through the evaluations by 49 referees nominated from scientists in related fields and the subsequent decision made by the EAVN combined Time Allocation Committee, a total of 25 proposals (854 hours) were accepted. Regarding global mm-VLBI, EHT observations were carried out remotely in March 2023 due to the outbreak of COVID-19.

(2) Results of Research

In FY 2022, 4 papers based on KaVA (3 on active galactic nuclei, 1 on massive star forming regions), and 9 papers based on EAVN (1 on array review, 6 on active galactic nuclei, 2 on galactic astrometry) were published in peer-reviewed journals. Nine out of them include significant contributions from members of Mizusawa VLBI Observatory as co-authors. Here some works are highlighted. Tazaki et al. (2022) applied the sparse modeling imaging technique to M87 EAVN 22 GHz data, and they demonstrated that low frequency wave VLBI images also allow us to accurately constrain the structure of the formation regions of relativistic jets. EHT Collaboration et al. (2022) reported the results from the 2017 SgrA* multi-wavelength observing campaign including EHT and EAVN, and EAVN data greatly helped to constrain the interstellar scattering properties towards the source, which was crucial for successfully imaging of the black hole shadow with the EHT. In Asanok et al. (2022), they monitored water vapor masers in the massive star forming region W49N, and revealed the detailed structure such as bipolar outflows together with accurate proper motion measurements. Sakai et al. (2023) performed KaVA/EAVN astrometry observations towards G034.84-00.95 that is located in the extreme outer galaxy, and they estimated the kinematic distance to the source to be 18.6 kpc (±1.0 kpc), demonstrating the powerful capability of KaVA/EAVN astrometry. Other than the above publications, a white paper on the Thailand 40-m radio telescope was also published, in which tight collaboration with EAVN is highlighted.

Regarding mmVLBI/EHT, 12 papers (including the above-mentioned multi-wavelength paper) were published in peer-reviewed journals. Especially, 10 of them (6 collaboration papers and 4 official papers) were about the first EHT results on the Galactic Center SgrA* based on the 2017 EHT campaign. The research results were featured in various media. Other than EHT, one paper on M87 based on 3 mm global VLBI observations, in which one of the corresponding authors is a member of Mizusawa VLBI Observatory, was accepted in a refereed journal.

4. Future Planning

As for the SKA observatory project, construction of both SKA MID, to be built in South Africa, and SKA LOW, to be built in Australia, commenced in July 2021, and the production of subsystems and site infrastructure has started based on the construction sharing by the participating Member countries. NAOJ participated in the Assembling, Integration, and Verification (AIV) as in-kind contributions. NAOJ has observer status on the SKA Council to understand the construction status of the SKA and to explain the status of research in Japan. Japan has participated in the relevant SKA Finance Committee, SKA Contracts Committee and SKA In-Kind Contribution Committee as well and took part in their deliberations.

The SKA1 Study Group (SKAJ) was organized under Mizusawa VLBI Observatory for a period of three years from FY 2019 to conduct preliminary research and in-kind contributions to the SKA1 program. Based on the results of three year's activities, an SKA1 project proposal was submitted, and the results of the review led to the conclusion that it was appropriate to proceed with activities as a subproject at this stage. FY 2022 was a transitional period, including project review, and the group continued its activities as a study group.

SKAJ mainly focused on the research on the three major Japanese themes (cosmic reionization, cosmic magnetism, and pulsars) established by the SKA Consortium, which represents the SKA research community. And SKAJ shared the cost of the MWA participation fee with universities in Japan and continued the research of cosmic reionization. Moreover, research on cosmic magnetism, pulsars, and active galactic nuclei using other SKA precursors such as Australia's ASKAP and South Africa's MeerKat was conducted. Through the grant by the National Institutes of Natural Sciences' Accelerated Program for Strategic International Research Exchange, two researchers from India were invited from February to March 2023 for joint research on pulsar timing arrays using the Indian GMRT and seven researchers from Japan visited India for it. Two researchers were invited from Australia and two young researchers were sent to Australia for joint research on cosmic magnetism by using ASKAP. In addition, three lecturers were invited from abroad for a workshop on data analysis of cosmic reionization, cosmic magnetism, and pulsar timing arrays from March 2 to 6, 2023, and 18 young researchers from Japan participated in the workshop.

On the engineering side, SKAJ participated in the Assembling, Integration and Verification (AIV) activities based on the MoU with SKA Observatory from January 2022, and developed test contents and created test procedures for SKA1 LOW AA0.5 with 1FTE. For SKA MID, we agreed with the SKA Observatory and the South African Radio Observatory to participate in DISH AIV activities with 0.5 FTE and started the collaboration for it. Development of a VLBI recorder was initiated with the aim of being adopted in the development program at the SKAO. The data rate of VLBI recording is required to be 100 times faster than the conventional VLBI recording system, and for this purpose, the development of a high-speed protype system based on the VLBI recorder developed in Japan was started. In addition, Osaka Metropolitan University initiated the basic design of the optical system to evaluate the feasibility of 15 GHz to 29 GHz observations at the SKA MID, and started collaborations with South Africa, the United Kingdom, Sweden, Switzerland, and other countries.

The employment of a specially-appointed researcher based on an agreement with SKA Observatory was continued, and scientific research planning was promoted. In addition, with regard to the development of a data analysis system, we participated as a member in the SKA Regional Steering Committee, which was organized by the participating countries, and actively took part in the conceptual design of the system. In Japan, we continued to develop a test system for the JPSRC, a networked data analysis and archiving system that we began to study jointly with the SKA Japan consortium in FY 2020 and constructed a test system of networked data analysis servers. Using this system, we have supported a Japanese team, which participated in the SKA Data Challenge 3 to verify the feasibility of the data analysis method and the amount of computation for cosmic reionization research by analyzing simulation data.

5. Geodesy and Geophysics

In order to monitor the position and shape of the VERA network, regular geodetic observations were conducted once to twice a month. VERA internal geodetic observation sessions using K-band were conducted once a month. Mizusawa Station conducted IVS sessions (IVS-T2P and AOV) using S- and X-bands once every two months. In AOV and IVS-T2P, wideband observations using OCTAD-OCTADISK2, and recorded data transfers to the IVS correlation center have been routinely conducted. In FY 2022, VERA internal geodetic observation was conducted 10 times and we participated in IVS sessions 6 times. The final estimates of the VERA station positions were reconstructed based on ITRF2020, which is newly released in 2022, and supplied to the astrometric analysis performed by VERA.

We carried out continuous GNSS(GPS) observations at VERA stations in order to monitor short term coordinate variations and to estimate atmospheric propagation delays. The analysis software GipsyX which is developed by NASA/JPL and Caltech is used in the analysis. The propagation delays (excess pass delays) vary irregularly in time. We produce essential correction data for VERA accurate astrometry through GNSS observations. The positioning result of GNSS and gravity observation data in Mizusawa show the viscoelastic relaxation process of the 2011 off the Pacific coast of Tohoku Earthquake. The strain and tilts observation data obtained at the Esashi Earth Tides Station are distributed in real time to several institutes and universities based on the research agreement among them.

6. System Development

As a development group, we are currently developing the dual-polarization and dual-frequency (K, Q) receiver system at a rate of 32 Gbps for VERA in accordance with the next

EAVN broad-band observing mode. In 2022, we implemented EMI countermeasures for RF and IF integrated switches with 16 inputs and 4 outputs for both polarization bands (Q, K, C, S, L), a down-converter for right polarization, and high-speed A/D converter (OCTAD), and re-installed (OCTAD) at all VERA stations. As a result, we could conduct VLBI test observations simultaneously at K and Q bands with dual-polarization using the K-band RF direct A/D system at the Mizusawa and Iriki stations, and get the first fringes. In addition, a simultaneous two-beam and dual-polarization observing mode is available in this new system, and we conducted test observations and could get the first fringe. Various CSV tests including the above new modes are currently ongoing.

Eight years have passed since the Mizusawa correlation center was established, and the time for server replacement is approaching. Therefore, as the next system, we are upgrading the software correlation system using GPUs and continuing to reduce the number of servers. In 2022, the development of the correlator using GPUs compatible with the new OS (rocky linux 9) was completed, and we started to evaluate it and conducted test correlations. We prioritized the processing of wideband dual-polarization observations (16 Gbps) that require high computational load and SETI observations that require high-dispersion spectroscopy (16M FFT points), and achieved 10-20 times faster processing than conventional processing (CPU).

7. Public Relations (PR) and Awareness Promotion Activities

(1) Open House Events (Numbers in <> are the number of participants)

The following open house events are held every year at each telescope site operated by Mizusawa VLBI Observatory.

- On April 24, 2022 The 13th Open Observatory Event held by the Ibaraki University Center for Astronomy, and NAOJ Mizusawa VLBI Observatory, Ibaraki Station. <Total 702 people>
- On August 7, 2022 The special open house event at VERA Ishigaki-jima Station held together with “The Southern Island Star Festival”. <66 people>
- The special open house of VERA Iriki Station jointly held with “The Yaeyama Highland Star Festival.” In 2022, the special exhibition was canceled to prevent the spread of the new coronavirus infections.
- From August 6 to August 28, 2022 Mizusawa district “Iwate Galaxy Festa”. In 2022, the schedule was dispersed to prevent the spread of new coronavirus infections. <Total 690 people>
- “Star Island” is the open house event held at VERA Ogasawara Station. In 2022, the special exhibition was canceled to prevent the spread of the new coronavirus infections.

(2) Regular Public Visits

Throughout the year, the following stations are open to the public on a regular basis. The four VERA stations are open to the public approximately every day except during the New Year’s season.

The numbers of visitors to each facility are as follows.

a) Mizusawa VLBI Observatory (VERA Mizusawa Station) 11,188 The campus is regularly open to the general public with the cooperation of the Oshu Uchu Yugakukan (OSAM: Oshu Space & Astronomy Museum) located in the campus.
b) VERA Iriki Station 1,038
c) VERA Ogasawara Station 6,640
d) VERA Ishigaki-jima Station 2,584

(3) Cooperation with Local Communities (Numbers in <> are the number of participants)

Various events were held in cooperation with Iwate Prefecture and Oshu City. Here are some of the most notable events.

a) We cooperated with special exhibitions, lectures, and workshops at libraries co-sponsored by the Southern Iwate Regional Development Bureau and the municipalities in the southern part of Iwate Prefecture.

• Special Exhibitions

Jul 23, 2022 (Sat)–Aug 25, 2022 (Thu) Higashiyama Library of Ichinoseki Public Libraries
Aug 2, 2022 (Tue)–Aug 16, 2022 (Tue) Kanegasaki Municipal Library
Sep 2, 2022 (Fri)–Sep 15, 2022 (Thu) Nishiwaga Town Culture Creation Hall (Galaxy Hall)
Sep 13, 2022 (Tue)–Sep 26, 2022 (Mon) Hiraizumi Municipal Library
Sep 23, 2022 (Fri)–Oct 26, 2022 (Wed) Kawasaki Library of Ichinoseki Public Libraries
Oct 12, 2022 (Wed)–Oct 24, 2022 (Mon) Hanamaki Library of Hanamaki City Libraries
Oct 28, 2022 (Fri)–Nov 23, 2022 (Wed) Senmaya Library of Ichinoseki Public Libraries
Dec 16, 2022 (Fri)–Dec 23, 2022 (Fri) Tono City Library
Dec 21, 2022 (Wed)–Jan 8, 2023 (Sun) Mizusawa Library of Oshu City Libraries

• Lectures and Workshops

Oct 29, 2022 (Sat) Senmaya Library of Ichinoseki Public Libraries / Workshop “Let's make the planets of the Solar System” Lecturer: Daisuke Sakai Specially Appointed Assistant Professor
Dec 12, 2022 (Sun) Tono City Library / Workshop “Let's make a twinkle twinkle galaxy ornament!” Lecturer: Fumie Tazaki Tokyo Electron Technology Solutions Ltd.

b) The Iwate Marugoto Kagaku Johokan (led by Iwate Prefecture), an IT science event for children and adults in Iwate Prefecture, is held every year and we participated in 2022 as well.

Jul 16, 2022 (Sat) Iwate Marugoto Kagaku Johokan in Kamaishi at Kamaishi Civic Hall TETTO <160 people>

Dec 16 (Fri) and 17 (Sat) 2022 Iwate Marugoto Kagaku Johokan at Big Roof Takizawa <400 people>

c) In 2022, we held a “Kirari Oshu City Astronomical Class” for elementary and junior high schools in Oshu City.

Aug 26, 2022 (Fri) Hirose Elementary School 4th, 5th, and 6th grade / “Expanse of the Universe” Lecturer: Tomohiko Ozawa <18 people>

Sep 6, 2022 (Tue) Mizusawa Minami Elementary School 6th grade joint / “What is a black hole?” Lecturer: Mareki Honma <107 people>

Sep 9, 2022 (Fri) Tokiwa Elementary School 4th grade / “Seasonal constellations and movement of the stars” Lecturer: Daisuke Sakai <115 people>

Sep 13, 2022 (Tue) Tokiwa Elementary School 6th grade / “Earth, Moon, and Solar System” Lecturer: Koji Matsumoto <112 people>

Oct 6, 2022 (Thu) Maesawa Junior High School 3rd grade joint (Class 1st, 2nd) / “What is a black hole?” Lecturer: Kazuhiro Hada <58 people>

Oct 6, 2022 (Thu) Maesawa Junior High School 3rd grade joint (Class 3rd, 4th) / “What is a black hole?” Lecturer: Kazuhiro Hada <58 people>

Dec 15, 2022 (Thu) Harikawa Elementary School 4th, 5th grade / “Seasonal constellations and movement of the stars” Lecturer: Noriuyki Namiki <11 people>

8. Education

(1) University and Post-Graduate Education

Regarding postgraduate education, Mizusawa VLBI Observatory assisted 3 doctoral and 3 master’s course graduate students from the University of Tokyo with their research. One of the master’s course students is from a foreign country. Each doctoral and master’s student got the degree in March 2023. In addition, a staff member of Mizusawa VLBI Observatory gives lectures at Tohoku University as a visiting professor.

(2) Research Experience for High School Students

Considering the improved situation of COVID-19, Mizusawa VLBI Observatory organized the educational program for high school students in Ishigaki Island, “The Churaboshi Research Team Workshop” with the support of JSPS, during summer vacation as usual. The event was co-organized with the Public Relations Center of NAOJ on-site at the VERA Ishigaki-jima Station and Ishigakijima Astronomical Observatory. Including 18 participants from outside Ishigaki Island, a total of 21 high school students experienced the lectures on astronomy, observatory tours, star watching, and observational studies with the VERA 20-m antenna.

02. Nobeyama Radio Observatory

1. Nobeyama 45-m Radio Telescope

(1) Charged Telescope Time

The 41st term (charged telescope time) started on September 1, 2022. This term was the first fiscal year of the charged telescope time, which was a newly introduced operation system, after the open use was terminated. The statistics of the conducted programs are as follows. “General Programs”: 34 programs including one program from abroad, “CSV Programs”: four programs, “Observation Tutorial Programs”: three programs. The number of the successful proposals for “Students Programs”, which are reviewed scientifically, is two proposals out of the three submitted proposals.

Remote observations were conducted from Mitaka, Kagoshima University, Osaka Metropolitan University, Nagoya University, University of Tokyo, Kyushu University, Keio University, ASIAA (Taiwan), etc.

(2) Improvements and Developments

(a) New Developments

- A new focal plane array receiver system for observations at 72–116 GHz (named “7BEE”) was installed on the 45-m telescope in August and commissioned to carry out performance evaluations as well as test observations. It employs seven beam elements, and allow observations of two polarizations and three bands. This development was supported by JSPS grant-in-aid KAKENHI Kiban S (Grant Number JP20H05645; PI: K. Tatematsu).

(b) Approved Development Programs

A total of five programs are in progress as follows. Nobeyama Radio Observatory (NRO) supported each program team in the installation of the instruments, particularly in hardware and software interfaces and in test runs.

- 3-band simultaneous observing system HINOTORI.
- Frequency-modulation local oscillation FMLO.
- eQ (30–50 GHz) receiver: The problems with the refrigerator and the cooled amplifier that occurred last year were repaired and the instrument was commissioned to carry out performance evaluations as well as test observations.
- Millimetric Adaptive Optics (MAO): A demonstration experiment was conducted with the wave-front sensor expanded to 5 elements.
- 100-GHz, 109-element MKID camera: After a test observation, the camera was removed from the 45-m telescope for refurbishment.

(c) Maintenance and improvements

Maintenance of the 45-m telescope, the receiver systems, computing system, etc. were performed as follows.

- Regularly scheduled and preventative maintenance was performed.
- Corrective maintenance due to some malfunctions in the following systems.
  - The crack in back structure of the antenna
  - The power-board of the SAM45 spectrometer
- Development of the observation preparation tool for overseas observers is underway.
- The H22 receiver had its amplifiers replaced with new cooled low noise amplifiers which improved the receiver sensitivity.

(3) Scientific Results

A total of 34 refereed journal papers were published on the basis of research using the 45-m radio telescope.

1) Results from the Legacy Programs and Open Use General Programs with the 45-m Telescope

Kaneko, H., et al. investigated the interstellar medium in four interacting galaxies in the early or middle stages of the interaction. They found that sSFR and SFE for the galactic scale are similar to those for the isolated galaxies, whereas the SFE is enhanced for the local kpc scale. This fact indicates the dense gas is not changed in the earlier stages of the interaction. Tatematsu et al. studied the velocity structure of 36 cores in Orion and found that inward motions were more dominant than outward motions in those targets. In addition, they found that the blue-skewed spectra are detected in 10 % of the samples, and one of them shows the core is at the last stage of starless cores judging from the chemical evolution factor. Enokiya et al. reanalyzed the high-density gas for the Sgr B region of the Galactic center and suggested a new scenario where the contiguous collision of two clouds having a velocity difference of 20 km/s triggered the formation of the Sgr B1 and Sgr B2 regions. Wu et al. performed a survey of 22 GHz H_2O masers for 178 O-rich AGBs in Sagittarius stellar stream and detected 21 masers including 20 first detections. They investigated the distribution of H_2O and SiO masers, and also they found an elongated structure toward the (l, b)~(340°, 40°) region. Kaneko, M., et al. conducted a detailed search of the molecular gas toward the Galactic center direction and found a cloud having peculiar velocity structure suggesting an intermediate-mass black hole is trapping the gas. Fujita et al. analyzed the FUGIN data, one of the legacy programs of NRO, using a machine learning technique and inferred the distances of the molecular clouds. They also identified 140 thousand clouds and made a catalog.

2. Research Support

(1) 1.85-m Radio Telescope (Osaka Metropolitan University)

With the 1.85-m radio telescope, they have conducted an extensive survey of molecular clouds along the Galactic plane using the molecular lines of carbon monoxide isotopologues in the 230 GHz band. In FY 2018, they started a new project supported by JSPS (Grant-in-Aid for Scientific Research on Innovative Areas). In this project, they will relocate the telescope to the Atacama site in Chile at an altitude of 2400 m, equipped with an ultra-wideband receiver (230–345 GHz), and carry out an extensive survey of molecular clouds along the Galactic plane and in the Magellanic Clouds in the southern sky. In preparation for the relocation, the development of the receivers was mostly completed by FY 2021, and for FY 2022, development of a software system enabling remote observations was mainly promoted at the Nobeyama site.

3. Public Outreach

(1) PR activities at Nobeyama Campus

Nobeyama Campus received a cumulative total of 37,690 visitors throughout the year. The open area for visitors has been limited to outdoor areas as a precaution against the spread of COVID-19, while from Feb. 13 2023, the exhibition room is opened reflecting that the alert level of Nagano Prefecture was reduced. The NMA observation building was operated by NINS as the NINS exhibition room until FY 2021, whereas the building has been operated by NRO as the NAOJ-NRO exhibition room from FY 2022.

Staff members conducted 11 guided tours and granted 25 requests for filming and interviews. One workplace visit by local high schools was conducted. The filming and interview requests were mainly about research activities and introducing NRO.

The annual Nobeyama Special Open House was held as an online event. The maximum number of connections for live streaming was about 500 and the total number of views for all content was about 84,000 in the three months after the event.

Moreover, we received and answered about 134 phone calls this year from the public regarding the regular opening of the observatory, observatory events, and general astronomy.

(2) Cooperation with Local Communities

The annual Nobeyama Special Open House was held online with contributions by Minamimaki Village Shinko-kosha, Minamimaki Village, Minamimaki village society of commerce and industry, Nagano Prefecture, and Nagano Prefecture Board of Education. However, “Jimoto Kansha Day (Thanks Day for the Locals)” for local communities (Minamimaki and Kawakami Villages) by 3 Nobeyama institutes was cancelled.

Moreover, the “Nagano Prefecture is Astro-Prefecture” liaison council promoted the activities such as monitoring night sky condition in the prefecture. The 7th meeting was held online and on-site at Bunka-hall in Kiso-Bunka-Koen on December 10 with about 50 participants. Some activity reports and a discussion on future activities were presented.

4. Education

Five master’s course students and one doctoral course student from Osaka Metropolitan University and one doctoral course student from the University of Electro-Communications were accepted for education.

5. Misc. Activities

(1) Activities related to the Agreement on Mutual Cooperation between NAOJ and Minamimaki Village

In 2018, NAOJ and Minamimaki Village signed an agreement on mutual cooperation to support PR activities for scientific results of NAOJ and the utilization of the facilities of NRO for the tourist and education activities of Minamimaki Village. Some activities were conducted, such as paid sigh-seeing tours around Nobeyama Campus by Minamimaki Village Shinko-kosha. They had 69 paid group tours and filmings.

(2) Hiring, Transfer (incoming)

None

(3) Retirement, Transfer (outgoing)

Takami, Masaki: Leader of Accounting Section, moved to Shinshu University

Maekawa, Jun: Research Supporter, retired

Takahashi, Shigeru: Research Supporter, retired

(4) NRO Conference Workshops and Users Meeting

- December 20–21, 2023, Hybrid (in-person and on-line)
  FY 2022 ALMA/45-m/ASTE Users Meeting (Organizing Committee: Misato Fukagawa, Masumi Shimojo, Ken Tatematsu, Tetsuhiro Minamidani, Takeshi Kamazaki (NAOJ))

03. Solar Science Observatory (SOL)

The Solar Science Observatory (SOL) project, as a COE of solar observations in Japan, operates the Hinode satellite and ground-based solar telescopes to pursue the development of solar research by acquiring and accumulating multi-wavelength data. The project also carries out the development of advanced technology for next-generation solar observations.

1. Hinode Space Observatory

The scientific satellite Hinode is an earth-orbiting satellite that was launched on September 23, 2006, by ISAS/JAXA, as Japan's third solar observational satellite following Hinotori (1981) and Yohkoh (1991). Hinode is equipped with three telescopes: the solar optical telescope (SOT), the X-ray telescope (XRT), and the extreme ultraviolet imaging spectrometer (EIS). In addition to observations of the detailed magnetic field and velocity field of the solar photosphere, it carries out simultaneous observations of the radiance and velocity field from the chromosphere to the corona. The telescopes equipped on the Hinode satellite were developed through international collaboration based on cooperation between ISAS/JAXA and NAOJ with contributions by the US NASA and the UK STFC. The European Space Agency ESA, and the Norwegian Space Center NSC also join in its scientific operations. NAOJ played a central role in the development of the science payload in Japan and has been making a significant contribution to the science operation and data analysis since its launch. The data acquired with Hinode are released to everyone as soon as the data are ready for analysis. The Hinode Science Working Group (SWG), composed of representatives from the international teams, offers support in scientific operation and data analysis. It has a total of 17 members, including three from SOL: Y. Katsukawa as SOT PI, H. Hara as EIS PI, and T. Sakurai, professor emeritus, as a project scientist. The Science Schedule Coordinators (SSC) have been organized to leverage the open-use observation system. Two Japanese members from SOL (T. Watanabe, professor emeritus, for EIS and T. Sekii for SOT followed by J. Okamoto in the latter half of the year) join the SSC activity. The SSC serves as a contact point for observation proposals from world solar physics researchers to use Hinode and promotes joint observations between Hinode and the other science satellites and ground-based observatories. New science results have been obtained via joint observations with SDO, IRIS, and ALMA as well as long-term standalone observations by Hinode. The number of Hinode-related refereed papers published in FY 2022 is about 60. The Hinode science payload had been steadily observing the Sun from space, except for the SOT filtergraph instrument which was terminated in February 2016. Since March 2022, the spacecraft operation has continued with the attitude control around the Sun-directed axis using a geomagnetic sensor and gyro.

ISAS/JAXA approved the fourth mission extension for the period from FY 2021 to FY 2023, and has conducted science operations to continuously observe rising activity toward the solar maximum using techniques such as observations of magnetic fields in the polar regions and full-disk mosaic observations, as well as to promote joint observations with rocket and balloon experiments conducted by the SOL project. The JAXA-led Hinode project will be terminated in order to focus on the next solar mission SOLAR-C, and the results and lessons learned from Hinode will be transferred to SOLAR-C. After FY 2024, the operation framework will be shifted to one in which operations will be continued by a late-stage operations team within ISAS.

Solar Data Archive System (SDAS) in the Astronomy Data Center (ADC), which developed from the open-use data analysis system of the Hinode Science Center and NSRO (Nobeyama Solar Radio Observatory) in addition to the data archive/public release system of the former Solar Observatory, takes the role of archiving and public release of the solar data. The data analysis functionality has been integrated into the ADC Multi-wavelength Data Analysis System (MDAS). The SOL project is jointly operating SDAS and MDAS with ADC. The SOL project is jointly operating Hinode Science Center at the Institute for Space-Earth Environmental Research, Nagoya University, where value-added Hinode data are maintained and published such as a flare catalog, model of magnetic fields above active regions, and magnetic field data in the solar polar regions.

2. Ground-based Observations at Mitaka Campus

The SOL project continues to conduct observations at Mitaka Campus to obtain basic data for solar research and to help satisfy the public demand for monitoring its possible influence on the global environment. The primary observations are infrared spectro-polarimetry for full-disk magnetic field measurements both in the photosphere at 1.565 microns and in the chromosphere at 1.083 microns with the Solar Flare Telescope (SFT). The other observations include full-disk Hα, Ca K, continuum, G-band imaging observations, and relative sunspot number measurements as a proxy of long-term solar magnetic activity. The solar activity has been gradually increasing since 2019 after the solar minimum, and useful data such as active regions and flares have been obtained in the new cycle. To ensure stable operation, we are replacing aging parts of the instruments.

Some of the most advanced data accumulated are those for magnetic fields in the solar atmosphere. The magnetic field observations that were conducted with SFT starting from 1992 have provided vector magnetic fields in the photosphere with a field of view covering active regions by observing an absorption line in the visible wavelength range. These observations have now been replaced with near-infrared Stokes polarimetric observations since 2010 for higher precision measurements of magnetic fields both in the photosphere and in the chromosphere. In addition, we are developing key technologies required in future solar observing instruments, such as an infrared camera with an H2RG detector.

NAOJ has long-term solar observation data in the form of films, photographic plates, and sketches acquired since the time of its predecessor, the Tokyo Astronomical Observatory. The data are being digitized for the study of long-term variations in solar activity. In particular, the historical data of total solar eclipses are being digitized intensively. The past and new observation data are stored in the common server of ADC and are available on our webpage. In order to promote the use of the data, we have made the Hα imaging data searchable on the Virtual Solar Observatory (VSO), a solar data retrieval system in the US. We are planning to increase the number of data available on VSO in the future.

3. Nobeyama Solar Radio Polarimeters

The Nobeyama Radio Polarimeters (NoRP) monitor the microwave radiation from the Sun, specifically at seven frequencies (1, 2, 3.75, 9.4, 17, 34, and 80 GHz), and measure its circular polarization to study solar cycle activity and particle acceleration phenomena associated with solar flares. Although the Nobeyama Solar Radio Observatory (NSRO) was closed at the end of FY 2014, the observation of intensity and circular polarization at the seven frequencies, conducted over 70 years, continues because of its importance in monitoring long-term solar activity. Since FY 2019, the SOL project started to take responsibility for the operation and maintenance of the radio polarimeters in cooperation with Nobeyama Radio Observatory (NRO) and the solar physics community in Japan. The replacement of critical components since the last fiscal year has been successful, and stable operation has been maintained at all frequencies, and multiple radio bursts accompanying flares have been detected with the increasing solar activity. To promote the use of NoRP data, we published a paper (Shimojo & Iwai 2023) describing the history of the instrument and observations over 70 years, especially the evolution of the instrument since 1994, when observations started at Nobeyama and the details of the database available at the Solar Data Archive System.

4. Rocket and Balloon Experiments

The SOL project is working to develop advanced technology for next-generation solar observations by sounding rocket and stratospheric balloon experiments.

The CLASP series of sounding rocket experiments aims to measure solar magnetic fields in the chromosphere and transition region through high-precision polarization observations in the ultraviolet wavelengths. The SOL project has led, in cooperation with research groups in the U.S. and Europe, CLASP (in 2015, the world's first successful spectropolarimetric observation of the hydrogen Lyman alpha line [wavelength: 121.6 nm]), CLASP2 (in 2019, the world's first successful spectropolarimetric observation of ionized magnesium lines [h&k, wavelength: 280 nm]), and CLASP2 reflight, CLASP2.1, (in 2021, successful scanning observation using the CLASP2 instrument). In FY 2022, we worked on scientific outputs that further extend the CLASP2 initial results, including the detection of the Hanle and magneto-optical effects and the extraction of magnetic field information along the height by applying an inversion code, and published two scientific papers and one instrument paper. We have completed the calibration of the data acquired by CLASP2.1 in cooperation with the US team, and have started the data analysis for scientific results.

SUNRISE-3 is the third flight of the international balloon project Sunrise carrying the 1-meter aperture telescope for solar observations. in which Germany, Japan, the United States, and Spain are participating. The SOL project is in charge of the near-infrared spectro-polarimeter SCIP (Japanese PI: Katsukawa), which will be installed on SUNRISE-3 and will simultaneously observe many spectral lines with a resolution higher than that of the Hinode satellite. These observations will allow us to observe the three-dimensional magnetic field structure from the photosphere to the chromosphere and its time evolution and clarify the transport and dissipation processes of magnetic energies. The balloon gondola, telescope, and instruments were reassembled at the ESRANGE launch site in Kiruna in April 2022, and final tests for alignment, image formation performance, etc. were conducted. A timeline was developed for efficiently coordinating onboard instruments in the flight operation. We had a launch opportunity on July 10, delayed one month from the original schedule due to a delay in NASA logistics. However, due to a shock generated at the launch, a part in the gondola, for which the US team was responsible, failed and was unable to point at the Sun. For the safe recovery of the telescope and the instruments, the operation was terminated about 5 hours after the release, and the gondola was descended in Sweden. The SCIP was operated without any problems during the flight, and post-recovery tests confirmed that the SCIP was in good health. The results of the scan mirror mechanism, high-precision polarization calibration, and optomechanical design obtained through the development of SCIP have been published in three refereed papers in collaboration with the Advanced Technology Center. Development of onboard image processing and thermal design have also been drafted in a paper in cooperation with the Spanish team. In addition, research on methods for analyzing high-precision polarization data of the chromosphere is ongoing.

The Focusing Optics X-ray Solar Imager (FOXSI) is a joint Japan-US sounding rocket experiment series to observe X-rays emitted from the solar corona by 2D focusing imaging and spectroscopy. It has successfully flown three times (FOXSI-1 to -3) to make the world's first observations of the solar corona during non-flaring periods. Based on these achievements, the fourth flight FOXSI-4 will realize an observation of a solar flare. FOXSI-4 is scheduled for launch in Spring 2024 and aims to understand plasma heating, energy transport, and particle acceleration in a solar flare. The Japanese group led by the project is developing key components such as a high-speed camera for X-rays, a high-precision X-ray mirror, a pre-collimator, and an X-ray filter. In FY 2022, these basic developments were completed, and the fabrication of flight products was started. These developments are being carried out in collaboration with ATC and the CMOS camera team of the Subaru Telescope. The team is also working on the data calibration of the last three FOXSI experiments as well as on the creation of scientific results. The FOXSI-4 project was approved by NASA with the highest evaluation and, in Japan, was adopted by ISAS/JAXA as a small-scale program and the Grant-in-Aid for Scientific Research, International Cooperative Research Acceleration Fund (B). It was newly adopted in FY 2022 as a Grant-in-Aid for Scientific Research (A). The Japanese team for FOXSI-4 is led by the National Astronomical Observatory of Japan (PI: Narukage), with the participation of the University of Tokyo Kavli IPMU, ISAS/JAXA, and Nagoya University. Many graduate students are also participating in the FOXSI-4 project, contributing to the development of young researchers.

5. Cooperation with SOLAR-C Project

In the preliminary design of EUVST, a high-resolution, high-sensitivity UV telescope to be installed on the next solar observing satellite SOLAR-C, the SOL project contributes to realizing SOLAR-C by maximum use of the technical expertise in the optomechanical design, UV observation technology, and IF coordination with overseas institutions accumulated through the development of the rocket and balloon experiments. To refine the observation plan for SOLAR-C, we are conducting research on how the key processes of atmospheric heating are observed spectroscopically using numerical simulations etc. in the framework of the Hinode Science Center, which is jointly operated with Nagoya University.

6. Education

The SOL project accepted and supervised four Ph.D. students from SOKENDAI and two contract graduate students from the University of Tokyo. Two received a master’s degree at SOKENDAI or the University of Tokyo. The SOL project participated in the Tour of Solar Research Frontiers (March 2023) and introduced solar research at NAOJ to undergraduate students.

7. Public Outreach (PO) Activity

The SOL project has been conducting various public outreach activities for education and delivering the latest solar activity and the results obtained through the scientific research of the Sun to the public: web releases, homepage, social media, cooperation for exhibitions at science museums, media appearances for solar observations and space weather in response to requests for media interviews, providing materials to the media, etc.

8. Science and Community Meetings

The international Hinode Science Meetings have been regularly held to advance solar physics research with the Hinode satellite. The 15th Hinode Science Meeting was held September 19–23, 2022 in Prague, Czech Republic. A meeting of the Hinode Science Working Group was held on September 23, 2022, to discuss ways to continuously generate scientific results from Hinode and to share the status of mission extension in participating countries. The Japan Solar Physics Community Symposium was held February 20–22, 2023 at Nagoya University, where the latest research results from domestic instruments and foreign space- and ground-based observations were presented, and future plans for SOLAR-C and beyond were introduced and discussed.

9. Others

For the Daniel K. Inouye Solar Telescope (DKIST) on Haleakala in Hawai`i, a 4-meter aperture solar telescope led by the US, one person from SOL (Y. Katsukawa) is a member of the Science Working Group. In the second call for observation proposals for DKIST (Operation Commissioning Phase 2, OCP2) issued in 2022, three proposals submitted by Japanese researchers were accepted and two of them are from the NAOJ researchers. Based on a grant for enhancing collaborative research with DKIST (co-I: M. Kubo), we are conducting research using the data taken in OCP1 and numerical simulation studies assuming future DKIST observation data. For the European Solar Telescope (EST, 4 m) the SOL project participated in the SOLARNET project of the European solar community to develop an image slicer for IFU (Integral Field Unit) for the EST-prototype GREGOR solar telescope. In the next-generation global network solar observation project (ngGONG), which is led by NSO in the US, the SOL project has expressed our intention to cooperate with NSO for its realization based on the scientific and technological heritage obtained through near-infrared spectro-polarimetry with SFT at Mitaka Campus. We helped prepare a white paper about ngGONG submitted to the Heliophysics Decadal Survey in the US. The 10 cm coronagraph from the former Norikura Corona Observatory has been relocated to Yunnan, China, and its observation operations are underway at the site. Discussions have begun with the Chinese group regarding future scientific cooperation using the coronagraph data.

04. Subaru Telescope

1. Subaru Telescope Staff

As of the end of FY 2022, the Subaru Telescope staff consisted of 21 dedicated faculty members including five stationed at Mitaka and two stationed at Okayama, five engineers, one specially appointed associate professor, four senior specialist, and three administrative staff members. Additional staff members include one specially appointed assistant professor, six project research staff members, eight senior specialist, six administration associates, and one research supporter, all of whom are stationed at Mitaka; as well as one specially appointed associate professor, and two administration associates, all of whom are stationed at Okayama. Moreover, 12 research/teaching staff members, seven of whom are stationed at Mitaka and two of whom are stationed at Pasadena, and three engineers, one of whom is stationed at Mitaka, one of whom is stationed at Nobeyama, and one of whom is stationed at Mizusawa, are posted concurrently. The project also has 61 local staff members dispatched from the Research Corporation of the University of Hawai`i (RCUH), including scientific assistants; engineers in charge of software and observational instruments; technicians for facilities, machinery, vehicles, and laboratories; telescope/instrument operators; administrative staff; researchers employed for Grants-in-Aid for Scientific Research; Post-Doctoral fellows; and graduate students. These staff members work together in operating the telescope, observational instruments, and observational facilities; and in conducting open-use observations, R&D, public outreach, and educational activities.

2. Science Highlights

In FY 2022, Subaru Telescope produced many outstanding scientific outcomes, which were published in major international journals. Below are some examples:

(1) A brown dwarf orbiting the Sun-like star HIP 21152 was discovered using the Extreme Adaptive Optics System (SCExAO and CHARIS). HIP 21152 B was found to be the lightest brown dwarf with an accurately determined mass, approaching the mass of a giant planet. HIP 21152 B is expected to be a benchmark object for the study of the evolution of giant planets and brown dwarfs and their atmospheres.

(2) A massive supercluster of galaxies about 5.5 billion light-years away was discovered based on the Hyper Suprime-Cam data taken under the Subaru Strategic Program. Not only is there a strong concentration of galaxies and dark matter across an area of the sky roughly the size of 15 full moons, but there are at least 19 galaxy clusters associated with it, making it the largest supercluster ever identified in the Universe beyond 5 billion light years away.

(3) Hyper Suprime-Cam with Big Data techniques has made it possible to search wide areas, looking for transient phenomena which change rapidly with time. Astronomers discovered 20 fast-evolving transients in December 2020. One of them, MUSSES2020J was very dim in the first images but brightened significantly over the course of the observations, indicating that the team caught it at the very beginning of its occurrence. Follow-up observations confirmed that this event evolved much faster than normal supernovae and was about 50 times brighter. The team proposes calling this new class of events “Fast Blue Ultraluminous Transients” (FBUT).

(4) Using observations with Hyper Suprime-Cam, a giant tidal tail has been discovered emanating from a dwarf galaxy in the nearby M81 galaxy group. The galaxy, named F8D1, is remarkable on account of its low luminosity and large size and is now recognized to be one of the closest examples of an “ultra-diffuse” galaxy (UDG). This is the first time that such a stellar stream has been discovered in a UDG. Revealing F8D1 to be a galaxy in an advanced state of tidal disruption has implications for both the dynamical evolution of the M81 Group and for the origin of galaxies that exhibit UDG properties.

(5) An exoplanet was discovered by the Subaru Strategic Program using the infrared spectrograph IRD (IRD-SSP). This is the first discovery based on IRD-SSP. This planet, Ross 508b, is a super-Earth with about four times the mass of the Earth and is located near the habitable zone. Such a planet may be able to retain water on its surface. It will be an important target for future observations to verify the possibility of life around low-mass stars.

3. Open-use

The Open Use Program is conducted semiannually by inviting proposals from the public. The observation period is from February 1 to July 31 (semester A) for the year's first half, and from August 1 to January 31 (semester B) for the year's second half. Applications are accepted at the Subaru Mitaka Office of the National Astronomical Observatory of Japan. The Subaru Program Time Allocation Committee (TAC) reviews the proposals and selects which ones to accept based on domestic and international referee evaluations. In S22A, 46 proposals (65.5 nights including 1 ToO proposal night) {out of 132 proposals (256.56 nights)} were accepted. And in S22B, 35 proposals (46 nights including 2.0 ToO proposals nights) {out of 129 proposals (246.02 nights)} were accepted. For Intensive Proposals exceeding one semester, we allocated 22.5 nights (4 proposals) in S22A and 17.4 nights (4 proposals) in S22B. In addition, short-time assignment Service Program observations, were also conducted. Of the proposals selected for Open Use in S22A and S22B (excluding University of Hawai`i time), three (two in S22A and one in S22B) were foreign PI proposals. The total number of applicants, including co-researchers, was 884 foreign researchers compared to 2,256 domestic applicants, and the total number of researchers in the accepted proposals was 265 foreign researchers compared to 749 domestic researchers.

The total number of Open Use observers in S22A and S22B was 334 (including 103 foreign and 130 remote observers in Mitaka Campus). The Mitaka side handled the application and review of observation proposals, travel procedures for domestic researchers to observe, and travel expense payment administration, while the Hawai`i side prepared the observation schedule and provided support for observers' accommodation, transportation, and observations in Hawai`i. Open Use observations during S22A and S22B, including University of Hawai`i time, utilized 91.85 % of available observation time, excluding weather factors and scheduled downtime due to maintenance such as the primary mirror coating. About 2.41 % of the observing time was lost due to instrument trouble, 0.29 % due to communications system trouble, 5.27 % due to telescope trouble, and 0.18 % due to operation trouble.

Remote observations from the Hilo base facility were made on 16 nights (12 programs) during S22A and S22B. Remote observations from NAOJ Mitaka Campus were conducted for 40 nights (20 proposals including HSC/IRD Subaru Strategic Programs) with the participation of both summit observers and remote side observers, or only Mitaka remote side observers. In addition, 6.5 nights of service observations were conducted. Telescope time exchanges with Gemini and W. M. Keck observatories are conducted to make the best use of the telescope resources at the summit of Maunakea. Subaru Telescope and W. M. Keck Observatory exchanged 5.5 nights in S22A and 4.5 nights in S22B. Subaru Telescope users were able to use Gemini for 11.0 nights in S22A and 2.1 nights in S22B (excluding Fast-Track proposals), and from Gemini users were able to use the Subaru Telescope for 13.1 nights in S22A and 5.4 nights in S22B.

4. Telescope Maintenance and Performance Improvement

The following major repairs, maintenance, and changes were implemented in FY 2022.

(1) Primary mirror recoating:

The recoating work for the telescope primary mirror was performed to recovery the reflectivity of the primary mirror.

(2) Other activities:

We are accepting new observational instruments, repairing the outer wall of the dome, performing annual maintenance of the mechanical and electrical systems of the telescope / dome, and repairing sudden failures.

In addition, we have been working on the renewal of the dome air conditioning system and an upgrade of the telescope software to improve observation efficiency.

The other hand, we started the “Telescope Maintenance Group collaboration of NAOJ”. The purpose of this activity is to share know-how and maintenance plans for NAOJ telescopes, and to carry out, evaluate, and improve maintenance activities through cooperation among observatories.

5. Instrumentation

The following five facility instruments were provided for the open-use observations in FY 2022: HSC (Hyper Suprime-Cam), FOCAS (Faint Object Camera And Spectrograph), HDS (High Dispersion Spectrograph), IRCS (Infrared Camera and Spectrograph), MOIRCS (Multi-Object Infrared Camera and Spectrograph), and the 188-elements Adaptive Optics and Laser Guide Star system (AO188/LGS). As for the carry-in instruments, IRD (Infrared Doppler), SCExAO (Subaru Coronagraphic Extreme Adaptive Optics), and SWIMS (Simultaneous-color Wide-field Infrared Multi-object Spectrograph) were provided for the open-use observations. In addition, the following instruments/devices have been used in combination with SCExAO: CHARIS (Coronagraphic High Angular Resolution Imaging Spectrograph), FastPDI (Fast Near-Infrared Polarization Differential Imaging), MEC (MKID Exoplanet Camera), REACH (Rigorous Exoplanetary Atmosphere Characterization with High dispersion coronagraphy), and VAMPIRES (Visible Aperture Masking Polarimetric Imager for Resolved Exoplanetary Structures).

The operation of MOIRCS was resumed in January 2023, after its hibernation since February 2021 to facilitate the science operation of the carry-in instrument SWIMS. MOIRCS was successfully recovered in January 2023 and offered for open-use observations from February 2023. The upgrade of the LGS system was mostly completed and it was opened for open-use observation from February 2023.

