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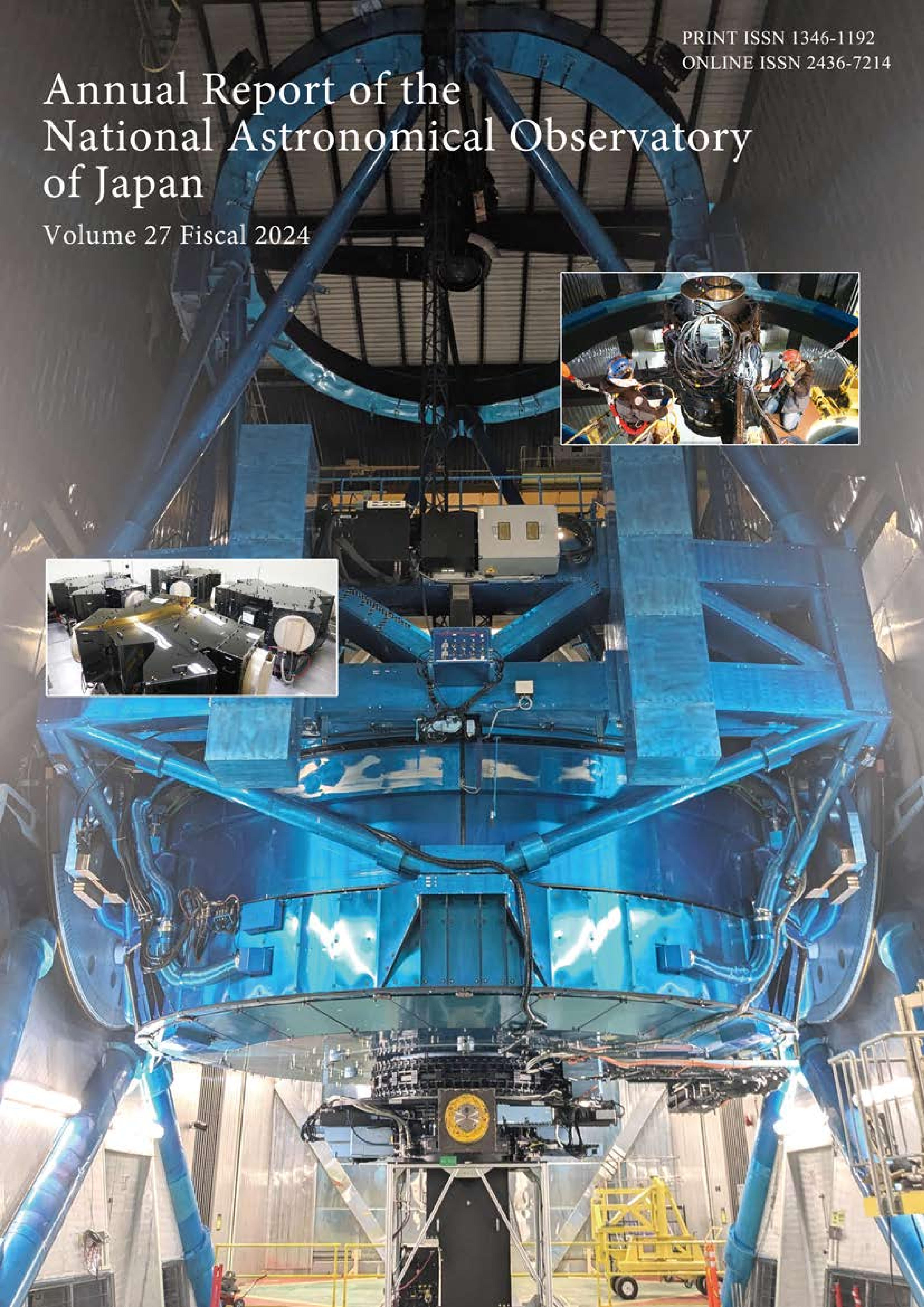

Cover Caption

Prime Focus Spectrograph (PFS) installed on Subaru Telescope. The telescope equips Prime Focus Instrument (PFI, a picture of the PFI exchange is in the top-right frame) at its prime focus, Metrology Camera System (MCS) at its Cassegrain Focus. The Spectrograph System (SpS, as in the picture in the left frame) stays in a dedicated clean room built on the upper floor of the dome. PFI and SpS are connected with about-55m-long fiber optics cables installed along the telescope and dome walls.

Back Cover Caption

The configuration design of about 2400 fibers of PFS used for the observation of M31 (symbols over an image of M31 taken by HSC on upper figure) and the spectra obtained from the observation (lower figures). From lower right to left, they show spectra of an HII region, a Wolf-Rayet star, a G dwarf star, an M dwarf star, a Nova, and a planetary nebula. Characteristic features to each type of object are observed on these spectra.

Postscript

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Annual Report of the National Astronomical Observatory of Japan

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Mamoru DOI

Director General of NAOJ

PREFACE

I am pleased to present the Annual Report of the National Astronomical Observatory of Japan for FY 2024.

The main mission of NAOJ is to provide large astronomical facilities that cannot be supported by individual universities to researchers throughout Japan through open use. As of FY 2024, NAOJ conducts open use observations with the Subaru Telescope and ALMA; radio observations with the East Asian VLBI Network and the Nobeyama 45-m Radio Telescope; synergetic observations with small and medium-sized telescopes in the optical-infrared wavelength domain; and solar observations with Hinode. In addition, we are promoting the Thirty Meter Telescope (TMT) project for the future. In theoretical research, we provide a numerical simulation environment through ATERUI, as well as archiving and publishing observation data acquired not only by NAOJ's telescopes such as the Subaru Telescope and ALMA but also including data acquired by university owned telescopes in Japan. Furthermore, the Advanced Technology Center leads various development activities. And many research results have been published, including those coming out of the Division of Science. In addition, educational activities are conducted in cooperation with the Graduate University for Advanced Studies and other universities. NAOJ also conducts various outreach activities, mainly through our Public Relations Center. In addition, a number of offices and other organizational infrastructure have been established to deal with various matters both internal and external. Here, I will mention the highlights of FY 2024. For full details, please refer to the reports contained in this volume.

A milestone in VERA astrometry was the first successful measurement in history of the annual parallax of the supermassive black hole Sagittarius A* in the center of the Milky Way Galaxy. A report compiling the results was published. The obtained distance to the center of the Milky Way Galaxy is 27,700 light years (with 15 % uncertainty). This is consistent with previous results, but has significance in that humanity's triangulation horizon has now extended as far as the Galactic center. This result was made possible by the long-term operation of VERA and the continuous improvement of its sensitivity over that time.

At the 45-m telescope at Nobeyama Radio Observatory, ASIAA in Taiwan has started development work on a new ultra-broad-band receiver eQ, which will be capable of covering 30-50 GHz. It has started producing preliminary scientific results including multiline mapping and the line search of high redshift objects. We look forward to the advancement of science using new frequency windows, including collaboration with the ALMA Band 1 receivers.

In the Solar Science Observatory, the "Hinode" satellite, Solar Flare Telescope, and Nobeyama Radio Polarimeters continue to observe, leading up to the solar activity maximum. The data obtained with “Hinode” have contributed to the publication of more than 50 papers. Relative sunspot number counts by the Sunspot Telescope and full solar disk magnetic field observations of the photosphere and chromosphere by the infrared spectropolarimeter on the Solar Flare Telescope are ongoing to provide continuous observations of long-term changes in the solar magnetic activity. In addition, the Solar Science Observatory is participating in the international balloon experiment Sunrise III to capture the 3-dimensional magnetic field structure in the solar atmosphere, and the joint Japan-U.S. sounding-rocket experiment FOXSI-4 to elucidate solar flare plasma heating and particle acceleration. Groundbreaking data were obtained from both experiments.

Two new satellite galaxies were found around our Milky Way Galaxy in the latest data taken by the Subaru Telescope’s ultra-wide field-of-view prime focus camera Hyper Suprime-Cam (HSC). Combined with previously discovered satellite galaxies, these new galaxies indicate that the number of satellite galaxies around the Milky Way is more than double the theoretically predicted number. This discovery creates new problems for the formation history of the Galaxy and the nature of dark matter which governs that formation. Also, the Prime Focus Spectrograph (PFS), the next large-scale observational instrument for the Subaru Telescope was made available for open use starting from March 2025. With the ability to collect spectra from approximately 2400 celestial objects simultaneously across its wide field of view with a diameter of 1.3 degrees, it can also cover a wide wavelength range from the visible to near infrared. Other 8 m to 10 m class telescopes do not have this capability. We can expect even more results from the Subaru Telescope thanks to the combination of images from HSC and spectra from PFS.

The Seimei Telescope, for which NAOJ administrates the open use, detected multiple prominence eruptions on a dwarf star and elucidated their natures through observations with a high time resolution of 1 minute. This provides important clues to understanding their effects on the environment around planets. Also, regarding the Okayama 188-cm Reflector Telescope, which has suspended operations since 2022, the dome shutter work was completed and scientific operations resumed in spring of 2025.

I would like to mention one of the results from the Center for Computational Astrophysics (CfCA) obtained with the supercomputer “ATERUI II”: the world’s first star-by-star simulations of globular cluster formation. It was shown that the massive stars which appear in globular cluster formation will go on to evolve into intermediate mass black holes. The operation period for “ATERUI II” ended in August 2024 and from December, the next generation supercomputer “ATERUI III” (HPE Cray XD2000) started operation in NAOJ Mizusawa Campus.

At ALMA, the Wideband Sensitivity Upgrade continued based on the ALMA2 plan. Design and development continued for projects including Band 8v2 receivers, the high speed Data Transmission System (DTS), and Total Power GPU Spectrometer (TPGS). In open-use observations, Cycle 10 achieved a record amount of observation time. In terms of scientific results in 2024 as well, ALMA achieved many important results in a wide range of fields, including the successful detection of hydrogen and oxygen in a galaxy 13.4 billion light-years away.

At the ASTE telescope, operations were conducted focusing on test observations with the world’s only on-chip integrated superconducting spectrometer, DESHIMA 2.0.

KAGRA suffered major damage due to the Noto Peninsula Earthquake on January 1, 2024. Restoration work began immediately, and repairs took about half a year to complete. After that, adjustments were made. As of March 3, 2025, KAGRA has attained a sensitivity equivalent to a detection distance of 4.2 Mpc for binary neutron star inspirals. Work to improve the sensitivity is ongoing, looking ahead to participating in the third phase (O4c) of the 4th international gravitational wave observation run (O4).

Regarding TMT, in July 2024 the United States National Science Foundation (NSF) conducted an external evaluation of the US Extremely Large Telescope Program (US-ELT Program) consisting of TMT and the Giant Magellan Telescope (GMT). The panel report released in December emphasized the scientific significance of the US-ELT Program and concluded that both the TMT and GMT projects are ready to move forward to the NSF Final Design Phase. In FY 2024, as in the previous fiscal year, NSF provided funds, and the development of the TMT design continued. Thanks to NAOJ’s active involvement in activities such as building trust through direct dialogue and educational support in Hawai`i, where TMT is slated to be built, and the decommissioning of two aging telescopes, which has been an issue for many years, the local situation in Hawai`i has improved significantly.

The JASMINE Project passed its mission definition review in July 2024 based on continued studies of observational instruments with satellite development manufacturer candidates and comprehensive conceptual simulations of data analysis based on mock observation survey data. The JASMINE Project also successfully prototyped a space-grade 2K × 2K pixel detector in cooperation with a domestic manufacturer.

The RISE Project, as the MMX Geodesy Science Strategy Team, dealt with the delay of the launch until 2026 by conducting integration tests of the laser altimeter and spacecraft and carefully confirmed the interface while revising at a fevered pitch the scan observation plan for shape modeling.

The SOLAR-C Project, in cooperation with JAXA, conducted fundamental design work for the EUVST observational instrument. Domestically, the observational instrument manufacturers conducted preliminary design reviews, and engineering model (EM) development started based on those reviews. As of the end of FY 2024, the EM primary mirror has undergone lightweighting, shape processing, and reflective coating processing. In addition, the interface design with overseas devices continued. EM production started for the telescope tube structure and the control systems.

The extremely-wide field-of-view multi-object spectrograph Prime Focus Spectrograph (PFS) for the Subaru Telescope saw the remaining two near-infrared cameras delivered and installed in June and August, enabling observations in the completed form with approximately 2400 fiber optics and 12 spectrograph cameras. After more than 30 nights of test observations, continuous analysis software development, and preparation of the observation framework, open-use observations with PFS started from the end of FY 2024.

The Subaru Ground Layer Adaptive Optics (GLAO) Project prototyped components for the wavefront sensor and laser guide star generation system. Performance evaluation was completed for the optics, sensor, and readout system. In the development of laser tomography adaptive optics (LTAO) combined with a control system prototype, a four-beam laser guide star generation system (4LGSF) was completed, and test observations were conducted. Regarding the adaptive secondary mirror, production of major optical components continued; along with evaluation of the mechanical and electrical parts; calibration tests; and the final design for the interferometric test of the wave front sensor.

The Astronomy Data Center computer system was replaced. The computing environment and the various archives were migrated to the new system. Regarding data publication, SMOKA started the release of data from GAOES-RV on the Seimei Telescope. Preparations continued for the release of data from PFS on the Subaru Telescope and photographic plates from the former Okayama Astrophysical Observatory. MASTARS is proceeding with consideration of data compression and conceptual design for a next generation archive shared with SMOKA. Regarding the use of processed data, through cooperation with Subaru Telescope, all of the data from the Hyper Suprime-Cam Subaru Strategic Program (HSC-SSP) have been processed and released to open-use researchers. Development continued for a user environment and a high-speed database to achieve research such as the detection of moving objects. The release of data from HDS on the Subaru Telescope through the JVO portal and cooperation with the Nobeyama/ASTE science archive continued.

The Advanced Technology Center (ATC) broadly advanced the development of equipment and techniques to support next-generation observational instruments. In the TMT project, design continued for the Infrared Imaging Spectrograph (IRIS) and Wide Field Optical Spectrograph (WFOS), contributing to international collaborative development. For ALMA, development continued towards second generation broadband receivers and a data transmission system; and continuous maintenance for existing receivers was conducted. Development continued for a ground layer adaptive optics system for the Subaru Telescope. For KAGRA, the gravitational wave telescope, ATC contributed to recovery work to repair the damage after the Noto Peninsula Earthquake, in addition to development for the vibration isolation system and auxiliary optics system. ATC also led the specification development for the telescope component and the optical design of the spectrograph for SOLAR-C and contributed to JASMINE following the mission definition review. ATC engaged in advanced technology development for infrared detectors, integral field spectroscopy techniques, adaptive optics techniques, and terahertz techniques with the goal of improving the capabilities of future observational instruments. The Social Implementation Program continued efforts to apply technology cultivated through the development of receivers for radio observations to quantum computing and research to use the optical-IR adaptive optics technology, that was developed for the Subaru Telescope and other telescopes, for satellite communications networks. Also, the “NAOJ Space Innovation Center Initiative” which will center on ATC was proposed to the “SX Research and Development Site” theme of the Space Strategy Fund and accepted. The goal is to apply NAOJ’s instrument development techniques to space technology development industries. We expect it to serve as a new framework to promote academic-industry cooperation.

The Public Relations Center (PRC) was busy with 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; responding to reports of discoveries of new astronomical objects; and providing the ephemeris and other astronomical information directly related to people’s everyday activities, such as sunrise and sunset times. For Comet Tsuchinshan-ATLAS, which became a public sensation, PRC conducted a livestream with commentary connecting Mitaka and Ishigaki Island, reaching 140,000 viewers. NAOJ’s Japanese X account has reached nearly 300,000 followers. In addition, this year marked the 100th anniversary since Tokyo Astronomical Observatory, the predecessor of NAOJ, relocated to what is now Mitaka City. In recognition of this, a commemoration ceremony and other events were held in cooperation with Mitaka City. In addition, the 4D2U Dome Theater projection equipment was renovated and screenings resumed. Through the Spectrum Management Office, work continued with domestic and international collaborators for the protection of the astronomy observation environment.

In the Division of Science, 325 papers were published, including: diversity in hydrogen-rich envelope mass of type II supernovae; characterization of supernovae interacting with dense circumstellar matter; and chemical reaction model calculations for carbon isotope fractionation of complex organic molecules in star-forming cores. The Division also produced other results such as the construction of a theoretical model for hazes in extra-solar planets; observations of a supernova including Japanese and Korean radio telescopes; and radio observations of mass loss changes at the time of star formation, which change the planetary system chemical environment.

As for the activities of the various offices, the Information Security Office strengthened the security system and international cooperation, and prepared for the replacement of the information network service. The Research Enhancement Strategy Office facilitated an external review for the Center for Computational Astrophysics; in addition to other activities related to the evaluation and research capability enhancement of NAOJ. The Industry Liaison Office responded to requests for collaboration from private companies, participated in exhibitions, and in October 2024 held an “Astronomy Lecture for Science Journalists” on the theme of “Technological Development in NAOJ and Collaboration with Industry 2” in cooperation with PRC, ATC, and CfCA. The Office of International Relations (OIR) supported the activities of the East Asian Core Observatories Association (EACOA) and the East Asian Observatory (EAO), handled international agreements and memorandums-of-understanding with overseas institutions, provided international researchers and students with support for living in Japan, and disseminated information at international conferences. In particular in FY 2024, the OIR led NAOJ’s display booth at the XXXII International Astronomical Union General Assembly held in August 2024 in Cape Town South Africa. Because NAOJ had decided to withdraw from EAO as of the end of February 2025, the OIR handled necessary adjustments and procedures for this process. The Human Resources Planning Office handled employment management for fixed-term employees in general, harassment and mental health cases, and individual labor issues, and conducted in-person training for leaders three times. The Safety and Health Management Office convened Safety and Health Committee meetings; promoted information exchange; and conducted periodic safety and health patrols and work environment measurements. They also held a safety and health workshop. The Engineering Promotion Office visited the ASTE telescope, VERA Ishigakijima Station, Nobeyama Radio Observatory, and Mizusawa VLBI Observatory to observe the work being done with the aim of implementing trail job rotations. It also conducted training as part of human resource development for technical staff.

This concludes my overview of NAOJ’s activities in FY 2024. More details can be found in the full report.