The upgrade projects of the Deformable Mirror (DM) and Near Infrarred Wavefront Sensor (NIRWFS) for AO188 have been actively underway. NIRWFS is planned to be operated as a carry-in device, has successfully done multiple engineering observations, and is under preparation to be made available in S24A. For HSC, fabrication of new filters by HSC users is still ongoing and we received and made available a narrow-band filter “NB872” in FY 2021. In addition, a project to fabricate ~20 intermediate-band filters is ongoing. For the Nasmyth Beam Switcher, which will improve the operation and management of IR Nasmyth instruments, we completed the procurements of the optical and mechanical parts, and started the assembly work.

6. Computers and Networks

The Subaru Telescope computing and network systems core system remained mostly stable with occasional network issues due to an increased number of powerline events affecting both the Base and Summit facilities. CDM (Computer and Data Management division) has worked to mitigate observing time loss due to network issues by deploying a backup VPN between the Summit and Hilo. CDM continues to support day workers with computing requests, and work to implement changes to the computing/network environment if it benefits Subaru staff, and doesn't compromise the integrity of the STN environment.

As major improvements CDM has finalized the STN6 (Subaru Telescope Network version 6) contract, prepared the current STN5 contract equipment for removal, and converted all physical servers and virtual machines services to updated operating systems. This work is necessary to allow for a smoother and faster transition between contract systems. The highlight of the new STN6 system is a decreased footprint from thirty (30) servers/storage devices in four (4) full rack enclosures to twelve (12) servers/storage/network devices in one half-sized rack at the Base Facility, with a reduction of a one (1) full rack to one half-sized rack at the summit. CDM has planned, tested and transitioned the contract network equipment of a single chassis environment, to a modular environment, reducing the network footprint, and improving the recovery time in case of component failure to minimize the observing time loss. With guidance from Mitaka ITSO (Information Technology Security Office), the 100 G Hi-speed Summit-Base-Mitaka network was established and tested during HSC observations. Further normal Hilo-Mitaka network traffic, Accounting, STARS, phones, and ADC related traffic were added to this network. As of the end of FY 2022, utilization of the 100 G network is increasing, with support for large data transmissions for other instruments. With the new network equipment supporting 25, 40, and 100 Gbps connections, CDM has invested in upgrading parts of new and existing server environments. OCS (Observation Control System) -GEN2 base and summit clusters have been upgraded to 80 Gbps core uplink, with redundant failover for servers. Current PFS and HSC Onsite Analysis server clusters have specific servers with 40 or 100 G connections to allow for maximum data transmission to support observation. CDM still participates in the Astronomical Community specifically to network and collaborate on large data transfer projects. Other highlights include the transfer of 400 TB of observation data and logs (STARS) from STN5 to the new storage server. This includes, validating the data using checksum and updating the database to ensure the proper storage location is recorded.

7. Education (Under-graduate and Graduate Courses)

In FY 2022, Subaru Telescope had 15 staff members jointly affiliated to SOKENDAI. Some of these staff members (including those jointly affiliated to other divisions) are the primary supervisors of eleven students, which comprise 1/3 of all the SOKENDAI students. Among these 11 students, 5 are supervised by staff members primarily affiliated to Subaru Telescope.

Subaru Telescope hosted 4 students through the Akamai internship program. Separately from the Akamai program, Subaru Telescope hosted 1 intern student. As part of the SOKENDAI summer student program, staff members in Hilo and Mitaka supervised 7 undergraduate students.

Turning to Subaru Telescope's contributions to the larger Japanese community, 5/16 graduate students defended their PhD/Master's theses using data from the Subaru Telescope. Among them, one SOKENDAI student affiliated to Subaru Telescope defended his PhD thesis. The HSC data reduction school was held in Mitaka in an onsite+online format and 33 people participated in the school, of which 11 also joined the hands-on data reduction session.

Subaru Telescope Okayama Branch

The Okayama Branch was established in FY 2018 primarily to provide open-use observing time to universities nationwide utilizing half of the observation time of the 3.8-meter New Technology Optical-Infrared Telescope (now named as "Seimei Telescope") at Okayama Observatory, Astronomical Observatory, Graduate School of Science, Kyoto University. It also cooperates in the use of the telescopes of the former Okayama Astrophysical Observatory by universities and the local government. Two research and academic staff members, one project associate professor, and two administrative supporters belong to the Okayama Branch as of the end of FY 2022.

1. Seimei Telescope

(1) Open use (calendar year)

In the first half of 2022 (January-June), 70 nights were provided. The number of applications was 22 (Classical: 11, Classical + ToO: 1, ToO: 10) and the number of nights requested was 93.37 (Classical: 65.1, ToO: 28.27), while the number of accepted applications was 19 (8, 1, 10) and the number of awarded nights was 83.27 (58, 25.27). Note that "Classical" refers to an observation that will be made on a pre-assigned date, and "ToO" refers to an observation that will be made upon the occurrence of an event of interest at a date and time indicated by the proposer. The total lost time during this period was 3.0 night. In the second half of 2022 (August-December) 63.5 nights were provided. The number of applications was 29 (13, 3, 13) and the number of nights requested was 125.995 (83.9, 28.133), while the number of accepted applications was 19 (9, 2, 11) and the number of awarded nights was 84.333 (56.2, 28.133). Total lost time during this period was 1.75 nights. During these periods, we provided accommodations for observers to stay onsite while taking appropriate measures to prevent the spread of novel coronavirus infections, and we carried out the open use without causing any infection clusters.

(2) Observing instruments

In 2022, the Kyoto-Okayama Optical Low-dispersion Spectrograph with the optical-fiber Integral Field Unit (KOOLS-

IFU) and the TriColor CMOS Camera and Spectrograph (TriCCS), which had been opened in 2021, were available. In the second half of 2022, the fast-imaging mode (10 to 98 fps) of TriCCS was newly available. Activities also included management and operation of environmental monitors, storage of acquired data, maintenance of computers and networks, and maintenance of facilities. Development and test observation of a high-dispersion spectrograph for precision radial velocity measurement (GAOES-RV), which is expected to become a new observatory instrument, were carried out.

(3) Development of remote and queue observations

In cooperation with Okayama Observatory of Kyoto University, the remote observation environment was conditionally opened to open use in the first half of 2022. Development of the queue observation system was started in 2022.

(4) Research results

The following example of important research results from observations with the Seimei Telescope was published in a paper in FY 2022.

(a) Observations of nearby (redshift $z < 0.04$) ultra-luminous infrared galaxies (ULIRG) at various stages of galaxy mergers were made using the KOOLS-IFU at the Seimei Telescope. Emission lines such as Hβ, [O III]λ5007, Hβ, [N II]$\lambda\lambda$6549, 6583, [S II]$\lambda\lambda$6717, 6731, etc. were observed with a wavelength resolution of R = 1500 to 2000. These observations yielded spatially resolved (approximately 200 to 700 pc) moment maps of the ionized gas of each galaxy and allowed the diagnosis of active galactic nuclei (AGN) within the central ~3–11 kpc diameter of the sample. The outflow of the [O III] emission line driven by an AGN tends to be stronger (i) towards the galactic center and (ii) with the merging stage. In particular, the outflow strength in the late-stage mergers is about 1.5 times stronger than that in the early-state mergers, which indicates that galaxy mergers could induce AGN-driven outflows and play an important role in the co-evolution of galaxies and supermassive black holes.

(5) Meetings

(a) Seimei Users Meeting

The fourth Users' Meeting was held online on July 26–27, 2022. Meeting Managers: Masaaki Otsuka, (Kyoto Univ.) (Representative), Mikio Kurita (Kyoto Univ.), Akito Tajitsu (NAOJ), Masayuki Akiyama (Tohoku Univ.), Shigeyuki Sako (Univ. Tokyo), Satoshi Honda (Univ. Hyogo). The maximum number of simultaneous connections was about 80, and the total number of participants was about 100.

(b) Seimei Subcommittee

The Subcommittee met eight times in FY 2022. Four of these meetings were for the time allocation to the open use observing proposals for the second half of 2022 and the first half of 2023. At the subcommittee meeting held in February 2023, the new instrument GAOES-RV was reviewed for open use in the second half of 2023, and it was accepted.

(c) Kyoto University 3.8-m Telescope Council

On September 16, 2022, the fifth meeting of the Kyoto University 3.8-m Telescope Council regarding the operation of the Seimei Telescope was held online by the Kyoto University Graduate School of Science and the National Astronomical Observatory of Japan (NAOJ). The meeting was attended by the Dean of the Graduate School of Science, Kyoto University, the Director General of NAOJ, and many others. The status of the operation was reviewed, and research results were reported.

2. Telescopes of the former Okayama Astrophysical Observatory

(1) 188-cm reflecting telescope

(a) On August 10, 2022, the operational council meeting to discuss the use of the 188-cm reflector telescope was held online by NAOJ, the Exoplanet Observation Research Center at the School of Science of the Tokyo Institute of Technology (TITech), and Asakuchi City.

(b) On the evening of September 29, 2022, when observers using the 188-cm telescope tried to open the dome slit for their observation, the upper door of the dome slit, which is a vertical type, fell down and became inoperable. Due to this accident, the 188-cm telescope became unusable and remained in that state until the end of the fiscal year (as of May 2023, discussions are underway for restoration).

(c) On March 16, 2023, the operation council was held at Asakuchi City Hall as a hybrid of face-to-face and online. A discussion was held on the use of the 188-cm reflector telescope, explanation of the situation of the dome accident, and recovery.

(2) Other telescopes

We also cooperated in the operation of the 91-cm reflector telescope, the 50-cm reflector telescope (MITSuME), and the Thirty Milli-Meter Telescope (TMMT).

3. Public Outreach

The Okayama Branch has no staff assigned to public relations and dissemination activities, so only the minimum necessary activities are carried out.

(1) In 2022, we started holding television stargazing events using the Seimei Telescope: June 2022 from Asakuchi City, September from the children's astronomical club at the Asakuchi City Okayama Astronomical Museum, and in December from Yakage Town. Each time about 30 people were invited to test the stargazing party. In March 2023, the Okayama Astronomical Museum held the first telescopic stargazing event for public

participants (approximately 20 people) with the cooperation of Kyoto University and NAOJ.

(2) In November 2022, the first “Asakuchi Observatory Festa” was held with the cooperation of the Asakuchi City Okayama Astronomical Museum and the Kyoto University Okayama Observatory.

05. Center for Computational Astrophysics (CfCA)

1. Overview

The Center for Computational Astrophysics (CfCA) has been operating a system of open-use computers for simulations centered around a general-purpose supercomputer, a general-purpose graphic processing unit (GPGPU) cluster, and a general-purpose PC cluster for small-scale calculations, carrying out research and development of computational astrophysics, and performing astronomical research with simulations. The new main supercomputer of the present system renewed in 2018, ATERUI II (Cray XC50), has a theoretical peak performance of 3 Pflops, which is the world's fastest supercomputer for astronomy. CfCA augmented the GPGPU cluster and general-purpose PC cluster in 2022. Efforts in visualizing astronomical data also continue.

2. Open Use of Computers

(1) General status

This year marked the fifth year of the upgraded astronomical simulation system, which includes the new open-use supercomputer Cray XC50. This computer is installed and under operation at Mizusawa VLBI Observatory. The users have been making academically significant progress as before.

While XC50 is leased for six years from Hewlett-Packard Enterprise (which acquired Cray), the center has built the following equipment to aid the open-use computer operations: a series of GPU nodes; two sets of PC clusters for small to medium-scale computation; large-scale file servers; a group of servers for processing computational output data; and an instrument network to encompass the overall computer system. These components are central to numerical simulations by researchers in Japan and overseas.

Computational resources of the XC50, GPU, and the PC clusters are allocated in accordance with a formal review process. The statistics of applications and approvals for this year are listed in the next subsection. Our center conducted a survey on the number of peer-reviewed papers published in English in this fiscal year on studies that involved the project's open-use computers. It turned out that 156 refereed papers (written in English) were published in this fiscal year.

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

(2) Operation stats for each of the facilities

Cray XC50

- Operating hours
  Annual operating hours: 8357.9
  Annual core operation ratio by users' PBS jobs: 95.41 %
- Number of users
  Category S: 0 adopted in the first term, 0 in the second term; total 0
  Category A: 15 adopted at the beginning of the year, 0 in the second term; total 15
  Category B+: 19 adopted at the beginning of the year, 1 in the second term; total 20
  Category B: 132 adopted at the beginning of the year, 13 in the second term; total 145
  Category MD: 30 adopted at the beginning of the year, 1 in the second term; total 31
  Category Trial: 28 (year total)

GPU system

- Number of users
  25 (at the end of the fiscal year)

General-Purpose PC farm

- Operating hours
  Annual operating hours: 8688 (a ballpark figure)
  Total number of submitted PBS jobs: 1331769
  Annual core operation ratio by users' PBS jobs: 98 % (a ballpark figure)
- Number of users
  69 (at the end of the fiscal year)

(3) Tutorials and Users Meeting

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

- Tutorial sessions for iSALE (WebEx + Slack)
  Lecture and hands-on training on the basics of the iSALE shock physics code
  June 17 - July 15, 2022
  10 attendees (+ 2 Associate Professors [Senior Lecturers] from outside NAOJ)
- Cray XC50 workshop for novice users (zoom)
  Introduction to the basic usage of XC50 for novice users
  August 22, 2022
  12 attendees
- Cray XC50 workshop for intermediate users (zoom)
  Introduction to debugging, performance analysis, and optimization of XC50 for intermediate users
  August 23, 2022
  10 attendees
- CfCA Users' Meeting (Onsite + zoom + Slack)
  Presentation of research results using the open-use facilities

in this department, and discussion of the operation of the equipment
January 26–27, 2023
January 26: 44 attendees (Onsite) + 62 (Online),
January 27: 36 attendees (Onsite) + 66 attendees (Online)
• Early spring school for N-body numerical simulations (zoom + Slack)
Lectures on N-body simulations, and programming practice using GPU and GRAPE-Library
February 6–9, 2023
14 attendees (for hands-on training and lectures), 1 attendees (for lectures only)
• GPU Workshop1 (zoom + Slack)
Lectures on CUDA programming basics and introduction of Singularity container
June 29, 2022
19 attendees
• GPU Workshop2 (zoom + Slack)
Implementation of fluid dynamics calculations and N-body simulations
January 17, 2023
26 attendees
• Numerical simulation school for hydrodynamics (Onsite + zoom + Slack)
Lectures on numerical magnetohydrodynamics and practice for MHD numerical simulations
February 20–23, 2023
15 attendees (Onsite) + 29 attendees (Online)

3. PR Activity

In FY 2022, the following press releases were issued from the center:
• "Massive Stars Moving around in Star Clusters"
June 8, 2022, Michiko S. Fujii (The University of Tokyo), Kohei Hattori (NAOJ/the Institute of Statistical Mathematics) et al.
• "Artificial Intelligence Solves the Mysteries of the Universe"
July 21, 2022, Yosuke Kobayashi (The University of Arizona), Takahiro Nishimichi (Kyoto University) et al.
• "Is Over-Eating to Blame for Bulges in Milky Way Bar?"
September 9, 2022, Junichi Baba (NAOJ)
• "Rare Earth Element Synthesis Confirmed in Neutron Star Mergers"
October 27, 2022, Nanae Domoto, Masaomi Tanaka (Tohoku University) et al.
• "Gold-rich Stars Came from Ancient Galaxies"
November 14, 2022, Yutaka Hirai (Tohoku University/ the University of Notre Dame) et al.

In addition, the following research results and news appeared on the CfCA website in Japanese only:
• "Chaotic Motions of Jupiter and Saturn are Key to the Formation of the Terrestrial Planets"
March 29, 2023, Patryk Sofia Lykawka (Kindai University), Takashi Ito (CfCA)

CfCA organized the following three events at the Iwate Galaxy Festa 2022, which was held from August 20 to 28, 2022.
• "Supercomputer "ATERUI II" Online Tour"
August 27, 2022, Navigator: Tomoya Takiwaki (CfCA), Live streaming on YouTube.
• Public Lecture "Light and Shadow of a Black Hole Explored by Simulation"
August 27, 2022, Speaker: Tomohisa Kawashima (ICRR/UTokyo), Live streaming of the on-site event (Oshu Space Museum Seminar Room) on YouTube.
• CfCA Research Poster Exhibition and Visualization Video Screening
August 20–28, 2022, at Oshu Space Museum Seminar Room.

On October 29, 2022, the Mitaka Open House Day 2022 was held, and two videos were premiered on the YouTube channel in collaboration with 4D2U. (See "4. 4D2U Project")

A Twitter account @CfCA_NAOJ and YouTube channel have been operated to provide the information on CfCA.

4. 4D2U Project

In FY 2022, the 4D2U project continued to develop and provide movie content and software.

The following simulation visualization videos were made available.
• "Massive Stars Moving around in Star Clusters"
June 9, 2022, simulation: Michiko S. Fujii (The University of Tokyo), visualization: Takaaki Takeda (NAOJ), visualized for press release.
• "Is Over-Eating to Blame for Bulges in Milky Way Bar?"
September 9, 2022, simulation: Junichi Baba (NAOJ), visualization: Hirotaka Nakayama, visualized for press release.
• "Gas Disk around a Black Hole"
January 31, 2023, simulation: Hiroyuki R. Takahashi (Komazawa University) and Ken Ohsuga (University of Tsukuba), visualization: Hirotaka Nakayama, released flat, fulldome, VR versions as 4D2U movie contents.
• "Formation of a Multiple-Star System"
March 9, 2023, simulation: Tomoaki Matsumoto (Hosei University), visualization: Hirotaka Nakayama, released fulldome and VR versions as 4D2U movie contents.

In addition, we continued development of the four-dimensional digital universe viewer "Mitaka" and released the following versions.
• Version 1.7.3
July 6, 2022, This version includes an enhanced planetarium mode and improved reproduction of planetary visibility and lunar eclipses.
• Version 1.7.4
February 28, 2023, This version adds features such as the display of terrestrial scenery in planetarium mode and the ability to specify constellation and asterism lines in three dimensions.

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

For the Mitaka Open House Day 2022, the following Japanese videos were premiered on YouTube as a joint project with CfCA.

• 4D2U video introduction by researchers "Asteroid Collisions and Shape Evolution"

Speaker: Keisuke Sugiura (ELSI, Tokyo Institute of Technology), Satoki Hasegawa (4D2U)

• Mitaka introductory video, "A 'special' space tour by the Mitaka developer (part 2): Visualization of the Milky Way"

Speaker: Tsunehiko Kato (4D2U)

In addition, we exhibited at the following events:

• "Innovation Japan 2022"

October 4–31, 2022, A visualization technology developed by Hirotaka Nakayama, "CG rendering method for stress-free stereoscopic viewing on an omnidirectional 3D display," exhibited online.

• "Kashiwanoha Innovation Fes 2022"

October 29–30, 2022, Mitaka demonstrations by Satomi Hatano and Tsunehiko Kato. Held at Kashiwanoha Conference Center.

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

5. External Activities

(1) Joint Institute for Computational Fundamental Science

The Joint Institute for Computational Fundamental Science (JICFuS) is an inter-organizational institute established in February 2009 as a collaboration base between three organizations including the Center for Computational Sciences (CCS) of the University of Tsukuba; the High Energy Accelerator Research Organization, known as KEK; and NAOJ to provide active support for computational scientific research. This organization continues to expand: 8 institutions joined in 2016, and 13 institutions in 2020. CfCA forms the core of NAOJ's contribution to JICFuS. In particular, the institute engages primarily in computer-aided theoretical research into the fundamental physics in elementary particle physics, nuclear physics, astrophysics, and planetary science. The scientific goal of the institute is to promote fundamental research based on computational science to encourage interdisciplinary research between these fields. In addition to its ability as a single organization, a major feature of the institute is the cooperation of each community to provide considerate and rigorous support to present and future researchers. Another important mission of the institute is to provide researchers around Japan with advice regarding efficient supercomputer use and the development of novel algorithms for high-performance computing to meet research goals from the perspective of computer specialists. In addition, JICFuS was chosen as the organization responsible for "Priority Issue 9 to be Tackled by Using the Post-K Computer" in FY 2014. From FY 2020, JICFuS performs two new programs: Programs for Promoting Research on the Supercomputer Fugaku. One is "Simulation for basic science: from fundamental laws of particles to creation of nuclei" and the other is "Toward a unified view of the Universe: from large scale structures to planets." CfCA mainly joins the second one.

This year, Eiichiro Kokubo conducted research on "Accumulation of Microplanets and Planet Formation in Protoplanetary Disks" using N-body and SPH codes. Kazunari Iwasaki conducted research on "Formation of molecular clouds and molecular cloud cores in the Milky Way and global magnetohydrodynamic simulation considering solid particles in protoplanetary disks" using a mesh-type fluid code. Mami Machida conducted research on "black hole accretion disks and relativistic jets," and Tomoya Takiwaki conducted research on "Elucidation of the mechanism of 3D supernova explosions by first-principles calculations of neutrino radiation transport," both using a mesh-type fluid code. These four projects are still in the process of tuning the code in preparation for the large scale run on Fugaku. In addition, the budget was used to buy GPUs and increase the storage capacity in order to analyze and store the huge amount of data that will be generated in future large-scale calculations.

Representing CfCA, Professor Eiichiro Kokubo and Associate Professor Tomoya Takiwaki of NAOJ participate in bimonthly JICFuS steering committee meetings to engage in deliberations on spurring computational-science-based developments in astrophysics research through discussions with other committee members who specialize in nuclear and elementary particle physics.

(2) HPCI Consortium

As a participant in the government-led High-Performance Computing Infrastructure (HPCI) project since its planning stage in FY 2010, the center has engaged in the promotion of the HPC research field in Japan, centering on the use of the national "K" and "Fugaku" supercomputers. Note that although the center is involved with the activity at JICFuS mentioned in Section 5.1, the activity in the HPCI consortium is basically independent from it. The HPCI consortium is an incorporated association established in April 2012, and the center is currently an associate member that is able to express views, obtain information, and observe overall trends in the planning, although we are devoid of voting rights as well as the obligation to pay membership fees. Continuing from last year, a number of conferences and WG's have been held where participants discussed a next-generation national supercomputing framework. The national HPC flagship supercomputer, "Fugaku," has already been put into full-scale service, and there is much scientific discussion on how the user community should make the best use of this equipment.

6. Staff Transfers

(1) Staff members hired in this FY

Project Research Staff: Ideguchi, Shinsuke

Project Research Staff: Nozawa, Takaya

Project Research Staff: Keszthelyi, Zsolt

Research Supporter: Kimura, Chie

(2) Staff members who departed in this FY

Senior Specialist: Kato, Tsunehiko

Project Research Staff: Taki, Tetsuo

Project Research Staff: Nozawa, Takaya

Research Supporter: Ideguchi, Shinsuke

06. ALMA Project, NAOJ Chile, and ASTE Project

The ALMA project is a global partnership of East Asia (led by Japan), Europe, and North America (led by the United States) in cooperation with the Republic of Chile to operate a gigantic millimeter/submillimeter radio telescope deploying 66 high-precision parabolic antennas in the 5000-m altitude Atacama highlands in northern Chile. ALMA achieves a spatial resolution nearly ten times higher than that of the Subaru Telescope and the Hubble Space Telescope. Early scientific observations with ALMA began in FY 2011 with a partial number of antennas and full operation commenced in FY 2012. The 10th anniversary of the start of full operation was held in FY 2022, with a formal ceremony at the ALMA site and participation from all the regions, local authorities, and local communities. The ALMA 2 project will start from FY 2023. By continuing scientific observations and upgrading its observational capabilities, ALMA will continue to lead world astronomy in the coming decade. This report describes the progress of the ALMA project, which includes the results of the open-use scientific observations and public outreach activities.

The ASTE telescope is a single-dish 10-m submillimeter telescope located at Pampa la Bola in the Atacama highlands where ALMA is also located. It has been operated in the Southern Hemisphere to make headway into submillimeter astronomy that explores the spectrum invisible to the human eye, providing various possibilities and future prospects for research and development of ALMA. This report describes the progress of the ASTE telescope as well.

The mission of the NAOJ ALMA Project is to: implement the functions of the East Asian ALMA Regional Center, which provides support for users in East Asia; coordinate international project activities based on global partnership; formulate future project plans; and make budget requests. On the other hand, the mission of NAOJ Chile is to: take appropriate safety and security measures for Chile-based staff members and their families, and establish an environment where they can engage in their activities safely and securely; provide the interface in Chile with the Joint ALMA Observatory (JAO), the other ALMA Executives, and Chilean institutions; and establish, organize, and maintain an exchange scheme for scientists and engineers between NAOJ and Chilean universities and institutes.

Under NAOJ Chile, the ASTE project has been promoting and pioneering submillimeter astronomy while providing a platform for new technology development and submillimeter observation data to the scientific community through the operation of the ASTE telescope. In addition, NAOJ established a Study Group for the Next Generation Very Large Array (ngVLA) in FY 2019, under the umbrella of the ALMA Project. The ngVLA Study Group has been assessing, together with the scientific community, scientific opportunities for a possible future contribution from Japan to ngVLA; and has initiated development studies which will allow NAOJ to contribute timely to construction if supported by the Japanese scientific community and budget processes.

1. Progress of the ALMA Project

The 9th round of ALMA open-use observations (Cycle 8) ended at the end of September 2022, with the 2nd highest number of observed hours in a Cycle. Cycle 9 observations started on October 1, 2022, and proceeded smoothly. However, the ALMA observatory in Chile suffered a cyberattack on its computer system on October 29, and observations were suspended. Scientific observations restarted around December 17, after the affected computer system servers and services were rebuilt. During 2018–2022, the ALMA Project established the framework to kick off the implementation of the ALMA2030 wideband sensitivity upgrade (WSU). In November 2022, the ALMA Board approved project proposals for the development of a second-generation correlator led by North America and a new data transmission system (DTS) led by East Asia in cooperation with North America. Regarding the development of new instrumentation, the production of Band 1 receivers was completed in Taiwan, and the commissioning review in November 2022 was successful. The commissioning review of the newly developed spectrometer for the Total Power Array (ACA spectrometer) was passed in November 2022. It is anticipated that Band 1 receivers and the ACA spectrometer will be used for PI science starting from Cycle 10, which will start in October 2023. In March 2023, ALMA celebrated its 10th anniversary since its inauguration. A ceremony was held at the OSF/AOS on March 13. The number of refereed publications with ALMA data has exceeded 3000. The paper on HL Tau has passed 1000 citations.

2. ALMA Open-Use and Scientific Observations

Cycle 8 observations finished on September 30, 2022. The number of science data acquisitions on the 12-m Array in Cycle 8 was the 2nd highest in ALMA’s history. The subsequent transition to Cycle 9 on October 1 was completed smoothly. For Cycle 9, a total of 1,769 proposals were submitted requesting 27,912 hours of time on the 12-m Array, which is the most ever requested in a single cycle. The main capabilities of Cycle 9 include: interferometric observations using at least forty-three 12-m antennas; ACA observations (interferometric observation with at least ten 7-m antennas and single-dish observation with at least three 12-m antennas); eight frequency bands (Bands 3, 4, 5, 6, 7, 8, 9 and 10); and maximum baselines of 16.2 km. From Cycle 9, longer baseline high-frequency (Band 8, 9, and 10) observations are available, providing the highest angular resolution of ALMA at about 10 milliarcsecond. In addition, fast regional mapping for solar Total Power observations, spectral line VLBI in Band 3, and continuum VLBI capabilities in Band 7 have become newly available from Cycle 9.

During the initial period of Cycle 9, on October 29, the Joint ALMA Observatory in Chile suffered a cyberattack on its computer systems, forcing the suspension of astronomical observations. After the recovery efforts, PI science observations were resumed in mid-December.

ALMA open-use observations have been producing a number of scientific results. The following paragraphs highlight some of the scientific achievements made by East Asian researchers.

An international team of astronomers, led by Yuichi Harikane, an assistant professor at the University of Tokyo, and Akio Inoue, a professor at Waseda University discovered a distant galaxy named HD1, which is about 13.5 billion light-years away. This discovery implies that bright systems like HD1 existed as early as 300 million years after the Big Bang. This galaxy is one of the targets of the James Webb Space Telescope.

A team of astronomers, led by Shinya Komugi, an associate professor at Kogakuin University, discovered for the first time a faint radio emission around a giant galaxy with an energetic black hole at its center by using ALMA data. The radio emission is released from gas that is excited directly by strong radiation from around the central black hole. The result was obtained through high dynamic range imaging. The team expects to understand how a black hole interacts with its host galaxy by applying the same technique to other quasars.

A research team led by Tomohiro Yoshida, a graduate student at the Graduate University for Advanced Studies, SOKENDAI, and Hideko Nomura, a professor at NAOJ discovered that the abundances of different molecular species vary significantly around a site of planet formation by using ALMA data. Using a newly developed method, the team measured the carbon monoxide isotopologue ratio, which can be used as a new "fingerprint" to trace the origins of materials, in the protoplanetary disk around the star TW Hydrae. The team found significant differences in this ratio depending on the region. This new "fingerprint" will provide a new method for understanding where and how the materials of the Solar System and exoplanets were created and transported.

An international team led by Kazuki Tokuda, Project Assistant Professor at Kyushu University/NAOJ, and Toshikazu Onishi, a professor at Osaka Metropolitan University conducted ALMA observations toward massive young stellar objects in the Small Magellanic Cloud, which is characterized by a low abundance of elements heavier than helium, similar to the galaxies 10 billion years ago. The target provides a detailed observational view thanks to its relatively short distance from the Earth. In this study, researchers detected a bipolar gas stream flowing out of the "baby star" Y246 and determined that the molecular flow has a velocity of more than 54,000 km/h in both directions. In the present Universe, growing "baby stars" are thought to have their rotational motion suppressed by this molecular outflow during gravitational contraction, accelerating star growth. The discovery of the same phenomenon in the Small Magellanic Cloud suggests that this process of star formation has been common throughout the past 10 billion years. The team also expects this discovery to bring new perspectives to studying star and planet formation.

At the heart of nearly every galaxy lurks a supermassive black hole. But not all supermassive black holes are alike: there are many types. Quasars, or quasi-stellar objects, are one of the brightest and most active types of supermassive black holes. An international group of scientists (under lead author Hiroki Okino, a Ph.D. student at the University of Tokyo and NAOJ) published new observations of the first quasar ever identified — the one labeled 3C 273, located in the Virgo constellation – that show the innermost, most profound parts of the quasar's prominent plasma jet. This ground-breaking work was made possible by a closely coordinated set of radio antennas around the globe, a combination of ALMA and the Global Millimeter VLBI Array.

Gamma-ray bursts are the most luminous explosions in the Universe, allowing astrophysicists to observe intense, short-duration gamma rays. Gamma-ray bursts are classified as either short or long, with long gamma-ray bursts being the result of massive stars dying. Hence they provide clues about the evolution of the Universe. Gamma-ray bursts emit gamma rays as well as radio waves, optical light, and X-rays. When the conversion of explosion energy to emitted energy, i.e., the conversion efficiency, is high, the total explosion energy can be calculated by simply summing over all the emitted energy. But when the conversion efficiency is low or unknown, measuring the emitted energy alone is not enough. A team of astrophysicists succeeded in measuring a gamma-ray burst's hidden energy by using ALMA and the Very Large Telescope. The team was led by Dr. Yuji Urata from the National Central University in Taiwan and MITOS Science CO., LTD, Professor Kenji Toma from Tohoku University's Frontier Research Institute for Interdisciplinary Sciences, and graduate student Asuka Kuwata from Tohoku University.

The role of the magnetic field in the star-formation process is an extensively debated topic. How strong is the magnetic field? Can it guide material on the way to the star? When and where can gravity overpower the magnetic field? Recently, an international research team led by Patrick Koch at Academia Sinica Institute of Astronomy and Astrophysics (ASIAA), used ALMA to resolve the magnetic field structure in the W51 e2 and e8 high-mass star-forming regions with an unprecedented resolution of 0.1″. Compared to the earliest magnetic field observations in this region with a resolution of 3″, this is an improvement in resolution by a factor of about 1000 in area. This only becomes possible with ALMA's exquisite sensitivity and resolution which now sharpen our view of the magnetic field by a factor of 1000, making visible details as small as 500 au for the first time.

Asako Sato, a graduate student at Kyushu University, and her team used ALMA to reveal fast gas outflows from a baby star strongly colliding with nearby dense gas where a group of baby stars is being born. This result suggests that the outflow collision shakes the cradle of the baby stars and has a significant impact on the ongoing star formation process. This study provides insight into the star formation process within cluster-forming regions where baby stars are born simultaneously in a crowded and complex environment.

An international research team led by Keiichi Maeda, a professor from the Graduate School of Science at Kyoto University, and Tomonari Michiyama, ALMA Joint Postdoctoral Fellow from the Graduate School of Science at Osaka University, discovered the first example of a supernova, known as SN 2018ivc, showing an unprecedented rebrightening at millimeter wavelengths about one year after the explosion by using ALMA. The analysis revealed that the dying massive star ejected a large amount of its envelope due to a strong binary interaction with a companion star that took place about 1500 years before the explosion. In a paper published in The Astrophysical Journal Letters, the team posited that this rebrightening event in SN 2018ivc provides a missing link between supernovae that occur in binary star systems and those that involve solitary massive stars.

3. Educational Activities

The NAOJ ALMA Project continues to collaborate with the Joint ALMA Observatory (JAO) to create and maintain a Japanese version of "ALMA Kids," a website for children, with the aim of providing opportunities for more people to learn about the mechanisms of ALMA and its scientific results in a fun way. ALMA Kids provides up-to-date content for the younger audiences, introducing various results from the latest ALMA observations. However, the "ALMA Kids" website was affected by the cyberattack and it has not been available since then. The final update was done in early September. The Project has developed educational content, mainly targeting elementary school students, called "Why ALMA Workshop" which explains the basics of radio astronomy by combining videos and worksheets. This content is available on the Project website.

The Project continues to release science news posters aimed for the younger generation visiting science centers and planetariums. Two new posters were released in FY 2022. In addition, the Project now provides short anime ("manga") explaining the basics of radio astronomy and interferometry. In FY 2022, this effective medium of manga was also adopted to convey the upgrade of the data transmission system as a part of the Wideband Sensitivity Upgrade (WSU) which will be carried out during the ALMA 2 project phase. All posters and manga are available on the NAOJ ALMA website.

4. Public Outreach Activities

In FY 2022, ALMA scientific observation and development results were covered by 45 newspaper/journal articles, and ALMA was featured by one television program. On December 31, 2022, a staff member of the NAOJ ALMA Project appeared in a web show with an antenna under maintenance at the ALMA Operations Support Facility (OSF) in Chile. The NAOJ ALMA website posted 21 news articles and 6 press releases. Mailing-list-based newsletters have been issued on a monthly basis with approximately 2,000 subscribers. Day-to-day information is posted in a timely manner on Twitter (@ALMA_Japan) with nearly 67,000 followers as of the end of FY 2022. Impressive images are often posted on Instagram, which achieved 10,000 followers.

In FY 2022, 7 lectures were given for the general public, of which one was held online and one was held with the speaker participating remotely. In May-June 2022, the NAOJ ALMA Project exhibited a joint booth with the NAOJ TMT Project at the Japan Geoscience Union Meeting (held both onsite and online). NAOJ ALMA provided video contents for Nobeyama Open House Day held online due to COVID-19. NAOJ Open House Day in Mitaka was held in hybrid style in October. Onsite exhibits of the NAOJ ALMA Project were posters, models of an antenna and the Atacama Desert, virtual tour of Chajnantor, and so on. Workshops for children were not held due to COVID-19. Two lectures were given online.

ALMA's 2014 ground-breaking HL Tau results exceeded 1,000 citations in 2022. The NAOJ ALMA Project actively publicized this record, including posting on the website. Public relations to provide information about JAO's recovery from the cyberattack also played an important role. NAOJ ALMA supported the public relations activities for the 10th anniversary ceremony held in Chile in March of 2023. Also, the planning and preparation of novelty goods has progressed for the 10th anniversary ceremony in Japan scheduled in May of 2023.

From mid-March 2015, ALMA began accepting public visitors to the OSF at an altitude of 2,900 meters, but due to the outbreak of COVID-19 in Chile, it stopped accepting public visits in March 2020. As of the end of FY 2022, public visits remain suspended except for VIPs, Media, and the staff's family and friends.

5. International Collaboration (Committees, etc.)

For the international ALMA project, meetings are held frequently by various committees. In FY 2022, many of the meetings continued to be held online as during FY 2021, due to the COVID-19 pandemic, but by the end of the fiscal year, in-person meetings resumed, including the ALMA Board meeting held face to face in Santiago (Chile) in November. The ALMA Board and the ALMA Scientific Advisory Committee (ASAC) held online meetings as necessary, while the ALMA East Asian Science Advisory Committee (EASAC) held online meetings three times. Meetings were held more frequently by groups in charge of specific tasks to implement the international project in close cooperation.

6. Workshops

- July 5 and 7, 2022: ALMA Data reduction tutorial (introductory level), in collaboration with the Astronomy Data Center, held online
- December 19, 2022: ALMA Grant Fellow Symposium 2022, NAOJ Mitaka Campus and online
- December 20–21, 2022: ALMA/45m/ASTE Users Meeting 2022, NAOJ Mitaka Campus and online
- February 27–28, 2023: ALMA Data reduction tutorial (beginner-intermediate level), held with the Astronomy Data Center, NAOJ Mitaka Campus
- March 7–10, 2023: ALMA BEARS workshop, NAOJ Mitaka Campus

• March 13, 2023: “ALMA 2030: Wideband Sensitivity Upgrade”, Special session in the ASJ 2023 Sprint Meeting, Rikkyo University and online

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

• Yuichi Matsuda: funded by the research support project of the Astrobiology Center (ABC), National Institutes of Natural Sciences (NINS)

8. Changes in Project Researchers

(1) Hired
• Andrea Silva: Project Researcher
• Piyali Saha: Project Researcher
• Takuma Izumi: Project Researcher
(secondment to Tokyo Metropolitan University)
• Anton Feeney-Johansson: Project Researcher
(secondment to the University of Tokyo)
• Sanemichi Takahashi: Project Researcher
(secondment to Kagoshima University)

(2) Departed or transferred
• Takuma Izumi: Project Resarcher
• Hiroyuki Kaneko: Project Resarcher
• Yuki Kudoh: Project Resarcher
• Tom Bakx: Project Resarcher
• Tomonari Michiyama: Project Resarcher

9. Main Visitors

• Apr. 13, 2022: Harumi Takahashi, Parliamentary Secretary for Education, Culture, Sports, Science and Technology (MEXT), visited NAOJ Mitaka Campus.
• May 24, 2022: Hideyuki Tanaka, Vice Minister of Education, Culture, Sports, Science and Technology (MEXT), visited NAOJ Mitaka Campus.
• Dec. 1, 2022: Thomas Zurbuchen, NASA Associate Administrator, visited NAOJ Mitaka Campus.
• Feb. 3, 2023: Ricardo G. Rojas, Ambassador of the Republic of Chile to Japan, visited NAOJ Mitaka Campus.

10. Progress of the ASTE Telescope

The cause of the antenna sub-reflector failure identified last fiscal year (FY 2021) was investigated and examined in cooperation with the manufacturer of the antenna. As a result, we concluded that an on-site inspection by the manufacturer's engineers was necessary. After procuring replacement parts to solve the failure, the ASTE telescope site was reopened in November, and the inspection of the sub-reflector was conducted together with the manufacturer’s engineers. The sub-reflector was restored at the beginning of December, but another failure was soon identified, so the investigation continued until mid-December. Based on the data obtained from the sub-reflector drive system at that time, we are continuing to investigate the cause and measures together with the manufacturer.

We tried to conduct the scientific commissioning operation of the wide IF band Band 8 receiver, the new spectrometer (XFFTS), and the frequency converter (IFDC), which were installed on the ASTE telescope last year (FY 2021) under two Grants-in-Aid for Scientific Research (PI: Oka, Keio University, and Tosaki, Joetsu University of Education), using actual celestial signals. However, due to the sub-reflector failure and bad weather conditions, it was decided to reschedule. The final operation verification test is expected to be conducted in the next fiscal year (FY 2023) after the sub-reflector is restored.

In FY 2022, three peer-reviewed papers were published, including 1 paper written by domestic researchers and two by overseas researchers. The decrease in the number of papers published was unavoidable due to the suspension of scientific observations due to the COVID-19 pandemic between FY 2020 and FY 2021 and the sub-reflector failure in FY 2021.

07. Gravitational Wave Science Project

The 4th International Gravitational-Wave Joint Observation (O4) was repeatedly postponed due to COVID-19 and natural disasters, and will finally be carried out for a net year and a half starting on May 24, 2023. The Large-scale Cryogenic Gravitational Wave Telescope KAGRA, which NAOJ is promoting with the Institute for Cosmic Ray Research (ICRR) of the University of Tokyo and the High Energy Accelerator Research Organization (KEK), aims to participate in O4 at the start (O4a) with a sensitivity in the binary neutron star merger range of 1–3 Mpc. In FY 2022, we made large efforts for instrument modification and interferometer commissioning to realize this goal.

The GWSP also began in earnest discussions on the development of next-generation gravitational wave telescope technology utilizing the TAMA300 facility, and launched new R&D initiatives and a framework for international cooperation.

1. Gravitational Wave Telescope, KAGRA

NAOJ GWSP plays an important role in the operation and management of KAGRA as one of the promoting organizations under the “Memorandum of Understanding on Promotion of Gravitational Wave Astronomy Using the Large-scale Cryogenic Gravitational Wave Telescope, KAGRA”. In particular, the GWSP is in charge of the Low Frequency Vibration Isolators, Auxiliary Optics, Mirror Evaluation, and Main Interferometer, and also contributes to the operation by providing members to the Executive Office, System Engineering Office, etc.

The main initiatives for FY 2022 were as follows.

(1) Main Interferometer and Commissioning
Overhaul work was completed for O4, including reinstallation of the Output Mode Cleaner and additional monitoring of the interferometer optical axis. Commissioning then proceeded, and the Power-Recycled Fabry-Perot Michelson interferometer was successfully put into operation. The problems of noise contamination in the vibration isolator and angular stability of the mirror, which had limited the sensitivity of the previous observation, were largely resolved, and the target sensitivity and operation stability for O4a were achieved.

(2) Vibration Isolation Systems: All of the vibration isolation systems (4 types, 19 units in total) were tested, their problems were corrected, and their control was optimized. In addition, a folding pendulum accelerometer was manufactured and evaluated in cooperation with ATC. This will be installed in KAGRA in the future.

(3) Auxiliary Optics: A total of 14 medium size optical baffles with vibration isolators were installed in the vacuum chambers to prevent stray light. In addition, the optical axis and stray light countermeasures of various input and output optical systems were reviewed, and the installation of the necessary steering mirrors and beam shields was completed.

(4) Mirror Evaluation: In order to replace the input-side sapphire mirrors (ITMs) of KAGRA with higher performance ones in O5, we started ITMs remanufacturing. Five Korean sapphire crystals were evaluated for optical absorption and birefringence, and the two best ones were selected and shaping processing was conducted. The GWSP also began new work on the development of a scattered light measurement system, birefringence measurement system, and spectroscopic analysis.

(5) Others: Various sensors installed in KAGRA contributed to KAGRA's noise hunting. In addition, two units of PCAL, a photon pressure calibrator for GW signals, were put into operation to enable automatic operation. Calibration of the calibrator itself is being performed continuously and has greatly improved stability compared to O3.

2. R&D in TAMA300 and ATC

Development of cutting-edge technologies for gravitational wave telescopes is underway at the TAMA300 first-generation interferometric gravitational wave antenna and the ATC laboratory at Mitaka Campus.

(1) Development of frequency-dependent squeezing (FDS) technology: Using TAMA300, we are developing a quantum optics technique called FDS to improve the sensitivity of gravitational wave telescopes over a wide bandwidth; in FY 2022, we specifically studied backscattering and mode mismatch loss to implement FDS at KAGRA.

(2) Detector R&D: In order to greatly improve the sensitivity of gravitational wave detectors in the future, a control method for Speedmeter-type interferometers is being studied. The theoretical analysis of the control has been published as a paper, and a proof-of-principle experiment will be conducted in the future. We are also discussing future applications of TAMA300, such as construction of a high-frequency specialized interferometer using Long-SRC, EPR Entanglement Squeezing, and so on.

3. Education

Two students of the Department of Astronomy at the University of Tokyo, one student commissioned by Tokyo Tech, and one research student from overseas are currently enrolled in the group and are supervised. With the increase in the number of students, the introduction of research papers in the group was renewed for the education of students. In graduate school and university education, lectures at Hosei University and the Graduate School of the University of Tokyo were given. In addition, social education activities such as “FUREAI (Friendly)

Astronomy” and visiting lectures at high schools were provided.

4. Outreach

Virtual tours of TAMA300 and KAGRA were conducted during the open house, and the KAGRA tour video was made available on YouTube. In addition, with black holes attracting much attention, a Japanese language article on gravitational wave black hole observations titled “New Eyes” was published in NAOJ News. In addition, a press release on the research on dwarf novae conducted by one of our master’s students as an undergraduate student and an article in the Wakayama Shimpo newspaper covering the “FUREAI (Friendly) Astronomy” lecture were posted as topics on the web page.

5. International Collaboration and Visitors

Due to COVID-19, the number of overseas visitors remained low (six), as in the previous year. Collaborations progressed with CNRS/APC (France), iLM (France), National Tsing Hua University (Taiwan), Myongji University, and KASI (Korea), with which international research exchanges have been active for a while.

6. Publications, Presentations, and Workshop Organization

The number of peer-reviewed papers published in international journals whose authors were members of GWSP was 24. The number of non-refereed papers was 2 in European journals and 4 in Japanese journals. There were 24 reports of lectures given at international conferences and 34 reports of conference presentations. There were no other reports of presentations or other publications in English or Japanese.

7. Acquisition of External Funds

In FY 2022, no external funds other than scientific research funds were obtained.

8. Staff Changes

- Michael Page (JSPS Foreign Research Fellow → Project Researcher)
- Marc Eisenmann (JSPS Foreign Research Fellow → Project Researcher)
- Rishabh Bajpai (Joined as Research Support Staff (Kakenhi))
- Naho Sakaguchi (Joined as Administrative Support Staff at Kamioka Branch)
- Mariko Doi (Joined as Administrative Expert at Mitaka Office (GWSP & JASMINE))
- Matteo Leonardi (Retirement → Associate Prof. in Trent Univ., Italy)
- Naoki Aritomi (Retirement from Project Researcher → Researcher at Caltech)
- Mie Ueda (Retirement from Administrative Expert in Mitaka office)

08. Thirty Meter Telescope Project

The Thirty Meter Telescope (TMT) Project is the work of an international collaboration to build an extremely large 30-meter telescope (Figure 1). For Japan's part, with the National Institutes of Natural Sciences (NINS) as an ultimately responsible body, NAOJ serves as an executing institute. In 2014, an agreement was concluded among participating organizations to found the TMT International Observatory (TIO) for the purpose of the construction and operation of the observatory; the construction was subsequently commenced. Japan is responsible for the production of the telescope primary mirror, the design and production of the telescope structure as well as its on-site installation and adjustment, and the design and production of science instruments. Heading the project for Japan is the TMT Project at NAOJ.

In Hawai‘i where TMT is slated to be built, with the State of Hawai‘i's approval of a Conservation District Use Permit (CDUP) for TMT construction on Maunakea in 2017, on-site construction was planned to start in FY 2019. However, demonstrations and a road blockade by those opposed to construction of TMT on Maunakea prevented full-fledged construction work at the summit region. Currently, TIO continuously engages with broader communities in Hawai‘i for building trust through direct dialogue, educational programs, and other community activities together with relevant organizations. As a TIO member, NAOJ actively takes part in these activities. The Hawai‘i State Legislature passed a bill that established a new management body called Mauna Kea Stewardship and Oversight Authority (MKSOA) with an overwhelming majority. The U.S., the Decadal Survey released in FY 2021, which is a report of the research community that identifies priorities for the coming decade, ranked a joint program called the U.S. Extremely Large Telescope Program (the US-ELT Program), including the TMT project, as a top priority for ground-based astronomy. In response to this outcome, the National Science Foundation (NSF) held a Preliminary Design Review (PDR) in FY 2022, which ended with favorable feedback from its external panel. As described below, NSF is currently conducting a review process to evaluate environmental effects, and is also assessing impacts on historic properties under Section 106 of the National Historic Preservation Act, in addition to the process toward a Final Design Review (FDR). Seeing major progress in the situation in Hawai‘i and NSF's possible investment of the U.S. federal funding in the project, TIO, NAOJ, and the other participating members are focused on essential activities in the overall process, including those that will pave the way to full-fledged construction once on-site construction restarts, while minimizing their expenditures.

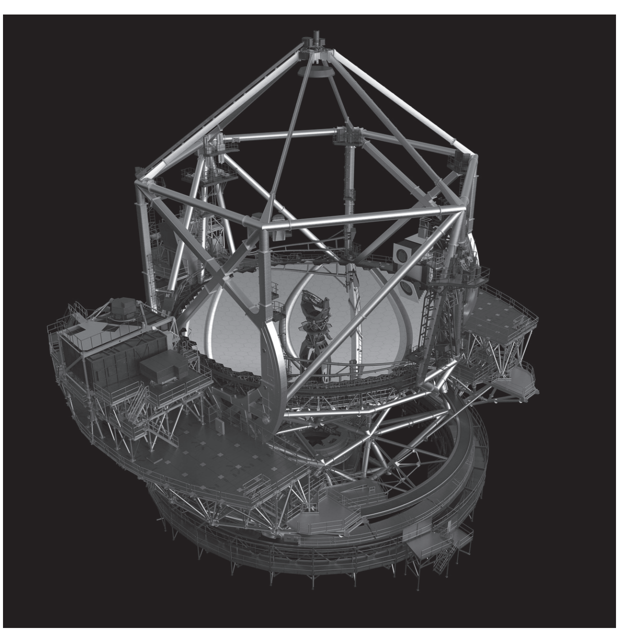


Figure 1: Rendering of TMT Telescope Structure Image. (Credit: TIO)

1. TMT Project Progress and Status of Construction Site

The construction of TMT is led by TIO established in 2014 and the participating countries and organizations (NINS, the University of California, the California Institute of Technology, the National Research Council of Canada, the Department of Science and Technology of India, the National Astronomical Observatories of the Chinese Academy of Sciences). Along with them, as the process is underway for NSF's participation through the federal funding, the U.S. Association of Universities for Research in Astronomy (AURA) participates as an Associate Member.

TIO, operated according to deliberations and decisions by the TIO Board of Governors, is overseeing the construction work performed at the institutes, as well as developing the on-site infrastructure. The Board of Governors convened a total of 5 meetings in FY 2022 mainly to discuss activities aimed at NSF's investment of the federal funding and issues relating to resumption of on-site construction, with 3 representatives from Japan in attendance: Director General Tsuneta, Vice-Director General Yoshida, and NAOJ TMT Project Manager Usuda. Several working groups were created under the Board of Governors to consider efforts for construction in Hawai‘i, as well as issues of the project operation, by holding meetings as frequently as in the previous fiscal year. One of them is the Business Plan Working Group chaired by the NAOJ Director General. This working group held 10 meetings to assess in detail the status and evaluation of members' in-kind contributions; and proposals to NSF which included TIO's funding plan based on that assessment. All the meetings were held online.

The U.S. Decadal Survey for astronomy and astrophysics decennially evaluates and identifies the most compelling challenges in the field of astronomy. According to the report published in 2021, the US-ELT Program, which will allow all-sky observation through TMT and the Giant Magellan Telescope (GMT, a telescope with an aperture of 24 meters currently under construction in Chile) working in concert, was ranked as a top priority for ground-based astronomy. In response to the survey results, NSF conducted the PDR for the US-ELT Program proposed by TIO along with NSF's National Optical-Infrared Astronomy Research Laboratory (NSF's NOIRLab) and GMT. The first part of the review of the TMT project was carried out in December 2022, focusing on the technical and outreach activities, followed by the second part in January 2023 to assess the project's management, costs, and schedule risks. The NAOJ TMT Project fully worked with TIO for both parts of the review. The review panel highly evaluated the technical portion, which includes Japan's telescope structure and other in-kind work, and the engagement activities in Hawai‘i. It concluded that the project was all ready for advancement to the final design phase of development while indicating that there were some outstanding issues on technical readiness, management, and schedule risks to be resolved by the FDR. Passing the PDR is an important step for inclusion in a future NSF budget request for construction funding. The budget request will need to be deliberated and passed by Congress and will then be signed into law by the President before NSF can fund the project. NSF will need to complete the FDR, the environmental review process, and the Section 106 consultation process under NHPA. Then, a Record of Decision will be published to announce NSF's decision. In addition to the proposal for the construction fund, TIO submitted proposals to NSF for funding the design and development of the primary mirror control, the secondary mirror, and other systems.

As for the situation in Hawai‘i, a CDUP was approved for the TMT planned site on Maunakea in September 2017, but demonstrations staged by those opposed to TMT on Maunakea, including a road blockade, prevented the full-fledged construction in July 2019. TIO recognized it had neither well understood the social issues behind the demonstration nor engaged in dialogue with broader communities in Hawai‘i, which had led to the failure to fully build trust with the Hawai‘i community. The Board of Governors decided on phased relocation of the TIO headquarters from Pasadena, California, to Hawai‘i, with the first step taken to relocate the Project Manager to the Island of Hawai‘i in June 2021 to start community-based activities. The NAOJ TMT Project Manager also moved to Hawai‘i Island in July 2021 to fully contribute to TIO's community engagement activities with an NAOJ Senior Specialist based in Hawai‘i who is currently seconded to TIO. In particular, they played a major role in developing and implementing a tutoring program for a broader array of communities as part of TIO's community engagement. Through dialogue with the communities, a strong need was expressed for educational support for children, in particular, those from low-income families. TIO started tutoring activities at schools that Maunakea observatories had not engaged in before, which generated great interest among local communities. This tutoring program was incorporated in the design and development proposal submitted to NSF, where the NAOJ staff were committed to its formulation.

In May 2021, the House of Representatives of the Hawai‘i State Legislature created a working group to discuss a new management structure for Maunakea, which subsequently released a report of recommendations in December. Based on the recommendations of the working group, a bill started to be deliberated at the state legislature in January 2022 for the creation of a new management structure that aims to particularly engage with the Native Hawaiian community. The bill was signed into law by the Governor in July 2022 (Act 255). In September 2022, 11 members for the new management structure, called Mauna Kea Stewardship and Oversight Authority (MKSOA), were appointed, some of whom were recommended by the heads of the Senate and House of Representatives, and the Maunakea Observatories. Their activities started in November to discuss the roles of the members, rules, schedules, and other matters by holding a monthly meeting.

In July 2022, NSF published a notice of intent to initiate the environmental review process and the Section 106 process under NHPA. Along with this, a draft Community Engagement Plan was released to help guide meaningful and effective engagement with the Hawai‘i community and other interested members of the public. Four public scoping meetings were held in Hilo, Na‘alehu, Kona, and Kamuela (Waimea) in August, and public comments were solicited by September. Reviewing more than 7,000 comments received, NSF is currently conducting the environmental review process and the Section 106 process under NHPA.

As for the alternative site on the island of La Palma of the Canary Islands in Spain, which was selected in 2016, the process for all permits needed for construction was completed in November 2019, including an environmental impact assessment. In an administrative appeal against the land concession, a court determined in July 2021 that there was a procedural problem, and annulled the concession, against which TIO appealed together with a local government and a local research institute. In September 2022, the Superior Court of Justice of the Canary Islands issued a judgment upholding TIO's appeal, declaring that the land concession is legal and valid. NAOJ expresses its support for relocation to La Palma in the case that construction in Hawai‘i becomes infeasible, provided that the project is expected to receive U.S. federal funding.

2. Japan's Progress on its Work Share – Development of Telescope Structure, Primary Mirror, and Science Instruments

For the construction of TMT, Japan is responsible for essential components of the telescope in accordance with the executed agreements: the design and production of the telescope structure and its control system; the manufacturing of the primary mirror; and the production of portions of the science instruments which are developed through international partnerships. While the restart of on-site construction is halted, Japan focused on designs and preparation for production in FY 2022, concentrating its efforts on essential work for the overall process instead of production. In FY 2022, the progress below was made.

(1) Manufacturing of Primary Mirror Segments

The TMT primary mirror, comprised of 492 segment mirrors, requires the manufacturing of 574 segment mirrors in all, with the replacements during mirror coating included. The process of manufacturing mirror segments is: fabrication of the mirror blanks, spherical grinding of the front and back surfaces, aspherical grinding and polishing of the front surface, hexagonal shaping, and mounting of the mirror segments onto support assemblies. It is followed by the final surface finish to be completed in the U.S. and coating with reflective metal to be performed on-site, before the mirror segments are finally installed on the telescope.

Of the above process, the plan calls for Japan to fabricate all the mirror blanks and to perform spherical grinding on all 574 segment mirrors. With the share of work for the processes beginning from aspherical grinding and polishing and ending with the mounting of the mirror segments on support assemblies distributed to other participating overseas institutes as well, Japan is leading this work for 175 of the mirror segments. In FY 2022, NAOJ's primary mirror team identified and examined a measure to protect the mirror surface when the hexagonal shaping work is performed. This is part of the effort to facilitate production of the primary mirror segments when full-fledged manufacturing of the segments is resumed, without affecting the entire schedule. As a result of their work, they singled out a possible protection coating to be used for large-scale production by choosing candidates and measuring the degree of deterioration after soaking them in the fluid used for the grinding process. The team was also devoted to developing a method to overcoat with epoxy resin the protection coating that had been stripped in a past trial. The experiment found that this can be a prospective method to be employed. In addition, a load test was carried out on an adhesive-bonded part to simulate the transport of segments to the U.S. after support assemblies were mounted on them, which confirmed no issues were observed.

(2) Design and Production of Telescope Structure and Its Control System

Japan is responsible for the design and production of the telescope structure, as well as its control system, which functions as a mount for the primary mirror, other optics systems, and science instruments, and points them in the direction of target astronomical objects. Following the baseline and detailed designs developed by FY 2016 and preparation for fabrication in FY 2017, FY 2018 saw the launch of the fabrication process for the telescope structure. In FY2022, continuing on from the previous fiscal year, with an eye toward production readiness reviews scheduled before full-scale production, the work was focused on the completion of interface documents and the development of production drawings. Two production readiness reviews (PRR2 and PRR3) were conducted to examine the main rotating mechanical structures that move around the azimuth and elevation axes, as well as the Nasmyth structure where the science instruments and other systems will be placed (Figure 2).

(3) Science Instruments

Steady progress was made through international collaboration in the design and fabrication of three first-light science instruments, which will be commissioned once the telescope is complete.

One of them is IRIS which stands for an InfraRed Imaging Spectrograph. Being in charge of its imager, Japan continues to engage in development that includes designing and prototyping in cooperation with the Advanced Technology Center. In FY 2022, the work was focused on action items indicated by the final design review of the imager held in FY 2021, and on preparation for a final design review of the entire instrument which is scheduled for FY 2024. The action items identified in the previous year's review were followed up by the team mainly through: modeling of the vibration analysis for the combined Narrow Field InfraRed Adaptive Optics System (NFIRAOS) and IRIS system, and the derivation of its transfer function; thermal analysis of the imager; verification of the position sensor's precision, production of a part that will be used for a mechanical interface to the vacuum chamber and its strength testing; and establishment of a structure to conduct experiments in collaboration with Tohoku University for assessing the performance of HAWAII-2 which will function as a detector used for the pupil optics. In order to prepare for the upcoming review, the team performed a system-level failure modes and effects analysis, and defined requirements by simulation for conceptual and preliminary designs of an optical simulator that will be used for performance assessment of the imager and the integral field spectroscope. Also, in June 2022, as U.S. manufacturer Teledyne may suspend the production line of an infrared detector that is intended to be used for the imager, NAOJ's IRIS team played a leading role in a trade study for alternative detectors in cooperation with the IRIS international team.

A Wide Field Optical Spectrometer or WFOS began the preliminary design phase in FY 2022, following the successful passage of the conceptual design review in FY 2021. Further progress was made in FY 2022. NAOJ's WFOS team performed

Figure 2: Two Production Readiness Reviews (PRR 2 and PRR3) for TMT's structure, which were held in person, were successfully completed in February 2023.

a trade study for the slitmask exchanger with the California Institute of Technology, and also explored the feasibility of manufacturing a large-scale optical glass substrate and a Volume Binary Grating. Their work also advanced optical and mechanical designs for the integral field unit, which is planned as future work, and examined where to place the unit within WFOS.

A Multi-Objective Diffraction-limited High-Resolution Infrared Spectrograph (MODHIS) is expected to pioneer the field of exoplanets, on which the U.S. Decadal Survey placed an emphasis. With its project management led by an NAOJ Associate Professor, MODHIS kicked off the first phase of a conceptual design in 2021 in partnership with the California Institute of Technology and the University of California, Los Angeles and San Diego. This phase aims to clarify the concept of the adaptive optics to be combined with the instrument and develop a conceptual design of the interface to TMT adaptive optics. The team's efforts also go into defining scientific and technical requirements to be satisfied by MODHIS. With the sights set on establishing an international development team, the Astrobiology Center's role in the MODHIS development is currently under consideration.

NAOJ staff who are based at the NAOJ California Office in Pasadena engaged in TIO's development activities. Their contributions are a considerable asset for TIO's work, including development of the control system for the primary mirror's segments, and development of user interface software for testing. They took part in extensive activities; one of the staff played a major role in developing a conceptual design of a coating facility for the secondary and tertiary mirrors, which was reviewed by another NAOJ staff member. Also, one of them served on a preliminary design review of maintenance, cleaning, and operation of mirror segments.

3. Planning of TMT Science, Instrumentation, and Operation with Research Communities

TIO's Science Advisory Committee, consisting of researchers from the participating countries and institutions, discusses science programs and instrumentation envisioned with TMT. In FY 2022, 3 meetings were held online, attended by 4 university researchers and the NAOJ TMT Project Manager on behalf of Japan. In view of the preliminary design review for potential participation by NSF, the committee held joint science meetings with GMT. As for development of instruments through international partnerships, a subcommittee on observation of exoplanets with TMT, chaired by University of Tokyo Professor Norio Narita, discussed research themes based on results of surveys conducted in each country. A sub-working group, created for development of a science operations plan once the telescope is completed, was attended by NAOJ Professor Wako Aoki. In December 2022 and January 2023, the TMT webinar was convened to provide information on the status of the project and the updating work of a document called the Detailed Science Case that describes the science that TMT will enable.

The TMT Science Advisory Committee, which is a domestic committee consisting of 13 researchers from universities and other institutes, reviewed issues of science programs, instrumentation, and operations. In FY 2022, NAOJ's funding program for research and development of TMT science instruments adopted 6 proposals to carry out research for development by 28 researchers at 12 universities and research institutions. To provide detail on new capabilities that will be brought by a suite of TMT next-generation instruments, the Roadmap to realize TMT next generation instruments was prepared by committee members and researchers. This roadmap was released to a wide range of communities. One of the meetings was convened at the University of Tokyo in March 2023, where a session for sharing information on TMT and the Subaru Telescope was open to anyone, including students.

More meetings were actively organized to explain the status of the project and engage in discussions for larger communities of astronomy in Japan. The NAOJ TMT Project held a workshop in June 2022 to keep participants informed on the status of the project and developments in Hawai'i, as well as the release of the above-mentioned development roadmap. The report on the project was provided at the annual meeting of The Astronomical Society of Japan, as well as a series of meetings which were attended by researcher communities of a broader range of fields, such as radio astronomy, theoretical astronomy, and high-energy astrophysics, in addition to the community of optical and infrared astronomy. The NAOJ Director General took a lead in providing an update on the project at all the meetings for the astronomy and astrophysics subcommittee of the Science Council of Japan and the Science Advisory Committee.

4. Public Relations, Outreach, and Education

Information on the TMT Project is provided on NAOJ's TMT Project website with a focus on updates regarding the situation at the Maunakea construction site and the work share progress made by Japan. Additionally, TMT Newsletters No.74 through 78 were delivered.

The outreach activities, which mostly had shifted from in-person to online lectures and classes in FY 2020 due to the COVID-19 pandemic, continued to capitalize on online opportunities in FY 2022, including a program of NAOJ called FUREAI (Friendly) Astronomy, which offers school children in Japan and overseas opportunities to learn about astronomy directly from astronomers. Some of the events took place in-person. There was a total of 48 sessions of lectures for the public and classes on demand.

Many events in Hawai'i, where TMT is slated for construction, gradually returned to in-person. The NAOJ TMT Project provided on-demand lectures in a science/technology education and PR event called "Journey Through the Universe" in FY 2022. It also offered hands-on activities at AstroDay, an event jointly organized with other observatories and science-related organizations in Hawai'i to invite the local community to explore the science happening on their home islands. In

Figure 3: The Hawaiian Kupuna leads the group of Maunakea Observatories at the Merrie Monarch parade held on Hawaiʻi Island in April 2022.

addition, through in-person dialogues with wider communities and in collaboration with community partners such as public schools and the State Department of Education, an after-school tutoring program for children, and workforce development programs for students are now among the core engagement activities. This partnership further established the after-school tutoring program, internship opportunities, a cultural exchange program, and environmental activities in the proposals to NSF. (Figure 3).

5. Organization

By the end of the fiscal year, three Professors, one Project Professor, six Associate Professors, two Assistant Professors, two Research Engineers, and a Senior Specialist, who is seconded to TIO, held positions in the NAOJ TMT Project. In addition, one Professor, two Associate Professors, one Senior Lecturer, two Assistant Professors, and one Senior Engineer from the Advanced Technology Center, the Subaru Telescope, and the NAOJ Chile Observatory have concurrent positions in the TMT Project, and take part in activities that include the development of TMT science instruments at the Advanced Technology Center.

With the aim of strengthening the close partnership with TIO, three members are assigned to the NAOJ California Office in Pasadena. There are three members in Hawaiʻi working for TMT, one of whom is the Senior Specialist seconded to TIO.

In light of integrated operation of the Subaru Telescope and TMT in the future, schedules and a staffing allocation plan were continuously discussed and formulated in line with the long-term plan for operation with the Subaru Telescope. As part of the plan, the domestic administration and the public relations are integrated with the Subaru Telescope.

09. JASMINE Project

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

(1) Overview

The purpose of the JASMINE Project, NAOJ, is as follows. We participate in and contribute to the JASMINE mission of the Institute of Space and Astronautical Science/ the Japan Aerospace Exploration Agency (hereafter, referred to as ISAS/ JAXA), aiming to realize the world's first near-infrared high-precision astrometry and timeseries photometry. Note that ISAS/ JAXA changed the name of "Small JASMINE" to "JASMINE" in 2021.

We will perform the following missions to achieve the above purpose of the JASMINE Project.

1) To contribute to scientific verification and development of the instruments and the data analysis software for the JASMINE mission of ISAS/JAXA.

2) To provide the scientific community with a catalog of physical information, including parallaxes, proper motions, and light curves, for stars around the Galactic Center, through an international framework under the leadership of ISAS/JAXA.

JASMINE was selected by ISAS/JAXA in May 2019 as the unique candidate for the JAXA Competitive Middle-Class Science Mission No.3. According to the current progress schedule in the Space Basic Plan established by the Cabinet Office in Japan, the launch of JASMINE is scheduled for 2028. We are promoting JASMINE with the aim of improving the development stage at JAXA step-by-step. JASMINE has the following three primary scientific objectives.

1) To reveal the Milky Way's nuclear structure and formation history by measuring the distances and the motions of stars located as far as 26 thousand light-years away with high-precision astrometry observations in the near-infrared band.

2) To explore the formation history of the Milky Way related to the origin of human beings by revealing the evolution of the Galactic structures, which caused the radial migration of the Sun and other stars with their planetary systems.

3) To find Earth-like habitable exoplanets, taking advantage of the time-series photometry capability required for the precision infrared astrometry.

The mission objective of JASMINE is to use an optical telescope with a primary mirror aperture of around 36 cm to perform infrared astrometric observations (Hw band: 1.0–1.6 μm). A project objective is to measure as the highest precision annual parallaxes at a precision of less than or equal to 25 μas and proper motions, or transverse angular velocities across the celestial sphere, at a precision of less than or equal to 25 μas/year in the direction of an area of a few square degrees of the Galactic nuclear region to create a catalog of the positions and movements of stars within this region. JASMINE is unique in that unlike the optical space astrometry mission, "Gaia Project," operated by the European Space Agency (ESA), the same astronomical object can be observed frequently, and observation will be performed in the near-infrared band, in which the effect of absorption by dust is weak. JASMINE will help to achieve revolutionary breakthroughs in astronomy and basic physics, including the formation history of the Galactic nuclear structure (Galactic Center Archeology); the supermassive black hole at the Galactic Center; the gravitational field in the Galactic nuclear structure; the activity around the Galactic Center; formation of star clusters; the orbital elements of X-ray binary stars and the identification of the compact object in an X-ray binary; the stellar physicis; star formation; planetary systems; and gravitational lensing. Such data will allow for the compilation of a more meaningful catalog when combined with data from ground based observations of the line-of-sight velocities and chemical compositions of stars in the bulge.

Due to satellite operations, there are periods when astrometric observations towards the Galactic Center direction are not possible. In such periods, in order to utilize the unique features of the JASMINE satellite (its capability of high-precision photometric and highly frequent observations in the near-infrared band), we can plan to carry out transit observations to search for Earth-type planets that are expected to be in the habitable zones around M-type stars which are low mass red stars belonging to the main sequence. JASMINE dominates other missions for explorations of this type of exo-planet.

(2) Major Progress in FY 2022

1) Organization of the JASMINE Project

The JASMINE Project, NAOJ, is composed of two Professors, one Project Associate Professor, six Assistant Professors, one Project Assistant Professor, one Project Researcher, and one Technical Supporter. Significant contributions were also made by members of the following organizations: ISAS/JAXA; Kyoto University; the University of Tokyo; and the University College London, etc.

2) Overview of planning and developing JASMINE

We are establishing a JASMINE consortium consisting of researchers. The purposes of the consortium are to conduct the science study, and to prepare a data analysis team, data validation team, and outreach team. At present, about 60 domestic members are participating. In September 2022, we held a special session for JASMINE at the 2022 Autumn Annual Meeting of the Astronomical Society of Japan. We were able to listen to the opinions of many researchers and lectures in a wide range of fields.

Regarding the development of the satellite and observation instruments, a comprehensive review of the satellite/instrument specifications was carried out with the aim of reducing costs and technical risks, and then conceptual studies were conducted with satellite manufacturer company candidates. In addition, we are developing a domestic infrared camera for space in collaboration with the NAOJ Advanced Technology Center and ISAS/JAXA. Progress has been made in the implementation of performance evaluation tests on a prototype detector, the completion of a large-format prototype detector, the development of an on-orbit system for calibrating the sensitivity flatness of pixels on the detector, and the conceptual study on the structure/thermal design of the detector box assembly. Regarding data analysis, we are simulating stellar images in the field to be observed by JASMINE, using actual stellar observation catalogs covering the area near the Galactic center, and also we are developing a series of end-to-end simulators from estimating stellar image centers in the field to deriving astrometric parameters such as annual parallaxes. We are proceeding with such analysis considering various realistic and complex noise sources. In international cooperation, researchers at Heidelberg University visited NAOJ and deepened discussions on methods of analyzing astrometric data based on their knowledge of the Gaia data analysis. Furthermore, discussions on cooperation with the NAOJ Astronomical Data Center for the creation of an archive of observational data have started.

3) Nano-JASMINE

The JASMINE Project Office, the predecessor of the JASMINE Project, had also been promoting a plan for a micro-satellite project, Nano-JASMINE (with a primary mirror aperture of 5 cm). Nano-JASMINE aimed to produce scientific results based on the astrometric information for bright objects in the vicinity of the Solar System. This plan was terminated due to the repeated loss of launch opportunities caused by external factors and the degradation of the flight model (which was to be actually launched into space) of the satellite (completed in 2010). Although the JASMINE Project Office was not able to perform analysis using actual scientific data, we were able to achieve results in the development of a space telescope, the development of the detector subsystem, the establishment of data analysis methods, and the development of pipelines for the data analysis. The original objectives that NAOJ was supposed to achieve were largely achieved. In addition, the Nano-JASMINE plan also contributed to the promotion of JASMINE because the close international cooperative relationship with the Gaia team gained through the development of the Nano-JASMINE data analysis system has led to the current strong cooperation in the development of the data analysis system in JASMINE.

The flight model of the Nano-JASMINE satellite will be exhibited at the Oshu Space & Astronomy Museum, and the engineering model of the satellite, which is almost the same as the flight model, will be exhibited at the Gifu Kakamigahara Air and Space Museum. In this way, Nano-JASMINE will be utilized in outreach activities in the future.

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

1. Project Overview

In FY 2022, the RISE Project first and foremost worked as the Martian Moons eXploration (MMX) Geodesy Science Strategy Team (GSST) to continuously investigate the operation plans of MMX, introduce new software, and support the manufacture and tests of an onboard instrument. (i) We regularly had meetings online with the development team of the orbit/gravity field estimation software (GINS) produced by Centre national d'études spatiales (CNES) in France. To prepare for Landing Site Selection (LSS) training, we jointly improved GINS by incorporating laser altimeter (LIDAR) data and landmark data. At the same time, simulations have been conducted to retrieve the Phobos gravity field model from the tracking of Quasi-Satellite Orbits (QSO) at various altitudes. (ii) We attended monthly development meetings with the manufacturer of LIADR. We also attended Engineering Model (EM) tests and contributed to the data acquisition and performance analysis of the response of EM to various input energies. Further, we contributed to preparing Spacecraft Information Base version 2 (SIB2) and designing PI's Quick Look. (iii) The contract for utilization of the stereophotoclinometry shape-modeling tools (SPC) was attained, and regular meetings started. In March, the training session for SPC tools was conducted. (iv) We attended domestic and international Science Board meetings and discussed possible scientific research achievements. (v) We contributed to mid to long-term operation planning in the Mission Operation Working Team (MOWT). Also, we incorporated MOWT and the Mission Operation Preparation Working Team (MOPWT) to make detailed plans of imaging operations for the shape modeling considering the spacecraft attitude control, the number of necessary commands, and the feasibility of MDP processing. (vi) In the ground Data Processing WT (DPWT), we identified Level 0 data required for LSS. We investigated interpolation procedures of the spacecraft attitude data and their accuracy for LSS. In addition, (vii) we arranged the interface of LSS products training and confirmed the data processing flow in the Landing Site Selection Working Team (LSSWT).

Second, we opened the Hayabusa2 LIDAR data to the public. Regarding scientific achievements, we published a paper as coauthors on the surface albedo of Ryugu, which used LIDAR data. On the other hand, the gravitational potential of the column of uniform density was solved analytically to discuss the top-shaped figure of the Ryugu asteroid in view of slope stability and a change of rotation period. Also, one of the RISE Project members published a paper as the first author on the laser-link experiment conducted during the return to Earth of Hayabusa2 with the Institute of Space and Astronautical Science (ISAS) and National Institute of Information and Communications Technology (NICT).

Third, we held team meetings of the Planetary Science Working Group under the Science Strategy Committee and considered the role of planetary explorations in the National Astronomical Observatory of Japan. We had online meetings on February 28, May 9, July 4, and September 12 to prepare the WG report and a workshop open to the science community held in FY 2023. The RISE project was reviewed, and a three-year extension was approved.

2. Educational Activities

One RISE member educated a fourth-year graduate student at the University of Tokyo as an advisor. An internship student at Paris University joined the RISE project for three months to study Ryugu crater topography.

3. Outreach/PR

In FY 2022, the Project members volunteered two times for Kirari Oshu City Astronomy School as well as five times for FUREAI (Friendly) Astronomy classes. In addition, RISE members provided four special lectures for the public and one invited talk in a workshop.

11. SOLAR-C Project

1. SOLAR-C Project Overview

SOLAR-C is a JAXA satellite project under preparation and may become Japan's fourth solar observation satellite mission after Hinotori, Yohkoh, and Hinode. The plan is to realize the launch in the late 2020s. Through observations from the satellite, this project aims to elucidate the following mechanisms of solar magnetic plasma activities, which are significant problems in the field of solar physics and have an impact on space weather and space climate around the Earth.

(1) Formation mechanism of the hot solar atmosphere and solar wind
(2) Energy release mechanism of solar explosions

The primary science instrument on the satellite has high imaging resolution and sensitivity that are improved by nearly an order of magnitude compared with the similar instrument on the Hinode satellite. It also has the feature of being able to observe the hot solar plasma with temperatures ranging from twenty thousand to twenty million degrees nearly seamlessly. Japan will be responsible for the launch vehicle, satellite bus, and telescope section of the science instrument. The spectrograph section will be developed through international collaborations with the U.S. and European space agencies and institutions. NAOJ will play a leading role in the development of the telescope section.

The SOLAR-C project was proposed as the Solar-C_EUVST small satellite project in the JAXA public small satellite solicitation opportunity in January 2018. This proposal was nominated as a candidate for Publicly Offered Small Satellites 3 or 4 in July 2018, and the plan moved to the Mission Definition Phase (Pre-Phase-A2) in FY 2019. After the pre-project candidate down-selection pre-screening in February 2020, this project was selected as the JAXA Small Satellite 4 project in May 2020. Regarding international cooperation, NASA's participation in this project was decided in December 2020 based on NASA's Phase A study that had been underway since 2019, followed by the participation of European space agencies. After passing the Mission Definition Review in July 2022, the plan became a JAXA Pre-Project and was followed by finishing the System Requirement Review in December 2022. Afterward, we have been preparing for the System Definition Review scheduled in 2023 while proceeding with feasibility studies with overseas partner organizations.

2. Progress of the NAOJ SOLAR-C Project Activity in FY 2022

In FY 2022, the feasibility studies of the following aspects of the telescope section have proceeded using the JAXA front-loading and preliminary design expenses: (1) The design study of the primary mirror assembly (PMA) with tip-tilt and launch-lock mechanisms and development and evaluation of the bread-board model, (2) the selection of an adhesive for use at the primary mirror support through evaluation, (3) the design of the focus adjustment mechanism, (4) a light-weight design of the telescope structure considering equipment layout and integration, (5) the on-orbit temperature prediction and thermal deformation prediction of PMA, (6) the design of telescope control electronics and performance evaluation with the bread-board model of a control process, (7) mechanical interface of optical components and optical alignment procedures, (8) the study of optical measurement for the micro-vibration test, (9) the study of mechanical interface conditions between the satellite and the observation equipment and those within the science payload, and (10) the investigation of outgassing characteristics of a candidate skin sheet of CFRP sandwich panels. Through these design studies, the validity of the design has been confirmed for some critical items, while some issues in the initial design have been clarified.

Design meetings with overseas partner institutions were conducted through internet conferencing, as it was not possible to hold the design meetings in a conference room due to COVID-19.

3. SUNRISE-3 Project Support

Most SOLAR-C project members contributed to developing the science payload and the flight operation of the flight experiment of the Balloon Project SUNRISE-3 conducted in July 2022 in Kiruna, Sweden. Refer to the report of the Solar Science Observatory (SSO) for details.

4. Educational and Publicity Outreach Activity

The project staff has supervised three SOKENDAI graduate students. The project also participated in the Tour of the Solar Research Frontline to introduce domestic solar research to undergraduate students and introduced the project activities in research and development through the web.

5. Others

While NAOJ reimbursed the NAOJ SOLAR-C project activity for its general operation and contingencies, the expenses for the design and development of the telescope section are funded by JAXA. From the viewpoint of smoothing out the administrative work volume of SOLAR-C and SSO projects, the expense processes for the short-term experiment projects were conducted by this project.

The changes in the project staff are as follows. Y. Kawabata, Assistant Professor, was appointed in November 2022, and Y. Nodomi, Senior Specialist, and J. Sugimoto, Administrative Supporter, left the SOLAR-C project at the end of March 2023.

12. The Subaru Prime Focus Spectrograph (PFS) Project

1. Overview of the PFS project

The Prime Focus Spectrograph (PFS) is a next generation large-scale facility instrument of the Subaru Telescope. PFS will enable the observation of ~2400 objects simultaneously at wavelengths ranging from 0.38 μm to 1.26 μm with a spectral resolution of R ~ 2000–5000. It is expected to start open-use observation from FY 2024.

PFS has been developed under an international collaboration led by Kavli IPMU, Tokyo University. The collaboration consists of Kavli IPMU (Tokyo Univ.), NAOJ, ASIAA (Taiwan), Caltech/JPL, Princeton Univ., Johns Hopkins Univ., North East Participation Group (8 institutions, USA), Brazilian consortium, LAM (France), MPE/MPA (Germany), and Chinese PFS Participation Consortium (6 institutions, China).

The PFS A-project started in FY 2019 at NAOJ. It is responsible for the design and construction of the telescope infrastructure needed for PFS, as well as the operation and maintenance of the instrument. The PFS A-project is also heavily involved with PFS integration, commissioning, its performance verification, and the development of the data reduction pipeline and science database.

The A-project work will lead to the start of PFS operation, at which point PFS will transition to a Subaru Telescope facility instrument, and the PFS A-project will be dissolved.

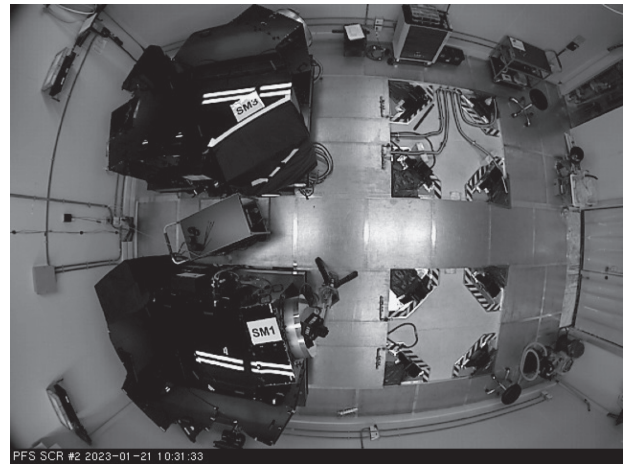


Figure 1: Top view of the spectrograph clean room, hosting 2 spectrograph modules (Jan. 2023).

Figure 2: All 4 science fiber cables installed on the telescope, holding ~2400 optical fibers (May 2023).

2. Progress in FY 2022

(1) Subsystems delivery and integration

PFS is composed of several subsystems, starting with the Prime Focus Instrument (PFI), hosting the ~2400 science fibers and their individual positioners, at the prime focus of the telescope. The next subsystem is made of 4 science fiber cables (CableB) running along the telescope. They bring the light to the 4 spectrograph modules (SpS) located in a dedicated clean room on the upper level of the dome. Each module is composed of 3 cameras, with a blue, red, and near infrared (NIR) channel. The last PFS subsystem is the Metrology Camera (MCS) located at the Cassegrain focus of the telescope, imaging and processing the positions of PFI and each science fiber.

PFS started FY 2022 with PFI and MCS already installed and tested on the telescope, 2 (out of 4) science fiber cables (CableB) installed, and 1 (out of 4) spectrograph module, hosting 2 cameras (1 blue and 1 red channel).

In Nov. 2022, the second spectrograph module (with its 2 visible cameras) was delivered from LAM (France) and integrated (see Fig. 1). It was immediately tested and used on sky during the Nov. 2022 engineering run.

The first NIR camera was installed on the first spectrograph module in April 2023 and was used on sky that same month.

The last 2 remaining science fiber cables (CableB#3 and #4) were installed in Feb. and May 2023 respectively (see Fig. 2). Both cables passed the initial fiber performance tests, but long-term stability monitoring is still ongoing to understand the correlation of optical fiber performance with the telescope movement, and other environmental conditions such as atmospheric temperature variation.

At the end of FY 2022, ~1200 science fibers (~50 %) were visible on 5 spectrograph cameras (2 blue, 2 red and 1 NIR channel).

(2) Engineering observation runs

From May 2022 to April 2023, 49 engineering observation nights were approved for PFS and 33 nights were used. There were 10 nights lost to bad winter weather and 6 nights lost to technical issues with the PFS instrument or the telescope itself.

PFS first engineering light was detected in Nov. 2022, with the successful alignment of the science fibers on stars and the detection of their spectra using the first spectrograph module. In April 2023, the first NIR camera took on-sky data for the first time (see fig. 3).

Beyond the instrument first light, the engineering observations have been crucial to get a better understanding of the instrument, including among others:

- Understanding the MCS and PFI reference frames and alignment.
- Testing and integrating the auto-guiding cameras to the telescope systems.
- Optimizing the fiber positioners' convergence speed and accuracy.
- Verifying the performance of the spectrographs (including the first NIR camera).
- Characterizing the PFS instrument.
- Taking calibration and commissioning data and testing the processing pipeline.
- Testing and optimizing the nighttime operation in collaboration with support astronomers.

(3) Observation procedures and policies

In FY 2022, a lot of progress has been made on the open-use observation framework, including on various processes from the PI proposal submission, through the ranking, to the time allocation; queue vs. classical mode observation; and data access. The scientific community at large was able to provide feedback on the observation procedures during the Subaru user-meetings and dedicated community meetings. The resulting basic observation framework was presented to the Subaru Science Advisory Committee (SAC) and agreed upon with the observatory in Nov. 2022.

Several software tools have been successfully developed to help the observatory optimize the PFS observation efficiency. Such software includes, among others, a tool used to create the PFS fiber configuration files used for each exposure, the Queue Planner (qplan) for creating the nightly schedule during queue mode observation, and the PFS pointing planner (PPP), which optimizes the telescope pointing to efficiently execute multiple observing programs in the same exposures (fiber-sharing). An online version of the PPP was also released to assist PIs with their proposal submission.

(4) Data reduction pipeline

The PFS team at NAOJ has been continuously contributing to the data reduction pipeline (DRP) in close collaboration with Princeton University and other PFS collaborators. NAOJ's contribution is the flux calibration part of DRP and an early version was integrated into the pipeline. It has been tested using data from the Nov. 2022 engineering observation. An important function of the pipeline is to check the quality of processed data and we made progress in this aspect as well. In particular, quality assurance tests of detectorMap, which describes the fiber position and wavelength, can now be made routinely. Another contribution to the PFS collaboration is the stable operation of the science database, which was in use throughout FY 2022.

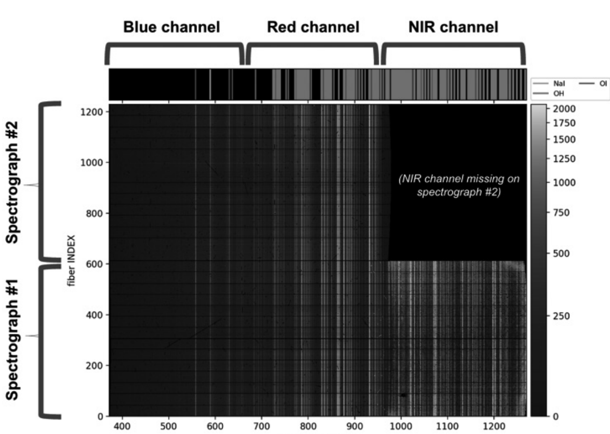


Figure 3: ~1200 night-sky background spectra detected on the first two spectrograph modules, including the first NIR camera.

13. The Subaru Ground Layer Adaptive Optics (GLAO) Project

1. Project Overview

ULTIMATE-Subaru is a survey instrument that will enable unprecedentedly wide-field and high-sensitivity survey observations with a high resolution comparable to the Hubble Space Telescope. The Subaru Ground Layer Adaptive Optics (GLAO) project aims to develop a GLAO system as a part of ULTIMATE, which will uniformly improve the seeing by a factor of 2 over a wide field of view up to ~20 arcmin in diameter. A primary science goal of ULTIMATE is to reveal the history of galaxy formation and evolution by an unprecedented near-infrared survey of the distant Universe.

In FY 2019, the GLAO project was accepted for the NAOJ call for A project proposals and has started the preliminary design phase. In the A-project period, the GLAO project aims to complete the preliminary design of the GLAO system and the prototyping of the key subsystems within 3 years, followed by final design, production, assembly, integration, and test phases. The GLAO project plans to implement the GLAO system at the Subaru Telescope and start its commissioning run by the end of FY 2028.

2. Staff

The GLAO project team mainly consists of members of Subaru Telescope. At the end of FY 2022, there were 1 associate professor and 1 research fellow dedicated for the GLAO project. There were also 1 affiliated associate professor, 1 senior specialist, 2 assistant professors, 1 research engineer, and 2 RCUH employees (engineering staff) appointed concurrently. There was also one associate professor at the Advanced Technology Center who participated in the GLAO development. In addition, the GLAO project received support from the instrument division technicians, day crews, and administration staff at Subaru Telescope.