M. Doi

I Scientific Highlights

(April 2024 – March 2025)

Enhancing the Understanding of the Modelling of GRBs via the Closure Relationships

DAINOTTI, Maria[1], BHARDWAJ, Shubham[1], BISSALDI, Elisabetta[2], FRAIJA, Nissim[3], SOURAV, Shashwat[4], GALVAN, Antonio[3]

1: NAOJ, 2: University of Bari, 3: Universidad Nacional Autónoma de México, 4: Washington University

Gamma-Ray Bursts, after more than 50 years from their discovery, still remain puzzling due to their emission mechanism. Thus, the investigation of theoretical modelling is needed to cast light on the surrounding environment. The closure relationships, which are the relationships between the temporal slope and the spectral indices in several parts of the lightcurves, help to test the standard fireball model, one of the most credited model in the GRB field. We continued with the multiwavelength observations that help verify the reliability of the standard fireball model in different frequencies and energy ranges contemporaneously. The current analysis started with a previous study [1] of 86 GRBs observed at high energies by the Fermi Large Area Telescope (LAT), observed from 2008 to 2018. We filtered GRBs in the Second Fermi-LAT GRB Catalog with a broken (21 GRBs) or simple power law (65 GRBs). We analyze the closure relations according to the synchrotron forward-shock model evolving in stratified environments ($n \propto r^{-k}$) with k ranging from 0 to 2.5. We find that the model without energy injection is preferred over the one with energy injection. In the current study [2], we analyze 14 GRBs observed contemporaneously in gamma rays by the Fermi Large Area Telescope, in X-rays by the Swift Telescope, and in the optical bands by Swift and many ground-based telescopes, including photometric data points observed by the Subaru Telescope. We find that the model without energy injection is preferred over the one with energy injection in all the investigated wavelengths. In the X-ray and optical bands, we explored all the cooling conditions and found a clear preference for SC for X-rays and SC/FC for optical. Within these cooling conditions, X-rays exhibit the highest rate of occurrence for the density profile with k = 0. At the same time, the optical band has the highest occurrence for k = 2.5 when no energy injection is considered. Although we can pinpoint a definite environment for some GRBs, we encounter degeneracies in others.

References

[1] Dainotti, M., et al.: 2023, *Galaxies*, **11**, 1.
[2] Dainotti, M., et al.: 2025, *ApJ*, **51**, 31.

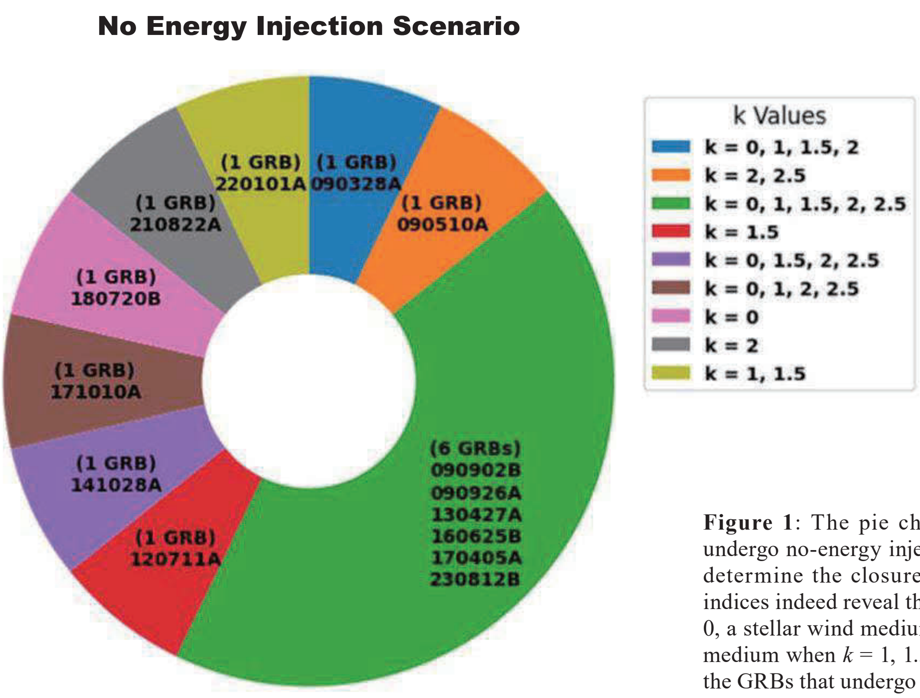

Figure 1: The pie chart shows the number of GRBs which undergo no-energy injection with the different values of k, which determine the closure relationships. The values of k indicate indices indeed reveal the presence of a constant medium when k = 0, a stellar wind medium when k = 2 or a stratified or fragmented medium when k = 1, 1.5, 2. Inside each box of the chart there are the GRBs that undergo those characteristics.

Machine Learning Identifies the Low-z and High-z GRBs

DAINOTTI, Maria[1], BHARDWAJ, Shubham[1], COOK, Christopher[2], ANGE, Joshua[2], LAMICHHANE, Nishan[3], BOGDAN, Malgorzata[4], Mc. GEE, Monnie[2], NADOLSKI, Pavel[2], MILIND, Sarkar[5], POLLO, Agnieszka[6], NAGATAKI, Shigehiro[7]

1: NAOJ, 2: Southern Methodist University, 3: Tribhuvan University, 4: Wroclaw University, 5: Indian Institute of Science Education and Research (IISER), 6: Jagiellonian University, 7: RIKEN

Nowadays, machine learning has dramatically changed the era of astronomy, and many techniques have been borrowed from several fields. Recent studies led by Maria Dainotti incorporated multiple machine learning models to add a new level of precision to identify if gamma-ray bursts (GRBs) — the most luminous and violent explosions in the universe — occur closeby or far away. In just a few seconds, GRBs release the same amount of energy our sun releases in its entire lifetime. Because they are so bright, GRBs can be observed at large distances — including at the edge of the visible universe — and aid astronomers in their quest to chase the oldest and most distant stars. However, because of the limits of current technology, only a small percentage of known GRBs have redshifts.

Dainotti and her teams combined GRB data from NASA's Neil Gehrels Swift Observatory with multiple machine learning models to overcome the limitations of current observational technology and, more precisely, estimate if a GRB occurs at redshift < or larger than 2, 2.5, 3 and 3.5. Because GRBs can be observed both far away and at relatively close distances, knowing where they occurred can help us understand the GRB density rate and the star formation rate. This research pushes forward the frontier in both gamma-ray astronomy and machine learning. and we have shown how AI overcomes the limits of follow-up observations. The novelty of this approach, compared to past studies comes from using several machine-learning methods together to improve their collective predictive power. This method, called Superlearner, assigns each algorithm a weight whose values range from 0 to 1, with each weight corresponding to the predictive power of that singular method. The advantage of the Superlearner is that the final prediction is generally more performant than the singular models. In addition, in our study Superlearner is also used to discard the algorithms which are the least predictive. This study, [1], allowed the classification to be improved by employing the Superlearner method on 251 GRBs with measured redshifts and plateaus observed by the Neil Gehrels Swift Observatory. Incorporating the plateau phase with the prompt emission, we have employed an ensemble of classification methods to unprecedentedly enhance the sensitivity, see Figure 1.

Additionally, we investigate the effectiveness of various classification methods using different redshift thresholds, mentioned above. We achieve a sensitivity of 87 % and 89 % with a balanced sampling for both z_t = 3.0 and z_t = 3.5, respectively, representing a 9 % and 11 % increase in the sensitivity over random forest used alone. Overall, the best results are at z_t = 3.5, where the difference between the sensitivity of the training set and the test set is the smallest. This enhancement of the proposed method paves the way for new and intriguing follow-up observations of high-z GRBs using both space-based satellites and ground-based telescopes. For instance, when a GRB is triggered by the satellites, users can use the web app to quickly discern whether the triggered GRB is of high- or low-z. In the future, this classification can even be automated and then promptly communicated through the Gamma-ray Coordinate Network, facilitating rapid and detailed follow-up observations by other ground-based telescopes, including the Subaru and the Kiso telescopes, and other future observatories, such as POLAR-2, THESEUS, and High-z GUNDAM.

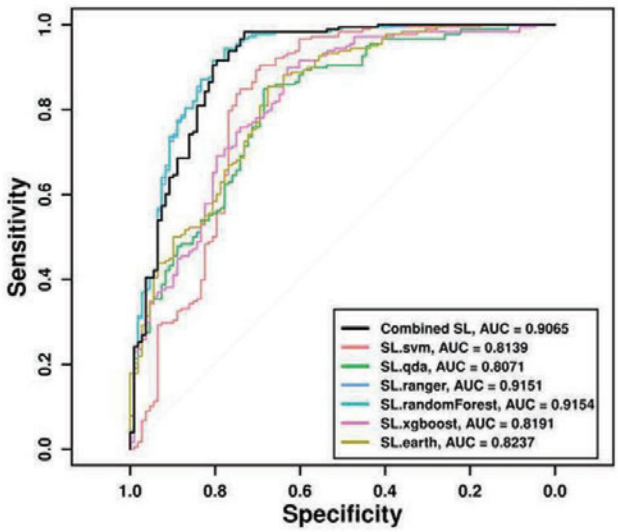

Figure 1: The sensitivity vs. specificity.

Reference

[1] Dainotti, M., et al.: 2025, *ApJS*, **277**, 31.

Characterization of Supernovae Interacting with Dense Circumstellar Matter with a Flat Density Profile

CHIBA, Ryotaro[1], MORIYA, Takashi J.[2]

1: Graduate University for Advanced Studies, 2: NAOJ

Some supernovae (SNe) are known to explode inside dense circumstellar matter (CSM). When the SN ejecta and CSM collide, the kinetic energy of the SN ejecta is dissipated. A fraction of this dissipated energy is converted into radiation. In this kind of SNe, the rise time (time between explosion and light curve peak) has been hypothesised to correspond to the diffusion timescale of photons within CSM [1]. However, in order to explain SNe with very long rise times of $\gtrsim 100$ d [2], this scenario requires unrealistically massive CSM with $\gtrsim 100\,M_\odot$ [3]. It has been proposed that such SNe can be naturally explained if the CSM density profile is assumed not to be wind-like ($\rho \propto r^{-2}$) and to be flatter ($\rho \propto r^{-s}$, $s < 1.5$) [4]. In this study, we explored how light curves of SNe interacting with flat density profiles change when photon diffusion inside CSM is taken into account.

The results of our study [5] showed that the qualitative behaviours of light curves can be classified into five distinct types (see Figure 1).

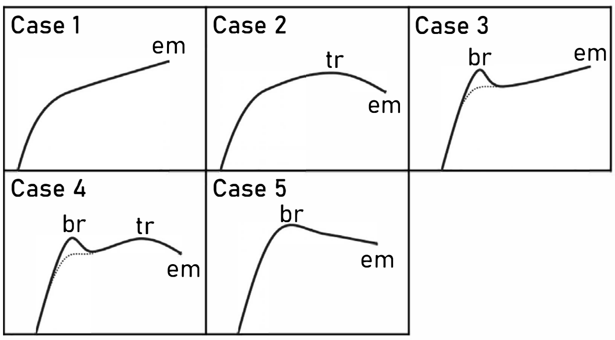

Figure 1: Classification of light curve shapes.

We also estimated which of the 5 light curve types corresponds to given CSM mass $M_{\rm CSM}$, and CSM radius $R_{\rm CSM}$. Figure 2 shows an example of the correspondence between CSM mass, CSM radius, and light curve shape.

Furthermore, we estimated the time and luminosity of each peak in light curves. Figure 3 shows an example of the correspondence between the CSM mass, radius, and the time and luminosity of the light curve peaks.

Finally, it was demonstrated that this model can explain SN light curves with comparable peaks separated ~ 100 d, such as that of SN 2005bf [6] and SN 2022xxf [7].

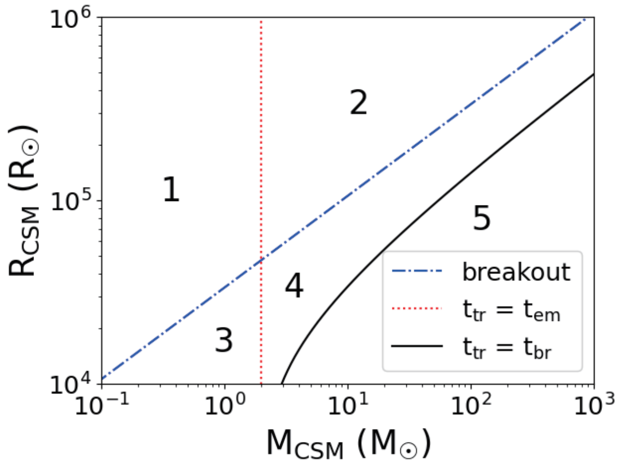

Figure 2: Example of the correspondence between the CSM mass $M_{\rm CSM}$, the CSM radius $R_{\rm CSM}$, and the light curve shape outlined in Figure 1.

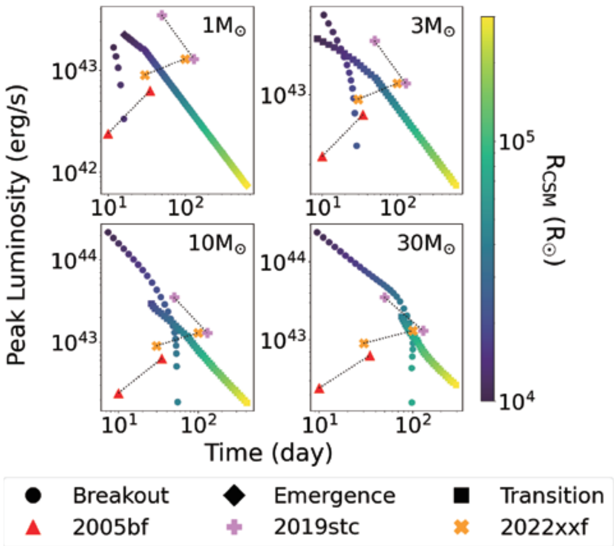

Figure 3: An example of the relation between the time and luminosity of each peak for different $M_{\rm CSM}$ and $R_{\rm CSM}$. $M_{\rm CSM}$ is represented in the top-right of each plot.

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Diversity in Hydrogen-rich Envelope Mass of Type II Supernovae. I. Plateau Phase Light-curve Modeling

FANG, Qiliang[1/2], MAEDA, Keiichi[2], YE, Haonan[2], MORIYA, Takashi J.[1/3/4], MATSUMOTO, Tatsuya[2/5]

1: NAOJ, 2: Kyoto University, 3: SOKENDAI, 4: Monash University, 5: Hakubi center, Kyoto University

Core-collapse supernovae (CCSNe) are catastrophic explosions that are believed to occur in massive stars (typically with ZAMS mass $M_{\rm ZAMS}$ larger than 8 $M_\odot$) once the fuel in their cores is exhausted. Type II supernovae (SNe II), which are the most commonly observed CCSNe, show hydrogen features in their spectra, indicating the presence of a massive hydrogen-rich envelope in their progenitors. The light curves of these objects are characterized by a long-lasting plateau illuminated by the recombination of the hydrogen elements in their outermost envelope. However, observations show wide variations of the duration and the brightness of the plateau [1]. Investigating the physical origins of this diversity is crucial for understanding the properties of their progenitor stars and the different evolutionary pathways that lead to these explosions.

In this work [2], we investigate the following problem: if the progenitors of all SNe II are hydrostatic red supergiant (RSGs) that are similar to those in the field or the progenitors observed from pre-SN images, can partial-stripping of their hydrogen-rich envelope explain the diversity of SNe II? To this end, we construct a large grid of RSG progenitor models spanning a wide range of $M_{\rm ZAMS}$ values, applying varying degrees of artificial envelope stripping to explore its impact on the resulting SN II light curves.

The survey of the light curve model grid reveals that, the light curve properties are sensitive to the hydrogen-rich envelope mass $M_{\rm Henv}$, but less affected by $M_{\rm ZAMS}$. For these light curve models, we establish an indicator based on their plateau magnitudes and durations to estimate $M_{\rm Henv}$. Additionally, we discuss the effects of material mixing and ^{56}Ni heating. Applying our model grid to a large sample of approximately 100 observed SNe II reveals a considerably broader range of hydrogen-rich envelope masses than predicted by standard stellar wind models. This finding suggests that, if SNe II are explosions of Galactic-like RSGs, to explain the diversity in the observed light curves, a significant fraction of them must have experienced substantial mass loss beyond the standard mass-loss prescription prior to their explosions. This finding highlights the uncertainties involved in massive star evolution and the pre-SN mass-loss mechanism.

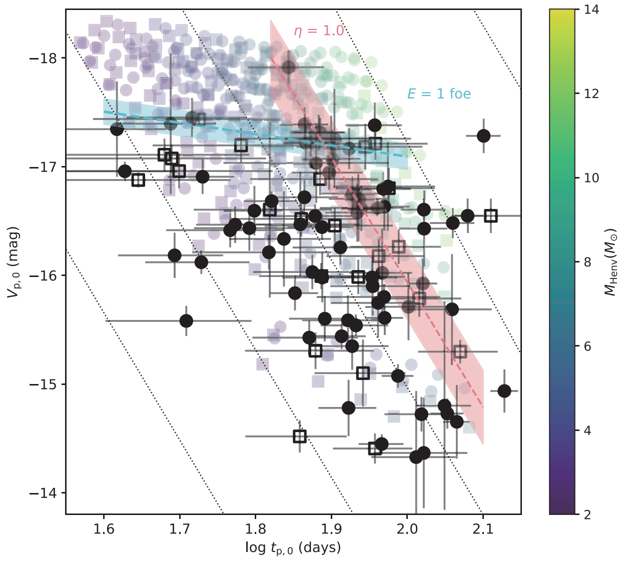

Figure 1: The comparison of the plateau magnitudes and the plateau duration, corrected for the ^{56}Ni heating, of the SNe II sample in this work (N = 99). The light blue strip indicates the range of models with explosion energy E = 1.0 × 10^{51} erg, while the pink strip indicates the models from RSGs evolved with stellar wind. The transparent points are the light curve models, color-coded by the hydrogen-rich envelope mass.

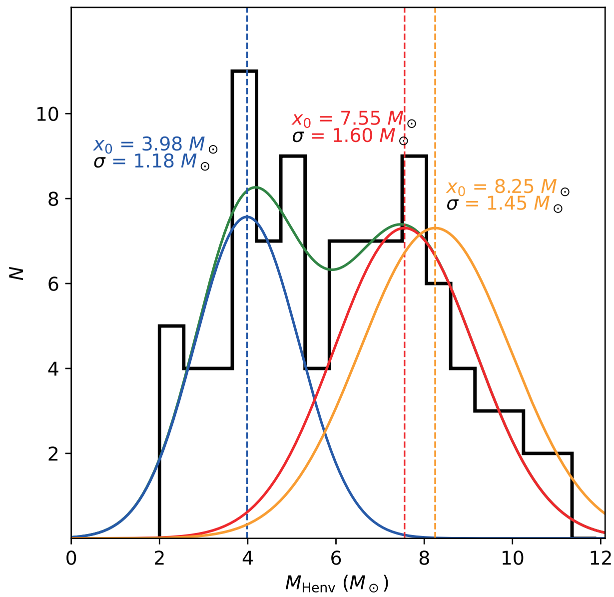

Figure 2: The bimodal distribution of $M_{\rm Henv}$ for SNe II in the sample, compared to the prediction of stellar wind models (orange line).