3. Major Progress in FY 2022

Based on the results from the conceptual design review for the ULTIMATE science instruments, which was completed in FY 2021, we decided to concentrate on the preliminary design of the GLAO system at the Cassegrain focus, which will realize the main science goals by using a near-infrared wide-field imager (WFI) at the Cassegrain focus covering 20 arcmin FoV in diameter. The development of GLAO for MOIRCS at the Nasmyth IR platform will be suspended until future plans for the Nasmyth IR platform are determined based on community demands, as the existing instruments on the Nasmyth IR platform need to be decommissioned.

The GLAO preliminary design has been completed for the wavefront sensor (WFS), the laser guide star facility (LGSF), and the control system. Since the final design of the adaptive secondary mirror (ASM) was completed in FY 2021, we started production of the thin shell mirror, which is the main optical component for the ASM. In FY 2022, we established a production process, procured the material for the shell mirror, and fabricated a production jig.

There was a preliminary design review for the GLAO system in November 2022. We received a review report from the review panels in February 2023 that endorsed the project to move forward to the next final design phase with some suggestions to improve the project.

To demonstrate the technology in the GLAO system, we have been conducting the upgrade of the Laser Guide Star (LGS) system for the existing AO system at the Subaru Telescope with the TOPTICA high-power laser. In FY 2022, we completed the performance evaluation of the laser guide star system and obtained the wavefront data using the proto-type Shack-Hartmann wavefront sensor (SH-WFS) developed by Tohoku University. We also developed an atmospheric turbulence profiler in collaboration with Tohoku University to measure the ground-layer atmospheric turbulence, which is crucial for the GLAO performance. We conducted the initial observation with the turbulence profiler at the Nasmyth OPT platform of the Subaru Telescope.

4. Education Activities and Internships

In FY 2022, the GLAO project accommodated two intern students under the supervision of the research and education staff. As a part of the SOKENDAI summer student program, we mentored a 3rd-year undergraduate student from Kwansei Gakuin University to perform research related to instrument development. We also mentored a student from the University of Hawai`i at Hilo for 4 months as an intern through the Hawai`i Space Grant Consortium (HSGC) program to provide research experience on observational studies of galaxies. In addition, we hosted four graduate students from Tohoku University and one from Sokendai staying for 1–2 months at the Subaru Telescope to conduct research related to the turbulence profiler or observational studies of galaxies.

5. Outreach

To inform the astronomical community and general public about the Subaru GLAO project and its scientific motivation and goals, we released news from the project on a public web site (https://ultimate.naoj.org). In FY 2022, the “Subaru Telescope 2.0” project was officially launched and a special web page for the “Subaru Telescope 2.0” project has been released on the Subaru Telescope official website. ULTIMATE-Subaru was highlighted on the Subaru Telescope 2.0 web page.

6. International Collaboration

The ULTIMATE science team is playing a central role in promoting the activities of the JSPS core-to-core program, "International research network toward the era of deep and wide near-infrared survey of the universe with space and ground-based telescopes (as known as SUPER-IRNET)". This program aims to significantly advance the next-generation near-infrared wide-field observation program, including ULTIMATE, through the collaboration of Japan, the United States, France, Australia, and Taiwan. In FY 2021 and the first half of FY 2022, a series of six online seminars was held, despite the fact that face-to-face meetings among researchers were largely limited due to COVID-19. In March 2023, the first face-to-face workshop "Near-Infrared Wide-Field Deep Space Exploration in the Universe I (SUPER-IRNET 1st Plenary Seminar)" was held with over 100 participants from the five partner countries.

14. Astronomy Data Center

The Astronomy Data Center (ADC) collaborates with observatories and universities to consolidate astronomical observation data. ADC archives them permanently and opens them to the astronomy community in a user-friendly way together with the data analysis environment to facilitate scientific research. To sustain and develop these activities and functionalities in the future, and to serve as a cross-project organization that supports various projects and observatories in NAOJ through the sharing of human, computers, scientific data assets, experience, and technology, we are restructuring the organization. As part of this effort, following an associate senior research engineer in the Data Archive Group hired in FY 2021, a new research engineer was hired in FY 2022 to provide technical support to the Data Application Infrastructure Group.

The rental computer system installed in March 2018, which has been used as an open-use data analysis system and data archiving systems, was to be renewed after five years of operation, but a contract was not signed because of high computer prices and long delivery times caused by a semiconductor shortage. Therefore, the operation of the current system has been extended until the end of June 2024, and the procurement procedure for a replacement is still underway.

The major activities in ADC are described below.

1. SMOKA

The SMOKA team has been conducting research and development on astronomical Databases, Data Archiving, and Data Analysis. SMOKA (https://smoka.nao.ac.jp/) publishes archival data of Subaru Telescope, Okayama 188-cm telescope, Kiso 105-cm Schmidt telescope (the University of Tokyo), two MITSuME 50-cm telescopes (Tokyo Institute of Technology), Kanata 150-cm telescope (Hiroshima University), NAYUTA 2-m telescope (University of Hyogo), and Seimei 3.8-m Telescope (Kyoto University).

SMOKA continues to operate stably in cooperation with the various observatories and has produced many scientific results. SMOKA is also a research infrastructure that allows for the revalidation of research results and supports the credibility of research results.

The total amount of opened raw observation data in SMOKA is about 38 million frames (397 TB) as of May 2023. SMOKA contributes to many astronomical publications. The total number of refereed papers using SMOKA data is 281 including 10 new publications in FY 2022 as of March 2023. The name “SMOKA” is specified as a source of “Data Availability” on many other papers. Object frames taken with the observing instruments TriCCS on the Seimei Telescope were newly opened in FY 2022. Transmission of huge amounts of data produced by Tomo-e Gozen (Kiso Observatory) and TriCCS were regularized with a combination of hard disk transfers and internet transfers.

We are operating a system that makes original all-sky monitor images at Higashi-Hiroshima, Okayama, Akeno, and Kiso available to the public (https://ozskymon.nao.ac.jp/ ; 34 TB as of May 2023). A system to publish digitized data from photographic plates taken at the Kiso Observatory several decades ago was developed and operated (https://pplate.nao.ac.jp/ ; 4 TB). A data service of Tomo-e Gozen (Kiso Observatory) stacked data was also being operated (https://archive.nao.ac.jp/tomoe ; 95 TB as of May 2023).

Two papers were published in the Report of NAOJ volume 23 on the development of the SMOKA/Tomo-e Gozen archive system and on the acceleration of astronomical database searches.

2. MASTARS

The operation of MASTARS, a data archive system in Mitaka for Subaru Telescope observers, was transferred to ADC working closely with the STARS data archive system in Hawai`i. As the amount of stored data increased, we setup a new storage server for expanding the data area and started operation in FY 2022. We also supported the upgrade of the archive systems due to the renewal of the IT system in the Subaru Telescope. Software tools (gitlab, redmine, etc.) were introduced and operated for use in development and upgrades.

In addition, we are preparing the data backup on a commercial cloud for data preservation in the case of disaster.

3. JVO (Japanese Virtual Observatory)

Detection of atomic and molecular emission lines was performed on the published ALMA FITS data, and the information on the detected lines was put into a database and published. In FY 2022, radial velocities for individual target objects were retrieved from the SIMBAD database, and the frequencies of the detected lines were then converted to the rest frame of the object. Previously, only the information from the FITS header was used, but since it is sometimes inaccurate, we attempted to use the SIMBAD database. The rest frequencies of detected lines based on both radial velocities were made available to users.

The size of the publicly available ALMA FITS data per file now exceeds 300 GB, and in the future, over 1 TB of data will be available. We have developed FITS WebQL, which implements a distributed processing mechanism to show the contents of such huge data cubes on the web browser interactively at high speed without downloading. A total of five computers read FITS data in parallel and synthesize images, enabling even 1 TB of data to be displayed within a few minutes. We also confirmed that the spectrum calculated at any position on the image plane can be smoothly plotted in real time. For data over 20 GB, this function was made publicly available for anyone from the JVO portal service. The development status of the FITS WebQL was presented at the

2023 Spring Meeting of the Astronomical Society of Japan.

In addition, several data catalogs of JAXA's scientific satellite AKARI were registered in the JVO system and started to be made public through the VO interface.

The number of accesses to all these JVO services in FY 2022 was 7.4 million and the total download volume was 12 TB.

4. HSC Data Analysis/Archiving Software Development

We continued to develop data analysis pipeline software to process Hyper Suprime-Cam (HSC) data accurately and efficiently, conducted data analysis, and developed and operated data archiving systems to make effective use of the processed data.

In the Subaru Strategic Program (SSP) with HSC (March 2014-), we have been analyzing the data with the developed pipeline and producing databases to store the processed results for researchers. The originally scheduled HSC-SSP observations were completed in December 2021, and the total full-color full-depth survey footprint has reached over 1000 square degrees. We plan to process all obtained data with an updated pipeline for the next (11th) data release for SSP collaborators. As the structure of the pipeline has been largely updated since the last data release, we have spent this fiscal year on preparation of the processing platform, execution of a test production run, and getting feedback from collaborators' evaluations. We experienced a relatively large system update. Nevertheless, we have maintained the data service functions and continued developing various user interface software for providing images and catalog products.

In addition, development to apply next-generation database technology to a high-speed search service for huge astronomical catalogs such as HSC-SSP is continuing after minor updates to the collaborative framework.

We have been involved in establishing data formats for PFS and developing and testing a science archive for PFS linked to the HSC data products in cooperation with Subaru Telescope.

5. Open-use Computer Systems and Services

Open-use of the data analysis computer system for astronomical research is one of the key services provided by ADC. The “Multi-Wavelength data analysis subsystem (MDAS)” procured under a rental contract has been in operation since March 2018. Since MDAS is scheduled to stop operation at the end of June 2024, we are currently preparing for the procurement and construction of the next system. A temporally disk space (1 Petabyte of network file system) was added to the system so that it can be used as a data storage space when migrating to the next system.

Open-use terminals and printers installed in two open-use computer rooms (Subaru and ALMA buildings) in Mitaka Campus were sequentially replaced with new equipment after March 2023.

We have been constructing and upgrading the “Large-scale data analysis system (LSC)” for analyzing big astronomical observation data taken with instruments like HSC. The LSC system has been in operation for general HSC observers since September 2019, the scope of users was expanded to researchers who wish to analyze HSC archival data in October 2020, and was further expanded to those who want to analyze observation data taken with any other instruments in January 2022.

Several workshops and hands-on tutorials were held with NAOJ projects to demonstrate to users how to use the specific software, applications, and the open-use systems. Due to the spread of COVID-19 from the winter of 2020, all workshops in FY 2020 and FY 2021 were held online, but in FY 2022, more workshops were conducted in a hybrid or face-to-face format at NAOJ. The dates and numbers of participants for the workshops in FY 2022 are as follows.

1. ALMA Data Reduction Workshop (1st, Co-host), July 5 and 7, 2022, 10 users
2. SOKENDAI Summer Student Program (provided analysis computers), August 1–31, 2022, 8 users
3. Subaru Telescope Data Analysis Workshop (Co-host), November 28–30, 2022, 11 users
4. ALMA Data Reduction Workshop (2nd, Co-host), February 27 and 28, 2023, 10 users
5. JAPAN SKA Data Analysis Workshop (Co-host), March 2–6, 2023, 12 users

15. Advanced Technology Center

1. Summary of Activities in ATC

The Advanced Technology Center (ATC) is the core research organization of the technological development at the National Astronomical Observatory of Japan (NAOJ), and is the research and development (R&D) center for advanced astronomical observation instruments, from radio waves to visible and ultraviolet light, both on the ground and in space. In FY 2022, although no ‘priority measures to prevent the spread of the virus’ were issued, operations were carried out while taking thorough measures to prevent infectious diseases, including telecommuting.

The reorganization into a matrix-type organization (see Figure 1) entered its second year of operation and has been substantially put into practice. In the process, for the first time, we carried out screening for accepting or rejecting job requests from outside projects.

Even with the corona disaster still continuing, facility tours have recovered to pre-corona disaster levels. We were able to stress the importance of ATC in NAOJ for the Italian Ambassador to Japan; Chilean Ambassador to Japan; Lebanese Ambassador to Japan, executives of overseas research institutes; visitors from the Cabinet Office, METI, and MEXT such as the State Minister, Administrative Vice Minister, and so on; executives of the National Institutes of Natural Sciences; private companies; etc.; and online visits by students.

Notable items in FY 2022 include the completion of the expansion of the SIS clean room for the development of superconducting devices for ALMA2 development, as well as the establishment of rules for the security control of electronic devices produced there and the building of a new storage area.

In addition, we have been actively engaged in industrial collaboration activities to apply the technologies developed at ATC to industrial applications, including the development of a microwave amplifier with ultra-low power consumption applicable to quantum computers and the study of industrial applications of adaptive optics technology used in the Subaru Telescope. In FY 2022, we prepared for the launch of the “Social Implementation Program” to promote these activities as ATC.

Details of the activities in FY 2022 are described below.

2. Developments for Prioritized Projects

(1) TMT Instruments

1) Infrared Imaging Spectrograph (IRIS)

The IRIS Imager team in ATC continued to study the issues raised at the IRIS Imager Final Design Review held in June 2021, as they did in FY 2021. System-level analysis and documentation have been conducted in preparation for the IRIS system-wide Final Design Review scheduled for FY 2024. The former involves the creation of an FEA model for vibration

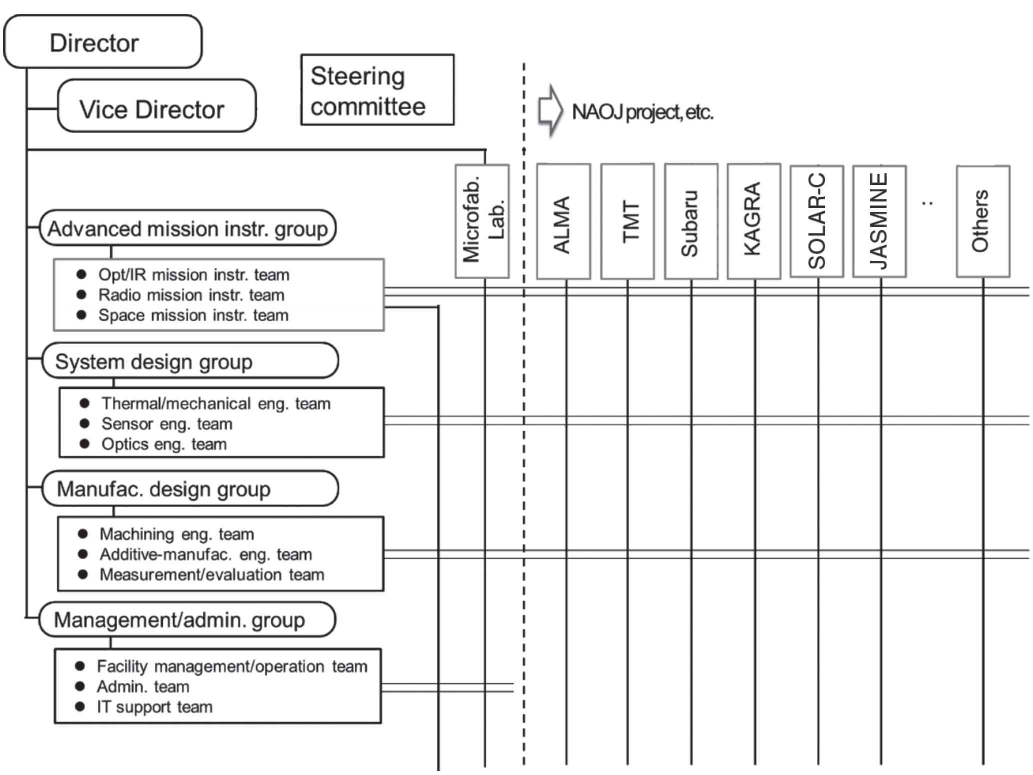


Figure 1: Matrix organization structure of ATC.

analysis integrating NFIRAOS adaptive optics and IRIS and the derivation of transfer functions, the creation of a model for opto-mechanical thermal analysis, and the demonstration of a prototype mechanical I/F with the cryostat; the latter involves system-level FMEA/reliability analysis, and requirement definition through simulations towards the preliminary design of an optical simulator to be used for performance evaluation of the Imager and IFS.

In June 2022, the IRIS international team was informed that the H4RG-10 detector from Teledyne, USA, which was to be used in the IRIS Imager, was discontinued. As the Imager interfaces with the IFS and cryostat for which the USA is responsible, the impact of a change in detector would have a wide-spread impact on the instrument; the IRIS Imager team in ATC led a trade study with an alternative detector, the H4RG-15.

2) Wide Field Optical Spectrometer (WFOS)

WFOS has moved to a preliminary design phase. In FY 2022, ATC contributed a trade study led by the California Institute of Technology on the slit mask unit based on our design study of the slit mask exchange mechanism. In addition, ATC investigated the manufacturability of high-quality large glass blanks and volume binary gratings which have high diffraction efficiency. ATC has studied an integral field unit (IFU) as a future upgrade. In FY 2022, we carried out the optical and mechanical designing.

(2) ALMA

1) ALMA Receiver Maintenance

NAOJ is in charge of the maintenance of the cold cartridge assemblies (CCAs) for three receiver bands - Band 4 (observation frequency: 125–163 GHz), Band 8 (385–500 GHz), and Band 10 (787–950 GHz) - for ALMA. By FY 2013, a total of 219 CCAs which had been developed and manufactured at NAOJ, or 73 units including 7 spares for each band, were shipped to the ALMA site. Most of the receivers have been installed and operated in the ALMA antennas for scientific observation. At ATC, the ALMA receiver maintenance team has been repairing the receiver cartridges that failed during operation since FY 2014. In FY 2022, two Band-4 receivers and one Band-10 receiver were repaired and delivered to the ALMA Operations Support Facility (OSF) in Chile. The receivers installed in antennas and scheduled to be repaired are one Band-4 and one Band-10 receiver. They will be removed from the receiver systems in the course of regular maintenance and will be returned for repair in FY 2023 or later. Although the frequency of repairs caused by aging failure is currently kept low, an increase of the failure rate cannot be denied when the wear failure period begins according to the bathtub curve. In order to continue the stable operation of ALMA, it is important to maintain a maintenance system in ATC that can quickly respond to ALMA receiver failures. The ALMA receiver maintenance team in ATC worked together with a resident engineer in Chile, who experienced the production of the receivers in Japan, to support the Joint ALMA Observatory for solving the problems for smooth operation of ALMA.

2) ALMA receiver development and upgrades

Continuing from FY 2021, we are supporting the development of ALMA Band 1 and Band 2 receivers and are studying with the Microfabrication Lab. and the ALMA project to develop broadband heterodyne receivers for ALMA2, which will significantly improve the telescope's performance and functionality. In addition, a development study of a data transmission system for future implementation in ALMA2 was started in FY 2022.

2-1) Receiver development for Bands 1 and 2

The Band 1 project (35–50 GHz), led by Academia Sinica Institute of Astronomy and Astrophysics (ASIAA) as a contribution to East Asia ALMA, completed its production phase. We have been contributing to the testing and production of corrugated horns; the support for cryogenic maintenance of cryocoolers at ASIAA; support for procurement and shipping of several important components; and support for shipment of receivers in cooperation with the NAOJ ALMA project. The production and performance verification of the Band 1 cartridge receivers in Taiwan has proceeded as planned, and the in-house testing and shipment of all receivers, including spares, were completed within FY 2022. Integration of the receivers in the telescope in Chile is ongoing.

NAOJ will also take responsibility for the maintenance of the Band 1 receivers in the operation phase from FY 2023, in parallel with the Band 4, 8, and 10 receivers, and therefore, the maintenance team for the Band 1 receivers and rebuilding equipment is being established in ATC, taking over responsibility from ASIAA in the post-production phase. Three NAOJ staff members have visited the Band 1 facility in Taiwan to learn the procedures for the inspection, assembly, and verification of the receivers to be shipped and to check the test equipment for transfer to NAOJ. This visit was helpful to plan for the transferring and upgrading of the test equipment and storing the spare cartridges and parts.

For the Band 2 (67–116 GHz) receiver being led by the European Southern Observatory (ESO), NAOJ is contributing to the design of the optics system and the design, manufacturing, and testing of optics components. The Critical Design Review (CDR) meetings were held in April and November of FY 2022 and were passed. In the evaluation of the pre-production receiver, two NAOJ staff members participated in the integration of the first receiver into the ALMA cryostat, which was conducted in Chile from February to March 2023. We have verified the installation method and procedure of the warm optics, for which NAOJ is in charge, and witnessed the testing of the receiver to identify risks and improvements toward the production and integration. In addition, we published a paper on the material characterization system with a high-precision analysis method for extracting the physical properties of dielectric materials used in quasi-optical lenses for Band 2 receiver optics.

2-2) Development for the next generation projects

Development of wideband receiver technology is underway to improve the performance of receivers. In FY 2022, the optics and waveguide circuits of the currently installed ALMA Band 8 receiver were analyzed in detail to identify improvements and develop a conceptual design for the upgrade. We also evaluated the performance of the fabricated corrugated horn and waveguide orthogonal transducer, and obtained results showing a significant improvement in performance over the currently installed Band 8 components. As for wideband microwave components for use in the intermediate frequency band, we started development of a cryogenic isolator with a company, and also the development of a hybrid coupler in collaboration with the University of Electro-Communications.

In the development of the terahertz receiver system, a silicon substrate with an antireflection structure fabricated in FY 2021 was mounted on a receiver as a vacuum window, and its performance was characterized. As a result, we obtained a similar performance in terms of beam characteristics and noise temperature as the vacuum window using a quartz substrate, which is currently used in ALMA. For the development of multi-beam receivers, the research and development of a superconducting monolithic microwave integrated circuit (MMIC) was continued, and the transmission line loss of the superconducting circuit and its effect on the sensitivity were investigated.

2-3) Data transmission system

The upgrade of the current ALMA data transmission system, called DTS hereafter, is implemented as part of the ALMA development roadmap, in particular, as part of the Wideband Sensitivity Upgrade. Together with the National Radio Astronomy Observatory (NRAO) and Korea Astronomy and Space Institute (KASI) we submitted the phase 1 project proposal to the ALMA board and it was approved in November 2022. The design of the DTS is in progress for the Preliminary Design Review (PDR) scheduled for Q2 2024. NAOJ has led the project since then and has developed the design. The interface meeting was held among the development teams of the DTS, Digitizer (which delivers the observation data to the DTS), and the second-generation Correlator (which receives the data from the DTS), in February 2023. The essential parameters as the design basis for DTS were approved in the meeting: the data transmission speed of 400 Gbps and the maximum data amount of 1.2 Tbps. A cooperative research agreement was concluded with the Photonic Network Laboratory and ICT Testbed Research and Development Promotion Center of the National Institute of Information and Communications Technology (NICT). In this context, the experiment for long-range data transmission by 400 Gbps optical transceivers was performed in the optical fiber link deployed between Koganei and Otemachi, Tokyo. The key specifications on the loss and length of the optical fiber link were obtained by the experiment.

(3) KAGRA

In collaboration with the Gravitational Wave Science Project, we are developing vibration isolation systems (VIS) and auxiliary optics systems (AOS) of the KAGRA interferometer and preparing instruments for evaluating the performance of new mirrors. At the Kamioka site, rapid progress is being made in overhauling KAGRA to enhance the performance of the laser interferometer, in preparation for the 4th international observation run (referred to as O4), which will start in May 2023. For the AOS device, ATC has responded to this by contributing to the improvement and delivery of the optical angle sensor covers and optical filter holder mechanism; the implementation of the middle-size baffle; and the design and installation of other stray light mitigation mechanisms. For the VIS device, emergency measures were taken to address the traverser malfunction, then finalization and evaluation works were conducted on various suspensions. Furthermore, ATC contributed to various commissioning works for the whole KAGRA interferometer, including the assembly of the piezo-equipped steering mirrors, as well as the design and installation of the optical bench windbreak. In addition, towards upgrade works for the 5th observation run, the production and evaluation of the folded pendulums, a core device for the acceleration sensors, were also carried out. Also, the conceptual design for a new compact vibration isolation device is ongoing. Maintenance and upgrading of the mirror evaluation system has been continued from FY 2021.

(4) SOLAR-C: satellite for a high-throughput solar EUV imaging spectroscopy

ATC has assisted in revising the specifications for the telescope section of the SOLAR-C instrument, coordinating mechanical and thermal interfaces for the optical and electrical assembly provided by foreign partner institutes, and cooperating to build a baseline optical alignment plan. In addition, ATC has assisted the preparation of clean room facilities, including vacuum chambers of various volumes and contamination monitoring systems, which are to be used during the development phase of the SOLAR-C project.

(5) Infrared Astrometric Observation Satellite JASMINE

ATC is in charge of developing detectors for imaging and a detector box assembly (DBA) for holding and cooling the detectors. The development of near-infrared detectors using InGaAs devices is being carried out by the Optical Infrared Mission Instrument Team of the Advanced Mission Instrumentation Group. The status of the development in FY 2022 is described in section **3**(1). The DBA, on the other hand, is being developed by the Thermal and Mechanical Design Team of the System Design Group. A radiator facing deep space will cool the DBA detector head down to ~200 K, and then Peltier devices will cool the detectors down to ~170 K. In FY 2022, as a conceptual study of the DBA, the team evaluated the performance of a candidate Peltier device in such a low-temperature environment (~200 K), and proceed with DBA thermal and structural design based on the evaluated performance. ATC has also supported the conceptual study of the JASMINE telescope, especially contributing to the clarification of telescope specifications and verification test plans based on experience acquired in the telescope development of the Hinode satellite.

3. Advanced Technology Development

(1) Near-infrared Image Sensor

Image sensors used at large scale observatories like the Subaru Telescope require extremely high performance such as high sensitivity, low noise, and large format. For a long time, our only choice was to purchase image sensors for astronomy from a company in the USA. Especially, it was more difficult to have image sensors for space use, since sensors for space use require extra specifications such as radiation tolerance and higher reliability. Image sensors are generally used in all astronomical instruments, and we cannot continue observational astronomical projects without high performance image sensors. We have successfully developed near-infrared image sensors for ground-based astronomy in cooperation with a domestic company. From FY 2021 to FY 2022, we developed an image sensor widely applicable to astronomical space missions funded by the JAXA ISAS's front loading program based on the sensor we have developed. In FY 2022, we evaluated a small format prototype sensor made last year with good results as we expected. We also manufactured the first prototype sensor of the large-format, near-infrared image sensor as we planned at the project beginning in FY 2021. We will evaluate the large format sensor in FY 2023.

(2) Technologies for integral field spectroscopy

Integral field spectroscopy (IFS) enables us to obtain spectra over an entire field of view in one exposure, which is suitable for studies on extended objects such as galaxies. Owing to this feature, IFS is becoming one of the major observing methods in optical and infrared astronomy. An integral field unit (IFU) is a key optical module realizing IFS. Generally, the IFU is a complex optical system requiring high precision, and therefore there are few institutions developing an IFU. ATC has developed basic technologies for the IFU and supported IFU developments in NAOJ and Japanese research institutes. ATC is now developing an IFU to verify the basic technologies developed so far, and plans to conduct a test observation using it. In FY 2022, we carried out optical designing of the IFU. In parallel, we conducted optical and mechanical designing of the WFOS IFU. In addition, although the University of Tokyo, RIKEN, and NAOJ completed an IFU for the near-infrared imaging spectrograph, SWIMS, in FY 2021, we found ghost images in the data taken in a commissioning run. In FY 2022, ATC investigated and identified the cause. After an easy refurbishment, the ghost images were dramatically suppressed.

(3) Adaptive Optics Technology

Adaptive optics, which enhances the accuracy of imaging or spectroscopy, is recognized as an important technology in astronomy. The basic studies for adaptive optics are in progress at ATC. In FY 2022, an experimental adaptive optics system was prepared and investigations on wave front sensing were newly started on the phase contrast wave-front sensing and phase diversity. The phase contrast wave-front sensor based on Zernike's phase-contrast interferometry enables a straight forward way to measure the distribution of optical phase and has a good accuracy at low light levels. Such enhancements to wavefront sensing in adaptive optics down to photon counting low illumination will expand the ability of astronomical observations. The phase diversity method is expected to have good accuracy down to several nanometers of optical phase. The use of the aforementioned adaptive optics is being considered as an experimental light source for the quantitative analysis of the phase diversity method by modulating the wave front phase at high level accuracy.

Recently, the expectations for the various applications of adaptive optics are increasing with the paradigm of 'social implementation.' The characteristics of the experimental adaptive optics above are evaluated regarding air turbulence, and the actual dynamic correction by the adaptive optics is demonstrated for enterprise and forum.

(4) Terahertz Technology

The terahertz experiment group supports development of superconducting detectors, cryogenic electronics, and cryogenic systems. In FY 2022, an optical cryostat was furnished for laboratory evaluation of terahertz intensity interferometry. A 0.8-K sorption cooler successfully cooled SIS photon detectors down to 0.8 K. Superconducting magnets and magnetic shields enable stable operation of the detectors. Dual-stage source-followers on cryogenic stages reduce the output impedance of the detector signal for wide bandwidth readout. A room temperature optical assembly made with the 3D metallic printer enables optical experiments using terahertz intensity interferometry with a baseline length of 100–500 mm using a 600-mm aperture spherical mirror (R = 4800 mm) and a blackbody source. Optical experiments with 600-GHz SIS photon detectors started around the end of the fiscal year.

MKID camera development in collaboration with the University of Tsukuba realized observation of star-forming regions at 100 GHz with the Nobeyama 45-m telescope, whose scientific results were presented in the Astronomical Society meeting and workshops.

The antarctic astronomy program was promoted in collaboration with the University of Tsukuba, Kwansei Gakuin University, and National Institute of Polar Research. An astronomy observing program of the galactic plane at 500-GHz and an intensity interferometry experiment were selected in the general observing program during 2023–2027 within the Xth (10th) Polar Campaign of NIPR.

(5) US-Japan Solar Flare X-ray Focusing Imaging-spectroscopic Sounding Rocket Experiment: FOXSI-4

FOXSI-4 is being prepared for launch in the spring of 2024. ATC is supporting the development and evaluation of high-speed cameras for soft X-rays using back-illuminated CMOS image sensors and a pre-collimator fabricated by the metal 3D printer. In FY 2022, a box that houses the electric boards of a high-speed camera for soft X-ray was machined from aluminum. In order to dissipate heat generated by the camera, this box is designed so that the heat sink attached to the electric board is in close contact with the bottom of the box. Vibration tests were conducted with the electric boards installed in the box, and it was confirmed that the boards can withstand the vibrations at the time of rocket launch. For the pre-collimator, jigs for evaluation tests were fabricated. These items were fabricated by the Additive Manufacturing Engineering Team of the Manufacturing Design Group.

(6) Balloon-borne Solar Observatory: SUNRISE-3

After completion of testing at the Max Planck Institute for Solar System Research (MPS) in FY 2021, pre-flight imaging performance, polarization calibration, and solar pointing were verified in Kiruna, Sweden, from April 2022. On July 10, 2022, SUNRISE-3 was launched, but we terminated the operation 5 hours after the launch because of the gondola failure. After the retrieval, we confirmed that the instruments were in good condition. We plan to repair the defective part of the gondola and re-fly SUNRISE-3 in 2024. We published a peer-reviewed paper on the results of optomechanical design and analysis, scan mirror mechanism, and high-precision polarization calibration obtained in the development of the SCIP near-infrared spectro-polarimeter.

4. System Design Group

The System Design Group designs and develops instruments for various astronomical projects and supports the planning and implementation of instrument performance verification. The System Design Group consists of three teams: thermal and mechanical engineering, optics engineering, and sensor engineering. In FY 2022, as in the previous fiscal year, we continued to respond to requests from projects both inside and outside NAOJ, and worked on instrument development, focusing on design work. In addition, one experienced engineer was added to the optics engineering team to augment the optical testing capability.

(1) Thermal and Mechanical Engineering Team

The team continued the mechanical design and related tests of TMT/IRIS, TMT/WFOS, TMT/STR, KAGRA, SOLAR-C (EUVST), SUNRISE-3, and JASMINE from FY 2021. In addition, the mechanical design of mirror holders for SAND and the conceptual mechanical design of the field spectrograph for TriCCS was newly started in FY 2022.

TMT: For TMT/IRIS, we addressed the issues raised at the final design review meeting (FDR1). In preparation for FDR2, we conducted thermal and structural analyses using the Imager finite element model, studied maintenance plans, designed the first lens mount for the Pupil-Viewing Optics, and investigated the impact of detector changes on the mechanical design. For TMT/WFOS, the conceptual and basic design of the WFOS IFU optical element holders and adjustment mechanisms were performed, and the space envelope was confirmed. In the SMX-CSU trade study, operational costs for mask manufacturing were calculated and reported. TMT/STR finalized the interface documentation and updated the structure model and assembly drawings for the production manufacturing readiness review meeting. The Production Readiness Pre-Manufacturing Review (2,3) was conducted and passed for the majority of the Nasmyth and Elevation structures.

KAGRA: KAGRA added, improved, and installed hardware for the auxiliary optics and vibration isolators on site, and made final adjustments and confirmations for the O4 observations for each vibration isolator. In addition, a sapphire mirror shipping container was designed and the container was provided to KAGRA for overseas transportation of the mirror for polishing.

Space Instrument: For SOLAR-C (EUVST), we supported the exchange of structural IF information between the Japanese manufacturer in charge of the telescope for the mission and the overseas organization in charge of the onboard instruments, especially the sharing of design progress and mathematical models. In addition, we have collected constraints on the AITV instrument system and proposed a measurement configuration for use in the USA. In JASMINE, we have developed a thermal structure design to meet the requirement of redundant cooling elements (TECs) in the conceptual study of the detector box. Elemental testing and test planning continued for TECs and the thermal straps were identified as technical risks.

Other projects: For TriCCS, the conceptual design of the mirror holders and alignment mechanisms for the field spectrograph was carried out. For SAND, the basic design of the mirror holders that include an alignment plan and adjustment mechanisms was done.

(2) Optics Engineering Team

The optics engineering team is responsible for the development of optical systems and specialized coating in astronomical instrument development.

1) Development of optical systems

The team has been actively involved in developing various astronomical instruments, including their optical design and performance verification. In Fiscal Year 2022, the team recruited a specialized engineer with expertise in optical metrology and optical assembly. Notably, the team has developed optical systems for multiple NAOJ projects, such as SOLAR-C (EUVST), KAGRA, and SUNRISE III. Additionally, the team has conducted joint research and development, including (1) developing integral field units for TriCCS for the Seimei Telescope, (2) conducting a feasibility study of a large space telescope with a group of microsatellites using diffractive optical elements, (3) developing integral field units for SWIMS for the Subaru Telescope, and (4) developing a wide-field submillimeter camera for the Greenland Telescope. Besides development, the team is actively engaged in consolidating the development requirements of multiple projects while simultaneously introducing necessary optical equipment for future needs. Specifically, in Fiscal Year 2022, the team procured ultra-high-precision spherical prototyping elements for the high-precision Fizeau interferometer, along with a corresponding holding mount.

2) Development of coating

Fundamental experiments are continued to design and to develop the concrete processes of coating, taking into account the applications and expected performance of inhomogeneous multilayers. A coating thickness monitor was newly installed, and various data as to the relation between the status of the coater and the film characteristics were obtained for longer processes in detail. A number of experiments have been undertaken to improve stability including ion-source electrodes modifications to improve long-time stability of the beam current and its profile; stabilization of power supply; lowering the ground resistance; and improvements of the process-gas and its introduction, have been undertaken. And improvements and optimization of the control software have continued.

(3) Sensor Engineering Team

The sensor engineering team has contributed to the development and maintenance of ALMA receivers and Subaru Telescope instruments (PFS, HSC).

For ALMA receivers, measurements and analyses of the designed and prototyped components were conducted with a view to upgrading Band 8 receivers for ALMA2, and an evaluation system was built for them. In addition, the maintenance of Band 1 receivers is being transferred from ASIAA to NAOJ.

As for the development of superconducting devices, our team was in charge of fabricating SIS devices for Band 8 receivers and NbTiN deposition experiments for Band 10 devices for ALMA2.

The experimental results showed that the current density control of SIS junctions can be controlled with high accuracy, which had been an issue. For future development, we succeeded in fabricating a device for loss measurement of integrated circuits and a vacuum window with a double-sided antireflection structure that achieves terahertz transparency across a wide bandwidth. We are also developing a through-hole fabrication technique using superconducting films for integrated circuits.

In the development of a next-generation detector for the Subaru Telescope, we were responsible for a CMOS evaluation and electronics development, as well as for overall coordination of the development, and the development is proceeding as planned.

5. Manufacturing Design Group

The Manufacturing Design Group engages in a comprehensive manufacturing process to fabricate experimental and observational instruments, from fabrication to verification. All three teams (Additive Manufacturing (AM) Engineering Team, Machining Engineering Team, and Measurement and Evaluation Team) cooperate with each other to meet the various needs from NAOJ projects and other institutions through manufacturing. In FY 2022, the AM Engineering Team, now in its third year of operation, responded to several requests. And the whole group had the opportunity to study and implement the process from additive manufacturing to finishing key parts such as interfaces by machining. We also work with the Thermal and Mechanical Engineering Team of the System Design Group on fabrication work. The number of requests for manufacturing and measurement in FY 2022 is shown in table 1.

Table 1: The requests for fabrication and measurement in FY 2022.

From FY 2021	3
FY 2022	
Advanced Technology Center	18
ALMA, ASTE, ngVLA	22
TMT/IRIS, Subaru Telescope	10
KAGRA	4
Solar Science Observatory, SOLAR-C, FOXSI-4	9
RISE	8
JASMINE	1
Astrobiology Center	1
Foundation for Promotion of Astronomy	1
External Organizations	
The University of Tokyo (TAO, SWIMS)	8
Osaka Metropolitan University	1
Tokyo Metropolitan University	1
Total	84
To FY 2023	10

(1) Machining Engineering Team

The Machining Engineering Team has responded to fabrication consultations and fabrication requests ranging from major NAOJ projects to groups at ATC and open-use users. And, for users who wanted to work on their own, we provided guidance as needed.

The main requests are as follows:

i. Regarding TMT/IRIS, fabrication of parts for element tests is being conducted by the Thermal and Mechanical Engineering Team of the System Design Group.

ii. Fabrication of lens holder base and cryostat test parts for ALMA Band 2 receiver

iii. Fabrication of a folding pendulum for KAGRA. After fabrication, performance tests were conducted and the results were fed back into the next process. (to be continued in the following fiscal year).

iv. Support for post processing of metal 3D printers

The main products are as follows.

- Corrugated horns for ALMA Band 1 receiver
- KAGRA QPD circuit covers
- Parts for ngVLA
- Mirror Frame for ATC THz Intensity Interferometer
- Filter holder for Tomo-e GOZEN camera for Kiso Schmidt Telescope, University of Tokyo

As for fabrication by the Ultra-Precision Section, we have finished processing thin polyethylene sheets to be used as samples for material property tests in the ALMA radio frequency range, and fabricated flat mirrors for terahertz intensity interferometer. In addition, we supported other teams for the fabrication of a processing holder and samples of laser effects on metal additive manufacturing.

(2) Additive Manufacturing (AM) Engineering Team

FY 2022 was the third year of the operation phase for the AM Engineering Team, the team is entering the application of equipment operation and modeling. Based on the knowledge and experience acquired from the development and manufacturing of ALMA Band 1 corrugated horns, which had been intensively pursued until FY 2021, the team tried various types of manufacturing with aluminum materials. For KAGRA QPD circuit covers, which were continued from FY 2021, we designed and manufactured another type of cover. At the same time, we continued to study surface treatment, which we had been evaluating since FY 2021, and proposed a design that would make the surface treatment more effective as well as the treatment method, and manufactured and delivered 21 pieces. In the manufacturing of the filter holder for the Tomo-e Gozen camera, which is installed on the Schmidt Telescope at the University of Tokyo's Kiso Observatory, the largest scale product of the fiscal year, we made a prototype to respond to the request of the observation operator to place the filter holder, which is installed in front of the detector, on a spherical surface along the telescope's focus, by combining the external shape manufacturing by the metal 3D printer and detail machining. After confirming the installation on site, we completed the installed product. During this fabrication, the team experienced manufacturing of the largest size of the equipment and learned the basic information and techniques for the manufacturing of large parts. Based on the experience with the ALMA receivers, we produced several components for radio astronomy instruments. In collaboration with Osaka Metropolitan University, we evaluated the performance of waveguides in the 6.5–12.5 GHz band and fabricated prototypes of an Ortho-mode Transducer. Also, prototypes of horns and an Ortho-mode Transducer for ngVLA were fabricated.

(3) Measurement and Evaluation Team

The Measurement and Evaluation Team makes full use of various measurement instruments to verify and confirm the accuracy of products by the Machining Engineering Team and AM Engineering Team. In addition, LEGEX910, a large 3D measurement machine managed by the Management and Administration Group, is used to respond to requests for open use measurements. In FY 2022, we conducted research on the latest measurement instruments and shared the information among the staff.

6. Management and Administration Group

The Management and Administration Group has been established to promote smooth support for projects both within ATC and outside the Institute, including open-use, and is now in its second year of operation. The Administrative Support Team has had to be reestablished with the replacement of 2/3 of the staff, but in addition to its normal duties, the team has renewed the ATC web page and posted ATC News about once a month. ATC adapted shoe covers to make the tours more comfortable for foreign visitors, taking into consideration their lifestyle, etc. 34 tours (290 people in total) were handled, which is back to the level before COVID-19. The IT Support Team has set up a process to register information assets with ATC, and continues to register existing and new information assets.

Operation of the facilities for Fiscal Year 2022 are as follows.

(1) Optical shop

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

In FY 2022 the function of the optical shop in Instrument Development Building (2) was moved from Room 110 to Room 111 due to the expansion of the SIS clean room, and maintenance was performed on all equipment. In addition, the UV-Vis-NIR spectrophotometer UV3600 made by SHIMADZU CORPORATION, which was installed at the end of FY 2021, has been started up and is now available for open use. The number of users in FY 2022 is as follows.

- The number of users for open use
  - The number of annual users: 274
    NAOJ: 222 (including 178 from ATC),
    External organizations: 52
  - Use of LEGEX910 (large-scale 3-D measurement machine): 10
    Number of operating days: 26
- Technical consulting for users: 28
  - Giving lectures on how to use the measurement instruments
  - Technical support on measurement methods

(2) Space chamber

As for experimental development support, we assisted basic experiments using vacuum chambers for the SOLAR-C project. In terms of equipment management, a turbo molecular pump of the large space chamber was overhauled in preparation for future environmental tests of a satellite telescope. In addition, safety and improvement plans for work at-heights for the space chamber are being discussed. We also investigated failures of a turbo-molecular pump in the other medium-sized vacuum chamber and prepared for the replacement of the pump. Software for measuring instruments was continuously developed and operated as needed.

(3) Facility Management and Operation Team

The Facility Management and Operation Team conducted periodic inspections of the buildings, electrical equipment, cold evaporator (CE), cranes, forklifts, draft chambers, and other equipment according to law; and implemented the overall repair plan, including construction and hazardous materials management for laboratories including clean rooms (CR). We were responsible for the supply and management of frequently used organic solvents and waste treatment. In addition, we were in charge of a NAOJ safety training course (CE practical training) as needed. Team members got skills and qualifications, and were able to promote the sharing of inspection and operational works for each facility. As a result, better load balancing was achieved than in FY 2021. We will continue to promote the acquisition of qualifications within the team. In response to the COVID-19 disaster, we regularly replenished the alcohol used for disinfection in ATC building entrances and rooms.

The CR temperature control problem and the fan filter units (FFUs) stoppage were partially corrected. Further improvement will be considered for temperature inhomogeneity near the equipment where there is a lot of heat generation. We will continue to investigate the cause of the FFUs outage problem, as the frequency of outages has decreased but the issue is not fully resolved. The circulating cooling water pipelines in particular buildings were inspected and cleaned to reduce deterioration of water quality, and we installed water improvement systems for them.

7. Open-Facility Program, Joint Research and Development Program

ATC accepts external researchers based on two programs, one is an Open-Facility program which only uses common-use facilities of ATC and the other is a Joint Research and Development program which is a collaborative development with ATC members.