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Formation of Chondrules and Igneous Rims by Shock Waves

MATSUMOTO, Yuji[1], KUROSAWA, Kousuke[2], ARAKAWA, Sota[3]

1: NAOJ, 2: Kobe University, 3: Japan Agency for Marine-Earth Science and Technology

Meteorites are fragments of small bodies formed during the formation of planets, and contain information about the early solar system. One of the main components of meteorites is the chondrule, a spherical particle with a typical diameter of 1 mm. Chondrules are formed by flash heating events in the protoplanetary disk.

A leading candidate mechanism for flash heating is shock waves. A shock wave decelerates the gas in the protoplanetary disk, and the gas temperature rises. In contrast, dust particles are not directly affected by the shock wave. This results in high relative velocities between the gas and dust, which are on the order of the shock wave velocity, typically ~10 km s^{-1}. Due to this relative velocity, the dust experiences gas drag, which decelerates and heats it (e.g., [1]).

Chondrules are often surrounded by smaller particles, which are called rims. Rims are divided into two types: fine-grained rims and igneous rims. Fine-grained rims are typically 1 μm in size, while igneous rims are 10 μm in size and show evidence of a high degree of melting. Igneous rims were thought to form from the melting of fine-grained rims, but igneous rims are thicker than fine-grained rims on the same types of chondrites, suggesting the presence of additional accretion processes [2].

We have investigated the accretion of igneous rims onto chondrules in shock waves. We calculated the accretion of igneous rims in a one-dimensional shock model, following the approach of [3], who considered collisions between chondrules in the post-shock region. Precursor dust for igneous rims is also melted in the post-shock region. Due to their smaller size, the precursor dust is decelerated more rapidly than the chondrules, resulting in high relative velocities between the chondrules and the igneous rim precursors. At just behind the shock wave front, the relative velocity between the chondrules and the igneous rim precursors is too high for accretion. Chondrules begin to accrete igneous rims after dust particles are in the supercooling phase, and the accretion process continues after solidification. To reproduce the observed thickness of igneous rims, chondrules must experience approximately 10 shock wave events [4].

Next, we have examined the possibility of chondrule destruction due to high-velocity collisions with dust in the post-shock region. We considered collisions between dust and both solid and droplet chondrules. When solid chondrules collide with dust, surface material is excavated and mass is lost according to the crater scaling law (e.g., [5]). Droplet chondrules, which have significantly lower strength than solids, are easily disrupted by high-velocity impacts, breaking into smaller droplets [6].

Our calculations revealed that the consequences depends on the chondrule size and shock velocity (Figure 1). When large chondrules experience low-velocity shocks, they remain solid and survive collisions with only minor mass loss. This case corresponds to the accretion of the igneous rims. However, large chondrules exposed to high-velocity shocks melt and are disrupted by a collision in the melting state. Small chondrules avoid collisions due to their lower relative velocities with dust and thus survive with minimal damage [7]. These results indicate that in shock waves where small rim precursor dust and forming chondrules coexist, the chondrules are likely to be destroyed in the post-shock region, making chondrule formation more difficult.

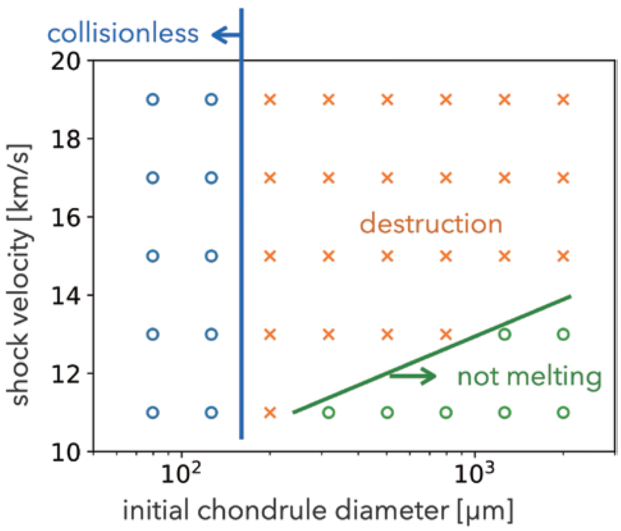

Figure 1: Typical results in [7]. Final states of the chondrules are plotted on the initial chondrule diameter and the shock velocity planes. The cases of the chondrule survival and destruction are represented by the circle and cross symbols, respectively. The collision and melting conditions are plotted by the blue and green lines.

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Solar Migration Driven by Dynamic Evolution of the Milky Way

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Understanding the Solar System's birthplace and migration within the Milky Way is essential for linking galactic evolution to planetary system formation. While the Solar System now orbits around 8 kpc from the Galactic center, it likely did not form there. Previous studies suggest a formation closer to the center, around 5 kpc [1].

This hypothesis is supported by the Solar System's chemical composition. Its high abundance of heavy elements (e.g., carbon, oxygen, iron) exceeds that of nearby coeval stars. Such high-metallicity stars tend to form in the inner Galaxy, indicating a metal-rich birth environment. In contrast, the current outer-disk location implies significant radial migration over 4.6 Gyr. However, the mechanisms behind such movement have remained unclear.

To address this, we ran test-particle simulations incorporating the Milky Way's time-dependent structure. Our results show that the evolving Galactic bar and spiral arms are key drivers of migration. Two main mechanisms were identified: (1) gradual outward movement due to bar slowdown under dark matter influence [2], and (2) scattering by transient spiral arms [3]. Both can shift the Solar System by around 3 kpc, with around a 1 % chance of reaching its current orbit [4].

We also examined environmental changes during migration, such as cosmic radiation and cometary flux. The results suggest a shift from the high-radiation inner Galaxy to a more stable outer region, potentially favoring life on Earth. These findings extend the classic "Galactic Habitable Zone" concept by introducing "Galactic Habitable Orbits" — a framework that considers both orbital migration and environmental evolution.

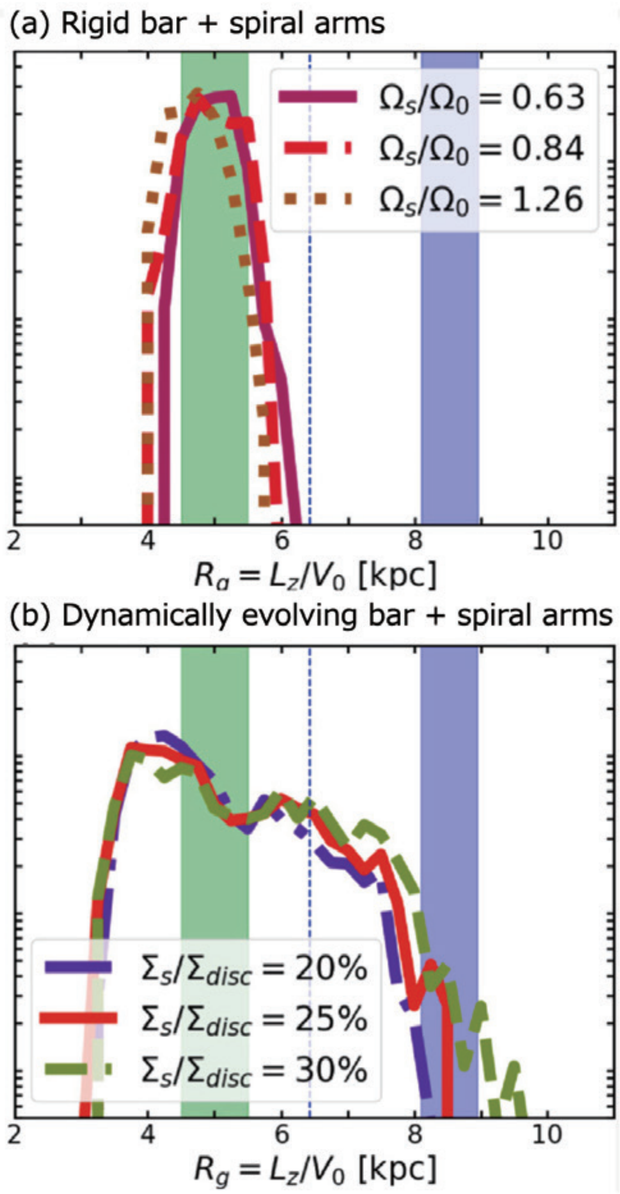

Figure 1: Probability distribution of the orbital radius reached by the Solar System 4.6 Gyr after its formation at a Galactocentric distance of approximately 5 kpc. Top: Results from a model in which both the Galactic bar and spiral arms behave as rigidly rotating structures. Bottom: Results from a model where the bar slows down over time and the spiral arms wind up due to differential rotation.

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Uncovering the Ghostly Remains of an Extremely Diffuse Satellite in the Remote Halo of NGC 253

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NGC 253 is a barred spiral galaxy located in the Sculptor group. It has a similar luminosity and virial radius to the Milky Way and M31, making it a prime object for comparative studies with these galaxies. In recent years, attention has focused on the faint satellite system of NGC 253. The PISCeS survey used Magellan/Megacam resolved star photometry to discover five new dwarf satellites of NGC 253, with two of them, Scl-MM-dw2 (hereafter MM-dw2) and Scl-MM-dw3, independently discovered as NGC253-dw2 and Donatiello II, respectively. [1] proposed two further dwarf galaxy candidates from Dark Energy Survey data and [2] suggested another one from DECaLS data, both from integrated light analyses. [3] confirmed these latter systems with Hubble Space Telescope photometry and undertook a comprehensive study of the NGC 253 satellite system as a whole, finding it to be deficient in luminous satellites compared to systems of similar stellar mass.

We present the discovery of NGC253-SNFC-dw1 (hereafter SNFC-dw1), a new satellite galaxy in the remote stellar halo of NGC 253 [4]. The system was revealed using deep resolved star photometry obtained as part of the Subaru Near-Field Cosmology Survey that uses the Hyper Suprime-Cam on the Subaru Telescope. It lies at a projected separation of 83.4 kpc from the center of NGC 253. We have used the TRGB method to derive consistent distances to SNFC-dw1 and NGC 253, finding them to lie at 3.62 ± 0.2 Mpc and 3.5 ± 0.2 Mpc, respectively, confirming SNFC-dw1 is a bound satellite. Although rather luminous ($M_V = -11.7 \pm 0.2$) and massive ($M_* \sim 1.25 \times 10^7 M_\odot$), SNFC-dw1 is one of the most diffuse satellites yet known, with a half-light radius of $R_h = 3.37 \pm 0.36$ kpc and an average surface brightness of ~30.1 mag arcmin^{-2} within the R_h. The colour-magnitude diagram shows a dominant old (~10 Gyr) and metal-poor ([M/H] = −1.5 ± 0.1 dex) stellar population, as well as several candidate thermally-pulsing asymptotic giant branch stars. The distribution of red giant branch (RGB) stars is asymmetrical and displays two elongated tidal extensions pointing towards NGC 253, suggestive of a highly disrupted system being observed at apocenter (see Figure 1). NGC253-SNFC-dw1 has a size comparable to that of the puzzling Local Group dwarfs Andromeda XIX and Antlia 2 but is two magnitudes brighter. While unambiguous evidence of tidal disruption in these systems has not yet been demonstrated, the morphology of NGC253-SNFC-dw1 clearly shows that this is a natural path to produce such diffuse and extended galaxies. The surprising discovery of this system in a previously well-searched region of the sky emphasizes the importance of surface brightness limiting depth in satellite searches.

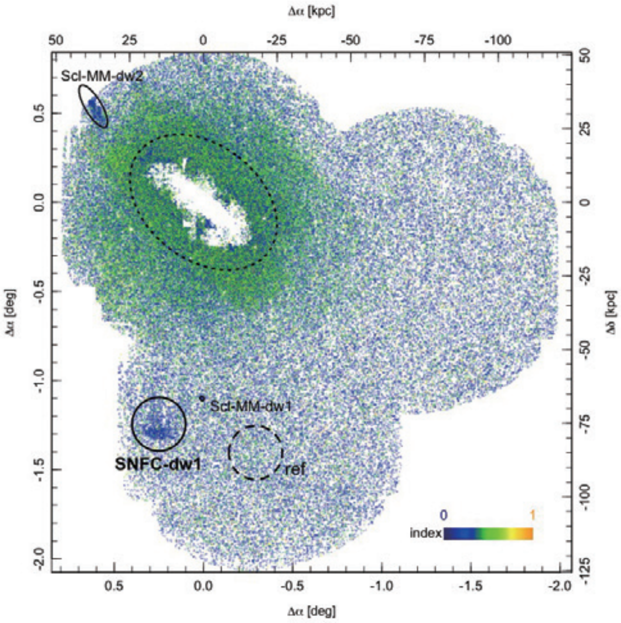

Figure 1: The spatial distribution of RGB stars around NGC 253. The color of each point indicates its metallicity, as the bluest (index = 0) and reddest (index = 1) colors correspond to [M/H] = −2.2 and −0.4, respectively. The location of SNFC-dw1 and the previously known satellites within the footprint are indicated.

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Discovery of Merging Twin Quasars at z = 6.05

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When the first stars and galaxies began to shine, their ultraviolet radiation spread throughout the universe, initiating the (re-)ionization of the intergalactic medium. This marked the end of the dark ages followed by the cosmic dawn, the crucial period leading to the universe we observe today. How did galaxies and the supermassive black holes at their centers evolve during this period? To address this major issue of astronomy today, we have been conducting a decade-long search for quasars in the distant universe. By exploiting the unique wide-field observing capability of the Subaru Telescope, we have discovered approximately 200 quasars in the cosmic dawn. But until now, no pairs of such quasars had been found. When screening the images of candidate quasars by eye, we serendipitously found two adjacent sources that are very red and appear similar. To confirm whether this pair is truly composed of physically-associated quasars, we conducted follow-up observations using FOCAS on the Subaru Telescope. We have successfully confirmed that the two sources are indeed quasars in the cosmic dawn, located 12.9 billion light-years away from Earth [1]. The supermassive black holes powering those quasars are nearly identical in mass (roughly 100 million solar masses), making them "twins". Detection of structures connecting the two quasars, both from Subaru and follow-up ALMA observations, suggests that they are in the process of merging. While the standard cosmology suggests that galaxies grow via frequent mergers, no merging pair of quasars has been found in the cosmic dawn. The present results mark the first confirmation of such a pair, and is a significant discovery for understanding of how supermassive black holes evolve within merging galaxies.

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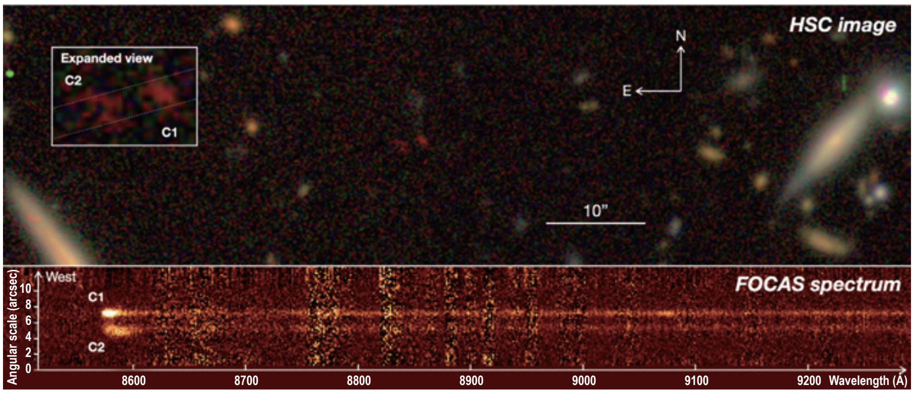

Figure 1: Top: three-color (r-, i-, and z-band) composite image around the pair quasars (named C1 and C2), the two reddest sources at the center. North is up and east to the left, and the image size is approximately 90 arcsec × 25 arcsec. The limiting magnitude for point sources is ~26. The inset shows an expanded view of C1 and C2, with the thin dotted lines representing a 1.0-arcsec slitlet used for FOCAS spectroscopy. Bottom: two-dimensional FOCAS spectrum of C1 (upper trace of light) and C2 (lower trace).

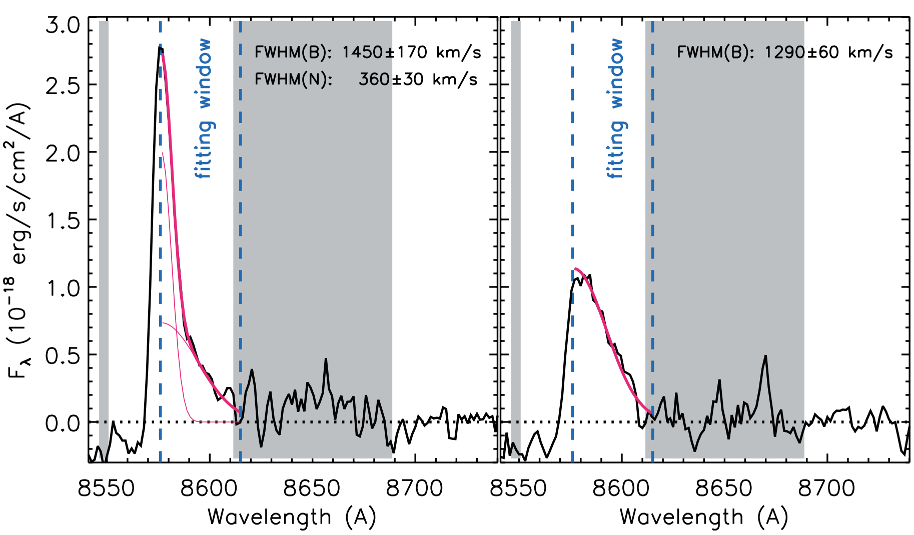

Figure 2: Continuum subtracted spectra of C1 (left) and C2 (right) around Lyα. The thick red lines represent the best-fit models, while the thin red lines (only in C1) represent their broad and narrow components. The gray shaded area marks the wavelength range affected by strong sky emission.

Spin Parity of Spiral Galaxies IV - Differential Reddening of Globular Cluster Systems of Nearby Spiral Galaxies

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Determining the 3D spin vector of galaxy observationally is non-trivial. While derivable from a galaxy's rotational field and projected axis ratio of the galaxy's image, the spin vector exhibits a fourfold degeneracy. For spiral galaxies, one can use the fact that spirals are trailing to reduce the degeneracy twofold. The final ambiguity is resolved only upon identifying the area side of the tilted disk, which is an impractical task for trigonometric distance measurements.