We made calls for these programs twice every fiscal year. In FY 2022, we accepted 16/1 Joint Research Development programs in the first/last calls, and 13 Open Facility programs. Although we limited entry to ATC due to COVID-19, we normally operated these programs except for disinfection of hands, body-temperature measurement upon entry, and wearing a mask in the building in FY 2022.

8. Micro-fabrication Laboratory

The Micro-fabrication Laboratory has upgraded its film deposition and exposure systems and other equipment, as well as the associated utilities, in order to address aging facilities and equipment. The new equipment has increased the diameter of prototype substrates (from 35 mmΦ to 4 inches), making it possible to mount approximately eight times as many chips in terms of area. In addition, the introduction of maskless lithography equipment will allow the Laboratory to respond flexibly to frequent design changes, and the Laboratory will maintain the technology and facilities for fabricating Nb/Al/AlNx/Al/Nb junctions with high critical current density, which is extremely important for SIS junctions required for ALMA receivers, as well as the film deposition equipment for fabricating low-critical-current junctions required for peripheral circuits. In addition to maintaining the fabrication technology and equipment for Nb/Al/AlNx/Al/Nb junctions, which have extremely important high critical current density. Furthermore, for FY 2023, we are expanding analytical equipment and automating resist coating and development, and are proceeding with utility maintenance and installation work for this purpose. By automating new processes and improving technologies, ALMA is preparing a stable manufacturing base for the development of high-performance devices for future development. We constructed an expanded new clean room for the ALMA2 project, a superconducting device storage room, and an environment for managing design and process recipes data, all of these works were conducted in collaboration with the Facility Management and Operation Team. Furthermore, we are developing devices for the industrial application of these technologies to quantum computers.

(1) Expansion of the SIS clean room

The SIS CR expansion construction has been completed. As a result, the area of the SIS CR was increased 1.3 times from 210 m^2 to 270 m^2 to provide space for newly introduced manufacturing and inspection equipment. At the completion inspection, the cleanliness of the CR was measured and found to be ISO Class 1. This is the world's highest level for superconducting device CR.

(2) Strengthening of electronic device security management system

Since some of the electronic devices used in the ALMA receivers are subject to export control, the security control rules for these electronic devices and related information were determined, and NAOJ established the “Rules for Management of Electronic Devices Fabricated in the SIS Clean Room” and the “Procedure for Transfer of Electronic Devices Fabricated in the SIS Clean Room.” In accordance with these rules, a new storage area for device management was built and NAS-based management of design, fabrication, and test data was started. The management rules for electronic devices will be gradually applied to the management of other sensors.

9. Industrial collaboration activities

ATC cooperated with the Industrial Collaboration Office in order to apply the technologies developed at ATC for astronomical instruments to society. In FY 2022, ATC participated in the “Science Photonics Fair” for the first time as a part of NAOJ. ATC contributed to the fair by preparing presentation materials to introduce our technologies, exhibiting processed parts, and serving as a booth attendant.

Supported in part by JST (Moonshot R&D) (Grant No. JPMJMS2067) and JSPS KAKENHI (Grant Nos. JP18H03881, JP19H02205, and JP22H04955), we have devised a new concept of superconducting microwave low-noise amplifiers for use in radio wave detectors for radio astronomy observations, and successfully demonstrated a high-performance cooled amplifier with power consumption three orders of magnitude lower than that of conventional cooled semiconductor amplifiers. This result is expected to contribute to the realization of large-scale multi-element radio cameras and error-tolerant quantum computers, both of which require a large number of low-noise microwave amplifiers.

In the field of adaptive optics technology, which compensates for atmospheric turbulence to obtain a clear image of celestial objects, there is growing interest in its application to optical instruments for purposes other than astronomical observation, such as communications, and in FY 2022 we provided technical consulting services to private companies.

Preparations were made to launch the “Social Implementation Program” in FY 2023 for ATC as a whole to promote these industrial collaboration activities.

16. Public Relations Center

1. Overview

The Public Relations Center engages in the publication, promulgation, and promotion of scientific achievements made not only by NAOJ but also by others in the field of astronomy in general to raise public awareness; responds to reports of discoveries of new astronomical objects; and provides the ephemeris and other astronomical information directly related to people's everyday activities, such as sunrise and sunset times. The Public Relations Center is comprised of 9 offices (including Ishigakijima Astronomical Observatory) and 1 unit: the Public Relations Office, the Outreach and Education Office, the Spectrum Management Office, the Ephemeris Computation Office, the Library Unit, the Publications Office, the IAU Office for Astronomy Outreach (OAO), the Time Keeping Office, Ishigakijima Astronomical Observatory, and the General Affairs Office.

2. Personnel

In FY 2022, the Public Relations Center was composed of Director Hitoshi Yamaoka and the following staff members: 2 project professors, 2 associate professors, 2 associate professors (senior lecturers), 2 assistant professors (one of whom holds concurrent posts), 1 research engineer, 1 engineer, 1 unit leader, 6 senior specialists, 2 project research staff members, 2 research experts, 2 administrative experts, 1 research supporter, 14 public outreach staff members, 4 re-employment staff members, and 1 Senior Specialist.

On April 1, Leader of the Library Unit Iori Koshihara and Senior Specialist Yoshiaki Tamura arrived in the Time Keeping Office.

On May 31, Administrative Expert Kana Endo (Ishigakijima Astronomical Observatory) resigned.

On June 1, Administrative Expert Akiko Ishii arrived in Ishigakijima Astronomical Observatory.

On September 1, Project Research Staff Natsuki Hayatsu arrived in Ishigakijima Astronomical Observatory.

On October 1, Associate Senior Research Engineer Tetsuharu Fuse arrived in the Time Keeping Office.

On October 31, Administrative Expert Akiko Ishii (Ishigakijima Astronomical Observatory) resigned.

On November 1, Administrative Expert Sumiko Mimura arrived in Ishigakijima Astronomical Observatory.

On December 25, Public Outreach Staff Ryo Sato (Public Relations Office) resigned.

On March 31, Public Outreach Staff member Yumi Hibino (Outreach and Education Office) and Public Outreach Staff member Masaharu Ishizaki (Outreach and Education Office) resigned.

3. Public Relations Office

The results of NAOJ's research projects and joint research with other universities and research institutes were actively publicized through press conferences and web releases. In addition, we are producing and posting online videos and news article to widely disseminate information about topics at the forefront of astronomy and astronomical phenomena, and promoting the use of SNS. We conduct new forms of public outreach such as Citizen Astronomy and exhibits at international events in response to the mid-term goals and suggestions from the External Review.

(1) Online-Based Information Sharing

The Public Relations Office runs the NAOJ website (https://www.nao.ac.jp/en/), disseminating information via the internet. In Fiscal Year 2022, the total access count for the NAOJ website was approximately 12.65 million page views.

The Office opened Twitter, Facebook, Instagram, and Flickr accounts in both Japanese and English sequentially from 2010, actively disseminating information on social networking services. As of the end of March 2023, the Japanese Twitter account has nearly 268,000 followers, and the English version of the Twitter account has more than 9,400 followers. Information dissemination via the English version of Twitter, as well as the release of visual images on Instagram have been conducted continuously this year.

NAOJ e-mail newsletters No.237–243 were issued, introducing research results and NAOJ hosted events. A total of about 11,100 subscription addresses have been registered as of March 31, 2023. (almost unchanged from the previous year)

We continued to produce videos explaining astronomical phenomena and research results, and videos introducing outreach activities. Including English versions, 18 original videos were produced. In addition, a total of 11 livestreams were held, including astronomical phenomena such as the total lunar eclipse and occultation of Uranus; and the occultation of Venus; Special Open House Day lectures, and livestreams of celestial objects using the 50-cm Telescope for Public Outreach. In particular, the livestream of the total lunar eclipse and occultation of Uranus attracted a lot of attention, with 1,849,851 live views and a total of 2,016,018 views including archive views. The livestreams of celestial objects have been very popular, and in addition to distribution via YouTube, they are an official program by DWANGO Co., Ltd., which manages niconico Live, a video streaming service, and our viewers are increasing. In addition, an explanatory video was made before the lunar eclipse. On May 24, 2022, a collaborative project with the Ministry of Education, Culture, Sports, Science and Technology (MEXT) titled "GIGA School Special Lecture ~Let's Look at the Universe to Understand the World~" was held. The Mitaka Large Seminar Room and the Subaru Telescope Observation Room were connected online, and lectures and Q&A sessions were conducted in real time. The event was streamed on YouTube Live, and the archive was viewed 12,477 times (as of the end of March 2023).

(2) Research Result PR

There were 30 research result announcements (compared to 23 in FY 2022 and 30 in FY 2021). We released all the research releases in both English and Japanese. Press conferences (including online conferences) were held in connection with 3 of these releases. All presentations were sent to reporters via e-mail press releases to an original media list in addition to being published online.

The 28th “Astronomy Lecture for Science Journalists” was held on December 1, 2022 on the theme of “Technological Development in NAOJ and Collaboration with Industry,” with 18 lecturers and 14 guests of ATC participating.

(3) Activities as NAOJ’s Public Relations Center

In addition to the Center’s regular task of aiding research result releases, in order to raise awareness of NAOJ overseas, NAOJ holds booths at international conferences where the press, researchers, and educational officials gather. This year, we exhibited at the American Association for the Advancement of Science Annual Meeting (AAAS2023, March 2–5, 2023, Washington, DC). To support outreach efforts of other projects, we contributed to revamping project websites. The Citizens Astronomy project “GALAXY CRUISE” conducted with the support of Subaru Telescope, has received cooperation from the Outreach and Education Office since FY 2022. The second season, which targets fainter galaxies, began on April 18, 2022. This year, campaigns were held in August and at the end of the year. As of the end of March 2023, a total of 11,322 people from 102 countries and regions (including 7,675 participants from Japan) had registered to participate.

(4) New Astronomical Objects

In cooperation with the Outreach and Education Office, four staff members handled reports of new astronomical objects and other communications submitted to NAOJ. In this fiscal year, there were a total of 48 reports including confirmation requests for new celestial object candidates and other reports. The contents were: 39 novae/supernovae, 6 comets/cometary objects, 1 luminous object, and 2 moving objects. Among many reports of previously known celestial bodies or observational errors, a report in January 2023 was reported through NAOJ to the Transient Name Server operated by the IAU Supernova Working Group and recognized as the discovery of supernova 2023fu. A report in February 2023 was communicated through NAOJ to the IAU Central Bureau for Astronomical Telegrams (CBAT) and was recognized as an independent discovery of the nova V6596 Sgr. In addition, a total of 15 dwarf novae and flare stars were reported.

4. Outreach and Education Office

In FY 2022, the COVID-19 pandemic forced us to suspend, scale down, or restructure many of our outreach and education activities.

(1) Public Visits

A total of 12,684 people participated in Mitaka Campus Public Visits (former name was Visitors’ Area) in FY 2022. In addition, the group tours in 2022 consisted of 62 general tours (1561 guests), for a total of 14,245 guests visiting Mitaka Campus. Measures were taken to prevent the spread of COVID-19, such as restrictions on Public Visits and restrictions on the acceptance of group tours.

Regular stargazing parties, which before COVID-19 were usually held twice a month (the day before the 2nd Saturday① and the 4th Saturday②) with the 50-cm Telescope for Public Outreach, were held online twice a month until October (the 4th Saturday stargazing party in October was canceled due to Mitaka Open House Day). Starting from November ① was held online and ② was held onsite on a reduced scale. Online events were held 18 times and accumulated 1,851 views as of the end of March 2022. Onsite events with a capacity of 60 guests were held 5 times, and a total of 220 people participated.

Regular public screenings at the 4D2U Dome Theater were originally scheduled to be held three times a month (1st, 3rd Saturday, and the day before the 2nd Saturday) on a reservation basis. As preventative measures against the spread of COVID-19, the event capacity was reduced (usually 40 seats, 14 seats in April, 20 seats after May), but screenings were held on 34 days during the year, and 1,781 people participated. In addition, screenings for school groups resumed in July, and 349 people participated in 15 events. “Astronomers’ Talks” mini-lectures and public screenings for groups were both canceled. There were 53 group tours (544 people) organized and a total of 2,674 guests watched the 4D2U stereoscopic movies.

(2) Telephone Inquiries

Telephone inquiries are accepted from 9:30 to 17:00 on normal business days. Due to personnel reductions, we have continued to have only one person on-duty since fiscal 2020, but had two people on-duty on the day before (November 7) and the day of the total lunar eclipse and occultation of Uranus (November 8). In addition, to prevent the spread of COVID-19, we have been working from home or commuting as appropriate since FY 2020.

The number of telephone inquiries to which we responded this fiscal year totaled 3,260, of which 488 were from the media. The topics (and number) of the inquiries were: Solar Ephemeris (351), Lunar Ephemeris (340), Ephemeris (62), Time (12), Solar System (776), Universe (240), Astronomy (235), Other (1244). The number of letter inquiries totaled 56, of which 16 were official documents.

(3) Media Reception

We received 131 interview and filming requests from various media, out of which the following filmings were conducted: 32 newspaper articles; 37 TV programs (17 news programs, 6 science programs, 14 others); 22 publications (9 magazines, 5 books, 8 others); 14 websites and contents; 4 radio programs; 4 others. From FY 2019, we started to charge a fee for commercial filming and photography in the campus; this fiscal year, we accepted a request for a shooting for 1 publication.

(4) Educational and Outreach Activities

The “FUREAI (Friendly) Astronomy” project, now in its 13th year, continued to provide classroom visits and online lectures as in the previous year. These lectures were delivered at 112 schools, 69 in Japan and 43 overseas, by 70 instructors and attended by 7,933 pupils, with the number of attendees per lecture ranging from 4 to 406. In 13 years, 90,611 students in total have attended the lectures in 1,013 schools inside and outside Japan.

“Mitaka Open House Day” was held in hybrid format for the first time, with both online and on-site (advance registration, limited capacity) events. We participated as part of the secretariat under the direction of the steering committee, and contributed to some of the displays and content. This year’s event was held on October 28 (Friday, live-streamed) and October 29 (Saturday, hybrid events) with the theme “Time and Astronomy.” It was co-hosted by the Astrobiology Center, National Institutes of Natural Sciences; the Institute of Astronomy, the School of Science, the University of Tokyo; and the Department of Astronomical Science at the School of Physical Sciences of the Graduate University of Advanced Studies. At the onsite event, hands-on exhibits, mini-lectures, tours of research facilities usually inaccessible to the public, etc. were restarted and 419 people selected from among the applicants participated. Although it was a small number of people, it was the first lively Open House Day in a long time. Online, in addition to the main lecture streaming, mini-lectures, video content distribution, online puzzles, etc. were held. The number of video contents distributed was 31, the maximum total number of simultaneous connections was 1,000, and the total number of views in the first month after release was 65,480.

(5) Community Activities

The “Mitaka Picture Book House in the Astronomical Observatory Forest” welcomed 25,165 visitors in FY 2022. The Office supervised an exhibition, “You Can’t See It But It’s There; Here and in Space.” (July 2022 to June 2023). We also cooperated with an opening ceremony, modern and traditional Tanabata events, moon viewing event, and other events. In addition, through the “Mitaka Picture Book House in the Astronomical Observatory Forest, Picture Book Original Drawings Hallway Exhibit Contest” which started from FY 2013, the Outreach and Education Office cooperated in the selection of 6 winning books.

“Mitaka TAIYOKEI walk,” a stamp collecting event that takes place every Fall under the joint auspices of Mitaka City and Mitaka NETWORK University Organization, was held in a contactless way to avoid any potential spread of COVID-19, with a smartphone application collecting digital stamps instead of physical ones. During the event, lectures on the Solar System, a stargazing party, and a workshop for building an actual telescope were held as “Mitaka TAIYOKEI walk-related lectures,” in which NAOJ cooperated.

The Office also provided the venue for “Astronomy Course for Apprentice Starry Sky Guides, Star Sommelier Mitaka - Let’s Become Apprentice Starry Sky Guides! -” hosted by Mitaka NETWORK University Organization, and assisted by providing teachers and workshops. We also contributed to selecting lecturers for “Astronomy Pub” (currently held online).

The “Information Space of Astronomy and Science,” which is jointly operated by Mitaka City, Mitaka NETWORK University Organization, and Mitaka Town Management Organization, marked the 8th anniversary since its opening in September 2015. In FY 2022, a total of six exhibitions were held at this facility, of which the one titled “Exposing the True Nature of Black Holes” was planned and held by NAOJ. The total number of visitors was 12,362 in 2022, still about 2,900 less than in 2019 due to the effects of the novel coronavirus. The total number of visitors since its opening exceeded 100,000 this year, and we helped with an event to commemorate this milestone.

(6) Merchandizing Business

We run “Astronomical Events Information” on the NAOJ website to provide monthly star charts and information on planetary and other remarkable astronomical phenomena. We created a breaking-news page in response to Comet C/2022 E3 (ZTF), which appeared bright from January to February 2023.

This fiscal year, intended particularly for the media, an article detailing the remarkable astronomical phenomena of the year (the total lunar eclipse and occultation of Uranus on November 8) was created and posted on “Astronomical Events Information.” In addition, two corrections were made to update the information on the “Frequently Asked Questions” page, which summarizes the answers to questions the Telephone Inquiries service frequently received from the public.

5. Spectrum Management Office

The Spectrum Management Office (SMO) is tasked with protecting the astronomical observation environment from visible light to radio waves. The SMO currently consists of four members, of which three are dedicated members (Head, an associate professor, and a research supporter) and one holds a concurrent post. SMO members participated in 5 international meetings and 26 domestic meetings this year. In addition to these, the SMO also participated in email discussions and video conferences and responded to media inquiries.

(1) International Meetings

The SMO participated in Working Party 7D (WP7D) hosted by ITU-R, the radiocommunication sector of the International Telecommunication Union (ITU) responsible for radio astronomy issues, and contributed to the discussion. This year’s WP7D meetings were held from April 25 to 29, and from September 28 to October 5, in a hybrid format online and at the ITU headquarters. The main topics on the agenda were the study of compatibility between radio astronomy and mobile phones in the 43 GHz band, harmonics entering radio astronomical bands, and the sharing of frequency bands above 71 GHz between active services and radio astronomy. In addition, although lunar surface development is attracting much attention from the Artemis program and private space development companies, the radio quiet region on the lunar surface, where radio emissions from Earth are blocked (the shielded zone of the Moon), is important as a future radio telescope installation site. For this reason, issues related to mitigation technology in the case that radio astronomical facilities are established on the lunar surface were also discussed, and a new ITU-R Question was adopted by the ITU. The SMO also participated in online meetings as needed to exchange opinions and strengthen relationships with people involved in the protection of radio astronomy.

(2) Results and Current Status of Domestic Issues Discussed

Among the issues discussed by the MIC Information and Communications Council, the major ones related to radio astronomy are described here.

1) Frequency Expansion for Wireless LAN into the 6 GHz Band: In response to the congestion of the wireless LAN bands, the 6 GHz band (5.925–6.425 GHz) was newly allocated to wireless LAN in September 2022 in addition to the conventional 2.5/5 GHz bands. In FY 2022, with the aim of further expanding the band, a study on frequency sharing in the 6.425–7.125 GHz band and a technical study of a wireless LAN system with greater power emission were conducted. In this frequency band, 6.665–6.66752 GHz, where the CH_3OH maser emission line is located, radio astronomy is protected. Based on the results of a study concluded in FY 2021, it has been concluded that radio astronomy and wireless LAN cannot share this band due to the large amount of interference expected to radio astronomy. Although the introduction of a mechanism to prohibit radio emissions or adjust the output power of wireless LANs only in areas around radio telescopes and other radio stations was also considered, no conclusion was reached on the technical framework from the viewpoint of sharing between radio astronomy and other radio services. Studies will continue in FY 2023.

2) Studies on the 76–77 GHz Band Sharing with Vehicle-Borne Millimeter Wave Radar: To ensure a wide angle and a sufficient range, studies to improve vehicle-borne radar have been ongoing. In this frequency band, both radar and radio astronomy are supposed to use the same frequency band. To prevent radar systems from interfering with radio astronomy observations, the SMO participated in informal meetings with millimeter-wave radar manufacturers and discussions in the MIC 76 GHz Low Power Millimeter-Wave Radar Working Group. Although the results of the joint study conducted by the radar development companies were discussed, it could not be said that sufficient studies were conducted to prevent harmful interference, and the discussion was postponed to FY 2023.

3) Sharing between satellite cellular phones and radio astronomy in the 1.6 GHz band: When a new service using the satellite mobile phone system via the Globalstar satellites was developed, we studied the possibility of sharing radio band resources with radio astronomy. As a result, restricted areas were established around NAOJ VERA Mizusawa Station, Ishigakijima Station, and JAXA Usuda Deep Space Center to protect radio astronomy. An operation agreement was signed on March 23, 2023 between the NAOJ Public Relations Center and IPmotion Inc., which develops Globalstar satellite services in Japan.

(3) Application for Receiving Equipment Designation:

Designation of receiving equipment should be conducted based on the Radio Law, Article 56. Once it is approved, a radio station must be operated in such a way as not to cause interference or any other obstruction that impairs the operation of radio astronomy stations or equipment designated by the Ministry of Internal Affairs and Communications. This fiscal year, we applied for continued protection of the Nobeyama 45-m Radio Telescope, and the protection designation procedures were completed on March 10, 2023.

(4) Light Pollution:

There are concerns about the detrimental effects to astronomy from mega-constellations such as Starlink and OneWeb comprised of a large number of satellites. SpaceX, which operates the Starlink satellites, launched VisorSat equipped with a shade to reduce reflected light, and Ishigakijima Astronomical Observatory in cooperation with the Optical and Infrared Synergetic Telescopes for Education and Research (OISTER) conducted visible and near infrared observations of the satellite; and prepared a report (published in April 2023). The SMO assisted with analysis and interpretation of the data obtained at Ishigakijima Astronomical Observatory. In addition, the SMO committed to ongoing participation in the digital camera night-sky brightness survey being conducted by the Ministry of the Environment and we submitted observation results from Chichijima in the Ogasawara Islands and Mitaka City.

(5) Activities for Raising Awareness of Frequency Resource Management

To make more people aware of frequency resource management, the SMO participated in the Special Open House Day of Nobeyama Radio Observatory and Mitaka Open House Day 2022, explaining our activities to the guests. In addition to continuous updates to our webpage, an opinion submission form was created on the website to promote two-way communication with citizens about frequency resource management. In addition, an overview of light pollution was introduced in “SANKEI Kid's News” on January 19, 2023, and distributed to elementary and junior high schools (more than 6,000 schools) nationwide. In FY 2022, there were 10 media interviews about negative impacts on astronomy by light pollution from ground-based sources or mega-constellations, and those situations were covered by newspapers, magazines, web articles, etc.

6. Ephemeris Computation Office

(1) ECO published the "Calendar and Ephemeris 2023" and compiled the ephemeris section and several parts of the astronomy section from the "Rika Nenpyo 2023" (Chronological Scientific Tables). ECO also posted the "Reki Yoko 2024" in the official gazette on February 1, 2023. In addition to those paper-oriented products, ECO maintains web versions of the "Calendar and Ephemeris" and the "Reki Yoko" and updated their data simultaneously with the release of "Reki Yoko." The "Handbook of Scientific Tables" -The international edition of Rika Nenpyo- was released in May. We promoted the book through a web release; leaflet distribution and sample presentations at IAU and AAS Meetings; and advertisements in the "Astronomical Herald."

(2) ECO featured the total lunar eclipse with the lunar occultation of Uranus; the 1st sunrise of the year; and the lunar occultation of Venus on its website. In cooperation with the "Astronomical Events Information" by the Outreach and Education Office, ECO displayed the radiant points of the Perseid, Geminid, and Quadrantid meteor showers and the location of Comet ZTF in the Sky Viewer. In FY 2022, there were over 37 million page views for the ECO website.
https://eco.mtk.nao.ac.jp/koyomi/index.html.en

(3) The Japan Association for Calendars and Culture Promotion hosted Mini Forum, its 12th General Meeting, and the Calendar Presentation Ceremony. These were also delivered via a remote conference service.

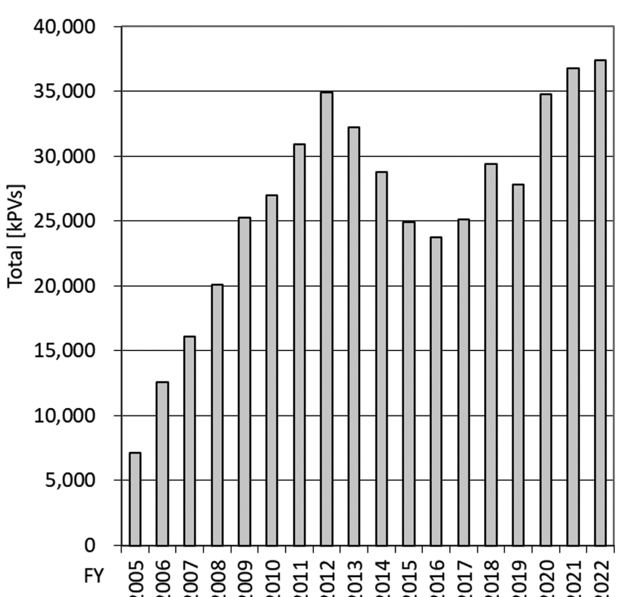


Figure 1: Pageviews for ECO Website.

(4) ECO holds regular exhibitions presenting NAOJ's invaluable collection of historical archives of Japanese and Chinese books in collaboration with the library. The theme of the 60th regular exhibition was "The Antikythera mechanism from the collection of the National Archaeological Museum of Athens." In addition, we published a new catalogue featuring pamphlets from the 41st through the 60th exhibitions. Past exhibitions are available at the Rare Materials Exhibition website.
https://eco.mtk.nao.ac.jp/koyomi/exhibition/

7. Library Unit

The Library Unit collects and sorts scientific journals and books in order to make them available for the research and study of NAOJ researchers and students. With the continuing digitalization of scientific materials, it has also become our responsibility to ensure access to electronic media academic resources.

Before the COVID-19 pandemic, the Mitaka Library was open to non-NAOJ affiliated users on weekdays, but the library has been closed to the public since March 2020. Even in such a situation, however, the library continues to lend materials that are not available at any other libraries or provide photocopies of these materials to non-NAOJ affiliated users. The library materials are provided to the general users through their local public libraries, and to researchers and students affiliated to other institutions through the libraries of their institutions. With both original materials and photocopies combined, 50 materials were provided this fiscal year.

The library holds many important documents, the most prominent of which are those written by the Tenmonkata, Shogunate Astronomers of the Edo Era. These documents are stored in a dedicated room where the environment is strictly controlled. Some of the collections are digitized and available on the Library Unit website.

For the Mitaka Open House Day 2022, held in October, the Library Unit created special web pages listing books related to this year's theme and other materials housed in the library. The number of books and journals owned by Mitaka Library and each observatory and the condition of continuing NAOJ publications are published in Section XI Library, Publications.

8. Publications Office

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

- Annual Report of the National Astronomical Observatory of Japan Volume 34 Fiscal 2021 (Japanese)
- Annual Report of the National Astronomical Observatory of Japan Volume 24 Fiscal 2021 (English)
- 23nd Report of the National Astronomical Observatory of Japan
- NAOJ 2023 Pamphlet (English)

• NAOJ News, No. 337–No. 339 (Summer 2022, Autumn 2022, Winter-Spring 2023)
• NAOJ Calendar (The 18th in the series)

NAOJ News underwent a major renewal in FY 2022 to focus on general-public readers. Copies for distribution were sent to schools and community facilities in Mitaka City, as well as member institutions of the Japanese Society for Education and Popularization of Astronomy, planetariums, and public observatories nationwide. Web-based surveys were conducted in accordance with each issue, and based on the results we will develop more effective content for the magazine. Website development is continuing for the shift to digital publication. In new publications, the English edition of the Sandcastle TRPG was released.

9. IAU Office for Astronomy Outreach (OAO)

The IAU Office for Astronomy Outreach (OAO) is a joint venture between the IAU and the National Astronomical Observatory of Japan (NAOJ). The OAO is primarily responsible for managing the IAU's communication and accessibility initiatives and supporting the international network of IAU National Outreach Coordinators (NOCs) in over 120 countries and with 350+ volunteer representatives.

In the 2022 fiscal year, we have marked an important milestone in the lifetime of the Office for Astronomy Outreach (OAO). To commemorate our 10th Anniversary, we focused on the sustainable growth of the OAO initiatives, consolidated the work assessed in 2021 by the OAO External Review and added some special projects.

The 10th Anniversary special projects included NameExo Worlds 2022, bringing together students, educators, amateurs, and exoplanetary scientists to collaborate in astronomy outreach in their communities and put forward names for one of 20 available exoworlds. The program received 603 submissions from 91 countries, engaging 52 National Panels formed by NOCs. Under One Sky funded five projects (2000€ per project) that connected indigenous with non-indigenous knowledge, spanned from remote communities to urban centers, and built multidisciplinary resources for the public to further engage with their astronomical traditions. The call received 33 proposals from 24 countries.

We also highlight the Communicating Astronomy with the Public Triptych, including the CAP Conference held in hybrid format from 12–16 September 2022, hosted by Macquarie University in Sydney, under the theme: Communicating Astronomy for a Better World. There were 111 participants in-person in Sydney and a further 133 online participants, in total representing 43 countries. Issue #31 of the CAP Journal was published in October 2022. And CAP Trainings hosted five editions: abstract writing (66 registrants), OAO-JWST on First Images (100+ registrants from 60 countries), Relationship Building at IAU GA XXXI (10+ participants), OAO-JWST on Image Processing (96 registrants from 50+ countries), and OAO-CXC on Image Accessibility (100+ registrants from 25+ countries).

Other OAO Activities in 2022 included: 1,684 Kaifu-NAOJ Telescope Kits sold; Dark and Quiet Skies Awareness Month in May, with an art contest (202 submissions from 13 countries), a seminar (nearly 3,000 views), and a social media campaign that highlighted 25 events worldwide; and the OAO presence at the IAU General Assembly (GA) in Busan in August, with a KASI-OAO Special Outreach event, the OAO GA Sessions and the Press Conference and Press Release for NameExo Worlds 2022. "Meet the IAU Astronomers!" had 65 meeting requests in 29 countries, and 220+ IAU members signed up (50 countries). In October, "100 Hours of Astronomy" saw 196 registered activities and events in 55 countries. "Telescopes for All" concluded with 110 entries from 30 countries and the engagement of 44 NOCs (15 telescopes awarded).

10. Timekeeping Office Operations

The Time Keeping Office operates four cesium atomic clocks together with a hydrogen maser atomic clock at Mizusawa VERA Station, and constructs "Central Standard Time" of Japan. The facilities contribute to the determination of UTC (Coordinated Universal Time) by BIPM (Bureau International des Poids et Mesures) through international time comparison. The NTP (Network Time Protocol) server at the Time Keeping Office provides standard time on a network. This service has been in great demand; about 3 million daily visits have been recorded.

11. Ishigakijima Astronomical Observatory

FY 2022 became the year that we implemented a paid admission system. In public outreach, the facilities were open to the public throughout the year, and the total number of guests was 3,477. Moreover, the observatory was involved in broadcasts of astronomical events. In education, we welcomed group tours and inspections. In research, 1 refereed paper was published, bringing the total number of papers published based on data from Ishigakijima Astronomical Observatory to 31.

(1) Public Outreach Activities

[Guided Tours, 4D2U Theater, Stargazing Sessions]

The facility was opened to the public through cooperation with Ishigaki City, Ishigaki City Education Committee, and Specified Nonprofit Corporation Yaeyama Hoshinokai. In fiscal 2022, paid admission began for the purposes of expanding services and improving safety and security. We limit the number of visitors, hours, and the number of times, and disinfect thoroughly as preventative measures against the COVID-19 pandemic. The annual number of visitors was 3,477, and the cumulative number of visitors was 154,163. Lightning strikes around the observatory in June damaged the telescope dome and water supply facilities. It took several months to restore each facility, with the telescope dome finally being restored in March 2023. During that time, the 40-cm telescope on the roof of the Hoshizora Manabi no Heya (Starry Sky Study Room) was utilized.

[Special Events, Co-sponsorships, Cooperative Events, etc.]

We were involved in photography for public outreach including a moonbow and Comet ZTF; photography and streaming videos with the “Southern Cross Monitor” and “Milky Way Monitor;” support for the broadcast of the November total lunar eclipse (based in Mitaka Campus, 2,010,000 views); and the live broadcast of the March occultation of Venus (270,000 views). The “Southern Island Star Festival” we co-hosted in August had 894 live viewers and 6,875 views including archive views. And 250 people attended the star festival held in Yonaguni Island which we also co-sponsored. There were 16 articles in newspapers and other media including Mynavi Gakumado, and there were 25 cases of assistance with news gathering. In March, a member of the observatory received the Yoshihide Kozai Award presented by the Nonprofit Public Organization: Foundation for Promotion of Astronomy. The 3,200 km “Stamp Rally” held with Nayoro Observatory KITASUBARU had 20 people complete it.

(2) Educational Activities

There were 18 inspections and educational group tours held in cooperation with Ishigaki City, Ishigaki City Education Committee, Specified Nonprofit Corporation Yaeyama Hoshinokai, and the Ishigaki Youth House with a total of 212 guests. Particularly noteworthy, we received an inspection tour by 12 members of the House of Representatives in July, and an inspection tour by Liberal Democratic Party Policy Research Council Chairperson Koichi Hagiuda and 16 other members of Parliament in December. The Chura-boshi Research Team Workshop for high school students was held in August with 20 participants from across Japan. We also worked for local education activities, including classroom visits for local elementary students and lectures for the local citizens.

(3) Research Activities

One refereed paper in a western journal was published in FY 2022, on the topic of small celestial bodies in the Solar System. The total number of papers including results based on Ishigakijima Astronomical Observatory observational data reached 31. Project Research Staff Member Natsuki Hayatsu arrived in September. There were 4 presentations at domestic and international conferences, and two papers were submitted to peer-reviewed journals. Observations with the Murikabushi Telescope were suspended long-term from June through the end of the fiscal year due to a lightning strike.

17. Division of Science

1. Overview

We will report the FY 2022 research activities in the Division of Science based on the following vision and philosophy of the division:

- Achieve fruitful research results based on liberal ideas of individuals, and achieve world-leading scientific results. Expand the horizons of astronomical knowledge by developing new fields such as efficient collaborations between theory and observations, multi-wavelength astronomy, and multi-messenger astronomy. In addition to developing important research, we nurture creative ideas to develop new fields.
- Utilize large telescopes and supercomputers in NAOJ to achieve top-level research results as a world-leading research division. Contribute to the promotion of future plans of NAOJ from a scientific perspective.
- Actively promote the education of young researchers, including students in graduate schools, to attract both Japanese and oversea researchers in the next generation who will lead world-wide research activities. Become a career path center for astronomical researchers worldwide.
- Strengthen astronomy research in Japan by creating new science through collaboration with domestic and international researchers, including other Projects in NAOJ. Play an important role in promoting internationalization in the astronomical field in Japan.

The members of the Division of Science cover a wide variety of themes in astronomy research from the early Universe to the formation and evolution of galaxies, stars, and planets, activities of compact objects, and plasma phenomena in astronomy and astrophysics – from various aspects of the astronomical hierarchical structure, such as dynamics and material evolution. Taking advantage of the facilities of NAOJ, such as the super-computers of NAOJ, the Subaru Telescope, ALMA, and the Nobeyama radio telescope, we stimulate collaborations among theoretical and observational astronomers working on various wavelength ranges. Also, we proceed with interdisciplinary research on the physics of neutrinos, gravitational waves, elementary particles, and atomic nuclei as well as planetary science. The division members are also actively participating in developing the science for future observational projects.

In order to facilitate highly competitive world-leading research activities, the Division of Science offers a superb research environment as a base for astronomy research accessible to researchers in Japan and overseas. We are beginning to see a return to direct domestic and international interaction even with continuing concerns about COVID-19, and visitors from other universities and research institutions in Japan are increasing. We have gradually begun to arrange opportunities for interaction among members. In addition to the regular lunch meetings of educational staff conducted online, we have held workshops and social events with all members in a hybrid format. The division actively organizes international and domestic workshops for the fields of theoretical and observational astronomy, as well as a cross-disciplinary field between astronomy and planetary science, to promote research activities in various related fields of astronomical science.

To maintain and further develop our high-level research capabilities and research environment, we underwent an international external review this year during March 1–2 for the first time since the Division of Science was set up. The review committee members were invited to Mitaka Campus for two days to interview staff, post-doctoral fellows, and graduate students. Committee members praised the high quality and quantity of research, incorporating theory and observation since its beginning.

2. Current Members and Transfers

In FY 2022, the dedicated faculties of the Division of Science included five professors, three associate professors, one project associate professor, and six assistant professors, in addition to one adjunct professor, one adjunct associate professor, one adjunct assistant professor, and one adjunct senior specialist who concurrently held a primary position at the Center for Computation Astrophysics (CfCA). Accordingly, the research activities on exoplanets, the formation and evolution of planets, supernovae, time domain astronomy, and multi-messenger astronomy have been strengthened. In addition to these faculty members, the division was served by ten project assistant professors (including NAOJ fellows), nine project researchers, two special postdoctoral researchers of Japan Society for the Promotion of Science (JSPS), two research supporters, as well as two administrative supporters (one is from Feb. 1) who gave full support to all activities of the division.

3. Output of Our Research

There were 173 refereed research papers published by the division members as authors. Some of the research results are presented as the research highlights listed at the beginning of this report. The following includes research in which the division members took leading roles:

- Top-heavy stellar mass distribution in galactic nuclei inferred from the universally high abundance ratio of [Fe/Mg] (D. Toyouchi, K. Inayoshi, M. N. Ishigaki, and N. Tominaga) [Japanese Language]
- Radio VLBI: still leading advancements in understanding the formation of high-mass stars at high resolution (R. A. Burns, et. al., + many more)
- Narrow Fe-Kα Reverberation Mapping Unveils the Deactivated Broad-Line Region in a Changing-Look Active

Galactic Nucleus (H. Noda, M. Kokubo, K. Morihata, et al.)
- A Long Time Ago in a Galaxy Far, Far Away: A Candidate $z \sim 12$ Galaxy in Early JWST CEERS Imaging (S. L. Finkelstein, et al., including P. Behroozi)

The following research results are released on the division's website (https://sci.nao.ac.jp/main/articles-en/) as research highlights:
- Exploring Atmospheric Properties from Eclipse Data for 25 Hot Jupiters: New Phase in Exoplanet Atmosphere Research (Ikoma, et al.)
- Brief Encounter with Mysterious Heavenly Event (Jiang, Tominaga, Moriya, et al.)
- Measuring the Universe with Star-Shattering Explosions (Dainotti, et al.)
- Scientists Reveal Distribution of Dark Matter around Galaxies 12 billion Years Ago – Further Back than Ever Before (Ouchi, et al.)
- New Material "Fingerprint" to Understand Planetary System Formation with ALMA (Yoshida, Nomuira, Furuya, et al.)
- Discovery of Two Temperate Super-Earths, the Outer One Orbits in the Habitable Zone (Ikoma, et al.)
- New theory predicts Earth-like aqua planets exist around red dwarfs (Ikoma, et al.)
- Machine Learning Reveals How Black Holes Grow (Behroozi et al.)
- Model-Independent Method to Weigh Protoplanetary Disks (Yoshida, et al.)
- Crisis in Cosmology: Statistics on the rescue. (Dainotti, et al.)
- An empirical method for mitigating an excess up-scattering mass bias on the weak lensing mass estimates for shear-selected cluster samples (Hamana, et al.)
- Spiral arm high-mass protostellar accretion disk revealed by radio telescopes (Burns, et al.)
- Magnetism in High-Mass Stars (Keszthelyi, et al.)

4. International and Domestic Collaborations and Cooperations

(1) International and Domestic Workshops

Restrictions on international meetings due to COVID-19 were relaxed this year. The division members organized or co-organized the following international and domestic workshops as a hub of science activities, collaborating with international and domestic colleagues. This contributed to stimulating research activities in astronomy and cross-disciplinary fields.

International Meetings

- IRCC-AFP Meeting 2022 (Oct. 24–28, 2022 at Mitaka)
- France-Japan Galaxy Formation Workshop (Nov. 16–17, at The University of Tokyo)
- Molecules in Extreme Environments: Near and Far (Nov. 23–25, 2022 at Mitaka)
- Star Formation in Different Environments 2022 (Aug. 21–27, 2022, Vietnam/Quy Nhon)

Domestic Meetings

- Rironkon symposium 2022 (Dec. 21–23, 2022, Fukushima)
- 11th Observational Cosmology workshop (Dec. 14–16, 2022, Mitaka)
- SKA-precursor ISM-WS2022 (June 27–28, 2022, Mitaka)
- First star/First galaxy workshop 2022 (Nov. 10–12, 2022, Tokushima University)

(2) International and Domestic Observation Projects

In order to proceed with efficient collaborations between theory and observations, and multi-wavelength astronomy, the members of the division contributed to the following observation projects. Also, the members contributed to the promotion of international and domestic future plans related to astronomy, including the plans for large telescopes in NAOJ from a scientific perspective.
- GREX-Plus white paper (Fujii, Nomura)
- LST white paper (Kobayashi, Furuya, Nomura)
- ULTIMATE-Subaru white paper (Kobayashi)
- Subaru SAC (Moriya, Ikoma)
- GREX-PLUS science working group (Moriya, Nakajima, Ouchi, Nomura)
- Subaru/NINJA project (Moriya, Tominaga, Ouchi)
- ULTIMATE-Subaru science working group (Moriya, Nakajima)
- HSC SSP transient working group (PI: Moriya, Kokubo)
- Euclid Consortium (Moriya)
- LAPYUTA Working group (Science goal 4 Chief: Ouchi, Moriya, Tominaga, Ikoma)
- LST whitepaper (Moriya)
- Roman-J (Moriya, Nakajima, Ouchi)
- CASTOR working group (Moriya)
- TMT-J SAC (Tominaga)
- TMT WFOS Science Team (Nakajima)
- ESA M4 Ariel (co-PI: Ikoma)
- WSO-UV (Ikoma)
- HSC SSP weak lensing working group (Hamana)
- SKA1 study group (Machida)
- VLBI SAC (Machida)
- POSSUM Astrophysics Group1 (Machida)
- POSSUM Astrophysics Group2 (Machida, Omae)
- HST Cycle 30 Peer Review (Ouchi)
- HSC SSP high-z galaxy working group (Ouchi)
- Subaru PFS Collaboration (GE co-chairman: Ouchi, Kokubo)
- HETDEX Collaboration (PI: Ouchi)
- HSC SSP AGN working group (Kokubo)
- ALMA-IMF Management team (Nakamura)
- CARMA-NRO Orion Survey Collaboration (Nakamura)
- Subaru proposal reviewer (Nomura)
- BISTRO (Nakamura, Iwasaki)
- NASA Swift Cycle 19 Review (Dainotti)
- NASA postdoctoral Program Review (Dainotti)
- Fermi-LAT mentors (Dainotti)

5. Educational and Outreach Activities

The division actively promotes the education of young researchers, including students at graduate schools, to become a career path center for astronomical researchers worldwide. In FY 2022 the graduate students in the Division of Science included thirteen SOKENDAI students (nine doctoral and four master course students) and nine students in the University of Tokyo (six doctoral and three master course students), and one student in Konan University (master course student). In addition, the members of the division engaged in the education of graduate and undergraduate students in the following universities and also high school students.

• Graduate student: Univ. Chinese Academy of Science (Fujii)
• Graduate student: University of Salerno (Dainotti)
• Graduate student: Scuola Meridionale Superiore of Naples (Dainotti)
• Graduate student: Jagiellonian University (Dainotti)

The members of the division actively engaged in lectures at the University of Tokyo and many other institutes and universities. In addition, spring school by the Division of Science for undergraduate and master course students was organized in February 2023. The members also engaged in outreach activities by offering lectures to the public.

18. Library

The purpose of the National Astronomical Observatory of Japan (NAOJ) Library is to organize and preserve books and other valuable materials, and to make them available to NAOJ staff, collaborating researchers, and others who wish to conduct academic research or surveys. The library was established in 1988, taking over the collection of the Tokyo Astronomical Observatory of the University of Tokyo in the Mitaka, Okayama, and Nobeyama areas and the Latitude Observatory in the Mizusawa area. With the incorporation of NAOJ in 2004, the Library was established in accordance with Article 20.3 of the General Rules for Organization and Operation of the National Institutes of Natural Sciences (General Rules No. 1, April 1, 2004). According to the Rules of the Library of the National Astronomical Observatory of Japan (National Institute of Natural Sciences Rules No. 41, April 1, 2004), the Director of the Library is the Director of the Public Relations Center (PRC), and the administrative work of the Library is handled by the Library Section of PRC.

The collection includes many Japanese and Chinese books and documents related to the history of astronomy and calendar studies, including those originating from the Shogunate's astronomical office in the Edo period. As part of the storage and management of these materials, we have been microfilming rare Japanese and Chinese books and documents since 1984, when the Tokyo Astronomical Observatory started to do it, in cooperation with the Calendar Computation Office, and have been providing these materials to researchers. From 2009 to 2010, the microfilms were digitized and made publicly available on the website, and from 2013, digital images of the rare books themselves are being created.

In order to comply with the new application of the Information Disclosure Act related to incorporation, a new entrance for off-premises users was established in FY 2004, and began operation in April 2005. On the other hand, a common MISHOP entry card key system was installed at the existing entrance for internal users, allowing them to enter and leave the building throughout the day.

See page 086 for details on the activities of the Library Section in FY 2022, and Chapter XII, 1 (page 138) for the library collection.

19. IT Security Office

IT Security Office (ITSO) has the following missions to ensure information security at NAOJ while operating and protecting information assets at NAOJ.

A) Management of servers that are open to the public.
B) Management education for the administrators of servers, etc., and matters related to operation rights and licenses.
C) Inspection and measures related to services for the public.
D) Management of accounts and licenses for network usage.
E) Management of recording, storage, and analysis of traffic data.
F) Management of high-level confidential information management book.
G) Management of the network.
H) Other matters necessary to ensure information security.

Based on these tasks, ITSO is performing the following six items.
① Build and operate zero-trust and integrated communications services based on Microsoft 365 services.
② Build, migrate, and operate network and telephony services.
③ Provide information service infrastructure such as virtualization and bare metal public servers.
④ Operate cost-effective external and internal network services in cooperation with various R&D networks, etc.
⑤ Conduct security-related operations (CSIRT) in cooperation with the Administrative Division, NINS, and MEXT.
⑥ Collect information and collaborate with other organizations.

The highlights of our activities in FY 2022 are as follows.

(1) Reorganization of Datacenters

The ITSO has international connections to the Subaru Telescope and NAOJ Chile Observatory through interconnections with the academic and educational R&D networks, ARENA-PAC, and TRANS-PAC for wide-bandwidth data transmission between the two observatories and Japan. The NTT.COM Otemachi datacenter served as the core of these data transmissions for more than 15 years. In 2022, the building was closed. ITSO worked the restructuring of the datacenters in Tokyo. In this project, we have deployed a new datacenter and 100 Gbps–400 Gbps transmission network. Now our new datacenters have interconnections with ARENA-PAC, TRANS-PAC, SINET6 of the National Institute of Informatics, and JGN of the National Institute of Information and Communications Technology.

(2) High bandwidth data transmission with Subaru Telescope HSC

With the cooperation of the University of Hawai`i and ARENA-PAC, we constructed a high-bandwidth network between Subaru Telescope and Tokyo to support HSC's remote observation tests.

20. Research Enhancement Strategy Office

The Research Enhancement Strategy Office was established as part of the functional enhancement program of the National Institutes of Natural Sciences (NINS) to promote the enhancement of research capabilities in NAOJ. In FY 2022, the Director of the Human Resources Planning Office, the Research Assessment Manager, and the Finance Controller worked as institutional URA staff members through the Research University Enhancement Promotion Grant, and conducted their functional work using their respective expertise, which should not be performed by research staff.

In addition, to promote cross-disciplinary research, a research agreement was concluded with the Institute of Statistical Mathematics (ISM), and two young researchers (assistant professors) were seconded from NAOJ to ISM to develop astroinformatics/astrostatics, which attempts to discover new phenomena from large-scale observational data obtained with large telescopes, etc.

Furthermore, the Research Assessment Support Office and the Industry Liaison Office were established under the Research Enhancement Strategy Office to contribute to the acceleration of NAOJ's research capabilities through their respective specialized work. The activities of each office in FY 2022 are as follows.

1. Research Assessment Support Office

(1) Implementation of Project Evaluation

For the international external review of the Division of Science (March 2–3, 2023), as the secretariat of the NAOJ Project Review Committee, we supported the external review committee (two international and five domestic committee members) from the request for appointment as committee members to the preparation of the review plan and input documents by the Division of Science and managed the review process.

In addition, we supported the preparation of the final versions of the review reports (4 projects) for FY 2021[1].

(2) Planning of research evaluation methodology

We prepared a revised draft of the project review procedure and proposed holding an NAOJ overall evaluation, which has not been conducted since FY 2014.

In addition, to promote the collection and utilization of the results of open use and research, we drafted a policy for the NAOJ Repository together with the NAOJ Library and prepared for its release.

(3) Response to the Evaluation of the Inter-University Research Institute Corporation

Under the leadership of the Director General, together with the members of the Evaluation Task Force (Vice Director General Saito, Director of Research Coordination Motohara, and Associate Professor Machida) and the General Affairs Unit, General Affairs Group, we prepared materials and confirmed evaluation results for the "Evaluation of Performance for the Third Mid-term Period" by MEXT, and provided support for preparations for the Objective of the Fourth Mid-term Period

(4) Enhancement of Research Infrastructure

With the cooperation of various groups/projects/offices/centers within NAOJ, we conducted a literature survey and analysis, collected information on strengthening research capabilities, organized those research achievements, and presented our report.

In addition, as the LOC for the "NAOJ Future Planning Symposium 2022: How to decide and promote future plans" (December 7–8, 2022)[2], we supported the holding of the symposium together with the Research Support Unit.

In addition, we participated in the NINS Open Use/Collaborative Research Team and Research and Management Strategy Analysis Team and exchanged information on efforts and achievements to contribute to the strengthening of university research capabilities.

2. Industry Liaison Office

(1) Collaboration with private companies

One case each of joint research, entrusted research, and commissioned business, and two cases of academic consultation were realized with private companies. There are also several projects that are still under discussion, and NAOJ's system for handling industrial collaborations is being put in place.

(2) Participation in exhibitions

In order to promote NAOJ's technologies, we provided support for participation in exhibitions for the industrial sector.

- Innovation Japan 2022 (October 4–31): Adaptive optics technology and stereoscopic computer graphics technology
- Science Photonics Fair 2022 (November 9–11)

(3) Press Lectures

The 28th Astronomy Lecture for Science Journalists "Technological Development in NAOJ and Collaboration with Industry" was held on December 1, 2022 in cooperation with the NAOJ Public Relations Center. The lectures covered an overview of NAOJ's technological development, superconducting receiver development, and satellite instrument development, and were attended by 18 participants. This was followed by a tour of the Advanced Technology Center, which was attended by 14 people. The event received a good response, with articles in Jiji Press, Nikkan Kogyo Shimbun, Yomiuri KODOMO Shimbun, and other newspapers.

[1] https://www.nao.ac.jp/en/about-naoj/reports/external-review.html
[2] https://www.nao.ac.jp/for-researchers/naoj-symposium2022/indexE.html

21. Office of International Relations

The Office of International Relations (OIR) strives to promote internationalization at NAOJ by collecting and providing information on international research exchange and education and creating an environment where multicultural researchers and students can engage cooperatively in research and educational activities. Specifically, the main activities of the OIR include promoting international research collaboration, supporting visiting international researchers and students, and disseminating information at international conferences. In FY 2022, despite the continued impact of COVID-19, there was a slight increase in the number of incoming international visitors. While the office could not fully resume all its scheduled events, it took advantage of this time to reallocate its efforts to other activities.

1. Promoting International Research Collaboration

The OIR serves as the contact point for the East Asian Core Observatories Association (EACOA) and the East Asian Observatory (EAO) and manages both the EAO/EACOA budgets within NAOJ. The EACOA consists of four core observatories representing the East Asian regions: the NAOJ (Japan), the National Astronomical Observatories of China (China), the Korea Astronomy and Space Science Institute (Republic of Korea), and the Academia Sinica Institute of Astronomy and Astrophysics (Taiwan), and the EAO is operated by these EACOA members and the National Astronomical Research Institute of Thailand. In October 2022, the EAO/EACOA Review Meeting of NAOJ was established with the OIR as the secretariat. Since then, the OIR has been formally in charge of the EAO/EACOA operations at NAOJ. In November 2022, the EAO held its regular Board of Directors (BOD) meeting in Chiang Mai, Thailand, as a hybrid meeting, including the first face-to-face meeting in a long time since the outbreak of COVID-19. The OIR assisted the NAOJ representative in this meeting as well as in each of EAO's online meetings, such as special BOD meetings, and supported one post-doctoral young researcher (EACOA Fellow) whom NAOJ hosted under the EACOA Fellowship Program.

Besides the duties mentioned above, the OIR has been in charge of reviewing legal documents, such as agreements and memoranda for international collaboration between NAOJ and overseas institutions. In FY 2022, the office reviewed a total of 26 new or renewed international agreements and drafted revisions as needed. In July 2022, with the expectation of further advancing the cooperation between Japan and Lebanon in the field of astronomical research, the Director General of NAOJ and the President of Notre Dame University in Lebanon (NDU) signed a Memorandum of Understanding for Research and Academic Collaboration (MOU) for conducting joint observation and research on transient celestial bodies, asteroids, and variable objects. The signing ceremony was held online, with the attendance of the Ambassador of the Lebanese Embassy in Japan.

2. Support Services for International Researchers and Students

The Support Desk (SD) of the OIR offers a broad range of services to help international researchers and students overcome their difficulties in living in Japan. During FY 2022, to prevent the spread of COVID-19, the SD staff worked mainly remotely by providing consultation services over the phone, e-mail, and online conference systems. However, in some instances where on-site assistance was necessary or requested, the SD staff accompanied international researchers and students to municipal offices and other places to complete various procedures. In addition, the SD staff made full use of the "NAOJ Support Desk Registration Form," which was put into operation in FY 2021 as part of an effort to strengthen SD services. By having international researchers and students submit this form before their visit, the SD staff can obtain accurate information in a timely manner and be prepared to provide appropriate support for facilitating the relocation process to help establish an environment in which incomers can concentrate on their research as quickly as possible.

Since its launch in July 2021, the OIR has maintained its website to provide information to international researchers and students both inside and outside NAOJ. The website contains practical information on immigration procedures, accommodations, campus neighborhoods, daily life, and reference information for NAOJ host researchers and staff. Although all information is provided in both Japanese and English, according to the current statistics, one-fourth of the website visitors have read the English version, indicating that it is widely used among non-Japanese speakers. At the same time, active efforts to publicize the website have helped promote its use among NAOJ researchers.

In parallel with these services, the OIR continues to collaborate with a specialized company to offer beginner-level Japanese language classes to help international researchers and students quickly adjust to life in Japan. Starting in FY 2021, a new curriculum was introduced to provide a program that better suits the needs of students. Both the beginner and intermediate courses offer lessons that have been developed in response to the requests of former students, where a speech-centered method is used to provide "practical Japanese for daily life." In addition, by using supplementary learning tools such as e-learning and enhancing instructor presence, students are given the freedom to study at their convenience. The courses were well received by the students, who remained highly motivated to learn. As a result, in FY 2022, there were no dropouts aside from those who had to quit due to work-related reasons, and the majority of students were able to acquire more practical Japanese language skills.

3. Information Dissemination at International Conferences

The OIR has been exhibiting booths at international conferences to recruit international researchers by providing information about NAOJ's research activities and invitational programs. In FY 2022, the OIR engaged in the active dissemination of information to approximately 750 visitors to the NAOJ booth at the International Astronomical Union General Assembly (IAUGA 2022) held in Busan, Korea in August 2022, and approximately 600 visitors to the NAOJ booth at the 241st American Astronomical Society Meeting (241st AAS Meeting) held in Seattle, USA in January 2023.

Furthermore, the OIR supports other NAOJ departments that plan to host or participate in international conferences. As a part of this duty, the OIR has been working as a member of the local organizing committee to provide support for welcoming participants and to start preparations for setting up the NAOJ exhibition booth at the Asia-Pacific Regional IAU Meeting (APRIM 2023) to be held in August 2023 in Koriyama, Fukushima Prefecture.

22. Human Resources Planning Office

The main duties of the “Human Resources Planning Office” are to plan and implement staff performance management, talent development, and labor management; and to contribute to the continuity and development of NAOJ's business from a personnel perspective, while working closely with the Director General, NAOJ Executives, and the Administration Department. Specifically, the scope of work of the Human Resources Planning Office includes operation of the Objective Sharing and Talent Development System; development of leaders; planning and implementation of training programs; management of fixed-term employees; creation of a harassment-free work environment; and handling of individual labor issues.

In FY 2022, due in part to the impact of prevention measures against the spread of the novel coronavirus, face-to-face training programs could not be implemented, but the following initiatives were appropriately carried out.

1. Objective Sharing and Talent Development System

The “Objective Sharing and Talent Development System” was properly operated to set annual goals and evaluate the degree of achievement at the end of the fiscal year for research and education staff, technical staff, and annual salaried staff. The evaluation results of the “Objective Sharing and Talent Development System” were reflected in the diligence allowance (June and December) and January salary increase for research and education staff and technical staff, and in the annual salary amount for annual salary system staff.

2. General Employment Management for Fixed-term Staff

We supported appropriate employment policies for fixed-term staff, including more than 270 salaried staff in a wide range of employment categories (e.g., operating the Fixed-Term Employee Review Committee, operating the policy for hiring staff who are transitioning to the Mandatory Retirement System, etc.).

3. Handling of Harassment, Mental Health, and Individual Labor Issues

We responded promptly and courteously to consultations on harassment (consultations with the external consultation service, with internal counselors, and with the Human Resources Planning Office), and took appropriate measures, etc., based on fact-finding.

In addition, the Human Resources Manager worked with the Employee Affairs Unit of the Administrative Division on measures to prevent harassment (e.g., conducting training and preparing leaflets).

4. Others

The Human Resources Manager participated in the ALMA HR AG (Human Resource Advisory Group) as a member of NAOJ's delegation to ALMA's HR Advisory Group and actively exchanged ideas. The Office continued to coordinate and negotiate for Joint ALMA Observatory (JAO) staff recruitment and NAOJ staff seconded to JAO.

23. Safety and Health Management Office

The mission of the Safety and Health Management Office is to prevent accidents through appropriate management and operation of NAOJ facilities, equipment, and devices and to promote the creation of a comfortable work environment by maintaining the safety, health, and well-being of employees. Specifically, the office holds Safety and Health Committee meetings and promotes information sharing, conducts periodic safety and health patrols and work environment measurements, provides safety and health education, implements healthcare and safety and health training programs, and develops rules and manuals on workplace safety and health.

Although the director of the office had just been newly appointed in 2022, the office successfully implemented preexisting plans, including the continuation of COVID-19 infection prevention measures, the revision of the safety and health manuals, and the implementation of voluntary routine inspections of observatories, including overseas observatories.

1. Holding Safety and Health Committee Meetings and Promoting Information Sharing

The Safety and Health Committee promotes safety and health activities through the committees that are organized at each work site, namely the Mitaka (including the Okayama Branch, Kamioka Branch, and Thirty Meter Telescope (TMT) Project / California Office), Nobeyama, Mizusawa, Hawai`i, and Chile districts. The activities of each committee are reported and shared on a monthly basis. In addition to the monthly reports, committee members and observers from each district and branch participate in a quarterly all-hands meeting to share information. The month following a quarterly meeting, important matters are reported at the Project Director Committee, which is attended by all staff at the management level, including the Director General, Vice-Director Generals, and Directors of Projects and Centers.

In FY 2022, the committee successfully promoted the planned activities and achieved the following results.

2. Periodic Patrols and Environmental Measurements

The health officer (Safety and Health Management Office Staff) conducted regular weekly patrols at each workplace in the Mitaka district and left comments for improvement upon noticing any problems or points of concern.

Alongside the patrols, environmental measurements (illuminance, room temperature, humidity, discomfort index, Carbon Dioxide concentration, formaldehyde, and suspended particulate matter PM10) were conducted using a digital illuminance meter and Air Quality Monitor newly purchased in FY 2022, and quantitative data were used to check the workplace environment in more detail, which enabled the office to gain further insights into the areas for improvement.

In addition, at the end of September 2022, the Subaru Telescope / Okayama Branch hosted a special joint patrol program on safety management with the National Institutes of Natural Sciences. Furthermore, as a part of the voluntary safety and health routine inspections, the office conducted patrols at Nobeyama Radio Observatory in early September 2022, Mizusawa VLBI Observatory in early November 2022, and Subaru Telescope in late February 2023 and identified the status of maintenance and improvement measures for preventing the recurrence of accidents in each district.

3. Safety and Health Education

As in previous years, a safety and health workshop (special education for workers who transferred jobs or are engaged in hazardous operations) was held on May 11, 2022.

Course Content:

□Physicochemical Hazards of Chemical Substances
□Health Hazards of Chemical Substances
□Respirators
□Protections
□New Occupational Safety and Health Laws and Regulations

Participants who completed this course were certified as hazardous materials practitioners for handling “coolants, high-pressure gases, cold evaporators (CE), organic solvents, and specified chemical substances.”

Number of certificates issued: 78 (18 for NAOJ staff, 60 for students / external staff, etc.)

Other: 1 person participated in CE handling practical training.

The office also worked in cooperation with the Engineering Promotion Office to hold the “System Safety Training” on December 9, 2022.

Course Content:

□What is System Safety (Overview)
□Necessity of System Safety (Examples of Accidents)
□System Safety Methodology
Flow of Hazard Analysis, Hazard Countermeasures (Removal, Fault Tolerance, Risk Minimization, etc.)
□Effects of System Safety

Number of Participants: 61 (12 management-level participants, including Directors of Projects)

4. Healthcare and Safety and Health Training

In fulfilling the responsibilities of a health officer, the office assisted in promoting the following tasks.

□Health Examination
□Influenza Vaccination
□Stress Check
□Development of “Support Program for Employees Returning from Mental Health Leave”
□Health Consultation with Occupational Physicians in the Mitaka district
□General Lifesaving Course

5. Development of Rules and Manuals

The contents of the safety and health manuals (main and separate volumes; versions for each branch version) were reviewed. In addition to confirming the necessity of revisions and issuing revised versions, it was agreed that from now on, the office will regularly check the need for such revisions at intervals of 1 to 2 years.

□Revised “NAOJ Safety and Health Manual”

□Revised “NAOJ Branch Manuals”

24. Engineering Promotion Office

1. Outline

The Engineering Promotion Office (EPO) aims to improve the overall level of NAOJ's engineering capability and facility operation by coordinating the skill development of engineering staff. Specifically, EPO acts mainly on "assigning engineering staff", "engineering staff human resource development", and "other areas needed to improve the engineering capabilities."

2. Assignment of Engineering Staff

The engineering staff which consists of engineers and research engineers, work on NAOJ's engineering issues with advanced expertise and a high sense of responsibility.

EPO considers the balance between a long-term plan of human resource and technological capability development and the efficient completion of individual technology projects. Then, EPO prepares and maintains a human resources portfolio to make medium- and long-term personnel promotion and hiring proposals.

In FY 2022, we cooperated in the recruitment of one Associate Senior Research Engineer and three Research Engineers, and promoted one Senior Engineer, five Engineers, and hired one Engineer.

3. Engineering Staff Human Resource Development

Human resource development for engineering staff is being conducted based on the documents compiled for that purpose in FY 2020. Specifically we are systematizing the line of work based on the duties of engineering staff. We are also renewing the human resource development sheet, which had been simplistic in the past, and communicating the competency for each line of work and job level with superiors, so that the sheet can be used as a tool for career path planning.

As for training, 11 engineering staff participated in an e-learning English training course. In FY 2022, the external lecturers' training course on systems engineering including practical exercises, which has been conducted since FY 2020, was held jointly with the High Energy Accelerator Research Organization (KEK) with 40 participants from NAOJ. Systems safety training was conducted by NAOJ staff with 61 participants from NAOJ. For some training courses, lectures were recorded and made available for viewing from NAOJ to create an environment where participants can continue to take the courses.

The 42nd Symposium on Engineering in Astronomy 2022 was held without a hitch, entrusting the management of the symposium to the engineering staff. The symposium was attended by more than 90 engineers and researchers from NAOJ and elsewhere. The symposium aimed to provide a forum for engineers and researchers involved in astronomy to exchange technical information on the design, development, improvement, and daily operation of astronomical instruments, and to contribute to technological development in the field of astronomy.

4. Other areas needed to improve the engineering capabilities

As for the safety and product development assurance in NAOJ, a standard document of S&PA (Safety and Product Assurance) for NAOJ is being developed. We have developed the system to collect and communicate the alert information such as defects and the availability of products and parts that may be used in NAOJ, and to share the information with concerned parties. The operation method for this system has been studied.

25. Graduate Education Office

The Graduate Education Office was established in April 2022 to lay a basis for the sustainable and developing management of graduate education at NAOJ by systematically managing the efforts for graduate education related to the Graduate University for Advanced Studies (SOKENDAI), cooperative graduate schools, NAOJ Special Inter-Institutional Research Fellows, and others.

With the establishment of the Graduate Education Office, it is expected that the future leaders of graduate education at NAOJ will have the opportunity to accumulate experience in the management of graduate education under the auspices of an organizationally recognized effort. The Graduate Education Office also acts as a window for cooperation between NAOJ and other universities or research institutions.

The Graduate Education Office also oversees the Graduate Education Committee and the Committee of the Department of Astronomical Science, School of Physical Sciences, (reorganized as Astronomical Science Program, the Graduate Institute for Advanced Studies from FY 2023) at SOKENDAI. In FY 2022, in preparation for SOKENDAI's reorganization, the Graduate Education Office worked on curriculum reorganization; re-formulation of educational goals and basic policies; etc. In addition, the scope of the cooperative graduate school program with the Graduate School of Science at the University of Tokyo was expanded to include the Department of Earth and Planetary Science to further strengthen cooperative graduate school education at NAOJ. For graduate students, individual meetings between SOKENDAI students and members of the Graduate Education Office were arranged for all students to further enhance support for graduate students.

For further information, refer to section VII “Graduate Education.”

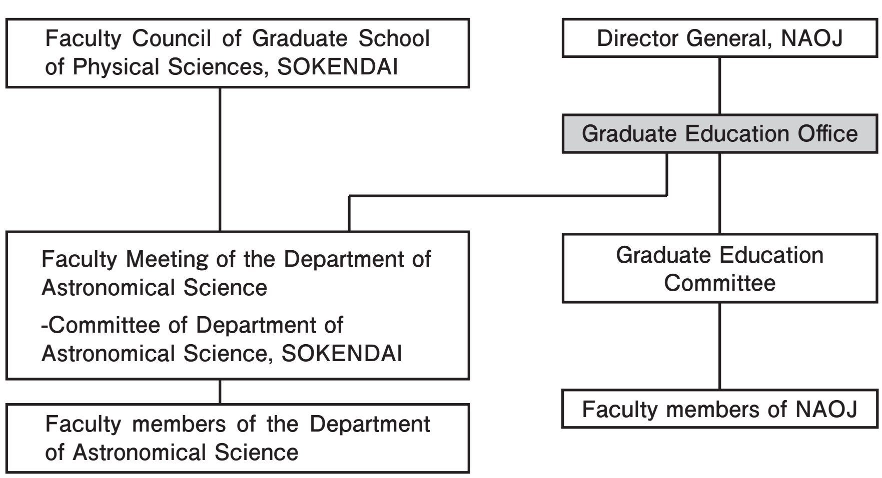
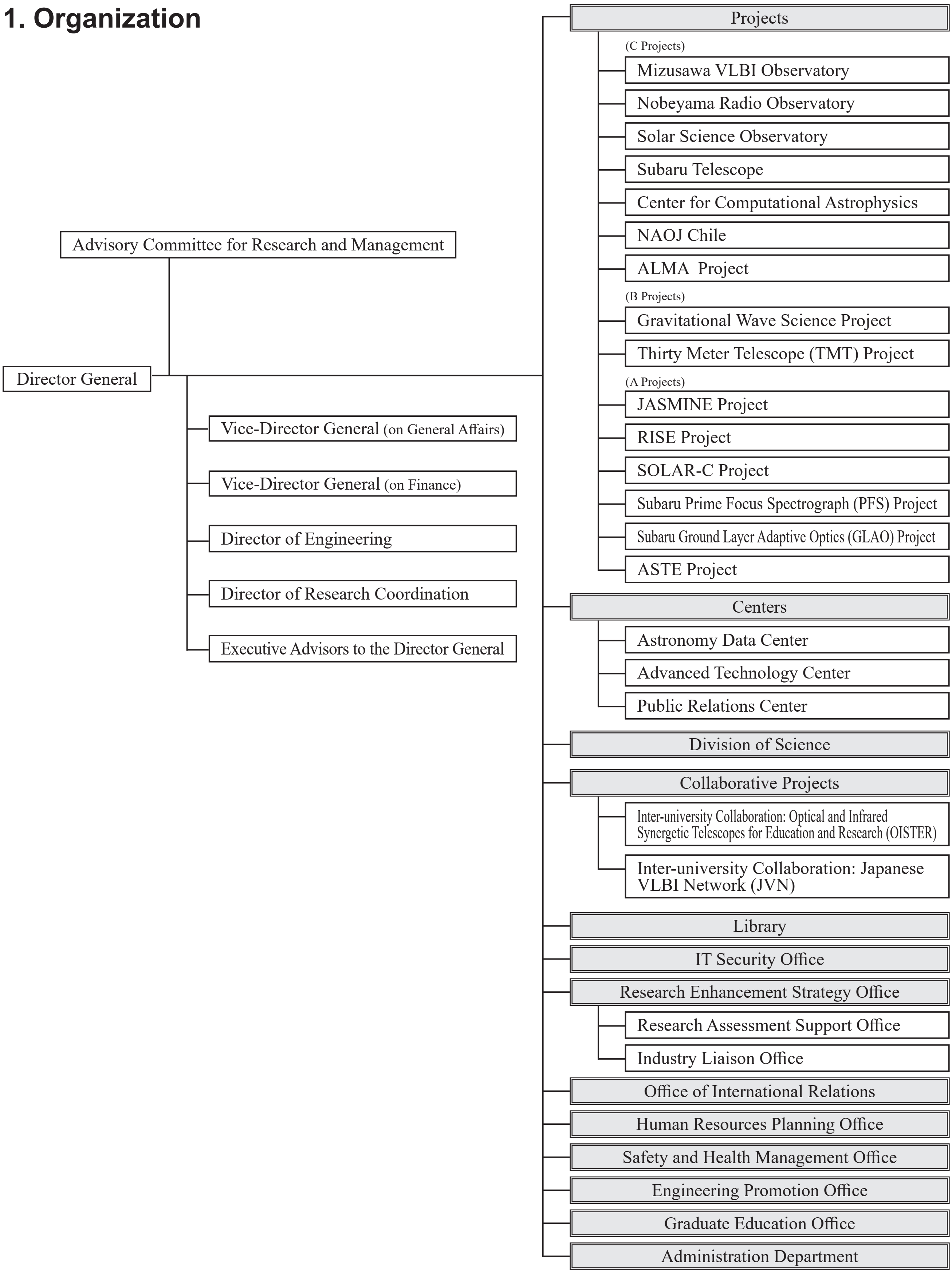


Figure 1: Organizational chart showing the position of the Graduate Education Office within NAOJ.

III Organization

1. Organization



2. Number of Staff Members

(2023/3/31)

Director General	1
Research and Academic Staff	149
Professor	31
Executive Engineer	1
Associate Professor	38
Senior Research Engineer	8
Associate Professor (Senior Lecturer)	6
Associate Senior Research Engineer	3
Assistant Professor	51
Research Associate	0
Research Engineer	11
Engineering Staff	40
Administrative Staff	58
Research Administrator Staff	2
Employees on Annual Salary System	152
Research Administrator Staff Transferring to the Mandatory Retirement System	1
Employees on Annual Salary System Transferring to the Mandatory Retirement System	3
Full-time Contract Employees	34
Full-time Contract Employees Transferring to the Mandatory Retirement System	2
Part-time Contract Employees	80
Part-time Contract Employees Transferring to the Mandatory Retirement System	15

3. Executives

Director General	Tsuneta, Saku
Vice-Director General	
on General Affairs	Yoshida, Michitoshi
on Finance	Saito, Masao
Director of Engineering	Uzawa, Yoshinori
Director of Research Coordination	Motohara, Kentaro
Executive Advisor to the Director General	Hiramatsu, Masaaki
Executive Advisor to the Director General	Kurasaki, Takaaki
Executive Advisor to the Director General	Sekiguchi, Kazuhiro

4. Research Departments

Projects

C Projects

Mizusawa VLBI Observatory

Director	Honma, Mareki
Professor	Honma, Mareki
Project Professor	Kobayashi, Hideyuki
Associate Professor	Hirota, Tomoya
Assistant Professor	Hada, Kazuhiro
Assistant Professor	Jike, Takaaki
Assistant Professor	Kouno, Yusuke
Assistant Professor	Sunada, Kazuyoshi
Project Assistant Professor	Sakai, Daisuke
Engineer (Gishi)	Ueno, Yuji
Engineer (Shunin Gijutsuin)	Takahashi, Ken
Engineer (Gijutsuin)	Sato, Gen
Project Researcher	Akahori, Takuya
Project Researcher	Kurahara, Kohei
Senior Specialist (Tokuninsenmonin)	Hachisuka, Kazuya
Senior Specialist (Tokuninsenmonin)	Oyama, Tomoaki
Senior Specialist (Tokuninsenmonin)	Ozawa, Tomohiko
Technical Experts	4
Research Supporters	2
Administrative Supporters	2

Administration Office

Head of Administration Office	Onuma, Toru
General Affairs Unit	
Leader	Onuma, Toru
Re-employment Staff	1
Administrative Supporters	3
Accounting Unit	
Leader	Kogawa, Hiroshi
Re-employment Staff	1
Administrative Supporter	1

Nobeyama Radio Observatory

Director	Tatematsu, Kenichi
Professor	Tatematsu, Kenichi
Project Associate Professor	Nishimura, Atsushi
Engineer (Gishi)	Handa, Kazuyuki
Engineer (Gishi)	Kurakami, Tomio
Engineer (Gishi)	Miyazawa, Chieko
Engineer (Gishi)	Takahashi, Toshikazu
Re-employment Staff	1
Research Supporters	2

Administration Office

Head of Administration Office	Tatematsu, Kenichi
General Affairs Unit	
Re-employment Staff	1
Administrative Supporters	2
Accounting Unit	
Administrative Supporters	2

Solar Science Observatory

Director	Katsukawa, Yukio
Professor	Katsukawa, Yukio
Associate Professor	Hanaoka, Yoichiro
Associate Professor	Ishikawa, Ryoko
Assistant Professor	Narukage, Noriyuki
Project Assistant Professor	Benomar, Othman Michel
Engineer (Gishi)	Shinohara, Noriyuki
Project Researcher	Ishikawa, Ryohtaroh
Senior Specialist (Tokuninsenmonin)	Morita, Satoshi
Research Supporters	2
Administrative Supporter	1

Subaru Telescope

Director	Miyazaki, Satoshi
Vice-Director	Hayano, Yutaka
Professor	Hayano, Yutaka
Professor	Miyazaki, Satoshi
Professor	Yoshida Michitoshi
Project Professor	Takami, Hideki
Project Professor *	Tamura, Motohide
Associate Professor	Koyama, Yusei
Associate Professor	Minowa, Yosuke
Associate Professor	Tanaka, Masayuki
Project Associate Professor	Kambe, Eiji
Senior Research Engineer	Iwashita, Hiroyuki
Senior Research Engineer	Kumura, Yoshinori
Assistant Professor *	Hirano, Teruyuki
Assistant Professor	Imanishi, Masatoshi
Assistant Professor	Ishigaki, Miho
Assistant Professor *	Kotani, Takayuki
Assistant Professor	Moritani, Yuki
Assistant Professor *	Nakajima, Tadashi
Assistant Professor	Okamoto, Sakurako
Assistant Professor	Okita, Hirofumi
Assistant Professor	Onodera, Masato
Assistant Professor	Ono, Yoshito
Assistant Professor	Pyo, Tae-Soo
Assistant Professor *	Suto, Hiroshi
Assistant Professor	Yanagisawa, Kenshi

Project Assistant Professor *	Hashimoto, Jun
Project Assistant Professor *	Hori, Yasunori
Project Assistant Professor *	Kuzuhara, Masayuki
Project Assistant Professor *	Livingston, John Henry
Project Assistant Professor	Shimakawa, Rhythm
Project Assistant Professor	Toba, Yoshiki
Research Engineer	Bando, Takamasa
Research Engineer	Omiya, Jun
Senior Engineer	Namikawa, Kazuhito
Engineer (Shunin Gijutsuin)	Hirano, Ken
Engineer (Shunin Gijutsuin)	Sato, Tatsuhiro
Engineer (Shunin Gijutsuin)	Sawatari, Koichi
Engineer (Shunin Gijutsuin)	Tsutsui, Hironori
Project Researcher	Hamano, Satoshi
Project Researcher	He, Wanqiu
Project Researcher *	Ishikawa, Hiroyuki
Project Researcher	Kawanomoto, Satoshi
Project Researcher *	Komatsu, Yu
Project Researcher	Mawatari, Ken
Project Researcher	Murata, Kazumi
Project Researcher	Nakata, Fumiaki
Project Researcher *	Nugroho, Stevanus Kristianto
Project Researcher *	Omiya, Masashi
Project Researcher *	Takahashi, Aoi
Project Researcher *	Takarada, Takuya
Project Researcher	Wong, Kenneth Christopher
Project Researcher	Yamashita, Takuji
Senior Specialist (Tokuninsenmonin)	Fujinawa, Toshiyuki
Senior Specialist (Tokuninsenmonin)	Harasawa, Sumiko
Senior Specialist (Tokuninsenmonin)	Ishii, Miki
Senior Specialist (Tokuninsenmonin)	Ishizuka, Yuki
Senior Specialist (Tokuninsenmonin)	Katakura, Junichi
Senior Specialist (Tokuninsenmonin)	Kobayakawa, Naoki
Senior Specialist (Tokuninsenmonin) *	Kusakabe, Nobuhiko
Senior Specialist (Tokuninsenmonin)	Mineo, Sogo
Senior Specialist (Tokuninsenmonin)	Morishima, Takahiro
Senior Specialist (Tokuninsenmonin)	Nakajima, Masayo
Senior Specialist (Tokuninsenmonin)	Oka, Shinji
Senior Specialist (Tokuninsenmonin)	Okura, Yuki
Senior Specialist (Tokuninsenmonin)	Shindo, Miwa
Senior Specialist (Tokuninsenmonin)	Tanaka, Mitsuhiro
Re-employment Staff	2
Administrative Expert	1
Research Supporters	2
Administrative Supporters	4

*concurrently appointed in NINS

Administration Department

Manager	Furuhata, Tomoyuki
General Affairs Unit	
Staff	Tamura, Makoto
Accounting Unit	
Leader	Sugawara, Satoshi

RCUH

RCUH Staff	68

Okayama Branch Office

Director	Tajitsu, Akito
Associate Professor	Izumiura, Hideyuki
Project Associate Professor	Tajitsu, Akito
Assistant Professor	Maehara, Hiroyuki
Administrative Supporters	2

Center for Computational Astrophysics

Director	Kokubo, Eiichiro
Professor	Kokubo, Eiichiro
Associate Professor	Takiwaki, Tomoya
Associate Professor (Senior Lecturer)	Ito, Takashi
Assistant Professor	Iwasaki, Kazunari
Project Researcher	Ideguchi, Shinsuke
Project Researcher	Keszthelyi, Zsolt
Project Researcher	Matsumoto, Yuji
Project Researcher	Nozawa, Takaya
Project Researcher	Taki, Tetsuo
Senior Specialist (Tokuninsenmonin)	Fukushi, Hinako
Senior Specialist (Tokuninsenmonin)	Hohokabe, Hirotaka
Senior Specialist (Tokuninsenmonin)	Kato, Tsunehiko
Research Expert	1
Research Supporters	3
Administrative Supporter	1

NAOJ Chile

Director	Watanabe Teruyuki
Vice-Director	Mizuno, Norikazu
Associate Professor	Minamidani, Tetsuhiro
Engineer (Gishi)	Kobiki, Toshihiko
Engineer (Shunin Gijutsuin)	Nishitani, Hiroyuki
Senior Specialist (Tokuninsenmonin)	Watanabe, Teruyuki

Chile Employee

Chile Employees	6

Administration Department

Manager	Watanabe, Teruyuki

General Affairs Unit

Staff	Iwasaki, Yumi

Accounting Unit

Senior Staff	Yamafuji, Yasuto

ALMA Project

Director	Gonzalez Garcia, Alvaro
Professor	Fukagawa, Misato
Professor	Gonzalez Garcia, Alvaro
Professor	Iguchi, Satoru
Professor	Kameno, Seiji
Professor	Mizuno, Norikazu
Professor	Sakamoto, Seiichi
Project Professor	Kiuchi, Hitoshi
Associate Professor	Asaki, Yoshiharu
Associate Professor	Hatsukade, Bunyo
Associate Professor	Okuda, Takeshi
Associate Professor	Sawada, Tsuyoshi
Associate Professor	Shimojo, Masumi
Associate Professor	Takahashi, Satoko
Project Associate Professor	Ishii, Shun
Project Associate Professor	Nagai, Hiroshi
Project Associate Professor	Nakanishi, Kouichiro
Senior Research Engineer	Kikuchi, Kenichi
Senior Research Engineer	Sugimoto, Kanako
Senior Research Engineer	Watanabe, Manabu
Assistant Professor	Ezawa, Hajime
Assistant Professor	Hirota, Akihiko
Assistant Professor	Izumi, Takuma
Assistant Professor	Kamazaki, Takeshi
Assistant Professor	Matsuda, Yuichi
Project Assistant Professor	Cataldi, Gianni
Project Assistant Professor	Imada, Hiroaki
Project Assistant Professor	Saito, Toshiki
Project Assistant Professor	Sanhueza Nunez, Patricio Andres
Project Assistant Professor	Tokuda, Kazuki
Project Assistant Professor	Wu, Yu-Ting
Project Assistant Professor	Zavala Sorano, Jorge Armando
Research Engineer	Nakazato, Takeshi
Research Engineer	Yamada, Masumi
Engineer (Gishi)	Kato, Yoshihiro
Engineer (Gishi)	Nakamura, Kyoko
Engineer (Shunin Gijutsuin)	Ito, Tetsuya
Engineer (Shunin Gijutsuin)	Shizugami, Makoto
Project Researcher	Algera, Hiddo Sunny Bouwe
Project Researcher	Bakx, Tom Johannes Lucinde Cyrillus
Project Researcher	Chen, Xiaoyang
Project Researcher	Cheng, Yu
Project Researcher	Feeney-Johansson, Anton Fiachra George
Project Researcher	Fudamoto, Yoshinobu
Project Researcher	Kaneko, Hiroyuki
Project Researcher	Kudo, Yuki
Project Researcher	Michiyama, Tomonari
Project Researcher	Miley, James Maxwell
Project Researcher	Saha, Piyali
Project Researcher	Silva Bustamante, Andrea Ludovina
Project Researcher	Sugahara, Yuma
Project Researcher	Takahashi, Sanemichi
Senior Specialist (Tokuninsenmonin)	Asanuma, Masumi
Senior Specialist (Tokuninsenmonin)	Ebihara, Eiichi
Senior Specialist (Tokuninsenmonin)	Fukui, Hideharu
Senior Specialist (Tokuninsenmonin)	Funakawa, Takashi
Senior Specialist (Tokuninsenmonin)	Ikeda, Emi
Senior Specialist (Tokuninsenmonin)	Inoue, Naoko
Senior Specialist (Tokuninsenmonin)	Kawasaki, Wataru
Senior Specialist (Tokuninsenmonin)	Konuma, Mika
Senior Specialist (Tokuninsenmonin)	Miel, Renaud Jean Christphe
Senior Specialist (Tokuninsenmonin)	Nakayama, Susumu
Senior Specialist (Tokuninsenmonin)	Otawara, Kazushige
Senior Specialist (Tokuninsenmonin)	Shakunaga, Takeshi
Senior Specialist (Tokuninsenmonin)	Shimada, Kazuhiko

Senior Specialist (Tokuninsenmonin)	So, Ryoken
Senior Specialist (Tokuninsenmonin)	Tagawa, Hiroaki
Senior Specialist (Tokuninsenmonin)	Uemizu, Kazunori
Senior Specialist (Tokuninsenmonin)	Yoshino, Akira
Senior Specialist (Tokuninsenmonin)	Zahorecz, Sarolta
Re-employment Staff	1
Technical Expert	1
Administrative Expert	1
Research Supporter	1
Public Outreach Staff	1
Administrative Supporters	3
Research Assistant Staff	1

B Projects

Gravitational Wave Science Project

Director	Tomaru, Takayuki
Professor	Tomaru, Takayuki
Associate Professor	Aso, Yoichi
Assistant Professor	Akutsu, Tomotada
Assistant Professor	Takahashi, Ryutaro
Engineer (Shunin Gijutsuin)	Tanaka, Nobuyuki
Project Researcher	Eisenmann, Marc
Project Researcher	Page, Michael Anthony
Administrative Expert	1
Research Supporter	1
Administrative Supporter	1

Kamioka Branch Office

Director	Tomaru, Takayuki
Assistant Professor	Chen, Dan
Project Assistant Professor	Washimi, Tatsuki
Senior Specialist (Tokuninsenmonin)	Ikeda, Satoru
Administrative Supporter	1

Thirty Meter Telescope (TMT) Project

Director	Usuda, Tomonori
Vice-Director	Aoki, Wako
Professor	Aoki, Wako
Professor	Usuda, Tomonori
Professor	Saito, Masao
Professor	Yamashita, Takuya
Project Professor	Kurasaki, Takaaki
Associate Professor	Iono, Daisuke
Associate Professor	Noumaru, Junichi
Associate Professor	Sugimoto, Masahiro
Associate Professor	Suzuki, Ryuji
Assistant Professor	Nishikawa, Jun
Assistant Professor	Yasui, Chikako
Project Assistant Professor	Tadaki, Kenichi
Research Engineer	Tazawa, Seiichi
Project Researcher	Lee, Kianhong
Senior Specialist (Tokuninsenmonin)	Kakazu, Yuko
Research Supporter	1
Senior Specialist (Tokumeisenmonin)	1

NAOJ California Office

Associate Professor	Hayashi, Saeko
Associate Professor	Terada, Hiroshi
Research Engineer	Nakamoto, Takashi

A Projects

JASMINE Project

Director	Gouda, Naoteru
Professor	Gouda, Naoteru
Professor	Kano, Ryouhei
Project Associate Professor	Kataza, Hirokazu
Assistant Professor	Miyoshi, Makoto
Assistant Professor	Ohsawa, Ryou
Assistant Professor	Tatsumi, Daisuke
Assistant Professor	Tsujimoto, Takuji
Assistant Professor	Ueda, Akitoshi
Assistant Professor	Yano, Taihei
Project Assistant Professor	Baba, Junichi
Project Researcher	Miyakawa, Kohei
Technical Supporter	1

RISE Project

Director	Namiki, Noriyuki
Professor	Namiki, Noriyuki
Associate Professor	Matsumoto, Koji
Assistant Professor	Araki, Hiroshi
Assistant Professor	Kikuchi, Shota
Assistant Professor	Noda, Hirotomo
Project Researcher	Yamamoto, Keiko
Administrative Expert	1
Public Outreach Staff	1

SOLAR-C Project

Director	Hara, Hirohisa
Professor	Hara, Hirohisa
Assistant Professor	Kawabata, Yusuke
Assistant Professor	Kubo, Masahito
Assistant Professor	Okamoto, Takenori
Engineer (Gishi)	Shinoda, Kazuya
Project Researcher	Oba, Takayoshi
Senior Specialist (Tokuninsenmonin)	Nodomi, Yoshifumi
Administrative Supporters	2