The color difference in globular cluster systems, caused by differential interstellar dust reddening, enables near-side identification (Figure 1). The first was demonstrated using M31 photographic photometry data [1], but this method remained unconfirmed for other galaxies until our study.

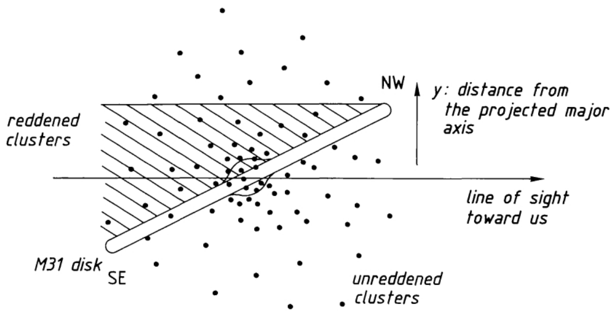

Figure 1: The concept showing the differential reddening of globular clusters due to dust in the galactic plane. Reproduced from [1].

We tested the concept via a geometrical model and CCD photometry data [2-4] of 3 nearby spiral galaxies, M31, M33, and NGC 253 [5]. The color difference of globular cluster systems due to differential reddening was confirmed again for M31 and newly for NGC 253 (Figures 2 and 3). We could not confirm the effect for M33 due to its small tilt and weaker interstellar reddening.

Our analysis supports the prevailing interpretation: the side of the disk on the minor axis, where the dust feature is more prominent and/or the color is redder, marks the near side. This advances using S/Z-wise spiral windings to judge the line-of-sight component of the galaxy's spin vector and study their distribution in the cosmic-scale spin distributions.

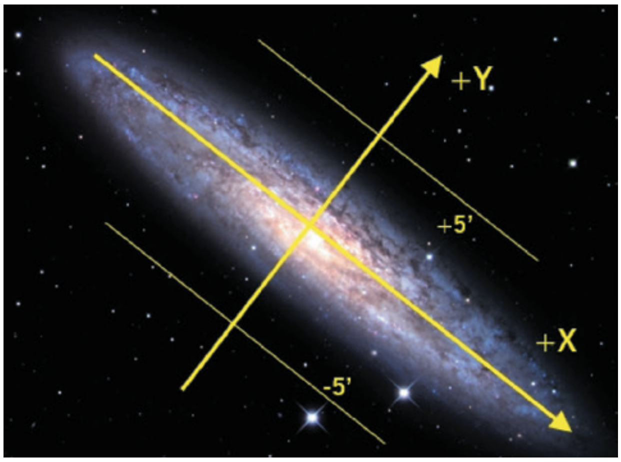

Figure 2: Geometry of NGC253. Image taken from PanSTARRS image cutouts.

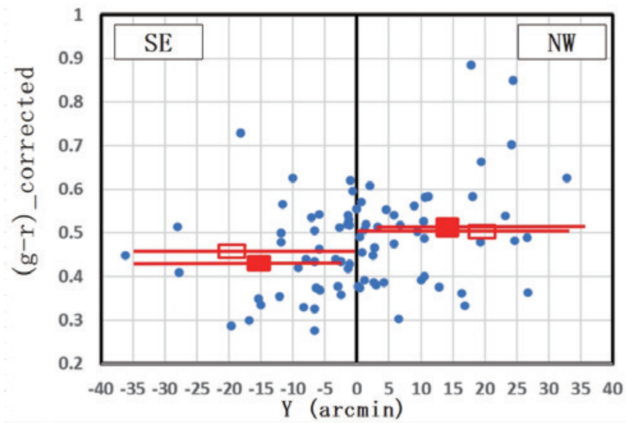

Figure 3: *Y* vs *g-r* distribution of 81 bona fide GCs in NG C253 [5]. The foreground Galactic reddening is corrected.

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A Possible Metal-dominated Atmosphere below the Thick Aerosols of GJ 1214 b Suggested by Its JWST Panchromatic Transmission Spectrum

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Sub-Neptunes are the most common type of exoplanet in this galaxy. It is thus essential to understand their nature to establish a unified theory of planet formation and evolution. Planetary bulk compositions can provide critical information on their origin, that is, the planet similar to an Earth-like rocky planet formed near the central star or a Neptune-like icy planet formed at distant orbits. However, the bulk compositions of sub-Neptunes remain elusive, as the possible presence of a hydrogen-rich atmosphere prohibits us from uniquely identifying interior compositions solely from the planetary bulk density. Atmospheric observations can provide additional information to break the degeneracy of interior compositions. However, many sub-Neptunes are known to host atmospheres veiled by clouds and/or hazes that hinder us to constrain atmospheric properties [e.g., 1].

Recently, JWST has enabled us to observe sub-Neptune atmospheres with unprecedented precision and wavelength coverage. In this study, we leverage the HST and JWST transmission spectrum of GJ 1214b [2,3,4]—an archetype sub-Neptune that host a heavily cloudy/hazy atmosphere—to constrain atmospheric properties. We used a suit of atmospheric radiative transfer, photochemistry, and aerosol microphysical models to thoroughly investigate the possible composition of GJ 1214b atmospheres. We find that the transmission spectrum of GJ 1214b can be well explained by a metal-dominated atmosphere veiled by thick photochemical hazes, where the hydrogen is no longer the main atmospheric constitutent [5]. Such a metal-dominated atmosphere is supported by a relative strength of CO_2 absorption feature to absorption feature of CH_4 and organic hazes. Relatively flat transmission spectrum across broad wavelength coverage also suggests a small atmospheric scale height, implying a small amount of hydrogen in the atmosphere. We tested a number of different assumptions on the uncertain haze production process and optical properties, thereby concluding that the metal-dominated atmosphere is robust against these uncertainties.

The metal-dominated atmosphere suggested by this study poses a number of interesting insights on the origin and nature of sub-Neptunes. Since the atmosphere no longer contains abundant hydrogen, the planetary core presumably contains rich ice; otherwise, it is difficult to explain the low bulk density of GJ 1214b. The current GJ 1214b orbits close to the central star, indicating that GJ 1214b was originally formed at distant orbits beyond H_2O snowline and subsequently migrated to the current orbit. Meanwhile, the model suggests that the atmosphere contains abundant CO_2 and/or CO rather than H_2O, which suggests the need for revisiting interior structure of sub-Neptunes that was modeled by H_2O as an analog of the ice component.

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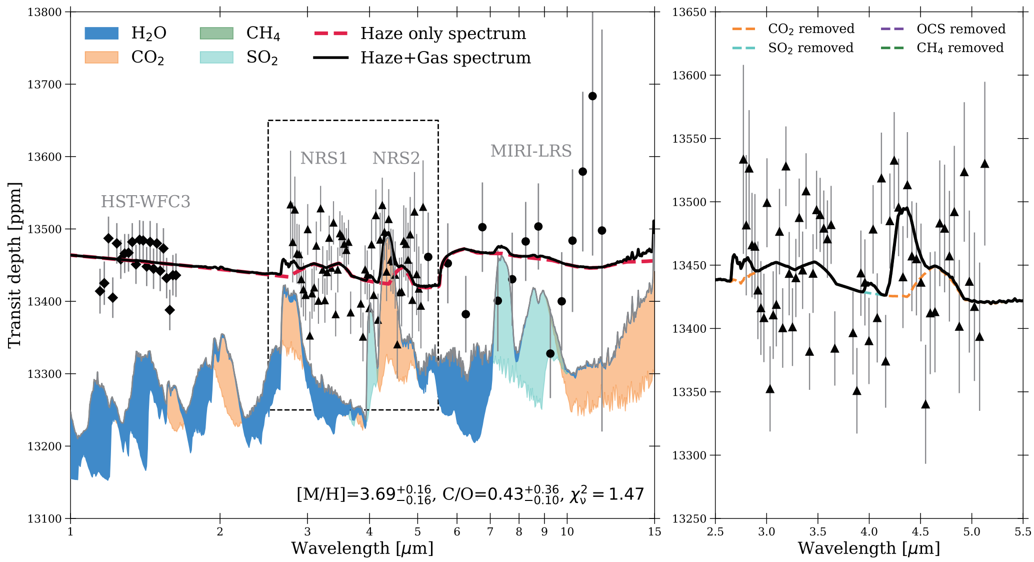

Figure 1: Transmission spectrum of GJ1214b and median model spectrum.

Chemical Evolution of a Crucial Element of Life, Phosphorus

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Phosphorus is a valuable element essential to life. This is because phosphorus is indispensable for forming DNA and RNA, which carry genetic information, as well as for constructing cell membranes. Since all living organisms are made up of cells, every single cell contains phosphorus. So, how exactly was phosphorus formed? Until now, it was believed that phosphorus was synthesized and released through supernovae. However, it has become clear that this "supernova origin theory of phosphorus" cannot adequately explain the observations. We can understand how the abundance of phosphorus in the Milky Way has changed from the past to the present by measuring the chemical compositions of stars using spectroscopic observations. Stars range from extremely old ones over 10 billion years old to young stars. The chemical composition of these stars reflects the abundance of various elements in the galaxy at the time of their formation. By measuring the phosphorus abundance in stars of various ages, we can trace how the amount of phosphorus in the Milky Way has changed over more than 10 billion years; we can understand the chemical evolution of phosphorus. However, this evolution revealed by observations could not be explained by the supernova origin theory. The amount of phosphorus predicted to be synthesized by supernovae is short of what is observed. For a long time, it was implicitly assumed that this discrepancy was due to some problem in the theoretical models of nucleosynthesis in supernovae, but little effort was made to resolve it. Amid such circumstances, we find that novae are responsible for synthesizing phosphorus.

A nova is a phenomenon in which a star suddenly appears to brighten. This occurs when gas from a companion star accumulates on the surface of a white dwarf (WD) in a binary system. Once the accumulated gas reaches a critical amount, a runaway nuclear reaction ensues, resulting in an explosive event observable as a nova. The recurrence of nova events on the same WD has been confirmed observationally and is known as a recurrent nova. This study focuses on a massive WD, which originates from a star with a mass about 7–8 $M_\odot$: on the heavy end for stars that become WDs. These massive WDs —about 1.3 $M_\odot$ compared to the average of 0.6 $M_\odot$— are composed of oxygen, neon, and magnesium, and novae originating from them are generally called oxygen-neon novae. Until now, novae had been rarely considered as the significant sources of elements except for lithium, because the amount of elements that they produce is overwhelmingly small compared to supernovae. However, this study found that oxygen-neon novae produce extraordinarily large amounts of phosphorus, unlike other elements. Furthermore, when the fact that nova explosions can occur repeatedly on the same oxygen-neon WD over more than a billion years is taken into account, the total amount of synthesized phosphorus far exceeds that of supernovae [1].

Figure 1 shows the results of a model calculation based on the nova origin theory of phosphorus. Observations sugget that the amount of gas released in each nova explosion varies, and by incorporating this variation into the model, it can successfully explain the large spread seen in the observational data. In contrast, traditional supernova models fail to reproduce the observed trends. It was also found that these heavy novae synthesize large amounts of chlorine along with phosphorus. Therefore, it is predicted that the chemical evolution of chlorine in the Milky Way should follow a path similar to that of phosphorus.

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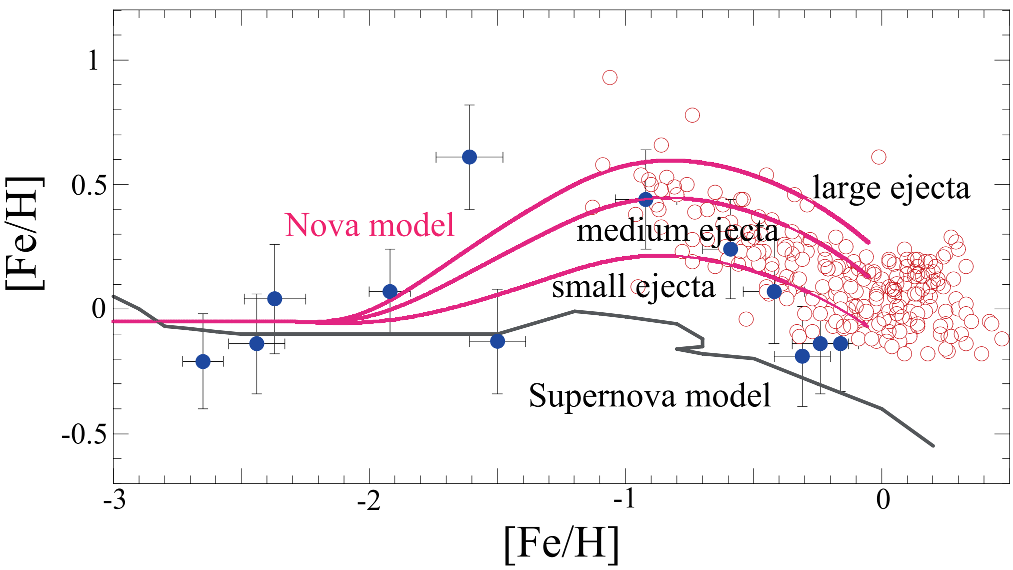

Figure 1: Comparison of the model results with the observational data. The red and blue circles denote the data from two literatures. The nova model successfully explains the observations, whereas the conventional supernova model does not match the observational data. The large dispersion in the observational data might reflect differences in the amount of gas ejected from novae. The supernova model is from [2].

Comparison of Solar Multifrequency Microwave Data with Other Solar Indices for Understanding Solar and Stellar Microwave Data

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The activity of the central star is critical to the habitability of an exoplanet. Stellar flares and wind, X-rays and ultraviolet emissions influence the space weather/climate, atmosphere and chemistry of an exoplanet. Knowledge of our Sun shows that these phenomena depend strongly on the magnetism of the central star.

Radio observations reveal the behavior of non-thermal electrons in stellar flares and the properties of stellar atmospheres and magnetic fields. For example, the total solar flux at 2.8 GHz (F10.7 index) is a useful proxy for the solar extreme ultraviolet (EUV) flux (wavelength, 10–121 nm) that affects Earth's upper atmosphere, because microwave and EUV radiation originate mainly from the same thermal plasma between the chromosphere and the corona. This is a major advantage of radio observations, considering that stellar EUV observations are difficult due to absorption by the interstellar medium. However, the study of the multi-frequency microwave relation is rare because microwave data observed continuously at multiple frequencies over solar cycles are rare, especially after solar observations with satellites became common.

Japan has been monitoring the total solar microwave flux and its circular polarization since the 1950s. The monitoring observations have continued to the present with multiple observation frequencies using the Nobeyama Radio Polarimeters. In this study, we compared the multi-frequency solar microwave data with other indices of solar activity and revealed their relationships [1].

We examined the relationships between the thermal microwave fluxes at 1, 2, 3.75, and 9.4 GHz, their circular polarizations, and several activity indices recorded during recent solar cycles and found that these relationships can be divided into two groups. In the first group, the relationship between the microwave fluxes and the solar indices, which are strongly related to the active regions, can be well fitted by a linear function. In the second group, the fitting function is frequency dependent. In particular, the microwave fluxes at 1 and 2 GHz can be well fitted to the total unsigned magnetic and extreme ultraviolet fluxes by using a power-law function. The trend changes around 3.75 GHz, and the trend for the 9.4 GHz fluxes can be fitted with a linear function. For the first time, we present the relationship between circular polarization and solar indices. We have also extrapolated these relationships of the solar microwave fluxes to higher values and compared them with the solar-type stars. We found that ε Eridani, whose microwave emission originates from a thermal plasma, follows the extrapolated relationship (Figure 1).

So far, the emission of only one star (ε Eridani) at 1–10 GHz has been confirmed as thermal emission. More solar-type stars should be observed with future radio interferometers to confirm that relationships based on solar data can be applied to stellar microwave data. We would detect thermal emission from a few hundred stars with the ngVLA. More solar-type stars should be observed with future radio interferometers to confirm that relationships based on solar data can be applied to stellar microwave data.

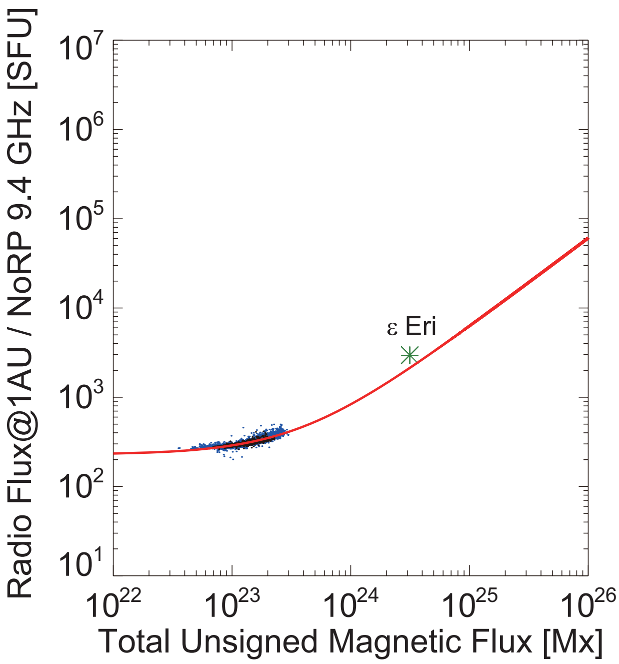

Figure 1: The relationship between the 9.4 GHz fluxes and the total unsigned magnetic fluxes of the Sun and ε Eridani. The blue and black dots indicate solar data, the red line shows the extrapolation from solar data, and the green asterisk shows the data of ε Eridani.

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Distribution of the Magnetic Field Strength in NGC 315

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In this study, we investigate the magnetic field strengths along the jet of NGC 315 [1]. NGC 315 is a giant elliptical galaxy known for its prominent radio jet extending over hundreds of kiloparsecs.

As shown in Figure 1, we estimated the angular velocity of rotation in the jet magnetosphere by comparing the measured velocity profile of NGC 315 [2] with the magneto-hydrodynamic jet model proposed by Tomimatsu and Takahashi [3]. Similar to the case of M87 [4], we find that the model can reproduce the logarithmic feature of the velocity profile and suggest a slowly rotating black hole magnetosphere for NGC 315. By substituting the estimated Ω_F into the jet power predicted by the Blandford-Znajek mechanism, we estimate the magnetic field strength near the event horizon of the central black hole as $5 \times 10^3\,\mathrm{G} \leq B_H \leq 2 \times 10^4\,\mathrm{G}$.

Next, we estimate magnetic-field strengths along the jet by comparing the spectral index distribution obtained from VLBI observations with a synchrotron-emitting jet model [5]. Then we constrain the magnetic field strength at a de-projected distance z from the black hole to be in the range $0.06\,\mathrm{G} \leq B(z) \leq 0.9\,\mathrm{G}$ for $5.2 \times 10^3\, r_g \leq z \leq 4.9 \times 10^4\, r_g$, where r_g represents the gravitational radius. The black region in Figure 2 corresponds to this estimated strength.

As presented in Figure 2, the combined field strengths measured at the event horizon and in the downstream section of the jet suggest that the accretion flow at the jet base is consistent with a magnetically arrested disk (MAD).

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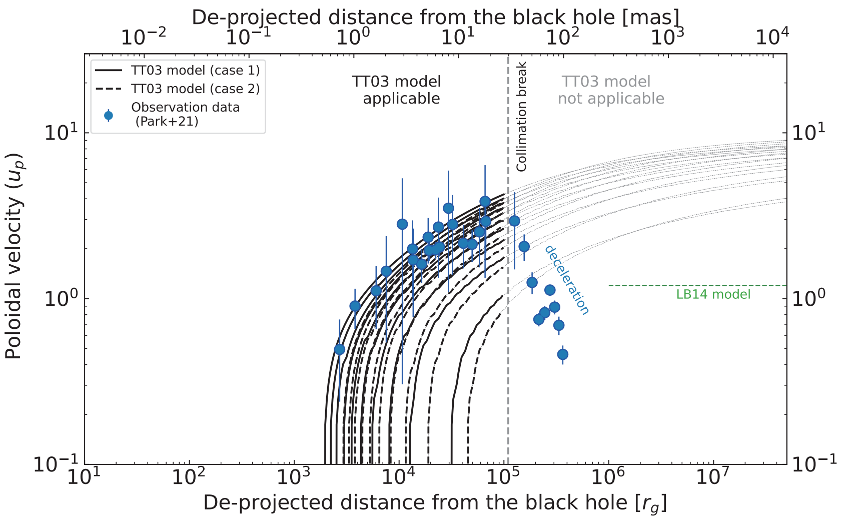

Figure 1: The comparison of observed and model-predicted jet velocity profile. The vertical axis presents the poloidal component of the jet's four-velocity. The blue circles are the measured velocity profile of the NGC 315 jet [2]. The solid curves show the velocity profile predicted by a MHD jet model [3]. The dashed vertical lines show the distance of the jet collimation break. Fore more details regarding the model parameters can be found in [1].

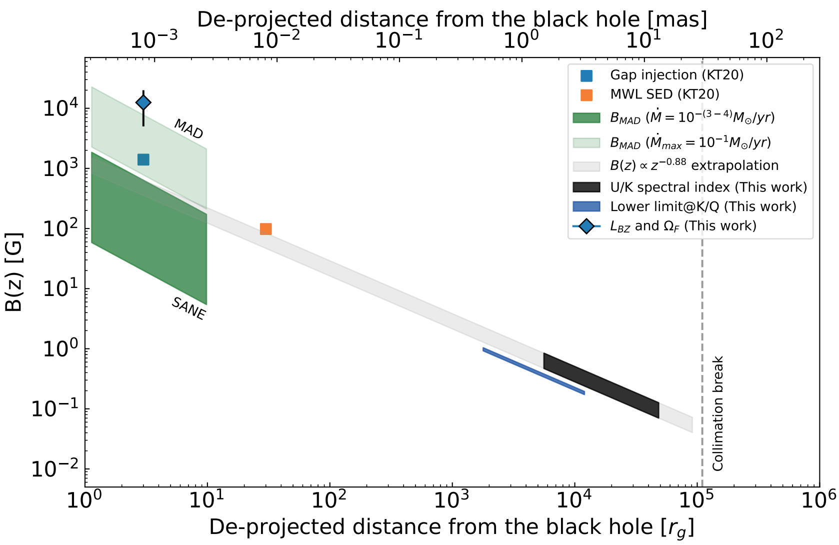

Figure 2: The distribution of the magnetic field strength along the NGC 315 jet. The black region shows $B(z)$ estimated by our spectral index map analysis made at 15 GHz and 22 GHz for the jet downstream region. The gray-shaded region is the extrapolation of the black area with the $B(z) \propto z^{-0.88}$. The MAD regime realizes for $B(z) \geq B_{\mathrm{MAD}}$, while the SANE regime is expected for $B(z) \leq B_{\mathrm{MAD}}$. At the horizon scale, B_H estimated in this work is plotted, which clearly shows $B_H > B_{\mathrm{MAD}}$.

Comparison of Coronal Hole and Quiet-Sun Chromosphere Using IRIS Mg II h and k Observations of Polar Off-limb Regions

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Solar quiet regions are divided into coronal hole regions (CH) and quiet-Sun regions (QS) (Figure 1). The global magnetic field in CH is considered open to interplanetary space, while that in QS is closed. To constrain the solar atmosphere and solar wind model, we statistically compared CH and QS in the chromosphere by quantitatively analyzing all available high-resolution spectral data sets of polar off-limb regions taken from the entire catalog of IRIS (Interface Region Imaging Spectrograph) satellite (Figure 2).

We extracted the characteristic quantities from the Mg II h and k line profiles and compared the dependence of those quantities on the height from the photospheric limb.

The main findings are as follows. First, the integrated intensities in the Mg II k line show a steeper decrease with height in QS while they remain bright at higher altitudes in CH (Figure 3). Second, the unsigned line-of-sight velocities in the Mg II k line generally increase with height in both regions, although the unsigned velocities in QS increase with height stronger than CH. Third, the Mg II k line widths increase just above the limb and then decrease with height in both CH and QS but are overall larger for CH than for QS, especially at the lower altitudes (Figure 4). Finally, we found the ratio of the Mg II k and h lines to show a two-step increase with height in both regions. Considering how the superposed off-limb spicules could be observed in the Mg II k line [1], the results suggest the CH spicules are higher, and the CH chromosphere exhibits faster motions than the QS [2].

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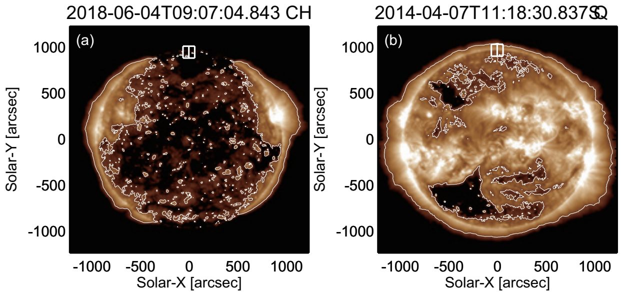

Figure 1: Solar coronal images (*SDO*/AIA 193 Å) of identified CH (a) and QS (b) data set examples at the time nearest to the start time of each IRIS data set. The white contours mark the intensity level of 100 DN s^{-1}. The location of the IRIS slit-jaw field of view (rectangles) and the IRIS slit (vertical lines) are also indicated.

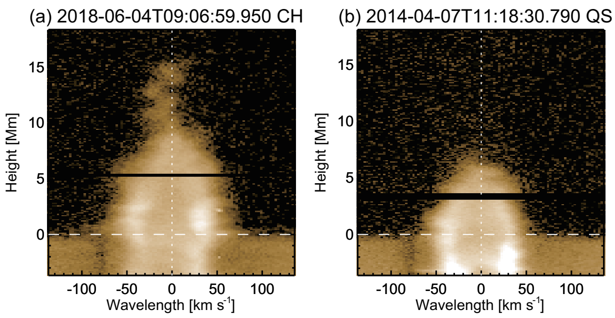

Figure 2: Mg II k line spectra along the slit for example data sets of CH (a) and QS (b). The position of the photospheric limb is marked by the horizontal line. The rest wavelength of the Mg II k line is shown by the vertical line, and the horizontal axis is converted to the corresponding Doppler velocity.

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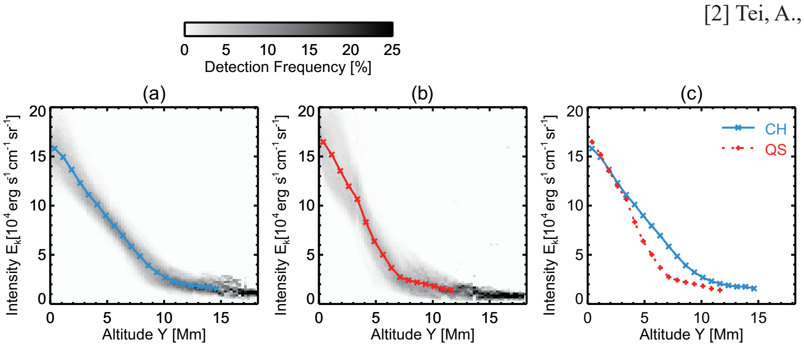

Figure 3: Distribution plots of integrated intensity in the Mg II k line for the combined CH (a) and QS (b) data. The grayscale indicates the detection frequency at each height, and lines with signs represent the median. Comparison of the medians of the distribution plots in panels (a) and (b) is shown in panel (c).

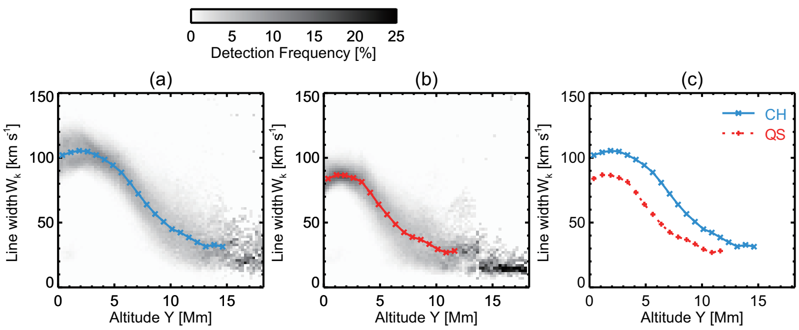

Figure 4: Same as Figure 3 but showing the Mg II k line width.

Emission Line Intensity Ratios of Fe XXVI/XXV/XXIV in Solar Flares Observed by Hinotori

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High-resolution spectra observed by the Solar X-ray spectrometer (SOX) on board the Hinotori mission are revisited [1]. Flat crystals slightly offset to the satellite spin axis produce automatic spectral scans for emission lines emerging from highly charged iron ions in solar flares every half-spin time period. All the downlinked data of the mission are converted to FITS format and major flare spectral data are revived as IDL save files in ISAS/DARTS [2,3].

Based on these data sets, single-temperature fits are performed for the emission line complex of highly charged iron ions in the wavelength range of 1.75–1.95 Å and compared with theoretical predictions. A total of 70 data points for the observed line-intensity ratios (x/w, y/w, q/w, j/w, and z/w) are obtained from SOX spectra taken at and after the maximum phases of the 13 large flares listed by Tanaka (1986) [4] which are time-integrated for four satellite spin periods (60–80 s).

Synthetic spectra with single electron temperatures estimated from j/w line-intensity ratios fit fairly well for Fe XXIV and Fe XXIII lines in the wavelength range of 1.85–1.88 Å, while intensity ratios of Fe XXV lines (x, y, z) and the inner-shell excitation line of Fe XXIV (q) to the Fe XXV resonance line (w) have systematic excesses. The empirical line-intensity ratios of the Fe He-like ion are determined by best effort in Table 1. Large data scatter comes from poor S/N ratios in SOX spectra.

A couple of causes and reasons are considered that modify theoretical ratios to the observed ratios. Qualitative analysis for plasma having a differential emission measure distribution in ionization equilibrium cannot explain the tendency of the observed line ratios. Decaying flare plasma still in transient ionization also cannot explain the observations, because $N(H)/N(He)$ is almost consistent with the ionization equilibrium condition, if the multithermal nature of flare plasma is considered for the Lyα^1/w ratios. The simplest and most likely explanation is that atomic parameters for these lines still have an ambiguity of 9 % – 20 %. Further precise measurements and modeling for the relevant atomic parameters are needed.

Table 1: Best Estimates for Observed Line Ratios.

j/w	q/w	x/w	y/w	z/w
0.250	0.213	0.252	0.334	0.390
0.300	0.240	0.260	0.346	0.403
0.350	0.267	0.266	0.356	0.414
0.400	0.293	0.271	0.365	0.424
0.450	0.319	0.276	0.373	0.434
0.500	0.345	0.279	0.380	0.443
0.550	0.371	0.283	0.387	0.452
0.600	0.396	0.285	0.393	0.461
0.650	0.422	0.288	0.398	0.469
0.700	0.447	0.290	0.404	0.478
0.750	0.472	0.292	0.409	0.487
error	±0.084	±0.076	±0.060	±0.058

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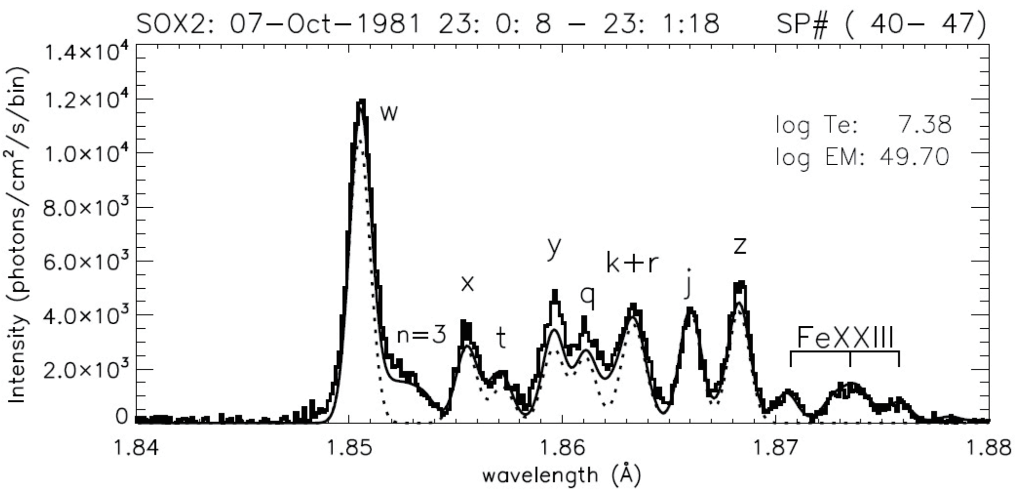

Figure 1: Iron ion spectra of 1981 October 7 limb flare. The ordination is intensity in units of photons cm^{-2} s^{-1} bin^{-1}. Synthetic spectra generated by CHIANTI ver. 10.02 [5] with isothermal assumption are shown by solid lines, and the contributions of individual strong lines, w, x, t, y, q, $k + r$, j, and z are shown by dotted lines. Electron temperature (T$_e$ [K]) and volume emission measure (EM [cm^{-3}]) are also indicated.

Re-examination of Sgr A* Structure Based on EHT 2017 Observations: The EHTC Ring Image as an Artifact

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Sgr A* is a supermassive black hole ($M_{BH} \sim 4 \times 10^6 M_\odot$) located at the center of the Milky Way. It is one of the few objects that allow direct observation of strong gravitational fields near a black hole. Based on EHT (Event Horizon Telescope) data obtained in 2017, the EHT Collaboration (EHTC) presented a ring-like structure interpreted as the black hole shadow [1].

However, we found that the ring structure reported by EHTC is likely an artifact. This is thought to be caused by the bumpy Point Spread Function (PSF) resulting from sparse u-v coverage. The PSF exhibits high-level sidelobes (up to 49.1 %) and deep negative minima (−78.1 %) relative to the main beam. The interval between the main beam and its sidelobes (about 49 μas) matches the diameter of the EHTC ring, with a deep negative minimum at the midpoint (Figure 1).

In our simulation, similar ring-like structures were reproduced using mock data composed only of noise or a point source, when self-calibration based on a ring model and restricted CLEAN regions were applied. This indicates that with sparse u-v coverage, an assumed model structure can be imprinted on the final image as an artifact.

Next, we present the results of our independent analysis. Using the public EHT data from April 7, 2017, we applied standard hybrid mapping techniques commonly used in VLBI analysis. Starting from a point-source model and performing iterative phase self-calibration, the final image showed an asymmetric structure elongated in the east-west direction.

This structure is consistent with previous observations at 86 GHz and the early EHT 230 GHz results. We interpret this asymmetry as a result of Doppler boosting due to a rapidly rotating accretion disk (about 60 % of the speed of light). The disk is observed at an inclination angle of approximately 40–45 degrees, leading to a brighter western side in the image (Figure 2).

Compared with the EHTC image, our image shows less than half the normalized amplitude residuals, indicating better consistency with the data. However, since Sgr A* exhibited significant flux variability during the observation, the derived structure is not a perfect static representation but likely reflects a representative or averaged structure during the observing period [2].

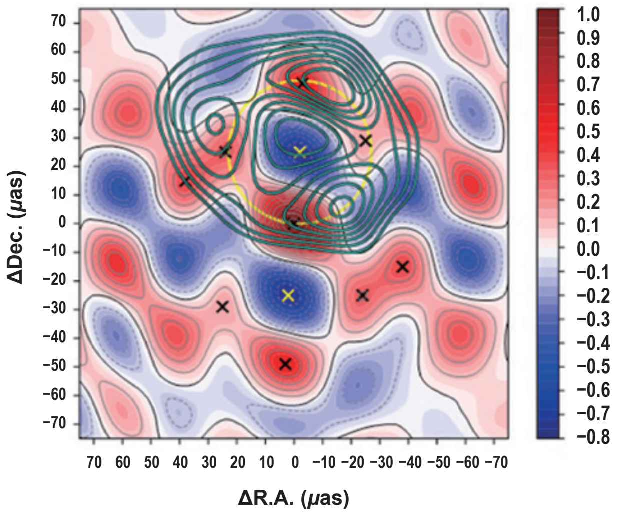
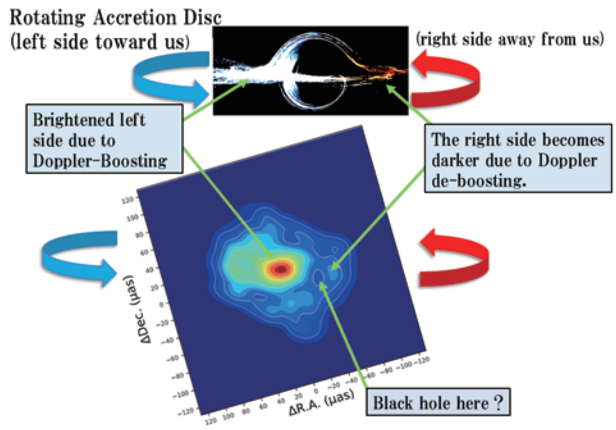


Figure 1: Point Spread Function (PSF). Red: positive, Blue: negative. Deep negative minima (yellow ×) are located at ±25 μas vertically. A circle with radius 25 μas centered on the northern minimum (yellow dashed line) includes multiple peaks (black ×). The interval of 49 μas as between main beam and sidelobe matches the EHTC shadow diameter (48.7 ± 7.0 μas). Green contours: EHTC ring image; three bright spots on the ring correspond to three PSF peaks.