Subaru Prime Focus Spectrograph (PFS) Project

Director	Rousselle, Julien

Subaru Ground Layer Adaptive Optics (GLAO) Project

Director	Minowa, Yosuke

ASTE Project

Director	Minamidani, Tetsuhiro

Centers

Astronomy Data Center

Director	Kosugi, George
Associate Professor	Furusawa, Hisanori
Associate Professor	Ichikawa, Shinichi
Associate Professor	Kosugi, George
Associate Professor	Takata, Tadafumi
Associate Senior Research Engineer	Morita, Eisuke
Assistant Professor	Shirasaki, Yuji
Assistant Professor	Yagi, Masafumi
Research Engineer	Koike, Michitaro
Project Researcher	Furusawa, Junko
Project Researcher	Onozato, Hiroki
Project Researcher	Ootsubo, Takafumi
Senior Specialist (Tokuninsenmonin)	Isogai, Mizuki
Senior Specialist (Tokuninsenmonin)	Kitada, Chihiro
Senior Specialist (Tokuninsenmonin)	Makiuchi, Shinichiro
Senior Specialist (Tokuninsenmonin)	Nakajima, Yasushi
Senior Specialist (Tokuninsenmonin)	Ozawa, Takeaki
Senior Specialist (Tokuninsenmonin)	Tanaka, Nobuhiro
Senior Specialist (Tokuninsenmonin)	Yamane, Satoru
Senior Specialist (Tokuninsenmonin)	Zapart, Christopher Andrew
Re-employment Staff	1

Advanced Technology Center

Director	Hirabayashi, Masayuki
Vice-Director	Fukushima, Mitsuhiro
Vice-Director	Ozaki, Shinobu
Professor	Motohara, Kentaro
Professor	Ozaki, Masanobu
Professor	Uzawa, Yoshinori
Project Professor	Mitsuda, Kazuhisa
Executive Engineer	Hirabayashi, Masayuki
Associate Professor	Fujieda, Miho
Associate Professor	Kojima, Takafumi
Associate Professor	Makise, Kazumasa
Associate Professor	Matsuo, Hiroshi
Associate Professor	Oya, Shin
Associate Professor	Shan, Wenlei
Senior Research Engineer	Fukushima, Mitsuhiro
Senior Research Engineer	Kanzawa, Tomio
Associate Professor (Senior Lecturer)	Nakaya, Hidehiko
Associate Professor (Senior Lecturer)	Ozaki, Shinobu
Associate Senior Research Engineer	Obuchi, Yoshiyuki
Assistant Professor	Oshima, Tai
Project Assistant Professor	Hattori, Masayuki
Project Assistant Professor	Tokoku, Chihiro
Research Engineer	Ezaki, Shohei
Research Engineer	Sato, Naohisa
Research Engineer	Tsuzuki, Toshihiro
Engineer (Gishi)	Kamata, Yukiko
Engineer (Gishi)	Kaneko, Keiko
Engineer (Gishi)	Omata, Koji
Engineer (Gishi)	Tamura, Tomonori
Engineer (Gishi)	Uraguchi, Fumihiro
Engineer (Shunin Gijutsuin)	Fukuda, Takeo
Engineer (Shunin Gijutsuin)	Hirata, Naoatsu
Engineer (Shunin Gijutsuin)	Hoshino, Masayuki
Engineer (Shunin Gijutsuin)	Ikenoue, Bungo
Engineer (Shunin Gijutsuin)	Inata, Motoko
Engineer (Shunin Gijutsuin)	Iwashita, Hikaru
Engineer (Shunin Gijutsuin)	Mitsui, Kenji
Engineer (Shunin Gijutsuin)	Miyachi, Akihira
Engineer (Shunin Gijutsuin)	Waseda, Koichi
Engineer (Gijutsuin)	Kohara, Naoki
Engineer (Gijutsuin)	Sakai, Ryo
Engineer (Gijutsuin)	Shimizu, Risa
Project Researcher	Kozuki, Yuto
Project Researcher	Murayama, Yosuke
Project Researcher	Nagai, Makoto
Project Researcher	Yoneta, Kenta
Senior Specialist (Tokuninsenmonin)	Kusumoto, Hiroshi
Senior Specialist (Tokuninsenmonin)	Morita, Masaki
Re-employment Staff	1

Technical Experts	2
Administrative Expert	1
Technical Supporter	1
Administrative Supporters	2
Research Assistant Staff	1
Senior Specialist (Tokumeisenmonin)	1

Public Relations Center

Director	Yamaoka, Hitoshi
Project Professor	Oishi, Masatoshi
Project Professor	Watanabe, Junichi
Associate Professor	Agata, Hidehiko
Associate Professor	Yamaoka, Hitoshi
Associate Professor (Senior Lecturer)	Hanayama, Hidekazu
Associate Professor (Senior Lecturer)	Hiramatsu, Masaaki
Associate Senior Research Engineer	Fuse, Tetsuharu
Assistant Professor	Umemoto, Tomofumi
Research Engineer	Katayama, Masato
Engineer (Shunin Gijutsuin)	Nagayama, Shogo
Project Researcher	Hayatsu, Natsuki
Project Researcher	Shibata, Takashi
Senior Specialist (Tokuninsenmonin)	Blumenthal, Kelly Anne
Senior Specialist (Tokuninsenmonin)	Filipecki Martins, Suzana
Senior Specialist (Tokuninsenmonin)	Ishikawa, Naomi
Senior Specialist (Tokuninsenmonin)	Komiyama, Hiroko
Senior Specialist (Tokuninsenmonin)	Lundock, Ramsey Guy
Senior Specialist (Tokuninsenmonin)	Pires Canas, Lina Isabel
Re-employment Staff	4
Research Experts	2
Administrative Experts	2
Research Supporters	2
Public Outreach Staff	13
Senior Specialist (Tokumeisenmonin)	1

Public Relations Office

	Yamaoka, Hitoshi

Outreach and Education Office

Director	Umemoto, Tomofumi

Ephemeris Computation Office

Director	Katayama, Masato

Spectrum Management Office

Director	Oishi, Masatoshi

Library

Leader	Koshihara, Iori

Publications Office

Director	Yamaoka, Hitoshi

The Office for Astronomy Outreach of the IAU

Director	Pires, Canas Lina Isabel

Administration Office

Director	Matsuda, Ko

Ishigakijima Astronomical Observatory

Director	Hanayama, Hidekazu

Time Keeping Office

Director	Watanabe, Junichi

Division of Science

Division Head	Ikoma, Masahiro
Professor	Ikoma, Masahiro
Professor	Kawabe, Ryohei
Professor	Nomura, Hideko
Professor	Ouchi, Masami
Professor	Tominaga, Nozomu
Associate Professor	Fujii, Yuka
Associate Professor	Machida, Mami
Associate Professor	Nakamura, Fumitaka
Assistant Professor	Dainotti, Maria Giovanna
Assistant Professor	Hamana, Takashi
Assistant Professor	Harada, Nanase
Assistant Professor	Kataoka, Akimasa
Assistant Professor	Morino, Junichi
Assistant Professor	Moriya, Takashi
Project Assistant Professor	Arzoumanian, Doris
Project Assistant Professor	Chiaki, Gen
Project Assistant Professor	Furuya, Kenji
Project Assistant Professor	Kokubo, Mitsuru
Project Assistant Professor	Nagakura, Hiroki
Project Assistant Professor	Nakajima, Kimihiko
Project Assistant Professor	Sugiyama, Naonori
Project Assistant Professor	Taniguchi, Kotomi
Project Researcher	Behroozi, Peter Spalding
Project Researcher	Ito, Yuichi
Project Researcher	Iwata, Yuhei
Project Researcher	Jiang, Jian
Project Researcher	Kikuta, Satoshi
Project Researcher	Ohno, Kazumasa
Administrative Experts	2
Research Supporter	1
Research Assistant Staff	3

5. Research Support Departments

IT Security Office

Director	Yoshida, Michitoshi
Vice Director	Oe, Masafumi
Associate Professor (Senior Lecturer)	Oe, Masafumi
Engineer (Gijutsuin)	Matsushita, Sayaka
Senior Specialist (Tokuninsenmonin)	Shingu, Uken
Re-employment Staff	1

Research Enhancement Strategy Office

Director	Iguchi, Satoru
Professor	Sekiguchi, Kazuhiro
Assistant Professor	Hattori, Kohei
Assistant Professor	Ishizuki, Sumio
Assistant Professor	Shirasaki, Masato
Senior Specialist (Tokuninsenmonin)	Asaga, Akitaka
Senior Specialist (Tokuninsenmonin)	Chapman, Junko
Senior Specialist (Tokuninsenmonin)	Hori, Kuniko

Research Assessment Support Office

Director	Saito, Masao
Assistant Professor	Ishizuki, Sumio
Senior Specialist (Tokuninsenmonin)	Hori, Kuniko

Industry Liaison Office

Director	Takami, Hideki

Office of International Relations

Director	Chapman, Junko
Senior Specialist (Tokuninsenmonin)	Chapman, Junko
Senior Specialist (Tokuninsenmonin)	Matsumoto, Mizuho
Research Supporter	1

Support Desk

Research Supporters	2

Human Resources Planning Office

Director	Yoshida, Michitoshi
Senior Specialist (Tokuninsenmonin)	Ishimoto, Tomoko

Safety and Health Management Office

Director	Mori, Yasushi
Senior Specialist (Tokuninsenmonin)	Mori, Yasushi
Technical Expert	1

Engineering Promotion Office

Director	Uzawa, Yoshinori
Senior Research Engineer	Fujii, Yasunori

Graduate Education Office

Director	Sekii, Takashi
Project Professor	Sekii, Takashi

Administration Department

General Manager	Fujita, Hisashi
Manager for SpecialMissions	Seto, Yoji
Senior Specialist (Tokuninsenmonin)	Harada, Eiichiro

General Affairs Group

Manager	Tanaka, Aiko
Deputy Manager	Onishi, Tomoyuki
Specialist (Information Technology)	Kawashima, Ryota
Specialist (Personnel Relations)	Yoshimura, Tetsuya
Senior Specialist (Tokuninsenmonin)	Ito, Yuko
Senior Specialist (Tokuninsenmonin)	Murakami, Sachiko
Senior Specialist (Tokuninsenmonin)	Suzuki, Yoshihiro
Re-employment Staff	1
General Affairs Unit	
Leader	Kawashima, Ryota
Staff	Isozaki, Yuka
Staff	Saito, Masahiro
Administrative Expert	1
Administrative Supporter	1
Personnel Unit	
Leader	Chiba, Yoko
Senior Staff	Ouchi, Kaori
Staff	Okawa, Makoto
Staff	Tsuchiya, Sota
Administrative Expert	1
Payroll Unit	
Leader	Furukawa, Shinichiro
Senior Staff	Tsuji, Misato
Staff	Takahashi, Sachiko
Staff	Yamamoto, Kyoko
Staff	Yokota, Banri
Administrative Supporter	1
Employee Affairs Unit	
Leader	Yamaura, Mari
Senior Staff	Tanaka, Masashi
Staff	Inoue, Wakaho
Administrative Expert	1

Research Promotion Group

Manager	Hosoya, Akio

Senior Specialist (International Relations)	Seto, Yoji
Specialist	Iida, Naoto
Senior Specialist (Tokuninsenmonin)	Fujikawa, Hiroaki
Administrative Supporter	1
Research Support Unit	
Leader	Goto, Michiru
Administrative Expert	1
Administrative Supporter	1
External Funding Unit	
Specialist (External Funding)	Ihara, Yuko
Staff	Kashiwa, Hidekazu
Administrative Expert	1
Graduate Student Affairs Unit	
Leader	Kitabayashi, Kaya
Administrative Expert	1
Administrative Supporter	1
International Academic Affairs Unit	
Leader	Sato, Yoko
Financial Affairs Group	
Manager	Kawazu, Hironori
Deputy Manager	Yamamoto, Futoshi
Specialist (Audit)	Chiba, Satoko
General Affairs Unit	
Leader	Kikkawa, Hiroko
Staff	Naraoka, Aone
Administrative Supporter	1
Budget Unit	
Leader	Yamamoto, Shinichi
Senior Staff	Sugimoto, Naomi
Administrative Supporter	1
Asset Management Unit	
Leader	Ishikawa, Junya
Senior Staff	Okubo, Kazuhiko
Receiving Unit	
Leader	Ishikawa, Junya
Administrative Supporters	3
Accounting Group	
Manager	Tahara, Yuji
Specialist (Contracts)	Sato, Kanako
Accounting Unit	
Leader	Okazaki, Maya
Administrative Supporters	2
Procurement Unit	
Leader	Miura, Susumu
Senior Staff	Nakagawa, Yukie
Staff	Fukuhara, Miyuki
Staff	Manabe, Yuta
Administrative Expert	1
Administrative Supporter	1
Facilities Group	
Manager	Kataoka, Toru
Deputy Manager	Murakami, Kazuhiro
Senior Specialist (General Affairs)	Yamanouchi, Mika
General Affairs Unit	
Leader	Tsukano, Satomi
Administrative Supporter	1
Facilities Direction Unit	
Leader	Murakami, Kazuhiro
Administrative Supporters	2
Maintenance Unit	
Leader	Watanabe, Tsuyoshi
Staff	Hayashi, Yuki
Staff	Kawahara, Iori

6. Personnel Change

Research and Academic Staff

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2022/4/1	Fujieda, Miho	Hired	Advanced Technology Center, Associate Professor	
2022/4/1	Chen, Dan	Hired	Gravitational Wave Science Project, Assistant Professor	(Gravitational Wave Science Project, Project Researcher)
2022/7/1	Kikuchi, Shota	Hired	RISE Project, Assistant Professor	
2022/8/1	Osawa, Ryou	Hired	JASMINE Project, Assistant Professor	
2022/10/1	Oya, Shin	Hired	Advanced Technology Center, Associate Professor	(Subaru Telescope, Project Associate Professor)
2022/10/1	Fuse, Tetsuharu	Hired	Public Relations Center, Associate Senior Research Engineer	
2022/11/1	Kawabata, Yusuke	Hired	SOLAR-C Project, Assistant Professor	
2023/1/1	Ozaki, Masanobu	Hired	Advanced Technology Center, Professor	
2023/1/1	Izumi, Takuma	Hired	ALMA Project, Assistant Professor	(ALMA Project, Project Researcher)
2023/1/1	Koike, Michitaro	Hired	Astronomy Data Center, Research Engineer	(Subaru Telescope, Senior Specialist)
2023/3/1	Hatsukade, Bunyo	Hired	ALMA Project, Associate Professor	
2022/7/31	Sekii, Takashi	Resigned	(Graduate Education Office, Project Professor)	Solar Science Observatory, Associate Professor
2022/11/30	Leonardi, Matteo	Resigned		Gravitational Wave Science Project, Assistant Professor
2023/2/6	Nakamura, Koji	Resigned		IT Security Office, Senior Research Engineer
2023/3/31	Yoshida, Michitoshi	Resigned	(Subaru Telescope, Project Professor (Distinguished Professor))	Subaru Telescope, Professor
2023/3/31	Kawabe, Ryohei	Retired		Division of Science, Professor
2023/3/31	Sekiguchi, Kazuhiro	Retired		Research Enhancement Strategy Office, Professor
2022/4/1	Koyama, Yusei	Promoted	Subaru Telescope, Associate Professor	Subaru Telescope, Assistant Professor
2022/5/1	Katsukawa, Yukio	Promoted	Solar Science Observatory, Professor	Solar Science Observatory, Associate Professor
2022/8/1	Aoki, Wako	Promoted	Thirty Meter Telescope Project, Professor	Thirty Meter Telescope Project, Associate Professor
2022/10/1	Hirota, Tomoya	Promoted	Mizusawa VLBI Observatory, Associate Professor	Mizusawa VLBI Observatory, Assistant Professor
2022/10/1	Furusawa, Hisanori	Promoted	Astronomy Data Center, Associate Professor	Astronomy Data Center, Assistant Professor

Engineering Staff

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2022/7/1	Kohara, Naoki	Hired	Advanced Techonology Center, Engineer	
2023/3/31	Kobiki, Toshihiko	Retired		NAOJ Chile, Engineer
2023/3/31	Shinohara, Noriyuki	Retired		Solar Science Observatory, Engineer
2022/11/1	Takahashi, Ken	Promoted	Mizusawa VLBI Observatory, Engineer	Mizusawa VLBI Observatory, Engineer
2022/11/1	Sawatari Koichi	Promoted	Subaru Telescope, Engineer	Subaru Telescope, Engineer
2022/11/1	Hirano, Ken	Promoted	Subaru Telescope, Engineer	Subaru Telescope, Engineer

Administrative Staff

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2022/4/1	Tanaka, Aiko	Hired	Administration Department General Affairs Group, Manager	(Niigata University)
2022/4/1	Yamamoto, Futoshi	Hired	Administration Department Financial Affairs Group, Deputy Manager	(The University of Tokyo)
2022/4/1	Chiba, Satoko	Hired	Administration Department Financial Affairs Group, Specialist (Audit)	(Tokyo Medical and Dental University)
2022/4/1	Okazaki, Maya	Hired	Administration Department Accounting Group Accounting Unit, Leader	(Tokyo Medical and Dental University)
2022/4/1	Koshihara, Iori	Hired	Public Relations Center Administration Office Library, Leader	(The University of Tokyo)
2022/4/1	Tsuchiya, Sota	Hired	Administration Department General Affairs Group Personnel Unit, Staff	
2022/4/1	Yamamoto, Kyoko	Hired	Administration Department General Affairs Group Payroll Unit, Staff	
2022/9/1	Tsukano, Satomi	Hired	Administration Department General Affairs Group, Specialist	(Tokyo Medical and Dental University)
2022/4/30	Matsukura, Koji	Resigned		Administration Department General Affairs Group Personnel Unit, Staff
2022/7/31	Takami, Masaki	Resigned	(Shinshu University)	Nobeyama Radio Observatory Administration Office Accounting Unit, Leader
2022/9/30	Hiramatsu, Naoya	Resigned	(Tokyo Medical and Dental University)	Administration Department Facilities Group General Affairs Unit, Staff
2023/3/31	Tahara, Yuji	Resigned	(National Institute of Informatics)	Administration Department Accounting Group, Manager
2023/3/31	Yamaura, Mari	Resigned	(Research Organization of Information and Systems)	Administration Department General Affairs Group Employee Affairs Unit, Leader
2022/4/1	Ouchi, Kaori	Promoted	Administration Department General Affairs Group Personnel Unit, Senior Staff	Administration Department General Affairs Group Personnel Unit, Staff
2022/4/1	Tanaka, Masashi	Promoted	Administration Department General Affairs Group Employee Affairs Unit, Senior Staff	Administration Department General Affairs Group Employee Affairs Unit, Staff
2022/4/1	Sugimoto, Naomi	Promoted	Administration Department Financial Affairs Group Budget Unit, Senior Staff	Administration Department Financial Affairs Group Budget Unit, Staff
2022/4/1	Tsuji, Misato	Reassigned	Administration Department General Affairs Group Payroll Unit, Senior Staff	National Institutes of Natural Sciences Administrative Bureau General Affairs Division, Senior Staff (Ministry of Education, Culture, Sports, Science and Technology-Japan, Administrative Intern Trainee)
2022/4/1	Morita, Akitsugu	Reassigned	National Institutes of Natural Sciences Administrative Bureau General Affairs Division, Staff (Ministry of Education, Culture, Sports, Science and Technology-Japan, Administrative Intern Trainee)	Administration Department Accounting Group Procurement Unit, Staff
2022/7/1	Iida, Naoto	Reassigned	Administration Department Research Promotion Group, Specialist	National Institutes of Natural Sciences Administrative Bureau General Affairs Division Personnel Unit, Leader

Employee on Annual Salary System

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2022/4/1	Kurasaki, Takaaki	Hired	Thirty Meter Telescope Project, Project Professor	
2022/4/1	Toba, Yoshiki	Hired	Subaru Telescope, Project Assistant Professor	
2022/4/1	Saito, Toshiki	Hired	ALMA Project, Project Assistant Professor	(ALMA Project, Project Researcher)
2022/4/1	Tokuda, Kazuki	Hired	ALMA Project, Project Assistant Professor	
2022/4/1	Washimi, Tatsuki	Hired	Gravitational Wave Science Project, Project Assistant Professor	
2022/4/1	Chiaki, Gen	Hired	Division of Science, Project Assistant Professor	
2022/4/1	Ishikawa, Ryotaro	Hired	Solar Science Observatory, Project Researcher	
2022/4/1	Izumi, Takuma	Hired	ALMA Project, Project Researcher	(Subaru Telescope, Project Assistant Professor)
2022/4/1	Silva Bustamante, Andrea Ludovina	Hired	ALMA Project, Project Researcher	
2022/4/1	Nozawa, Takaya	Hired	Center for Computational Astrophysics, Project Researcher	(Division of Science, Project Researcher)
2022/4/1	Miyakawa, Kohei	Hired	JASMINE Project, Project Researcher	
2022/4/1	Kozuki, Yuto	Hired	Advanced Technology Center, Project Researcher	
2022/4/1	Yoneta, Kenta	Hired	Advanced Technology Center, Project Researcher	
2022/4/1	Iwata, Yuhei	Hired	Division of Science, Project Researcher	
2022/4/1	Jiang, Jian	Hired	Division of Science, Project Researcher	
2022/4/1	Morita, Satoshi	Hired	Solar Science Observatory, Senior Specialist	(Solar Science Observatory, Senior Specialist)
2022/4/1	Fukui, Hideharu	Hired	ALMA Project, Senior Specialst	(Research Enhancement Strategy Office (ALMA Project), Research Administrator Staff, Senior Specialist)
2022/4/1	Mori, Yasushi	Hired	Safety and Health Management Office, Senior Specialist	
2022/5/1	Ideguchi, Shinsuke	Hired	Center for Computational Astrophysics, Project Researcher	
2022/5/1	Ueda, Junko	Hired	ALMA Project, Senior Specialist	(ALMA Project, Project Assistant Professor)
2022/6/1	Kikuta, Satoshi	Hired	Division of Science, Project Researcher	
2022/7/1	Sakai, Daisuke	Hired	Mizusawa VLBI Observatory, Project Assistant Professor	
2022/7/1	Ebihara, Eiichi	Hired	ALMA Project, Senior Specialist	
2022/7/19	Shakunaga, Takeshi	Hired	ALMA Project, Senior Specialist	
2022/8/1	Sekii, Takashi	Hired	Graduate Education Office, Project Professor	(Solar Science Observatory, Associate Professor)
2022/8/1	Fujikawa, Hiroaki	Hired	Administration Department Research Promotion Group, Senior Specialist	
2022/9/1	Keszthelyi, Zsolt	Hired	Center for Computational Astrophysics, Project Researcher	
2022/9/1	Hayatsu, Natsuki	Hired	Public Relations Center, Project Researcher	
2022/9/1	Asanuma, Masumi	Hired	ALMA Project, Senior Specialist	
2022/9/1	Tagawa, Hiroaki	Hired	ALMA Project, Senior Specialist	
2022/9/20	Saha, Piyali	Hired	ALMA Project, Project Researcher	

2022/9/30	Kokubo, Mitsuru	Hired	Division of Science, Project Assistant Professor	
2022/10/1	Wu, Yu-Ting	Hired	ALMA Project, Project Assistant Professor	(ALMA Project, Project Researcher)
2022/11/1	Aso, Yusuke	Hired	ALMA Project, Project Assistant Professor	
2022/11/1	Murayama, Yosuke	Hired	Advanced Technology Center, Project Researcher	
2022/12/1	Eisenmann, Marc	Hired	Gravitational Wave Science Project, Project Researcher	
2022/12/1	Page, Michael Anthony	Hired	Gravitational Wave Science Project, Project Researcher	
2022/12/1	Inoue, Naoko	Hired	ALMA Project, Senior Specialist	
2022/12/1	Ishimoto, Tomoko	Hired	Human Resources Planning Office, Senior Specialist	
2023/1/1	Cataldi, Gianni	Hired	ALMA Project, Project Assistant Professor	(ALMA Project, Project Researcher)
2023/1/1	Lee, Kianhong	Hired	Thirty Meter Telescope Project, Project Researcher	
2023/2/1	Takahashi, Sanemichi	Hired	ALMA Project, Project Researcher	(Division of Science, Project Assistant Professor)
2023/2/1	Ono, Kazumasa	Hired	Division of Science, Project Researcher	
2023/2/1	Morita, Masaki	Hired	Advanced Techonology Center, Senior Specialist	
2023/3/1	Feeney-Johansson, Anton Fiachra George	Hired	ALMA Project, Project Researcher	

2022/4/30	Ueda, Junko	Resigned	(ALMA Project, Senior Specialist)	ALMA Project, Project Assistant Professor
2022/4/30	Tsukagoshi, Takashi	Resigned		Division of Science, Project Assistant Professor
2022/4/30	Hayashi, Yohei	Resigned		ALMA Project, Senior Specialist
2022/6/30	Baba, Takashi	Resigned		Administration Department Research Promotion Group, Senior Specialist
2022/8/14	Hull, Charles Lindsay Hopkins	Resigned		ALMA Project, Project Assistant Professor
2022/8/31	Sorahana, Satoko	Resigned		ALMA Project, Project Researcher
2022/9/30	Oya, Shin	Resigned	(Advanced Technology Center, Associate Professor)	Subaru Telescope, Project Associate Professor
2022/9/30	Aritomi, Naoki	Resigned		Gravitational Wave Science Project, Project Researcher
2022/10/31	Ueda, Junko	Resigned		ALMA Project, Senior Specialist
2022/11/30	Curotto Molina, Franco Andreas	Resigned		ALMA Project, Senior Specialist
2022/12/14	Aso, Yusuke	Resigned		ALMA Project, Project Assistant Professor
2022/12/31	Izumi, Takuma	Resigned	(ALMA Project, Assistant Professor)	ALMA Project, Project Researcher
2022/12/31	Cataldi, Gianni	Resigned	(ALMA Project, Project Assistant Professor)	ALMA Project, Project Researcher
2022/12/31	Koike, Michitaro	Resigned	(Astronomy Data Center, Research Engineer)	Subaru Telescope, Senior Specialist
2023/1/31	Takahashi, Sanemichi	Resigned	(ALMA Project, Project Researcher)	Division of Science, Project Assistant Professor
2023/2/28	Burns, Ross Alexander	Resigned		Division of Science, Project Researcher
2023/2/28	Iju, Tomoya	Resigned		Solar Science Observatory, Senior Specialist

2023/3/30	Kobayashi, Masato	Resigned		Division of Science, Project Researcher
2023/3/31	Tadaki, Ken'ichi	Resigned		Thirty Meter Telescope Project, Project Assistant Professor
2023/3/31	Baba, Jun'ichi	Resigned		JASMINE Project, Project Assistant Professor
2023/3/31	Mawatari, Ken	Resigned		Subaru Telescope, Project Researcher
2023/3/31	Murata, Kazumi	Resigned		Subaru Telescope, Project Researcher
2023/3/31	Taki, Tetsuo	Resigned		Center for Computational Astrophysics, Project Researcher
2023/3/31	Kato, Tsunehiko	Resigned		Center for Computational Astrophysics, Senior Specialist

2022/9/30	Wu, Yu-Ting	Contract Expired	(ALMA Project, Project Assistant Professor)	ALMA Project, Project Researcher
2022/9/30	Matsumoto, Mizuho	Contract Expired	(Office of International Relations, Employee on Annual Salary System Transferring to the Mandatory Retirement System Senior Specialist)	Office of International Relations, Senior Specialist
2022/11/30	Nakanishi, Takashi	Contract Expired		ALMA Project, Senior Specialist
2023/2/28	Shindo, Miwa	Contract Expired	(Subaru Telescope, Employee on Annual Salary System Transferring to the Mandatory Retirement System Senior Specialist)	Subaru Telescope, Senior Specialist
2023/3/31	Takami, Hideki	Contract Expired		Subaru Telescope, Project Professor (Distinguished Professor)
2023/3/31	Kiuchi, Hitoshi	Contract Expired		ALMA Project, Project Professor
2023/3/31	Oishi, Masatoshi	Contract Expired		Public Relations Center, Project Professor
2023/3/31	Kambe, Eiji	Contract Expired	(Subaru Telescope, Employee on Annual Salary System Transferring to the Mandatory Retirement System Project Associate Professor)	Subaru Telescope, Project Associate Professor
2023/3/31	Nagai, Hiroshi	Contract Expired	(ALMA Project, Associate Professor)	ALMA Project, Project Associate Professor
2023/3/31	Shimakawa, Rizumu	Contract Expired		Subaru Telescope, Project Assistant Professor
2023/3/31	Ishikawa, Ryotaro	Contract Expired		Solar Science Observatory, Project Researcher
2023/3/31	Nozawa, Takaya	Contract Expired		Center for Computational Astrophysics, Project Researcher
2023/3/31	Kaneko, Hiroyuki	Contract Expired		ALMA Project, Project Researcher
2023/3/31	Kudo, Yuki	Contract Expired		ALMA Project, Project Researcher
2023/3/31	Chen, Xiaoyang	Contract Expired	(ALMA Project, Project Researcher)	ALMA Project, Project Researcher
2023/3/31	Bakx, Tom Johannes Lucinde Cyrillus	Contract Expired		ALMA Project, Project Researcher
2023/3/31	Michiyama, Tomonari	Contract Expired		ALMA Project, Project Researcher
2023/3/31	Lee, Kianhong	Contract Expired	(ALMA Project, Project Researcher)	Thirty Meter Telescope Project, Project Researcher

2023/3/31	Otsubo, Takafumi	Contract Expired	(Astronomy Data Center, Project Researcher)	Astronomy Data Center, Project Researcher
2023/3/31	Furusawa, Junko	Contract Expired	(Astoronomy Data Center, Employee on Annual Salary System Transferring to the Mandatory Retirement System Senior Specialist)	Astronomy Data Center, Project Researcher
2023/3/31	Kozuki, Yuto	Contract Expired		Advanced Technology Center, Project Researcher
2023/3/31	Murayama, Yosuke	Contract Expired	(Advanced Technology Center, Project Researcher)	Advanced Technology Center, Project Researcher
2023/3/31	Oyama, Tomoaki	Contract Expired	(Mizusawa VLBI Observatory, Employee on Annual Salary System Transferring to the Mandatory Retirement System Senior Specialist)	Mizusawa VLBI Observatory, Senior Specialist
2023/3/31	Morita, Satoshi	Contract Expired		Solar Science Observatory, Senior Specialist
2023/3/31	Tanaka, Mitsuhiro	Contract Expired		Subaru Telescope, Senior Specialist
2023/3/31	Mineo, Sogo	Contract Expired	(Astronomy Data Center, Research Engineer)	Subaru Telescope, Senior Specialist
2023/3/31	Fukushi, Hinako	Contract Expired	(Center for Computational Astrophysics, Employee on Annual Salary System Transferring to the Mandatory Retirement System Senior Specialist)	Center for Computational Astrophysics, Senior Specialist
2023/3/31	Uemizu, Kazunori	Contract Expired	(ALMA Project, Employee on Annual Salary System Transferring to the Mandatory Retirement System Senior Specialist)	ALMA Project, Senior Specialist
2023/3/31	Kawasaki, Wataru	Contract Expired		ALMA Project, Senior Specialist
2023/3/31	Nodomi, Yoshifumi	Contract Expired		SOLAR-C Project, Senior Specialist
2023/3/31	Isogai, Mizuki	Contract Expired	(Astoronomy Data Center, Employee on Annual Salary System Transferring to the Mandatory Retirement System Senior Specialist)	Astoronomy Data Center, Senior Specialist
2023/3/31	Tanaka, Nobuhiro	Contract Expired	(Astoronomy Data Center, Employee on Annual Salary System Transferring to the Mandatory Retirement System Senior Specialist)	Astoronomy Data Center, Senior Specialist

Employees on Annual Salary System Transferring to the Mandatory Retirement System

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2022/10/1	Matsumoto, Mizuho	Hired	Office of International Relations, Senior Specialist	(Office of International Relations, Employee on Annual Salary System Senior Specialist)
2023/3/1	Shindo, Miwa	Hired	Subaru Telescope, Senior Specialist	(Subaru Telescope, Employee on Annual Salary System Senior Specialist)

Research Administrator Staff

Date	Name	Change	New Affiliated Institute, Position	Previous Affiliated Institute, Position
2022/9/30	Suzui, Mitsukazu	Contract Expired		Research Enhancement Strategy Office (Engineering Promotion Office), Senior Specialist
2022/12/31	Noda, Noboru	Contract Expired		Research Enhancement Strategy Office (Human Resources Planning Office), Senior Specialist

Cross-appointment

Date	Name	Term of Cross-appointment	Main Institute, Position	Affiliated in NAOJ, Position
2022/4/1	Kataza, Hirokazu	2022/4/1 ~ 2025/3/31	Japan Aerospace Exploration Agency Institute of Space and Astronautical Science, Associate Professor	JASMINE Project, Project Associate Professor
2022/7/1	Behroozi, Peter Spalding	2022/7/1 ~ 2024/10/15	University of Arizona, Associate Professor	Division of Science, Project Researcher

Foreign Visiting Researchers

Name	Period	Affiliated Institute
Mazzali, Paolo	2022/12/28 ~ 2023/2/2	Liverpool John Moores University (UK)
Pian, Elena	2022/12/28 ~ 2023/2/2	Italian National Institute of Astrophysics, Astrophysics and Space Science Observatory (Italy)

7. Advisory Committee for Research and Management

Members

From universities and related institutes

	Arai, Tomoko	Principal Staff Scientist at the Planetary Exploration Research Center, Chiba Institute of Technology
○	Kodama, Tadayuki	Professor at the Graduate School of Science, Tohoku University
	Ohashi, Masatake	Professor at the Institute for Cosmic Ray Research, University of Tokyo
	Omukai, Kazuyuki	Professor at the Graduate School of Science, Tohoku University
	Sakai, Nami	Chief Scientist at the RIKEN
	Sumi, Takahiro	Professor at the Graduate School of Science, Osaka University
	Takada, Masahiro	Professor at the Kavli Institute for the Physics and Mathematics of the Universe, University of Tokyo
	Tosaki, Tomoka	Professor at the Graduate School of Education, Joetsu University of Education
	Yamasaki, Noriko	Professor at the Institute of Space and Astronautical Science, JAXA
	Yokoyama, Takaaki	Professor at the Astronomical Observatory, Graduate School of Science, Kyoto University
	Yonekura, Masanori	Professor at the Center for Astronomy, Ibaraki University

From NAOJ

	Fukagawa, Misato	Professor in ALMA Project
	Kokubo, Eiichiro	Professor in the Center for Computational Astrophysics
	Kobayashi, Hideyuki	Project Professor in Mizusawa VLBI Observatory
	Miyazaki, Satoshi	Professor in Subaru Telescope
	Motohara, Kentaro	Director of Research Coordination
	Nomura, Hideko	Professor in the Division of Science
	Saito, Masao	Vice-Director General (on Finance)
	Uzawa, Yoshinori	Director of Engineering
	Watanabe, Junichi	Project Professor in the Public Relations Center
●	Yoshida, Michitoshi	Vice-Director General (on General Affairs)

● Chairperson ○ Vise-Chairperson
Period: April 1, 2022 - March 31, 2024

8. Professors Emeriti

Professors Emeriti (NAOJ)

Ando, Hiroyasu
Arimoto, Nobuo
Chikada, Yoshihiro
Fujimoto, Masakatsu
Fukushima, Toshio
Hasegawa, Tetsuo
Hayashi, Masahiko
Hiei, Eijiro
Hirayama, Tadashi
Inoue, Makoto
Ishiguro, Masato
Iye, Masanori
Karoji, Hiroshi
Kawaguchi, Noriyuki
Kawano, Nobuyuki
Kinoshita, Hiroshi
Kobayashi, Yukiyasu
Kodaira, Keiichi
Manabe, Seiji
Miyama, Shiyoken
Mizumoto, Yoshihiko
Nakano, Takenori
Nariai, Kyoji
Nishimura, Shiro
Nishimura, Tetsuo
Noguchi, Kunio
Noguchi, Takashi
Oe, Masatsugu
Ogasawara, Ryusuke
Okamoto, Isao
Sakurai, Takashi
Shibasaki, Kiyoto
Tomisaka, Koji
Watanabe, Tetsuya
Yamashita, Yasumasa
Yoshida, Haruo

IV Finance

Revenue and Expenses (FY 2022)

(Unit: ¥1,000)

Revenue	Budget	Final Account	Budget − Final Account
Management Expenses Grants	8,043,676	8,648,601	−604,925
Facilities Maintenance Grants	2,417,758	1,204,343	1,213,415
Subsidy Income	1,439,063	1,445,634	−6,571
Miscellaneous Income	14,908	134,692	−119,784
Industry-Academia Research Income and Donation Income	422,761	659,914	−237,153
Reversals of Reserves for Specific Purposes	0	135,000	−135,000
Total	12,338,166	12,228,184	109,982
Expenses	Budget	Final Account	Budget − Final Account
Management Expenses	8,058,584	8,338,794	−280,210
Employee Personnel Expenses	3,746,754	3,625,079	121,675
Operating Expenses	4,311,830	4,713,715	−401,885
Facilities Maintenance Expenses	2,417,758	1,204,343	1,213,415
Subsidy Expenses	1,439,063	1,445,634	−6,571
Industry-Academia Research Expenses and Donation Expenses	422,761	418,908	3,853
Total	12,338,166	11,407,679	930,487
Revenue-Expenses	Budget	Final Account	Budget − Final Account
	0	820,505	−820,505

V KAKENHI (Grants-in-Aid for Scientific Research)

1. Series of Single-year Grants for FY 2022

Research Categories	Number of Selected Projects	Budget (Unit: ¥1,000)		
		Direct Funding	Indirect Funding	Total
Scientific Research on Innovative Areas (Research in a proposed research area)	7	41,200	12,360	53,560
Transformative Research Areas (A)	2	37,500	11,250	48,750
Scientific Research (S)	5	184,000	55,200	239,200
Scientific Research (A)	10	104,800	31,440	136,240
Scientific Research (B)	19	62,200	18,660	80,860
JSPS Research Fellows	6	7,100	2,130	9,230
JSPS International Research Fellows	2	1,400	0	1,400
Publication of Scientific Research Results	2	1,190	0	1,190
Total	53	439,390	131,040	570,430

2. Series of Multi-year Funds for FY 2022

Research Categories	Number of Selected Projects	Budget (Unit: ¥1,000)		
		Direct Funding	Indirect Funding	Total
Scientific Research (C)	19	16,300	4,890	21,190
Early-Career Scientists	18	20,600	6,180	26,780
Fund for the Promotion of Joint International Research (International Leading Research)	1	38,300	11,490	49,790
Fund for the Promotion of Joint International Research (Fostering Joint International Research (B))	2	5,200	1,560	6,760
Total	40	80,400	24,120	104,520

VI Research Collaboration

1. Open Use

Type	Project/Center	Category	Number of Accepted Proposals	Total Number of Researchers	Notes
Open Use at Project/Center	Subaru Telescope	Subaru Telescope	81	336 (79)	53 Institutes, 13 Countries
	Subaru Telescope Okayama Branch	SEIMEI Telescope	41	114	16 Institutes
	Solar Science Observatory	Ground-based Solar Observatory	*	*	*
		Sun-observing satellite “Hinode”	**	**	**
	Mizusawa VLBI Observatory	VERA	25	102 (79)	47 Institutes, 15 Countries
	Astronomy Data Center		339	339 (21)	83 Institutes, 11 Countries
	Center for Computational Astrophysics		355	355 (26)	76 Institutes, 8 Countries
	Advanced Technology Center	Facility Use	13	42	10 Institutes
		Joint Research and Development	17	115	20 Institutes
	ALMA Project	ALMA (Cycle 8)	253	3418 (2997)	351 Institutes, 39 Countries
		ASTE	***	***	***
Charged Telescope Time	Nobeyama Radio Observatory	45-m telescope	46	–	–
Large-scale Collaborative-Observation Program	Mizusawa VLBI Observatory	VERA	16	80(3)	24 Institutes, 3 Countries
Joint Development Research			5		5 Institutes, 0 Countries
Research Assembly			16		9 Institutes, 0 Countries
NAOJ Symposium			0		0

The number of researchers at foreign institutes shown in brackets ( ) is included in the total.
The country count does not include Japan.
The period of ALMA (Cycle 8) is from October 2021 to September 2022.
* The observation data is open to the public on the web. No application is needed to use the data.
** Since the function of the Hinode Science Center has shifted to the Astronomy Data Center, there is no procedure of application and adoption as “Hinode”.
*** ASTE has cancelled the joint-use observations scheduled for FY 2022 due to the malfunctions of sub-reflector. The possibility of postponing adopted observation proposals to the following fiscal year or later is being considered.

2. Commissioned Research Fellows

Visiting Scholars (Domestic)

Name	Position at NAOJ	Affiliated Institute	Period	Host Project/Center/ Division
TANAKA, Yoshiyuki	Visiting Associate Professor	The University of Tokyo, Graduate School of Science	April 1, 2022 – March 31, 2023	Mizusawa VLBI Observatory

Visiting Scholars (Foreign)

Name	Position at NAOJ	Affiliated Institute	Period	Host Project/Center/ Division
Mazzali, Paolo	Visiting Professor	Liverpool John Moores University	December 28, 2022 – February 2, 2023	Division of Science
Pian, Elena	Visiting Professor	Italian National Institute of Astrophysics, Astrophysics and Space Science Observatory	December 28, 2022 – February 2, 2023	Division of Science

JSPS (Japan Society for the Promotion of Science) Postdoctoral Research Fellows

Name	Research Subject	Acceptance Period	Host Researcher
Kawabata, Yusuke	Investigation of the evolution of solar active regions with multi-wavelength observations	2022/4/1 – 2022/10/31	Katsukawa, Yukio
Okuya, Ayaka	Revealing planet formation around intermediate-mass stars from planetary remnants accreting on white dwarfs	2022/4/1 – 2025/3/31	Ikoma, Masahiro
Uyama, Taichi	Developing exoplanetary science by high-contrast imaging	2021/4/1 – 2024/3/31	Fujii, Yuka
Namekata, Kosuke	Observational and numerical studies of solar and stellar magnetic activities	2021/4/1 – 2024/3/31	Shimojo, Masumi
Yoshiura, Shintaro	Analysing the 21cm line at the Epoch of Reionisation using the sparse modelling	2021/4/1 – 2024/3/31	Honma, Mareki

JSPS (Japan Society for the Promotion of Science) Foreign Research Fellows

Name	Period	Host Researcher
Page, Michael Anthony	2020/11/30 – 2022/11/29	Aso, Yoichi
Eisenmann, Marc	2020/11/30 – 2022/11/29	Leonardi, Matteo
Ledger, Blake Steven	2022/6/9 – 2022/8/8	Iono, Daisuke

VII Graduate Education

1. Department of Astronomical Science, School of Physical Sciences, SOKENDAI (The Graduate University for Advanced Studies)

The Graduate University for Advanced Studies, SOKENDAI was established in 1988 via partnerships with inter-university research institutes for the purpose of advancing graduate education.

SOKENDAI currently consists of six schools: Cultural and Social Studies, Physical Sciences, High Energy Accelerator Science, Multidisciplinary Sciences, Life Science, and Advanced Sciences, and is offering doctoral education and research opportunities.

NAOJ has been accepting three-year doctoral-course students since FY 1992 and five-year- course students since FY 2006 for Department of Astronomical Science, School of Physical Sciences.

SOKENDAI is reorganizing its six graduate schools into the Graduate Institute for Advanced Studies to offer a 20-program system starting from April 2023. In accordance with this reorganization, Department of Astronomical Science is reorganized into Astronomical Science Program.

(1) Objective of Department of Astronomical Science

Department of Astronomical Science aims to train students, through observational, theoretical, or instrument development research in astronomy or in related fields, in an environment with the most advanced observational instruments and supercomputers, to be researchers who work at the forefront of world-class research; experts who carry out development of advanced technology; and specialists who endeavor in education and public outreach activities equipped with advanced and specialized knowledge.

Numbers of students to be admitted annually:
 Two (for the five-year doctoral course)
 Three (for the three-year doctoral course)
Degree: Doctor of Philosophy (Doctor of Science, or Doctor of Engineering, depending on the topic of Doctoral thesis)

(2) Admission Policy

Department of Astronomical Science seeks students with a strong interest in astronomy and the universe; a passion for unraveling scientific questions through theoretical, observational, and instrument-development research; and who have not only basic academic skills, but also the logical and creative aptitude required for advanced research.