Note: The image above is based on theoretical calculations. It is modified from the image calculated for the film Interstellar (James et al. 2015). The image below is the result of our independent re-analysis of the public EHT data.

Figure 2: Our derived image of the rapidly rotating accretion disk. Due to Doppler boosting, brightness differs between east and west.

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Transit Spectroscopy for K2-33b, an Infant Exoplanet around an M Star

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Young exoplanets are high-priority targets in the context of testing planetary formation and evolution as they retain primordial information on orbits and atmospheres at the time of formation. In particular, young transiting planets, whose orbits and atmospheres can be well characterized, are one of the most important targets in the recent transit spectroscopy by JWST.

K2-33b, an exoplanet with a radius slightly larger than Neptune, is an 8–11 million year-old transiting planet discovered in 2016 by the K2 mission, orbiting a pre-main-sequence M-type star with a period of about 5.4 days [1]. It has been reported that the planet radii estimated from visible (MEarth) and (near-)infrared (Spitzer) transit observations for K2-33b are significantly different; to account for the discrepancy, the effects of haze in the planet's atmosphere [2] and the scenario of a circumplanetary ring [3] have been proposed, but the reason for this difference is not exactly known.

We performed two transit observations of K2-33b using the near-infrared spectrograph IRD on the Subaru telescope, in order to elucidate the formation history and characteristics of the enigmatic planet K2-33b. Analyzing the IRD data during the transits, we constrained the stellar obliquity (the angle between the planet's orbital axis and the main star's rotational axis) for K2-33b. We found that the projected stellar obliquity for K2-33b is $\lambda = -6^{+61}_{-58}$ deg, through the modeling of the radial-velocity variation during the transit. Furthermore, we directly visualized the spectral line-profile variation (shadow of the planet) during the transit using a technique called "Doppler tomography", and independently constrained the stellar obliquity to be $\lambda = -10^{+22}_{-24}$ deg.

These results indicate that the orbital plane of K2-33b is nearly coplanar with the equatorial plane of the central star, suggesting that K2-33b formed in a protoplanetary disk that shared angular momentum with the central star, and evolved without chaotic orbital disturbance. In this study, we also investigated the stellar obliquities for similar young transiting planets measured in the past, and reported that the orbital axes of the planets and the spin axes of the central stars are aligned in all of the planetary systems with ages less than 100 million years.

When a transiting planet has a thick atmosphere, we can investigate the planet's atmosphere by probing the stellar-line variations during the transit (transmission spectroscopy). Using the same IRD data (during and outside the transit) as used for the obliquity measurements, we discussed the presence of excess absorption of stellar light by K2-33b's atmosphere. In particular, we investigated the Helium triplet line at 1083 nm and found that there exists an excess absorption by the Helium atmosphere during K2-33b's transit (Figure 1). While Helium has been detected in the atmospheres of many exoplanets in the past 5–10 years, K2-33b is the youngest exoplanet with a Helium upper envelop observed to date. Furthermore, based on the variation in the equivalent width of the Helium line, we also constrained the mass-loss rate of K2-33b due to atmospheric escape, and found that it is almost consistent with the energy-limited (100 % efficiency) mass-loss rate due to atmospheric heating by XUV irradiation from the central star.

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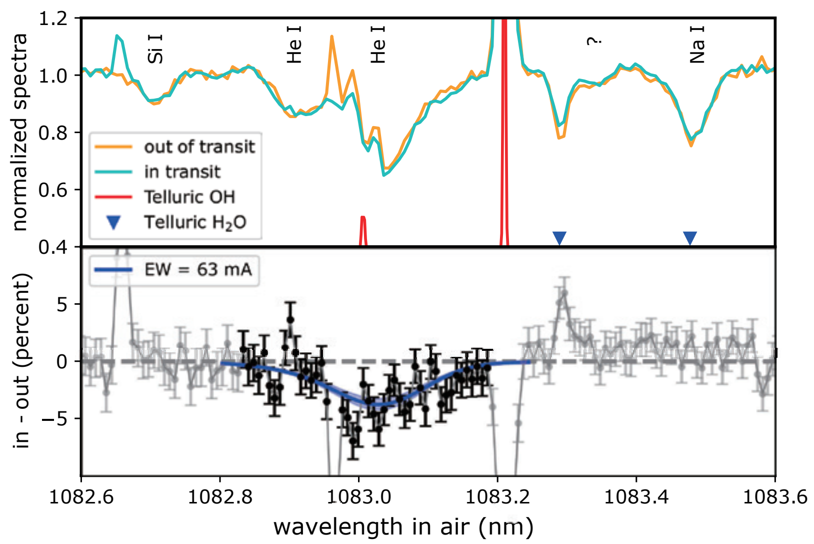

Figure 1: (Upper) Comparison of the mean IRD spectra during (cyan) and outside (orange) the transit (2021). (bottom) Residuals of mean spectra during and outside the transit [4].

Line Survey toward a Pre-cluster Clump in Serpens South with the Extended Q-band (eQ) Receiver

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Chemical compositions are good indicators of physical conditions and evolutionary stages of starless and star-forming cores. Carbon-chain molecules are one of the main constituents of the molecules detected in the interstellar medium. They have been known as early-type species because they are abundant in young starless cores and decrease in the evolved prestellar cores [1]. Recent observations toward the L1544 prestellar core show that complex organic molecules (COMs), which contain more than six atoms, can be detected even in the cold gas before a protostar heats its environment [2]. Hence, the chemical complexity has already grown at the initial stage of star formation.

The extended Q-band (eQ) receiver was installed on the Nobeyama 45m radio telescope. This receiver covers from 30 to 50 GHz and has the highest capability compared to the other Q-band receivers on single-dish telescopes [3]. We have conducted the Q-band (30–50 GHz) line survey observations toward the pre-cluster clump in the Serpens South cluster-forming region (d = 436 ± 9 pc), taking advantage of this receiver [4]. The target clump shows a low temperature and a high N_2H^+ column density and no star formation activity [5], but will likely form a protocluster in the near future.

The observations were conducted between February and April 2024. The beam sizes are 38.8″ and 36.6″ at 31 GHz and 43 GHz, respectively. These beam sizes correspond to ~0.08 pc at the source distance.

Figure 1 shows the overall spectrum from 30 to 50 GHz toward the target pre-cluster clump. The spectral noise levels were approximately 10–20 mK, depending on the frequency range. We have detected ~180 lines from 52 molecular species, including isotopologues. We derived the column density of each species and compared the chemical compositions between the target pre-cluster clump and other low-mass starless cores (the cyanopolyyne peak of Taurus Molecular Cloud-1 (TMC-1 CP) and the prestellar core L1544).

We compared the abundances of carbon-chain species between our target clump and TMC-1 CP. The chemical compositions in our target clump are very similar to those at TMC-1 CP. On the other hand, the abundances of COMs in our target clump agree with the prestellar core L1544.

We derived the deuterium fractionation of three species: HC_3N, *cyclic*-C_3H_2, and H_2CS. The derived D/H ratio of HC_3N is 1.72 ± 0.12 %, which is consistent with TMC-1 CP. On the other hand, the HDCS/H_2CS ratio is 11.3 ± 0.5 %, which agrees with that in the prestellar core L1544, and the D/H ratio of *cyclic*-C_3H_2 (7.8 ± 0.6 %) is between TMC-1 CP and L1544.

The pre-cluster clump has gas in at least two different chemical stages, which correspond to starless and prestellar cores. These results indicate that the densest and coldest prestellar cores have formed in the pre-cluster clump.

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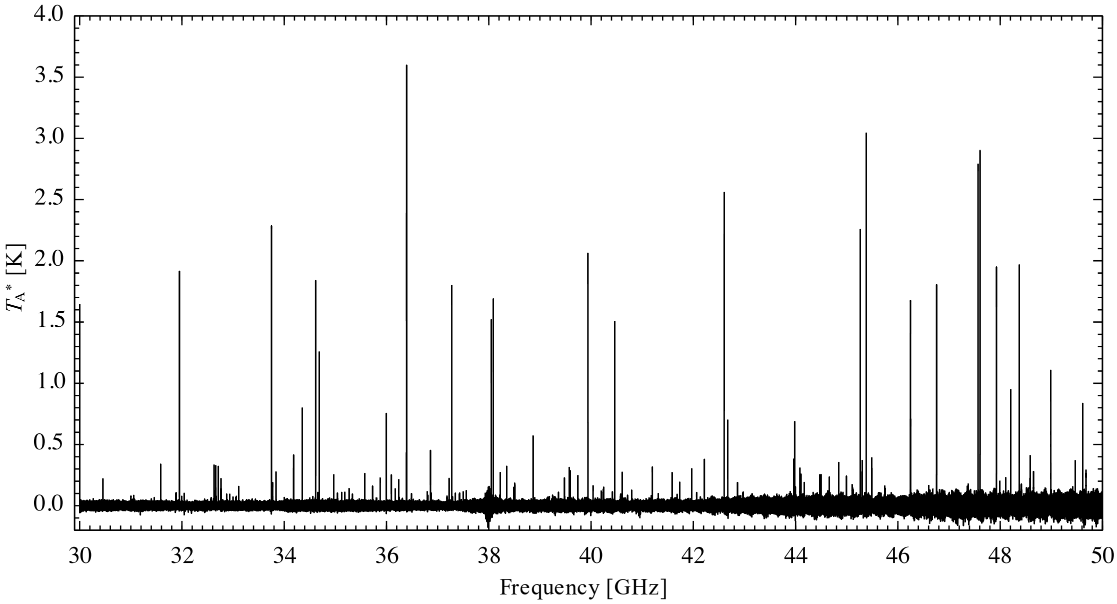

Figure 1: Overall spectrum (30–50 GHz) toward a pre-cluster clump in Serpens South.

Resident Time of the Oort Cloud New Comets in Planetary Region

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In the mid-20th century, a Dutch astronomer Jan Hendrik Oort predicted the existence of a spherical cloud of comets within 10^3 to 10^4 au from the Sun based on the fact that the distribution of orbital inclination of long period comets is nearly isotropic. This is the Oort Cloud. Although the existence of the Oort Cloud has become a consensus thanks to the accumulation of observation data and the progress of theoretical studies, no objects have yet been detected that unambiguously show the full structure of the Oort cloud. Unlike the study of the major planets, for which there is a wide variety of observational evidence, the reality of the Oort Cloud and comets originating from it (new comets) is not clear due to a lack of observational data. However, comets originating from the Oort Cloud are definitely arriving in planetary regions, and some of them have reached the vicinity of the Earth and have been observed. We followed the dynamical evolution of the new comets by numerical simulations based on new dynamical models of the Oort Cloud [1].

We describe the result of our numerical orbit simulation which traces dynamical evolution of new comets coming from the Oort Cloud. We combine two dynamical models for this purpose. The first one is semi-analytic, and it models an evolving comet cloud under galactic tide and encounters with nearby stars. The second one numerically deals with planetary perturbation in the planetary region. Although our study does not include physical effects such as fading or disintegration of comets, we found that typical dynamical resident time of the comets in the planetary region is about 10^8 years. We also found that the so-called planet barrier works when the initial orbital inclination of the comets is small. A numerical result concerning the temporary transition of the comets into other small body populations such as transneptunian objects or Centaurs is discussed.

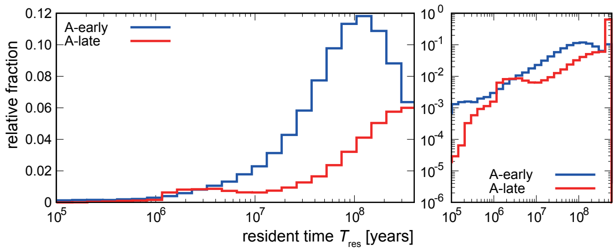

Figure 2: Distribution of the resident time T_{res} of the comets. The vertical axis of the left panel is on a linear scale, while that of the right panel is on a logarithmic scale. The vertical axis is normalized in both the panels so that the total value becomes unity for each period.

Reference

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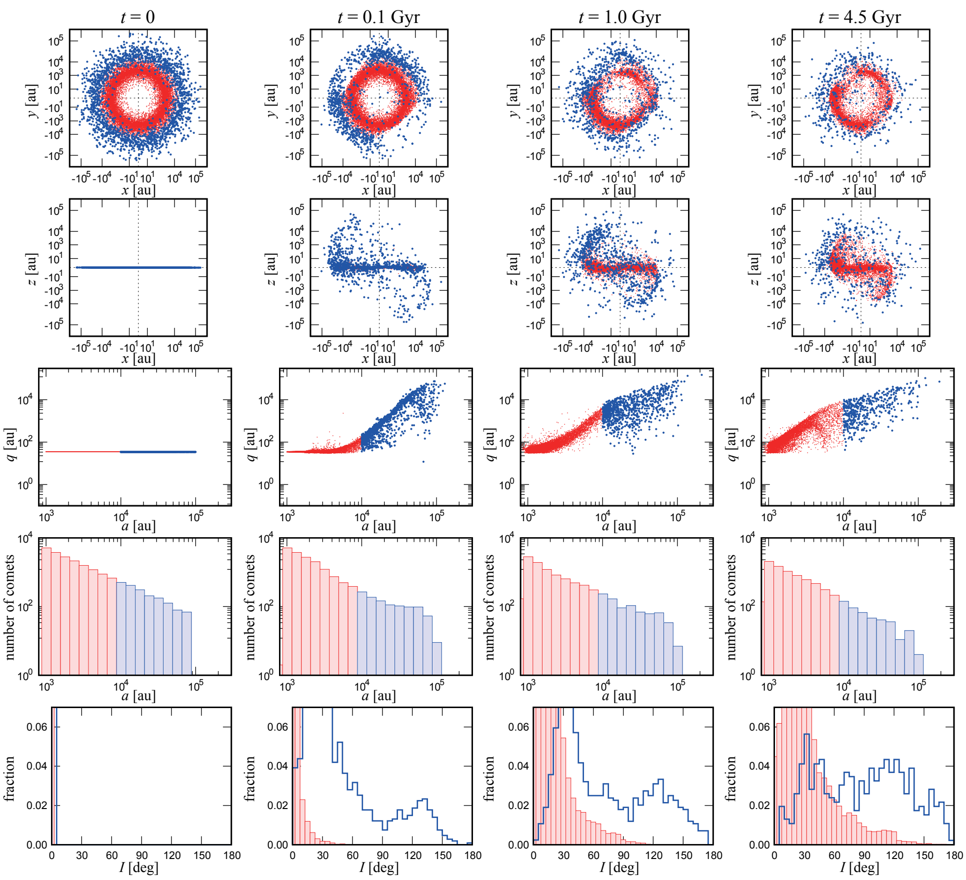

Figure 1: Example snapshots of the comet cloud evolution under the a star set. Top row: spatial distribution of the comets seen from the north (i.e. projected on the (x,y) plane). The (x,y) plane corresponds to the current ecliptic, and the x-axis is directed toward the current vernal equinox. The objects with semimajor axis $a <$ 10,000 au are plotted in red in all the panels, while other objects ($a \geq$ 10,000 au) are plotted in blue (we drew the blue dots slightly larger than the red dots). Second top row: spatial distribution of the comets seen from the current ecliptic (along the (x,y) plane). Third top row: scatter plots of semimajor axis a and perihelion distance q of the objects. Fourth top row: absolute number distribution of semimajor axis a of the comets. Bottom row: fractional distribution of orbital inclination I of the comets.

A Protocluster of Massive Quiescent Galaxies at $z = 4$

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Galaxies can be classified into two broad categories; blue spiral galaxies with active star formation and red elliptical galaxies with little ongoing star formation. Detailed spectroscopic studies of nearby massive elliptical galaxies indicate that elliptical galaxies formed in an intense burst of star formation in the early Universe followed by rapid quenching. The modern theory of galaxy formation and evolution predicts that galaxies grow progressively more massive with time. The formation of elliptical galaxies is therefore unexpected. A promising way to address the formation of massive elliptical galaxies is to identify just-formed elliptical galaxies in the early Universe and examine their properties in detail.

We focus on Ultra Deep Survey (UDS), where deep multi-wavelength data are available over a wide area. Using Keck MOSFIRE, we confirm a quiescent galaxy (QG), which is likely a progenitor of today's elliptical galaxies, at $z = 3.99$ [1]. QGs at such a high redshift are rare and the newly confirmed one is thus a good object to address the question raised above. Interestingly, the QG accompanies 4 more QGs within a distance of about 1Mpc (physical). This is the first over-density region of QGs discovered at such a high redshift.

Figure 1 shows the confirmed QG and distribution of galaxies around it. There is a large-scale structure extending in the N-S direction, and the QG over-density discovered here is part of the structure. The spectral energy distributions of these QGs are very similar, suggesting that they are quenched about the same time. The fact that these galaxies form the red sequence also supports the simultaneous quenching. Note that this is the highest redshift red sequence reported so far.

Our understanding of QGs at high redshift is rapidly improving thanks to James Webb Space Telescope (JWST). It cannot, however, find a rare system like ours due to its limited field coverage. Our work suggests that wide-field observations from the ground are highly important and complementary to JWST.

Reference

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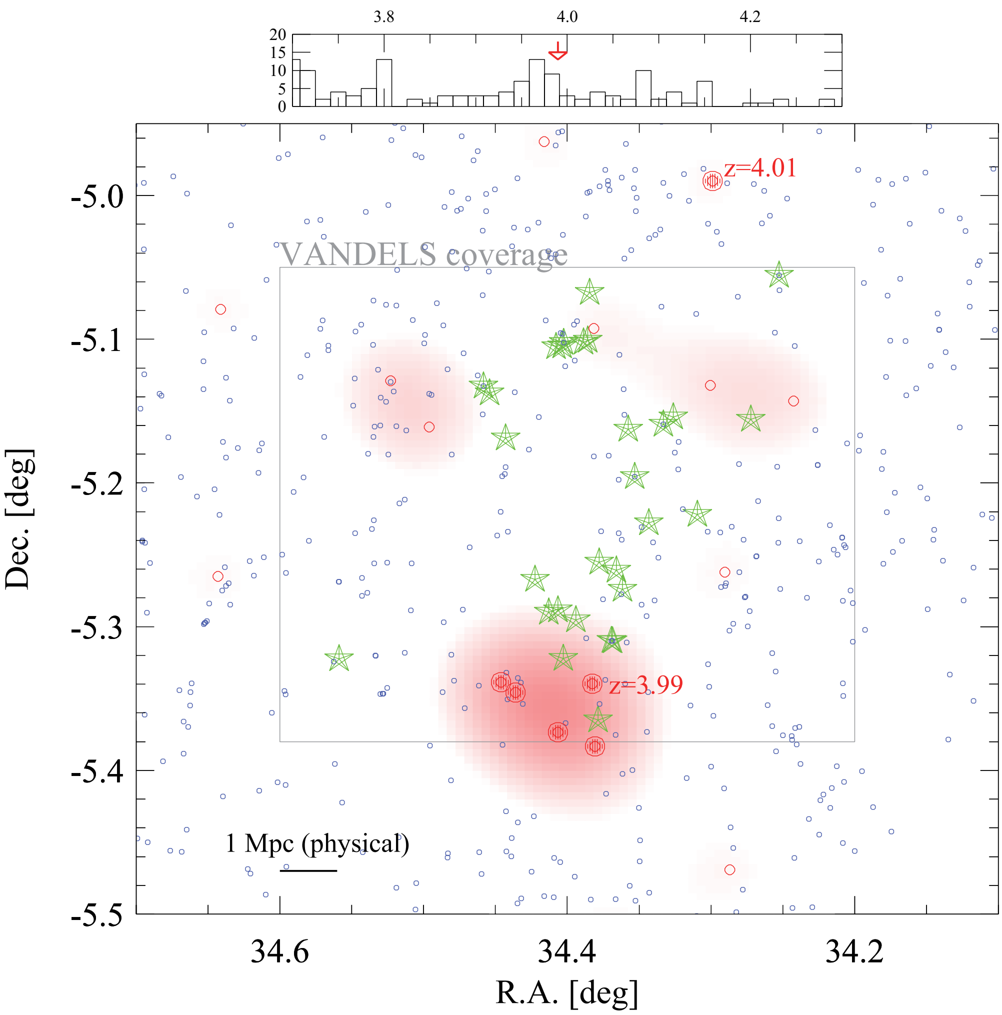

Figure 1: QG over-density at $z = 4$. The blue circles are star-forming galaxies at $z \sim 4$ selected on the basis of photometric redshifts. The red circles are QGs at similar redshifts. The filled red points are the spectroscopically confirmed QGs. A spectroscopic survey called VANDELS was carried out in UDS, and its field coverage is shown as the gray box. Spectroscopically confirmed $z = 4$ galaxies from VANDELS are shown as the green stars. The histogram on the top shows the VANDELS redshift distribution and the arrow indicates the redshift of our QG ($z = 3.99$).

Gradually Revealing the Structure of the Outer Solar System — Subaru Telescope and New Horizons' 20-Year Challenge

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1: University of Occupational and Environmental Health, Japan, 2: Chiba Institute of Technology, 3: JAXA, 4: NAOJ, 5: Chubu University, 6: University of Science and Technology of China, 7: Southwest Research Institute, 8: Herzberg Astronomy and Astrophysics Research Centre, 9: University of Victoria, 10: Planetary Science Institute, 11: Southwest Research Institute, 12: University of Virginia, 13: Kitt Peak National Observatory, 14: Massachusetts Institute of Technology, 15: Space Telescope Science Institute, 16: Northern Arizona University, 17: Southern Illinois University, 18: Harvard & Smithsonian, 19: National Central University, 20: NASA Goddard Spaceflight Center, 21: Carnegie Observatories, 22: Las Campanas Observatory, 23: CNRS, 24: Carnegie Institution for Science, 25: SETI Institute, 26: Johns Hopkins University Applied Physics Laboratory, 27: Institute for Astronomy, 28: Lowell Observatory, 29: University of Michigan, 30: University of Washington, 31: Kyoto University, 32: University of Arizona, 33: Khalifa University, 34: Independent Astronomer, 35: University of Southern Queensland, 36: Chiba Institute of Technology, 37: University of Texas at Austin, 38: NOIRLab, 39: Consejo Superior de Investigaciones Científicas, 40: Kindai University, 41: Observatoire de la Côte d'Azur, 42: Université Grenoble Alpes, 43: Institut de Planetologie et Astrophysique de Grenoble (IPAG), 44: Lunar and Planetary Institute (USRA)

We collaborated with NASA's New Horizons mission to search for Kuiper belt objects (KBOs) that the New Horizons spacecraft would flyby and for KBOs that could be observed directly from the spacecraft. During the 2004–2005 observations, we used the Subaru telescope + Suprime-Cam to search near Pluto and discovered 24 trans-Neptunian objects (TNOs) [1]. However, none of the TNOs we found had an orbit that would allow the New Horizons spacecraft to flyby. Since 2020, we have been working with the New Horizons mission again, this time using the Subaru Telescope + Hyper Suprime-Cam to search for TNOs. The goal is to find the next flyby target after Arrokoth, which was flybyed in 2019, and to search for KBOs that can be observed from within the Kuiper belt at close distance and with a large solar phase angle. Unfortunately, no Kuiper belt objects (KBOs) have been found for flybys while the spacecraft is in the Kuiper belt. However, 241 trans-Neptunian objects were discovered during observations from 2020 to 2023 (Figure 1) [2]. Two of these were discovered by the Japanese research team using a unique detection system called the JAXA Moving Object Detection System (originally used to detect near-Earth asteroids) after reanalyzing data analyzed by the North American mission team [3]. Most of the objects found in these New Horizons KBO surveys are new discoveries, and when their orbital distributions are plotted, it becomes clear that there are several objects beyond the known Kuiper belt region. Objects with heliocentric distances of 20–55 au are considered to be known Kuiper belt objects. There are few objects with heliocentric distances of 55–70 au, while 11 objects have been discovered in the 70–90 au range. The number of objects distributed beyond the Kuiper belt was significantly higher than the number predicted by the orbital distribution models of previous studies for trans-Neptunian objects. We interpret this to mean that our current knowledge of the outer Solar System is woefully inadequate, and that extensive observations are still needed to understand the true figure of the outer Solar System. Even if a probe were to go there, it would not provide a complete understanding. We are continuing observations with the Subaru Telescope and Hyper Suprime-Cam to determine the more precise orbits of the trans-Neptunian objects discovered in this study. The discovery of distant bodies and the clarification of their orbital distributions will shed light on the accretion and rearrangement of planetesimals in the history of the formation of the Solar System. Furthermore, by comparing these findings with exoplanetary systems, we may be able to establish a universal theory of planetary formation.

The spacecraft will continue to fly beyond the outer reaches of the Solar System. The second extended mission to explore interstellar space began in 2022. We look forward to continuing our collaboration with the New Horizons mission and to seeing the outer reaches of the solar system through the spacecraft's eyes before it leaves the solar system.

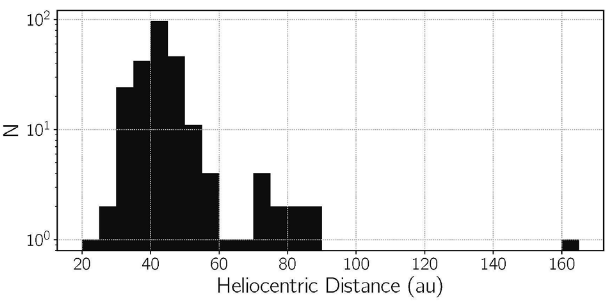

Figure 1: Distance distribution of Kuiper Belt objects discovered by HSC during 2020 and 2023 observations.

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High-Accuracy Polarization Measurements of the White-Light Corona during the 2023 Total Solar Eclipse

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We measured the polarization of the white-light corona during the total solar eclipse on April 20, 2023, which occurred under high solar activity [1]. Despite the short duration of totality, we were able to obtain high-accuracy polarization data. We derived the brightness and polarization of the K+F corona and estimated the brightness distributions of the K- and F-coronae using polarization information.

The employed instrument was the same one that was used for the 2017 and 2019 eclipse observations, and the analysis is also similar to that for the 2017 and 2019 eclipses [2]. However, there are significant advantages in this analysis. First, in contrast to the 2017 and 2019 eclipses, which occurred in the declining phase and near the minimum solar activity, the 2023 eclipse occurred during high solar activity. Second, eclipse polarimetry data are often calibrated using the polarization brightness measured by the K-Cor coronagraph of Mauna Loa Solar Observatory, but during the 2023 eclipse, K-Cor was not working. Our calibration can be done using solar disk images captured along with eclipse images, and therefore, we were able to obtain quantitative data without K-Cor data.

The polarization data of the corona are the key to estimating the amount of coronal hot plasma and its electron density distribution. Therefore, we examined the consistency between the eclipse data and those taken by the C2 coronagraph of the Large Angle Spectrometric Coronagraph (LASCO) on board the Solar and Heliospheric Observatory. Consequently, a systematic difference was observed; the polarization measured by LASCO-C2 [3] was approximately 30 % smaller than the results from the eclipse. Data from eclipses, which are captured under low background-sky-brightness and no scattered light due to the Sun's disk, can be a good calibration source of the brightness and polarization of the white-light corona.

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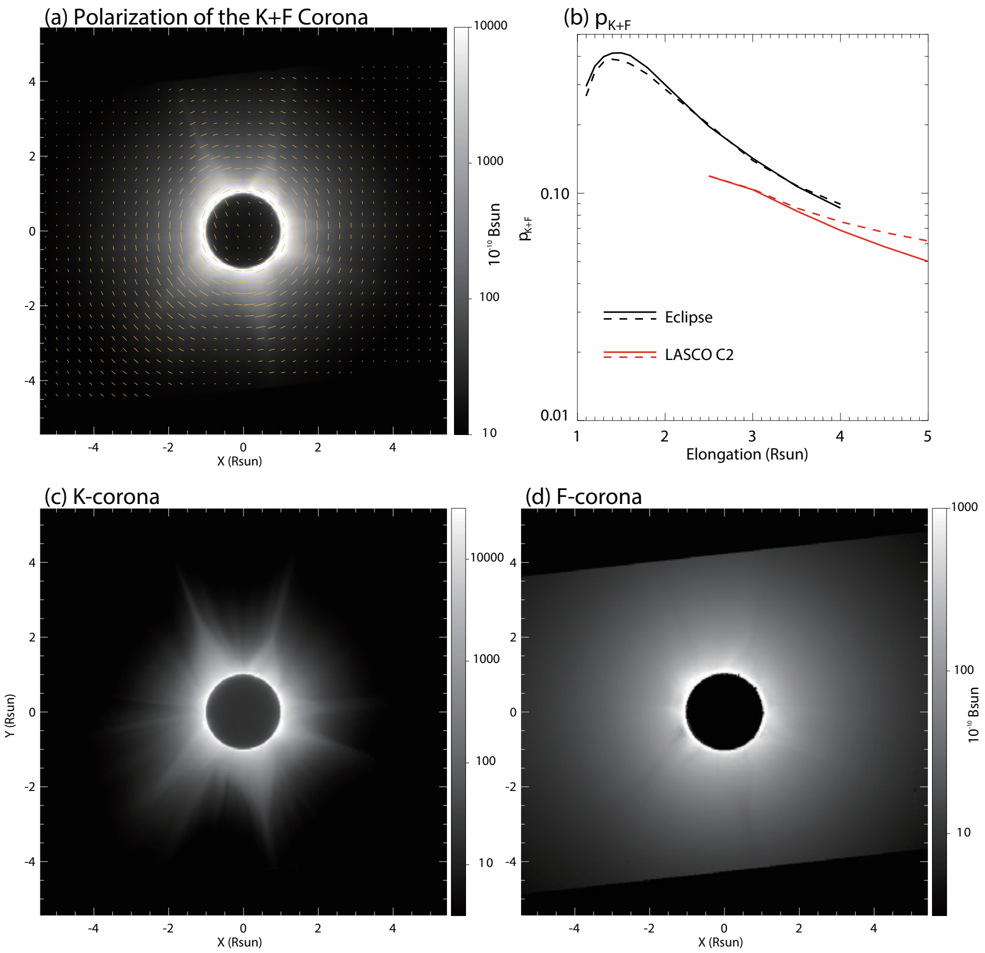

Figure 1: (a) Polarization map of the K+F corona after the elimination of the sky background covering 9.2 × 9.2 $R_\odot$ area obtained during the 2023 eclipse. The grayscale image presents Stokes *I* signals, and the degree and orientation of the linear polarization signals are depicted with orange ticks. The solar north is to the top. (b) Comparison of the degree of polarization of the K+F corona in the equatorial (solid lines) and polar (dashed lines) regions between the eclipse observation and LASCO C2 observation. (c)(d) Gray-scale maps of the K-corona and the F-corona for the area shown in panel (a).

Evaluation of Sunspot Areas Derived by Automated Sunspot-Detection Methods

HANAOKA, Yoichiro[1]

1: NAOJ

Long-term records of solar phenomena are key to understanding variations in solar activity. Besides the daily “international sunspot number”, which has been maintained from 1818 based on sunspot counts, the daily total sunspot area, the systematic measurement of which was started in 1874, is another important index of solar activity. However, the number of observatories that are deriving sunspot areas daily is decreasing, mainly because it requires considerable time and effort. Therefore, it is required to continue sunspot area measurements using automated methods with less manpower.

Sunspot-area measurements using digital images captured by two telescopes at the Mitaka campus of the National Astronomical Observatory of Japan are conducted using automated sunspot detection. One is the New Sunspot Telescope, which is a 10-cm refractor and has a 2K×2K CCD camera [1] (hereafter NEWSUN), and another is a part of the the Solar Flare Telescope, where a 12.5-cm refractor (T4) with a 2K×2K CMOS camera was installed [2] (hereafter SFTT4). The data from both instruments are processed with automated sunspot detection methods using thresholding to count the number of sunspots and derive the sunspot area (for SFTT4, an improved method is used [3]).

To verify the validity of the areas derived using these automated methods, we compared [4] between sunspot areas derived from Mitaka and those from the reference data by Mandal et al. [5] (hereafter MANDAL), who compiled a cross-calibrated daily sunspot-area catalog. The variations of sunspot areas of MANDAL, NEWSUN, and SFTT4 are shown in Figure 1(a). As presented in Figures 1(b) and 1(c), it was revealed that the correlation coefficients between them are high (0.96–0.97), whereas the areas in the Mitaka data are 70 %–83 % of those of MANDAL. The correlation is limited by the differences in observation times and detection capabilities of spots near the limb, with discrepancies in areas arising from different definitions of spot outlines. Given the high correlation and the ease of calibrating area discrepancies with a correction factor, automated sunspot detection appears promising for future sunspot-area measurements.

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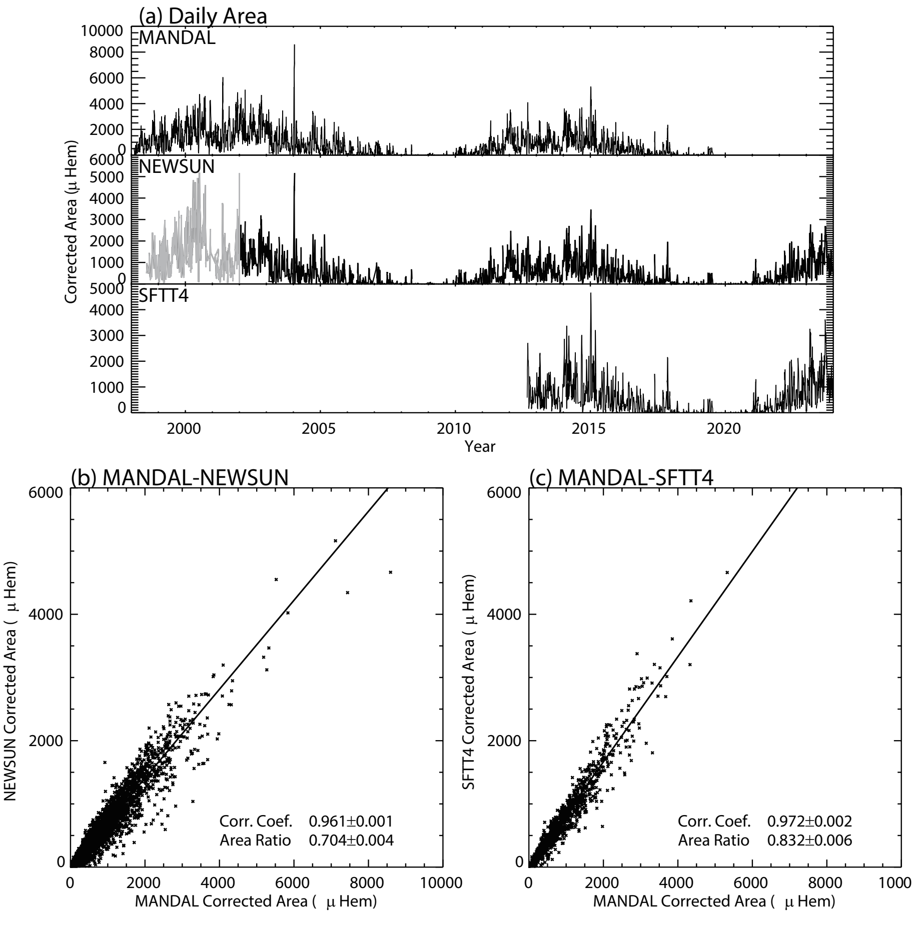

Figure 1: (a) Daily total sunspot areas (foreshortening-effect corrected) of MANDAL, NEWSUN, and SFTT4. The unit of area is 10^{-6} of the area of the hemisphere (μHem). For NEWSUN, the data until 2001 (shown in gray) were not used in this study because of their insufficient quality. (b)(c) Comparisons of corrected sunspot areas between (b) MANDAL and NEWSUN and (c) MANDAL and SFTT4. Daily data are shown by points, and the regression results are shown by lines. The correlation coefficients and the area ratios (the slopes of the regression lines) were annotated.

Active Galactic Nucleus Properties of ~1 Million Member Galaxies of Galaxy Groups and Clusters at $z < 1.4$ Based on the Subaru Hyper Suprime-Cam Survey

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Recent studies have revealed that the emergence of active galactic nuclei (AGNs) depends not only on their host galaxies but also on the environment in which they reside. Galaxy clusters, the largest self-gravitating structures, are an ideal laboratory for studying AGN environmental effects. Previous research [1] utilized the CAMIRA catalog[1] [2] discovered by the Subaru Hyper Suprime-Cam (HSC) to examine the statistical investigation of AGN "number fraction." However, two challenges arose: (i) a large statistical error due to low AGN number density, and (ii) inability to detect low-activity AGNs. Thus, we focused on the AGN "power fraction ($f_{\mathrm{AGN}} = L_{\mathrm{IR}}$ (AGN)/L_{IR})", the AGN contribution to total infrared (IR) luminosity. We calculated f_{AGN} for all member galaxies via spectral energy distribution (SED) analysis (Figure 1), defining the weighted mean of f_{AGN} as the cluster's AGN power fraction. This method's advantages include: (i) reduced statistical errors by using all member galaxy data, and (ii) inclusion of low-activity AGN. This study investigated the redshift and cluster-centric distance dependence of f_{AGN}.