(3) Department Details (Course Offerings)

Optical and Infrared Astronomy
 [Fields of education and research supervision]
 Ground-based astronomy / Optical and infrared telescope systems / Planets / Sun, stars, and interstellar matter / Galaxies and cosmology

Radio Astronomy
 [Fields of education and research supervision]
 Ground-based astronomy / Radio telescope systems / Sun, stars, and interstellar matter / Galaxies

General Astronomy and Astrophysics
 [Fields of education and research supervision]
 High-precision astronomical measurement / Astronomy from space / Data analysis and numerical simulation / Earth, planets, and the Sun / Galaxies and cosmology

(4) Education and Research Supervision

In observational research with the state-of-the-art optical-IR and radio telescopes, and theoretical research, the research efforts and the educational efforts are fused together to offer advanced-level education in astronomy and astrophysics. The department consists of the Optical Near-Infrared Astronomy Unit, Radio Astronomy Unit, and General Astronomy and Astrophysics Unit, but all three units cooperate in the education and research supervision of the students. To ensure that the students with a wide variety of backgrounds can perform original and creative research in the ever-developing field of astronomy, they are guided to focus on learning the basic astronomy in the first year. In order to focus on astronomical research, including the basis of observational astronomy, instrument development, and theoretical astronomy, from the second year onwards students learn subjects ranging from principles to applications of advanced technologies that will be the basis of astronomical observations; how to design, fabricate and test new instruments; and the forefronts of data acquisition and data analyses.

(5) Financial Supports

In order to provide the students economical basis upon which they can develop into young researchers skilled in conducting research effectively, the department has set up the Associate Researcher program in addition to Research Assistant system. In addition, the department has introduced the 'NAOJ Junior Fellow' system from FY 2020 to create an environment in which outstanding students can devote themselves more to their studies and research, and to further improve the standards of researchers produced by the department.

In FY 2022 there were 9 NAOJ Junior Fellows, 17 Associate Researchers, and 3 Research Assistants.

To further improve the research environment for the students, the department provides Oversea Travel Fund, to encourage the students to participate in international conferences to give English talks, conduct observations at various oversea observational facilities and so on, and Research Fund to help them pursue their own original ideas to plan and carry out research, experiments, etc.

(6) Undergraduate Students

For undergraduate students, and for students abroad, we run SOKENDAI Summer Students Program, Spring School and Asian Winter School to offer chances to experience research at the Department of Astronomical Science. Admission Guidance also targets undergraduate students.

In FY 2022, 22 students participated in the SOKENDAI Summer Students program. The Asian Winter School, conducted online, received 211 applications from 9 countries, and of these, 123 students participated in the program. In addition, 37 students participated in the Spring School, which was held onsite in Mitaka Campus for the first time in 3 years.

(7) Number of Affiliated Staff (2023/3/31)

Chair of the Department of Astronomical Science	1
Optical and Infrared Astronomy Course	
Professors	11
Associate Professors	8
Associate Professors (Senior Lecturers)	1
Assistant Professors	11
Radio Astronomy Course	
Professors	10
Associate Professors	12
Associate Professors (Senior Lecturers)	1
Assistant Professors	14
General Astronomy and Astrophysics Course	
Professors	11
Associate Professors	15
Associate Professors (Senior Lecturers)	1
Assistant Professors	18
Total	114

(8) Graduate Students (33 students)

1st year (5 student)

Name	Principal Supervisor	Supervisor	Title of Research Project
Kakimoto, Takumi	Tanaka, Masayuki	Iono, daisuke	A bird's eye view of galaxy evolution across cosmic time
Sato, Yoshiaki	Sekii, Takashi	Shimojo, Masumi	Study of High-Energy Phenomena in the Solar Corona Tackled with X-ray Imaging-Spectroscopy
Naito, Yoshihiro	Hara, Hirohisa	Ishikawa, Ryoko	Spectroscopic study of Alfvenic waves in the source region of high-speed solar winds
Hatano, Shun	Ouchi, Masami	Koyama, Yusei	Ionizing Sources of Early Galaxies and Cosmic Reionization Studied by Deep Spectroscopy
Watanabe, Kuria	Ouchi, Masami	Tominaga, Nozomu	Origin of Elements in Early Galaxies Studied by Deep Spectroscopy

2nd year (5 students)

Name	Principal Supervisor	Supervisor	Title of Research Project
Ikeda, Ryota	Iono, Daisuke	Tadaki, Kenichi Tanaka, Masayuki	Observational Studies of Distant Galaxies using ALMA
Ishigami, Shun	Hara, Hirohisa	Katsukawa, Yukio	Spectroscopic study at the site of coronal heating
Koshisaka, Shiori	Kotani, Takayuki	Fukagawa, Misato	Study of disks around pre-main sequence stars and extrasolar planets by high-contrast polarization direct imaging
Nishigaki, Moka	Ouchi, Masami	Takata, Tadafumi	Exploring the early phase of galaxy formation with large optical datasets
Yoshida, Tomohiro	Nomura, Hideko	Fukagawa, Misato	Research on Chemical Structure of Planet-Forming Regions by ALMA Observations of Molecular Lines

3rd year (9 students)

Name	Principal Supervisor	Supervisor	Title of Research Project
Naufal, Abdurrahman	Koyama, Yusei	Tanaka, Masayuki	Morphological Evolution of Galaxies across Cosmic Environment
Ishihara, Kousuke	Saito, Masao	Nakamura, Fumitaka	Study of high-mass star formation processes, focusing on hierarchical fragmentation
Sasaki, Shunsuke	Takiwaki, Tomoya	Machida, Mami	Turbulent-driven mechanism of core-collapse supernovae
Sugimori, Kanako	Tanaka, Masayuki	Onodera, Masato	Evolution of spectral energy distributions of galaxies over cosmic time
Tada, Shotaro	Kotani, Takayuki	Hayano, Yutaka Minowa, Yosuke	Development of a novel method to realize ultra-precision detector characterization for exoplanet and astrometric observation in space
Doi, Kiyoaki	Kataoka, Akimasa	Nomura, Hideko Fukagawa, Misato	Unveiling planet formation by observations of protoplanetary disks
BHARDWAJ, Shubham	Dainotti, Maria Giovanna	Tominaga, Nozomu	The Multiwavelength analysis of Gamma-Ray Bursts via machine learning
Ogami, Itsuki	Aoki, Wako	Furusawa, Hisanori	The Nature of the Andromeda Stellar Halo and Substructures Explored with the Subaru Telescope
Sato, Masato	Tominaga, Nozomu	Takiwaki, Tomoya	Supernova light curve and observation

4th year (9 students)

Name	Principal Supervisor	Supervisor	Title of Research Project
Kasagi,Yui	Kotani, Takayuki	Hayashi, Saeko Aoki, Wako	Search for extra-solar planets around young to late stars, and brown dwarfs for understandings planet formation at various evolutionary stages
Kashiwagi, Raiga	Iwasaki, Kazunari	Takiwaki, Tomoya	Study on star formation process induced by collisions between filamentary molecular clouds
Kobayashi,Umi	Tanaka, Masayuki	Nakanishi, Koichiro	Influence of galaxy interactions and mergers on AGN activities
Nakano, Suzuka	Nakanishi, Koichiro	Sekii, Takashi Tanaka, Masayuki	The interplay and co-evolution between galaxies and active supermassive blackholes
Masai,Takaho	Gonzalez Garcia, Alvaro	Uzawa, Yoshinori Kojima, Takafumi	Study of the effect of aberrations on aperture efficiency in radio telescopes towards high-performance multi-beam receivers at sub-mm wavelengths
Omae, Rikuto	Machida, Mami	Ouchi, Masami	Study of galactic magnetic field evolution using the polarization properties of intervening galaxies
Tashima, Yuta	Machida, Mami	Nakamura, Fumitaka	Study of the galactic magnetic fields using the MHD simulation and observational visualization
Hosokawa, Kou	Kotani, Takayuki	Minowa, Yosuke Fujii, Yuka	Development of high-contrast and high-spectral resolution spectrometer for the Subaru telescope and characterization of exoplanet atmospheres
Seo, Chanoul	Fujii, Yuka	Nomura, Hideko Ikoma, Masahiro	Atmospheres of sub-Neptune-sized exoplanets in contact with magma ocean

5th year (5 students)

Name	Principal Supervisor	Supervisor	Title of Research Project
Takemura, Hideaki	Nakamura, Fumitaka	Hirota, Tomoya	Study of star formation process focusing on the core mass function
Kambara, Nagaaki	Hara, Hirohisa	Murakami, Izumi (NIFS)	Spectroscopic diagnostics of highly ionised astrophysical plasma
Nishiumi,Taku	Hori,Yasunori	Aoki, Wako Izumiura, Hideyuki	Characterization of exoplanets with MuSCAT series
Liang, Yongming	Tanaka, Masayuki	Matsuda, Yuichi	Correlation between galaxy and IGM at $z \approx 2$ mapped by Subaru/HSC
Fukagawa, Nao	Aoki, Wako	Iono, Daisuke	Contribution of rotating massive stars to the chemical enrichment in the low-metallicity environments of dwarf galaxies

2. Education and Research Collaboration with Graduate Schools

Name	Affiliated Institute	Supervisor	Title of Research Project
Oki, Aika	The University of Tokyo	Honma, Mareki	Elucidation of the Central Structure of the Phoenix Galaxy Cluster by VLBI Observations
Ozawa, Yoshiki	The University of Tokyo	Fukagawa, Misato	Observational Study on Exoplanet Formation
Kambara, Yuki	The University of Tokyo	Kokubo, Eiichiro	Theoretical study on formation of planetary systems
Cha, Chaenae	The University of Tokyo	Motohara, Kentaro	Development of a NIR spectrograph NINJA and observational study of kilonova
Narita, Kanako	The University of Tokyo	Sakamoto, Seiichi	Observational Study of Material Evolution in Interstellar Space
Mitsuhashi, Kohei	The University of Tokyo	Tomaru, Takayuki	Gravitational Wave Observation by KAGRA
Ikebe, Souta	The University of Tokyo	Honma, Mareki	Analysis of Fast Radio Bursts with GPUs
Nishino, Yohei	The University of Tokyo	Tomaru, Takayuki	Studies for Gravitational Wave Telescope, KAGRA
Fukumitsu, Kakeru	The University of Tokyo	Katsukawa, Yukio	Study on an image restoration technique for high-resolution solar images
Homan, Shogo	The University of Tokyo	Motohara, Kentaro	Development of a camera unit for Y-band high dispersion spectrograph TARdYS for TAO telescope and evaluation of NIR array detectors.
Mizutani, Yohsuke	The University of Tokyo	Kokubo, Eiichiro	Planetary system formation from planetesimal rings
Yano, Yuta	The University of Tokyo	Nakamura, Fumitaka	Time variation in mass accretion rate on protostars due to merging molecular cloud cores
Fariyanto, Elika Prameswari	The University of Tokyo	Honma, Mareki	The M84 Jet Collimation Profile Analysis
Moritsuka, Akie	The University of Tokyo	Katsukawa, Yukio	Study of magneto-convection on the solar surface with spectro-polarimetric observations
Adachi, Hiroaki	The University of Tokyo	Fukagawa, Misato	Observational Research on Planetary-system Formation around Young Stars
Kofuji, Yutaro	The University of Tokyo	Honma, Mareki	Imaging super-massive black holes with mm VLBI
Chen, Nuo	The University of Tokyo	Motohara, Kentaro	Observational Study of Galaxy Formation and Evolution in the ZFOURGE-COSMOS Field
Morii, Kaho	The University of Tokyo	Nakamura, Fumitaka	Testing and Constructing High-mass Star Formation Theories by ALMA Observations
Kinoshita, Shinichi	The University of Tokyo	Nakamura, Fumitaka	MHD simulations of star formation
Takamura, Mieko	The University of Tokyo	Honma, Mareki	Measurement of Faraday rotation of NLSy1s using ultra-wideband VERA polarimetry
Mitsuhashi, Ikki	The University of Tokyo	Sakamoto, Seiichi	Exploration of the star-formation process in high-redshift galaxies using observations of submillimeter galaxies
Yoshida, Yuki	The University of Tokyo	Kokubo, Eiichiro	Theoretical Study on Formation of Planetary Systems
Okino, Hiroki	The University of Tokyo	Honma, Mareki	Observational study of active galactic nuclei jets with global VLBI network
Kushibiki, Kosuke	The University of Tokyo	Motohara, Kentaro	Development of an Integral Field Unit SWIMS-IFU and an Observational Study of Nearby LIRGs
Hoshino, Haruka	The University of Tokyo	Kokubo, Eiichiro	Theoretical Study on Formation of Planetary Systems
Yamazaki, Yuta	The University of Tokyo	Nakamura, Fumitaka	The Origin and Evolution of Heavy Elements in the Universe
Guo, Kangrou	The University of Tokyo	Kokubo, Eiichiro	Planetesimal dynamics in the presence of a massive companion
Lee, Sujin	The University of Tokyo	Honma, Mareki	Radio observations of pulsars/magnetars

3. Commissioned Graduate Students

Doctoral Course	Affiliated Institute	Period	Supervisor	Title of Research Project
Abe, Homare	Tokyo Institute of Technology	2022/5/1–2023/3/31	Aso, Yoichi	Measurement of birefringence in a sapphire mirror for the gravitational-wave telescope KAGRA
Uno, Shinsuke	The University of Tokyo	2022/4/1–2023/3/31	Uzawa, Yoshinori	Development of detector circuits for a submillimeter multichroic camera
Naganuma, Toyo	The University of Electro-Communications	2022/4/1–2023/3/31	Uzawa, Yoshinori	Development of the multi-chroic mm/submm wave camera
Niwa, Ayako	Tsukuba University	2022/6/1–2023/3/31	Matsuo, Hiroshi	Development of photon counting THz intensity interferometry
Huang, Shuo	The University of Tokyo	2022/4/1–2023/3/31	Kawabe, Ryohei	Observational study of submillimeter galaxies based on the multi-wavelength SED analysis
Masui, Sho	Osaka Prefecture University	2022/4/1–2023/3/31	Kojima, Takafumi	Development of superconductive circuits for next generation radio telescope
Matsumoto, Takeru	Osaka Metropolitan University	2022/4/1–2023/3/31	Nishimura, Atsushi	Development of a radio spectrometer with delay-line-based ramp-compare ADC implemented on FPGA
Miyato, Ken	The University of Electro-Communications	2022/10/1–2023/3/31	Nishimura, Atsushi	3D Molecular Cloud Mapping in the Milky Way
Yamasaki, Yasumasa	Osaka Prefecture University	2022/4/1–2023/3/31	Kojima, Takafumi	Development of wideband and multi-beam and optics for radio telescope

Master's Course	Affiliated Institute	Period	Supervisor	Title of Research Project
Okada, Hiroko	Konan University	2022/4/1–2023/3/31	Tominaga, Nozomu	Narrow-band survey and follow-ups of bright metal-poor star candidates
Kawashita, Sana	Osaka Prefecture University	2022/4/1–2022/9/30	Tatematsu, Ken'ichi	Development and commissioning of new 72–116 GHz 7-beam receiver for 45-m telescope
Koseki, Tomohiro	Tsukuba University	2022/4/1–2023/3/31	Matsuo, Hiroshi	Development of terahertz photon counting type intensity interferometer
Chinen, Tsubasa	Osaka Prefecture University	2022/4/1–2022/9/30	Tatematsu, Ken'ichi	Development and commissioning of new 72–116 GHz 7-beam receiver for 45-m telescope
Chounan, Yuuta	Tokyo University of Science	2022/4/1–2023/3/31	Makise, Kazumasa	Development and evaluation of high-Q superconducting resonators for superconducting quantum computers
Nakao, Yuuka	Osaka Prefecture University	2022/4/1–2023/3/31	Nishimura, Atsushi	Development of All-Digital Radio Spectrometer for wideband radio observation.
Nishimoto, Shinpei	Osaka Prefecture University	2022/4/1–2023/3/31	Nishimura, Atsushi	Multiple emission line analysis using machine learning
Masukura, Akihiro	Nagoya University	2022/1/1–2022/12/31	Shan, Wenlei	Research on the superconducting planar circuit for MMIC SIS receiver
Muramatsu, Hiromi	Tokyo University of Agriculture and Technology	2022/5/1–2023/3/31	Aoki, Wako	Ultra-high contrast imaging for direct observation of exoplanets
Yanagawa, Anri	Nara Women's University	2022/10/1–2022/11/30	Tanaka, Masayuki	Morphological study of member galaxy clusters viewed with Subaru HSC
Yoneyama, Sho	Osaka Prefecture University	2022/4/1–2022/9/30	Tatematsu, Ken'ichi	Development and commissioning of new 72–116 GHz 7-beam receiver for 45-m telescope

4. Degrees Achieved with NAOJ Facilities

Name	Degree	Title of Research Project
Liang, Yongming	Doctor of Philosophy, SOKENDAI	Correlation between Galaxies and IGM at $z \approx 2$ Mapped by Subaru/HSC
Takemura, Hideaki	Doctor of Philosophy, SOKENDAI	Study of Dense Core Property and Core Mass Function with Simulation and Observation Data to Reveal the Core Growth with Observations

VIII Public Access to Facilities

1. Mitaka Campus

[Open year-round]

Dates: April to March, 10:00–17:00

Every day except for New Year's season (December 28–January 4) and the following temporary closure days (4 days in total): October 29 (for Mitaka Open House Day, open to participants only), November 12 (due to equipment inspection), and February 11–12 (due to snowfall).

Visitors: 14,245 (of which 1,561 were in groups)

Open Facilities: Observatory History Museum (65-cm Telescope Dome), 20-cm Telescope Dome, Solar Tower Telescope, Exhibit Room, Repsold Transit Instrument Building (Transit Instrument Museum), Astronomical Instruments Museum, Gautier Meridian Circle Building, Old Library, 6-m Millimeter-Wave Radio Telescope

As a measure against the COVID-19 pandemic, only the building exteriors and the areas around the entrances were open to the public.

From April 9, public access to solar observation parties and inside the Observatory History Museum were allowed mainly on Saturdays and Sundays. From June 20 the interior of the Observatory History Museum was open during normal hours.

[Regular Star Gazing Party]

Dates: (Online)

April–October, Friday before second Saturday; fourth Saturday

November–March, Friday before second Saturday

(On-site) November–March, fourth Saturday

(Online) Viewers: Held 18 times, with the total number of maximum simultaneous connections reaching 1,851

Total Views: 20,107 (As of March 31, 2023)

(On-site) Visitors: Held 5 times, 60 guests each time for a total of 220 guests.

All on-site events until October were canceled due to the COVID-19 pandemic. Online events were broadcasted via Zoom to YouTube Live.

[4D2U Theater Showings]

Dates: Friday before second Saturday; first and third Saturdays

Capacity: 42 people per day during April, increased to 60 people per day in May

(reduced capacity due to the COVID-19 pandemic)

Visitors: 1,781 (36 events planned and 34 events held)

The April 2 event was canceled as a preventative measure against the COVID-19 pandemic.

The February 10 event was canceled due to snow fall.

[Special Open-House Event] Mitaka Open House Day

Dates: October 28 (Fri.), 2022, 19:00–20:00 (Online lecture broadcasts only)

October 29 (Sat.), 2022, 10:00–17:00 (Hybrid Format)

Topic: Time and Astronomy

Onsite Attendees: 419 (advance registration required)

Number of Contents:

Live streams and YouTube Premier events: 9

Video Contents: 22

Total Contents: 31

Total Maximum Simultaneous Connections: approximately 1000

Total Views in the First Month after the Release: 65,480

This event is jointly sponsored by NAOJ, the University of Tokyo Graduate School of Science Institute of Astronomy, the SOKENDAI Department of Astronomical Science, and the NINS Astrobiology Center. In FY 2021, instead of being held on-site at Mitaka Campus, Mitaka Open House Day was held online only on Saturday (broadcasted on YouTube Live and archived on our YouTube channel).

This event is jointly sponsored by NAOJ, the University of Tokyo Graduate School of Science Institute of Astronomy, the SOKENDAI Department of Astronomical Science, and the NINS Astrobiology Center. In FY 2022, taking preventative measures against the COVID-19 pandemic into consideration, the event was held in an onsite (limited capacity, advanced reservations required) and online hybrid format. The main lecture on Friday was broadcast over the internet only. On Saturday, Mitaka Campus facilities were opened, along with online streaming and web contents.

Ishigaki Island: Ishigakijima Astronomical Observatory

[Open year-round]

Dates: April to March

Open Hours: Wednesdays through Sundays and Holidays, 10:00–15:30 (except for the New Year's season; when Monday or Tuesday is a national holiday, the facility is closed on the following Wednesday)

Stargazing Sessions: Evenings on Saturdays, Sundays, and Holidays, (20:00–21:00), one 45-minute session per evening

4D2U Theater: 15:30–16:15, from Wednesdays to Sundays and on Holidays

Visitors: 3,477

Open Facilities: Murikabushi 105-cm optical/infrared telescope, Hoshizora Manabi no Heya (Starry Sky Study Room) (featuring exhibits of astronomical images, the 4D2U "four-dimensional digital universe," and stargazing sessions with the 40-cm telescope), interior of observation dome, and corridors (including exhibits of astronomical images)

* From June 11 to March 10, due to damage to the dome caused by lightning strikes around the facility, the 40-cm telescope has been used for all stargazing sessions.

[Special Open Day]

[Southern Island Star Festival 2022] (co-sponsored)

Dates: July 30 (Sat.)–August 7 (Sun.), 2022

Star Festival Live & the Ishigaki Island Starry Sky and Star Culture Lecture:

Held on August 6 (Sat.) at Painuhama-machi Green Park with 600 onsite guests in attendance (live streamed with the archived video available for viewing)

Star Festival Memorial Lecture: Held on August 7 (Sun.) at Ishigaki City Hall with 50 visitors (archived video available for viewing)

2. Mizusawa Campus

[Open year-round]

Dates: April to March (except for New Year's season), 9:00–17:00 daily

Visitors: 11,188

Open Facilities: Kimura Hisashi Memorial Museum, VERA 20-m antenna, 10-m VLBI antenna

The open house event is held at the campus with the cooperation of the Oshu Space and Astronomy Museum (OSAM: Yugakukan) located in the campus.
In addition, in order to prevent the spread of the novel coronavirus infection, the Kimura Hisashi Memorial Museum was temporarily closed starting from April 1, but reopened on July 1.

[Special Open Day] Held as Part of Iwate Galaxy Festival 2022

Dates: August 6 (Sat.), 2022–August 28 (Sun.), 2022

Visitors: 690

In light of the fact that novel coronavirus infections have not yet ended, we consulted with Oshu City and the Oshu Space and Astronomy Museum (OSAM: Yugakukan), and this year, the event was scaled down in size and was not concentrated on a single day, but instead was held over a period of time as several smaller-scale projects.

Iriki: VERA Iriki Station

[Open year-round]

Dates: April to March (except for New Year's season)

Visitors: 1,038

[Special Open Day]

The special open house is usually held as the "Yaeyama Highland Star Festival" organized by the executive committee led by Satsuma-sendai city hall and Kagoshima University. This year, in light of the measures to prevent the spread of the novel coronavirus, it was expected that the situation would continue to require that events be cancelled or infection prevention measures be taken to avoid crowding during the event period, and even if the event period was postponed, it would be difficult to implement. After consultation with the main committee members, it was decided to cancel the conference.

Ogasawara: VERA Ogasawara Station

[Open year-round]

Dates: April to March (except for New Year's season)

Visitors: 6,640

[Special Open Day]

In view of the fact that novel coronavirus infections have not yet ended, we decided to cancel this event in order to protect the health and safety of the participants and related people and to prevent the spread of the infection.

Ishigaki Island: VERA Ishigaki-jima Station

[Open year-round]

Dates: April to March (except for the New Year's season); premises are open to the public 24 hours/day, and the observation rooms are open during the hours of 10:00–16:30.

Visitors: 2,584

[Special Open day] The Special Open Day was held as a part of the Southern Island Star Festival.

Dates: August 7 (Sun.), 2022

Visitors: 66

In view of the fact that novel coronavirus infections have not yet ended, this year's event was held while prioritizing the health and safety of the participants and related people.

3. Nobeyama Campus

[Regular Open]

Open Time: 8:30–17:00 (every day except around New Year's Day (December 29 to January 3))

Visitors: 37,690

Open Facilities: 45-m Radio Telescope, Nobeyama Millimeter Array, Nobeyama Radioheliograph, etc. (just viewing)

[Open House Day] (held online only)

Date: August 28 (Saturday), 2022, 9:30–16:00 (available for access after the day)

Participants:

Public lectures:

~500 (am), ~400 (pm) (maximum viewers for live streaming)

~84,000 (total number of views in about the first 90 days)

Virtual space (poster session): ~200

Keyword rally (on-site): ~2500 (held during Aug. 26 – Oct. 30)

Nobeyama Open Campus Day 2022 was held online as a precaution against the spread of COVID-19. The theme was "40th anniversary and challenge." We had public lectures relating to research activities in Nobeyama Campus by 7 researchers such as Associate Prof. Tomomi Shimoikura (Otsuma Women's University) and Project Assistant Prof. Kotomi Taniguchi (NAOJ). The number of views for this live streaming reached over 400, and the total number of views in the first 90 days was more than 84,000. We also held a poster session in virtual space where researchers gave poster presentations. Twenty presenters were gathered through an open call for posters, and about 200 participants gathered to see the presentations. Moreover, we had a "keywords rally" event on-site. In that event, visitors find and collect keywords distributed over the entire campus to get NRO original goods.

[Jimoto Kansha Day (Thanks Day for the locals)]

This event could not be held due to prevention measures against the spread of COVID-19.

4. Subaru Telescope

[Summit Facility Tour]

The public tour program officially ended due to various circumstances.

Special tours: 15 groups, 75 visitors

[Base Facility Tour]

Special tours visitors: 4 groups, 206 visitors

*Subaru Telescope initiated a new program, Subaru Stars, to bring astronomy and STEM education to students and communities across the Island of Hawai‘i. This number includes a school field trip as a part of the Subaru Stars program.

[Public Information]

- Primary means of public information is posting at the official website https://subarutelescope.org
- Science results from the Subaru Telescope – 18 Japanese and 18 English articles
- Announcements and topics of special activities and events – 32 Japanese and 30 English articles.
- Press releases to the local media of Hawai‘i – 4 English releases
- Social media official accounts
  - Twitter accounts – SubaruTelescope (Japanese), SubaruTel_Eng (English)
  - Facebook accounts – 国立天文台 (Japanese), National Astronomical Observatory of Japan, and Subaru Telescope Hawaii Outreach (English)
  - Instagram account – Subaru_telescope (English)
  - YouTube channels – SubaruTelescopeNAOJ (Japanese), SubaruTelescopeNAOJe (English), subarutel_starcamadmin (bilingual subchannel)

*Main targets of the English accounts: Twitter for the international community and Facebook and Instagram for the local community of Hawai‘i.

[Outreach]

1. Lectures, Workshops, etc., at Nearby Facilities:

41 cases, about 1,500 people in total

(Main Activities)

- School visits as a part of the Subaru Stars program
- Judges at a series of VEX robotics competitions for elementary, intermediate, and high school teams
- Classroom visits through the annual Journey Through The Universe program
- Support and supervision for A Hua He Inoa high school interns to propose Hawaiian names for a planet-and-star pair
- Supervision for a science fair project for a intermediate school student

2. Other Activities, including Outreach Events

1) In person Activities:

15 events, able to interact about 8,900 people.

(Main Activities)

- Merrie Monarch Parade
- AstroDay
- AstroDay West
- Career events (Career Fair, Career EXPO) for intermediate and high school students
- Science events at elementary schools
- Lili‘uokalani Gardens Christmas Light Show (as a member of Maunakea Observatories volunteer group Na Hoku Huihui)
- Maunakea Coin Contest (as a members of Maunakea Astronomy Outreach Committee)

2) Online Activities:

1 event, able to interact with about 100 people.

(Activity)

- Video message to Tsukimi no Kai event organized by the United Japanese Society of Hawai‘i

3. YouTube Live Streaming:

10 cases, about 389,700 views

(Main Activities)

- MEXT GIGA School, live from the Subaru Telescope summit facility
- Live streaming of the signing ceremony for the agreement on installation and operation of the Subaru-Asahi Star Camera, between NAOJ and The Asahi Shimbun Company (*)
- Live streaming of the total lunar eclipse (*)
- Live streaming of the Mauna Loa eruption (*)
- Live streaming of Geminids meteor shower (*)
- Live galaxy classification in the NAOJ citizen science project GALAXY CRUISE

(*) Streamed from the Asahi Shimbun Astro LIVE YouTube Channel. In addition, a 24/7 live stream from the Subaru-Asahi Star Camera is offered through cooperation with The Asahi Shimbun Company.

4. Volunteer Activities: 11 cases

In addition to traditional outreach activities, staff members participated in volunteer activities to contribute to the local community of Hawai‘i.

(Main Activities)

- Tutoring at Hilo High School
- Invasive Species Weed Pulls at Halepohaku, the mid-elevation facilities of Maunakea
- Maunakea Forest Restoration Project
- The Food Basket (Hawai‘i Island’s Food Bank), packing and delivery
- Cleanup work at Lili‘uokalani Gardens

5. Media Interview/Filming: 24 cases (7 Japanese, 17 English)

- 35 articles were published in newspapers in Japan
- 25 articles were published in media in Hawai‘i (including newspapers and online news websites)

IX Overseas Travel

Research and Academic Staff Overseas Travel

(Including employees on annual salary system.)

category / country/area	Business Trip	Training	Total
South Korea	9	0	9
China	0	0	0
Thailand	7	0	7
Taiwan	12	0	12
Hong Kong	0	0	0
Singapore	1	0	1
Indonesia	0	0	0
Philippines	0	0	0
Other areas in Asia	5	0	5
Hawai`i	19	0	19
U.S.A.	12	0	12
Australia	5	0	5
Italy	9	0	9
U.K.	4	0	4
France	4	0	4
Canada	5	0	5
Guam, Saipan	0	0	0
Germany	14	0	14
Other areas in Europe and Oceania	33	0	33
Mexico	1	0	1
Brazil	0	0	0
Africa	6	0	6
Other areas in South and Central America *	26	0	26
Total	172	0	172

* In typical years, most travelers to South and Central America go to Chile.

X Award Winners

Award Recipients	Affiliated Division	Job Title	Award	Date
Hada, Kazuhiro	Mizusawa VLBI Observatory	Assistant Professor	The 11th NINS Young Researcher's Prize	2022/7/16
Okada, Norio	Advanced Technology Center	Technical Expert	The 2022 Tokyo Merit Award (Technology Promotion)	2022/10/1
Yoneta, Kenta	Advanced Technology Center	Project Research Staff	The 8th OSJ/SPIE Student Award	2022/11/16
Yoneta, Kenta	Advanced Technology Center	Project Research Staff	The 11th Visible Infrared Scanner Workshop 2022 Young Presenter Gold Prize	2022/12/23
Mizusawa VLBI Observatory			Iwate Nichinichi Culture Award	2023/2/26
Hanayama, Hidekazu	Public Relations Center	Associate Professor (Lecturer)	2022 Yoshihide Kozai Award	2023/3/15

XI Library, Publications

1. Library

Number of books in each library (2023/3/31)

	Japanese Books	Foreign Books	Total
Mitaka	18,665	50,281	68,946
Nobeyama	1,128	5,891	7,019
Mizusawa	4,986	18,113	23,099
Hawai`i	1,699	4,683	6,382
Total	26,478	78,968	105,446

Number of journal titles in each library (2022/3/31)

	Japanese Journals	Foreign Journals	Total
Mitaka	371	1,675	2,046
Nobeyama	16	82	98
Mizusawa	659	828	1,487
Hawai`i	15	9	24
Total	1,061	2,594	3,653

2. Publication

Here we list continuing publications produced by NAOJ in FY 2022.

(Mitaka)

01) Report of the National Astronomical Observatory of Japan, Vol. 23: 1 issue (Digital Publication Only).
02) Annual Report of the National Astronomical Observatory of Japan (Japanese), no. 34, Fiscal Year 2021: 1 issue
03) Annual Report of the National Astronomical Observatory of Japan (English), vol. 24 Fiscal Year 2021: 1 issue
04) Calendar and Ephemeris, 2023: 1 issue
05) NAOJ News, No. 337–339: 3 issues
06) NAOJ Pamphlet 2023 (English): 1 issue
07) Rika Nenpyo (Chronological Scientific Tables), 2023: 1 issue

3. Publication Support

In FY 2022, the NAOJ Reprints were replaced by publication support.

National Astronomical Observatory publication support, No. 3581–3684: 104 issues.

XII Important Dates

April 1, 2022 – March 31, 2023

2022	
April 1	Hiroshi Nagai (Project Associate Professor), Koichiro Nakanishi (Project Associate Professor), Charles L. H. Hull (Project Assistant Professor, NAOJ Fellow) and Seiji Kameno (Professor, Joint ALMA Observatory) received the 2021 Shoichiro Yoshida Memorial/Nikon Astronomy Achievement Award for the achievement of realization of ALMA polarimetry observations and promotion of millimeter and submillimeter polarimetry science.
April 18	GALAXY CRUISE, NAOJ citizen science project, launched Season 2 with fainter galaxies.
April 19	Mizusawa VLBI Observatory announced that it will be the first National Astronomical Observatory of Japan (NAOJ) entity to conduct crowdfunding to support young researchers involved in black hole research, disseminate research results, and maintain facilities including telescopes and other research equipment.
April 20 –April 22	TMT Project set up the NAOJ booth at OPIE SPACE & ASTRONOMICAL OPTICS EXPO 2022 held at Pacifico Yokohama and showcased TMT, the 188-cm Telescope, and the Seimei Telescope in Okayama.
April 23	Subaru Telescope and TMT Project participated in Merrie Monarch Parade held in Hilo, the Island of Hawai‘i, as Maunakea Observatories members.
April 28	The Churaboshi Research Team Workshop, abbreviated as “Churaken,” called for applications to participate in this year's event to be held on Ishigaki Island (August 3 (Wed.) to August 5 (Fri.), 2012).
May 14	Subaru Telescope, its internal citizen science project PANOPTES, and TMT Project participated in the annual AstroDay event, in Hilo, the Island of Hawai‘i, and provided fun science activities at their booths to the local community.
May 22 –May 26	TMT Project and ALMA Project set up the NAOJ booth at the hybrid Japan Geoscience Union (JpGU) Meeting 2022 at Makuhari Messe and showcased TMT and ALMA.
May 24	Subaru Telescope scientists were in a live streaming of the MEXT GIGA School at the NAOJ YouTube channel from the summit facility, Maunakea, Hawai‘i.
June	Subaru Telescope released new data from Hyper Suprime-Cam Legacy Archive (HSCLA).
June 6 –July 14	Led by TMT International Observatory (TIO), TMT Project and Subaru Telescope staff members contributed to the summer tutoring program at Hilo High School.
June 22	Subaru Telescope started the brand new educational program Subaru Stars at the Na‘alehu Elementary School summer program in the southern part of the Island of Hawai‘i.
July 11 –September 2	Subaru Telescope suspended observations for the aluminum recoating of the primary mirror and telescope maintenance.
July 12	NAOJ and the University of Notre Dame (NDU) in the Republic of Lebanon held an online signing ceremony of a Memorandum of Understanding for Research and Academic Cooperation with the attendance of H. E. Mr. Nidal Yahya, Ambassador of the Lebanese Embassy in Tokyo.
July 29	Four Undergraduate interns of the Akamai Workforce Initiative program, supervised by Subaru Telescope mentors, presented at the Akamai Internship Symposium held at Grand Naniloa Hotel, Hilo, Hawai‘i.
July 30 –August 7	The “Southern Island Star Festival” was held for the 21st time this year, featuring evening live performances & star lectures/viewing sessions, commemorative lectures, and a special opening of the VERA Ishigaki-jima Station.
July 31	Subaru Telescope’s website for “Subaru Telescope 2.0” launched in English.
August 2 –August 11	The Office of International Relations, in cooperation with relevant departments at NAOJ, exhibited a NAOJ booth at the General Assembly of the International Astronomical Union (IAUGA 2022) held in Busan, Republic of Korea.
August 8	NameExoWorlds 2022 campain started.
August 10	It was announced that due to the Corona disaster, rather than being concentrated on a single day, the Special Open House Day held as part of Iwate Galaxy Festival 2022 (August 20 (Sat.) to August 28 (Sun.)) would be reduced in scale and held in the form of multiple smaller events over a period of time.
August 20 –August 28	“The Speical Open House Day held as part of Iwate Galaxy Festival 2022,” announced on August 10, was held both on-site and online.
August 28	Open House Day of Nobeyama Radio Observatory was held online. The number of viewers for live streaming reached over 400, and total number of views for all content in about the first 90 days was about 84,000.
September –May (2023)	TMT Project staff members contributed to the afterschool tutoring program every Wednesday at Hilo Intermediate School.

September 1	Undergraduate students of the SOKENDAI Summer Student program, supervised by Subaru Telescope scientists, gave online presentations about their study results.
September 13	NAOJ and The Asahi Shimbun Company held the signing ceremony for the agreement on installing and operating the Subaru-Asahi Star Camera on the Subaru Telescope, Maunakea, Hawai‘i.
September 21 –September 26	During the engineering observations, the Prime Focus Spectrograph (PFS) mounted on the Subaru Telescope successfully obtained the first spectra from target stars.
October 6	Mizusawa VLBI Observatory received support from a total of 1256 people through crowdfunding from April to June 2022, and those who agreed to have their names posted on the website are now listed in the manner they requested at the time of application (honorific titles omitted).
October 11	Satoshi Miyazaki, Director of Subaru Telescope, sent a video message to Tsukimi no Kai event organized by the United Japanese Society of Hawai‘i, the Island of Oahu.
October 28 –October 29	Mitaka Open House Day held in onsite/online hybrid format.
October 28 –May 5	A Subaru Telescope scientist helped and supervised A Hua He Inoa high school interns to participate and suggest Hawaiian names for an exoplanet-and-star pair as part of the International Astronomical Union (IAU) NameExoWorlds competition.
November 3	Masanori Iye, Professor emeritus of NAOJ and SOKENDAI, received The Order of the Sacred Treasure, Gold and Silver Star at the 2022 Conferment of Decoration.
November 5	Subaru Telescope, its internal citizen science project PANOPTES, and TMT Project participated in the annual AstroDay West event at a shopping center in Kailua-Kona, the Island of Hawai‘i, and provided fun science activities at their booths to the local community.
November 7 –November 8	Subaru Telescope and its internal citizen science project PANOPTES live-streamed the total lunar eclipse from the Island of Hawai‘i.
November 8	The Public Relations Center live streamed the lunar eclipse and occultation of Uranus.
November 14	Hidehiko Yuzaki, Governor of Hiroshima Prefecture, visited the summit facility of the Subaru Telescope, Mauakea, Hawai‘i.
November 14 –November 18	Director General Tsuneta made courtesy visits to Ministry of Foreign Affairs and others in Chile.
November 17	Subaru Telescope and its internal citizen science project PANOPTES participated in Career EXPO for high school students in Hilo and its vicinity, and introduced various jobs and career paths.
November 19	A Subaru Telescope exoplanet scientist gave a talk at the Exoplanet Revolution event held at ‘Imiloa Astronomy Center of Hawai‘i.
November 19 –February 4	Subaru Telescope and TMT Project staff members contributed to a series of VEX robotics competitions as judges for elementary, intermediate, and high school teams.
November 21	Subaru Telescope released the 3D virtual tour of inside and outside the summit facility's enclosure.
November 28 –November 30	Subaru Telescope (host) and Astronomical Data Center (co-host) held the Subaru Telescope Data Analysis Workshop in person at the NAOJ Mitaka Campus.
November 29	As a part of the Subaru Stars program, Subaru Telescope invited 3rd and 4th graders of Na‘alehu Elementary School to the Hilo Base Facility for an immersive field trip.
December 1	The 28th “Astronomy Lecture for Science Journalists” held on the theme of “Technological Development in NAOJ and Collaboration with Industry.”
December 7 –December 8	NAOJ Future Planning Symposium 2022 — How to decide and promote future plans —”was held at NAOJ Mitaka. The total number of participants over the two days was 558 (including online participants, 69% from inside NAOJ).
December 10	The 7th “Nagano Prefecture is Astro-Prefecture” meeting was held online at Bunka-hall in Kiso-Bunka-Koen by “Nagano Prefecture is Astro-Prefecture” liaison council, which consists of Nobeyama Radio Observatory, Kiso Observatory of the University of Tokyo, and so on. There were about 50 participants in the meeting.
December 12 –December 14	Subaru Telescope live streamed the Geminids meteor shower from Maunakea, Hawai‘i, for two consecutive nights with the cooperation of The Asahi Shimbun Company.
December 19	ALMA Grant Fellow Symposium 2022 was held at Mitaka Campus and online.
December 20 –December 21	ALMA/45m/ASTE Users Meeting 2022 was held at Mitaka Campus and online.
December 22	Liberal Democratic Party Policy Research Council Chairperson Koichi Hagiuda toured VERA Ishigaki-jima Station and Ishigakijima Astronomical Observatory.
December 23 –December 24	Subaru Telescope and TMT Project participated in the Lili‘uokalani Gardens Christmas Light Show in Hilo on the Island of Hawai‘i as a member of Maunakea Observatories volunteer group Na Hoku Huihui.

2023

January 8 –January 12	The Office of International Relations, in cooperation with the Subaru Telescope and other relevant departments at NAOJ, exhibited a NAOJ booth at the 241st Meeting of the American Astronomical Society (241st AAS Meeting) held in Seattle, USA.
January 13 –March 15	The Maunakea Coin Contest, open to K-12 students on the Island of Hawai'i, was held by the Maunakea Astronomy Outreach Committee. A Subaru Telescope staff member was one of the leaders of the contest.
January 31 –February 2	The annual Subaru Users Meeting FY 2022 was held in a hybrid style of on-site and online.
February 3	Ambassador of Chile to Japan visited NAOJ.
February 9	Subaru Telescope (as a member of Maunakea Observatories) and its internal citizen science project PANOPTES participated in Career EXPO for intermediate school students in Hilo and its vicinity, and introduced various jobs and career paths.
February 28	The National Astronomical Observatory of Japan, Mizusawa VLBI Observatory was selected for the 40th Iwate Nichinichi Cultural Award in the academic and research category by the Iwate Nichinichi Shimbun, which celebrated its 100th anniversary, and the award ceremony was held at Bellino Hotel Ichinoseki (Yamame, Ichinoseki City).
February 28 –March 4	Subaru Telescope and TMT Project staff members participated in the annual educational program Journey Through the Universe and delivered interactive presentations in classrooms at public elementary, intermediate, and high schools in Hilo, Hawai'i.
March 2 –March 3	As a part of the FY 2022 Project Review of NAOJ, the international external evaluation of the Division of Science was conducted at Mitaka Campus.
March 2 –March 5	The Public Relations Center co-Hosted an onsite booth with 4 other organizations at the American Association for the Advancement of Science Annual Meeting (AAAS2023 held in hybrid format).
March 7 –March 10	BEARS ALMA Proposal Workshop was held at Mitaka Campus.
March 13	The ALMA 10th anniversary ceremony was held in Chile.
March 24	The Public Relations Center live streamed the occultation of Venus.

Throughout the year

	Subaru Telescope provides the 24/7 live streaming from Maunakea, Hawai'i, with the Subaru-Asahi Star Camera in collaboration with The Asahi Shimbun Company.

XIII Publications, Presentations

1. Refereed Publications

Abbott, R., et al. including **Akutsu, T.**, **Aritomi, N.**, **Capocasa, E.**, **Eisenmann, M.**, **Flaminio, R.**, **Hirata, N.**, **Leonardi, M.**, **Nakamura, K.**, **Shoda, A.**, **Takahashi, R.**, **Tomaru, T.**, **Washimi, T.**, **Zhao, Y.**, **Aso, Y.**, **Chen, D.**, **Kozakai, C.**, LIGO Sci Collaboration, Virgo Collaboration, KAGRA Collaboration: 2022, All-sky search for gravitational wave emission from scalar boson clouds around spinning black holes in LIGO O3 data, *Phys. Rev. D*, **105**, 102001.

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Annual Report of the National Astronomical Observatory of Japan

Volume 25 Fiscal 2022

NAOJ
National Astronomical Observatory of Japan