As a result, we found that the AGN power fraction (f_{AGN}) increases with (1) increasing redshift and (2) increasing distance from the center of the cluster (Figure 2). Additionally, f_{AGN} was found to depend on the number of member galaxies (richness), the cluster mass, and the cluster morphology. In particular, mergers with massive galaxy clusters may trigger AGN activity in the outskirts of clusters, suggesting the importance of high-z merging clusters [3].

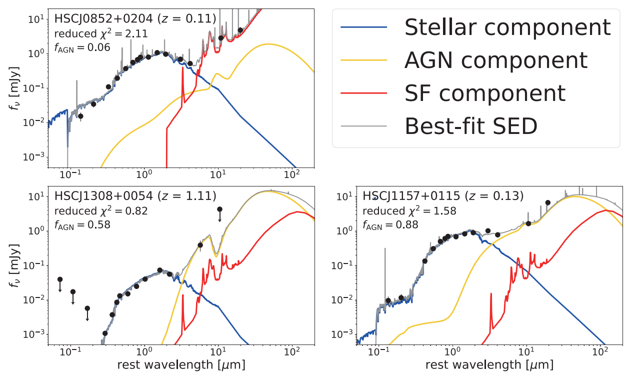

Figure 1: Examples of SED fitting for CAMIRA member galaxies.

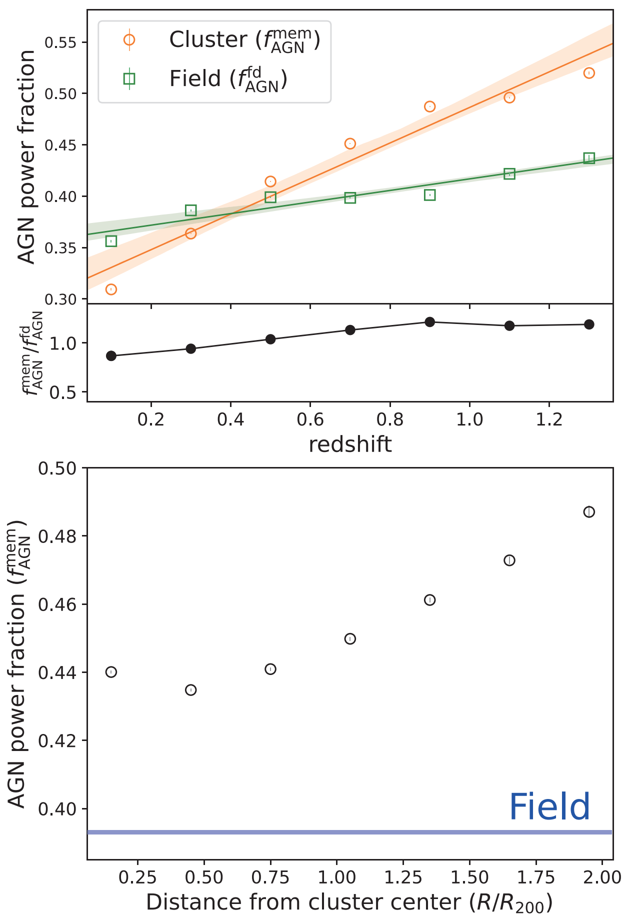

Figure 2: AGN fraction (f_{AGN}) as a function of (a) redshift and (b) cluster-centric radius (R/R_{200}).

References

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1 The CAMIRA catalog contains more than 27,000 clusters at $0.1 < z < 1.4$ with ~1 million member galaxies.

JASMINE: Near-infrared Astrometry and Time-series Photometry Science

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1: NAOJ, 2: Mullard SpaceScience Laboratory, University College London, 3: JAXA/ISAS, 4: The University of Tokyo, 5: SOKENDAI, 6: US Naval Observatory, 7: Kyoto University, 8: Centre for Astrophysics and Supercomputing, Swinburne University of Technology, 9: California State University, Sacramento, 10: Hirosaki University, 11: Kagoshima University, 12: International Centre for Radio Astronomy Research, The University of Western Australia, 13: Institute of Statistical Mathematics, 14: Astrobiology Center, 15: Institute of Astronomy, Graduate School of Science, The University of Tokyo, 16: Yukawa Institute for Theoretical Physics, Kyoto University, 17: RIKEN, 18: Lohrmann Observatory, Technische Universität Dresden, 19: Earth-Life Institute(ELSI), Tokyo Institute of Technology, 20: Code 667, NASA Goddard Space Flight Center, 21: University of Maryland, 22: Lowell Observatory, 23: MIT Department of Earth, Atmospheric and Planetary Sciences, 24: University of Virginia, 25: Osaka University, 26: Niigata University, 27: Laboratory for Atmospheric and Space Physics, University of Colorado, 28: National Solar Observatory, University of Colorado, 29: University College London, 30: Tsung-Dao Lee Institute, Shanghai Jiao Tong University, 31: The Hakubi Center/Kyoto University, 32: Astronomisches Rechen-Institut, Zentrum für Astronomie der Universität Heidelberg, 33: School of Physics, Faculty of Science, University of Sydney, 34: Tohoku University, 35: Jeremiah Horrocks Institute, University of Central Lancashire, 36: Max-Planck-Institut für extraterrestrische Physik, 37: Lund Observatory, Lund University, 38: Institut de Ciències del Cosmos (ICCUB), Universitat de Barcelona, 39: Universitat de Barcelona, 40: Institutd' Estudis Espacials de Catalunya (IEEC), 41: Dipartimento di Fisica e Astronomia "AugustoRighi", Università di Bologna, 42: INAF-Osservatorio di Astrofisica e Scienza dello Spazio di Bologna, 43: Utah State University Space Dynamics Laboratory, 44: Miyagi University of Education, 45: Institute for Cosmic Ray Research, The University of Tokyo, 46: KavliIPMU/The University of Tokyo, 47: School of Physics, University College Dublin, 48: European Space Agency (ESA), 49: Department of Physics, University of Surrey, 50: University of California, Los Angeles, 51: RESCEU/The University of Tokyo, 52: National Institute of Technology (KOSEN), Kochi College, 53: Waseda University, 54: Japan Space guard Association, Bisei Space guard, 55: Institute of Astronomy, University of Cambridge

The Japan Astrometry Satellite Mission for Infrared Exploration (JASMINE, Figure 1, [1]) is a planned M-class science space mission by the Institute of Space and Astronautical Science (ISAS), the Japan Aerospace Exploration Agency (JAXA). It is designed to perform high-precision astrometry and time-series photometry in the near-infrared (NIR) H_W-band, covering wavelengths from 1.0 to 1.6 μm. This mission is uniquely positioned to explore the most obscured regions of the Milky Way, particularly the Galactic Center and the Galactic mid-plane, which are inaccessible to optical missions like European Space Agency's Gaia due to severe dust extinction.

JASMINE's scientific objectives are centered around two major themes: Galactic Center archaeology and exoplanet discovery. The Galactic Center Survey (GCS) aims to map the structure, kinematics, and formation history of the Milky Way's central components, including the nuclear star cluster (NSC), the nuclear stellar disk (NSD), and the supermassive black hole (SMBH) at the heart of the Galaxy. By achieving Gaia-level astrometric precision in the NIR, JASMINE will provide important insights into the formation epoch of the Galactic bar, the nature of spiral arms, and the processes of radial migration in the inner disk. These observations will help resolve long-standing questions about the dynamical evolution of the Milky Way and the role of the central bar in shaping its structure.

The second major goal of JASMINE is to conduct an Exoplanet Survey (EPS) focused on detecting Earth-sized planets in the habitable zones of M-type stars. JASMINE's NIR capabilities make it particularly well-suited for monitoring mid-to-late M dwarfs, which are faint in the optical but bright in the infrared. JASMINE will perform high-cadence, high-precision photometry to detect transiting exoplanets, especially those with longer orbital periods that are difficult to observe with current missions like TESS (Transiting Exoplanet Survey Satellite). This survey will provide the new habitable-zone Earth-sized planets for future followup spectroscopic studies to characterize the atmospheres of the habitable-zone planets.

Technically, JASMINE is equipped with a 36 cm aperture telescope using a four InGaAs NIR detectors developed at NAOJ. It will operate in a Sun-synchronous orbit at an altitude of around 600 km, with a field of view of 0.55 × 0.55 degrees. The mission is designed to achieve astrometric precision of ~25 μas for stars brighter than $H_\mathrm{W} < 12.5$ mag, where $H_\mathrm{W} \approx 0.9J + 0.1H - 0.06(J - H)^2$, and photometric precision of approximately 1 mmag for bright stars. For GCS, each star will be observed about 60,000 times over the mission's nominal three-year duration, enabling both precise astrometry and robust time-series photometry.

Beyond its core objectives, JASMINE will contribute to a wide range of scientific investigations. It will provide accurate enough astrometry to detect intermediate-mass black holes through astrometric microlensing, provide new insights into the dynamics of star-forming regions and young stellar clusters, and enhance our understanding of X-ray sources and stellar populations in the Galactic bulge. JASMINE will also serve as a critical bridge between Gaia and its proposed successor, GaiaNIR [2], by demonstrating the power of NIR astrometry and laying the groundwork for future all-sky NIR surveys. With its unique capabilities and strategic timing, JASMINE is poised to make significant contributions to our understanding of the Milky Way and its planetary systems.

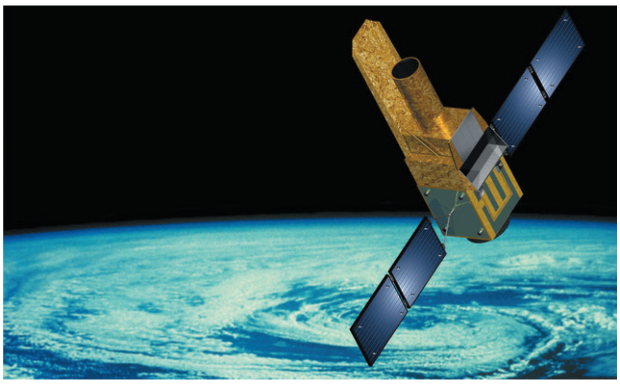

Figure 1: Artist's impression of JASMINE.

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The World’s Largest Stellar Catalog of Chemical Abundances

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The chemical composition of a star—often referred to as its “DNA”—is essential for understanding the era and environment in which the star was born. In the context of chemical abundance measurements, astronomers often focus on the star's metallicity [M/H]. However, if we can also determine the abundance of alpha elements [α/M] in addition to metallicity, we gain a more detailed understanding of the star formation history and the conditions under which stars formed.

Because we live in the Milky Way, we can estimate the detailed chemical compositions of individual stars in our Galaxy through spectroscopic observations. However, for faint stars, the required telescope time is long, making such observations costly. The Gaia satellite was primarily designed to obtain positional and velocity data for stars in the Milky Way for 1.6 billion stars. As a byproduct, Gaia also released Gaia XP spectra for 219 million stars, which are extremely low-resolution spectra with $R = \lambda/\Delta\lambda = 50$–100. In this study, I analyzed these large-scale but low-resolution XP spectra using machine learning to estimate ([M/H], [α/M]), and constructed the world's largest catalog of multi-dimensional chemical abundances [1]. Since I use only publicly available data, our observational cost was zero. The catalog of chemical compositions for 48 million stars generated in this study is available at **https://zenodo.org/records/10902172**.

In this study, I analyzed 48 million stars located in low dust extinction regions. Among these 48 million stars, we have detailed chemical abundances for ~100,000 stars from APOGEE DR17. Using these stars as training data, I modeled the relationship between spectral shape and chemical composition using machine learning. Specifically, I employed Quantile Regression Forests, which is useful due to its interpretability. The trained model achieved prediction errors of 0.0890 dex for [M/H] and 0.0436 dex for [α/M], meeting the accuracy requirements for Galactic archaeology.

The raw data obtained by Gaia is analyzed and processed by an organization known as DPAC, which consists of around 400 researchers. The cleaned and processed data is then made publicly available to users. The Gaia XP spectra used in this study were released by DPAC in 2022. Before the release of the XP spectra, some members of DPAC had already attempted to estimate [M/H] and [α/M] from the XP spectra using machine learning, just as I have done. Their results were published as a paper in 2021, prior to the data release [2]. In that work, they concluded that while [M/H] could be estimated from the Gaia XP spectra, [α/M] could not be reliably inferred. Given their results, inferring [α/M] seemed to be challenging. However, the sheer scale of the Gaia XP spectral dataset—covering 219 million stars—was highly compelling, and I dared to tackle this high-risk, high-reward problem. I appreciate the valuable feedback from my colleagues, especially Dr. Akifumi Okuno (Institute of Statistical Mathematics), Dr. Tadafumi Matsuno (University of Heidelberg), and Dr. Daisuke Taniguchi (NAOJ), among others.

Then, why did my machine learning model succeed? To explore this question, I interpreted the model using a technique called permutation feature importance (PFI) (Figure 1). The analysis revealed that the estimation of [α/M] relied not only on absorption lines of alpha elements (e.g., Mg I line at 518 nm) but also on the absorption lines of non-alpha elements that are closely related to alpha elements (such as the Na D lines at 589 nm). This finding highlights that the Gaia XP spectra are a treasure trove of diverse information, and further analysis of this dataset holds great promise.

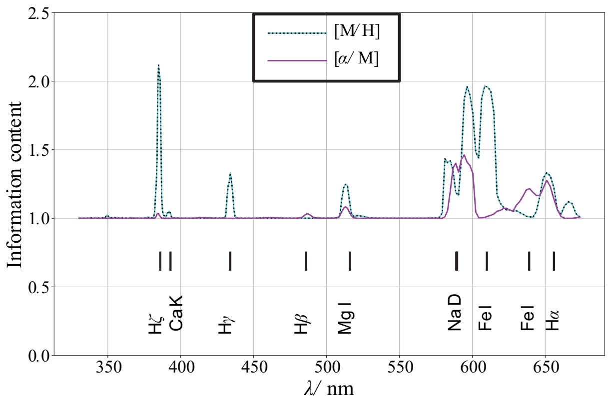

Figure 1: Visualization (via PFI method) of how our machine learning model utilizes the spectrum. The y-axis indicates the information content of the spectrum at each wavelength.

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Temperature or UV Field Tracers? Isotopomers HCN and HNC in the Case of the Barred-spiral Galaxy M83

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Molecular gas is the raw material of star formation. Various molecular species exist in the gas, and their abundances can reflect the physical conditions of the molecular gas. For example, the HNC/HCN ratio has been proposed as a thermometer based on observations of interstellar molecular clouds in our Galaxy [1,2]. However, recent studies have suggested an alternative hypothesis that the HNC/HCN ratio may be influenced not by temperature, but by ultraviolet (UV) radiation fields [3]. The aim of this study is to investigate the nature of this ratio on the scale of giant molecular clouds in the southwestern bar and central regions of the barred spiral galaxy M83, using observations from the Atacama Large Millimeter/submillimeter Array (ALMA), and to examine what influences this ratio more effectively.

We used a higher spatial resolution of 40–50 pc, and compared the HNC/HCN ratio with the star formation rate (SFR) derived from 3 mm continuum intensity, and the molecular mass estimated from HCN intensity (Figure 1). In the bar-end region of M83 (the junction of the galactic bar structure and spiral arm), we found that the HNC/HCN ratio does not depend on the star formation rate, star formation efficiency, or column density. If star formation affects gas temperature, then the scenario that the HNC/HCN ratio varies with temperature would not explain these results.

On the other hand, in the central region, we observed a trend where a higher star formation rate corresponds to a higher HNC/HCN ratio. Since increased star formation rate is usually associated with increased temperatures, this result is inconsistent with the hypothesis that the HNC/HCN ratio decreases with increasing temperature. Spectral analysis suggests that HCN is optically thick, while HNC is optically thin, indicating that such high HNC/HCN ratios may arise from this difference in optical depth. Furthermore, despite the high gas temperatures in the central region, the HNC/HCN ratio remains relatively high. While such high HNC/HCN ratios could be explained by high cosmic-ray ionization rates, this contradicts the observation that the HNC/HCN ratio is lower in regions with lower column densities, which are more affected by cosmic rays.

Additionally, we compared the large-scale (~200 pc) relationship between the dust temperature derived from the far-infrared continuum ratio in archival data from the Herschel telescope and the HNC/HCN ratio in the bar-end region. We found that regions with higher dust temperatures tend to have lower HNC/HCN ratios. While high dust temperature is consistent with both high gas temperatures and strong UV radiation, UV radiation is considered to have an influence in the larger spatial scale.

Above results suggest that the HNC/HCN ratio likely depends on UV radiation fields that influence interstellar material over relatively wide areas (about 100 pc scale) with low column densities.

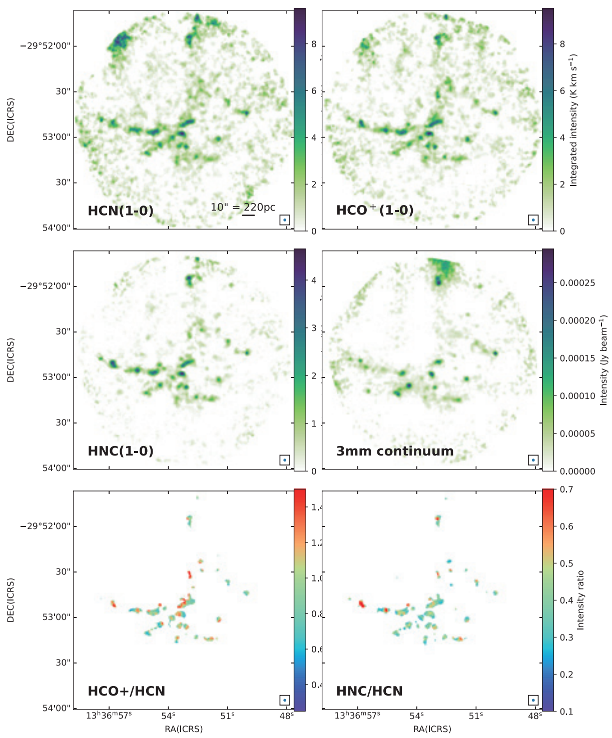

Figure 1: Integrated intensities of HCN, HCO^+, HCN, 3-mm continuum, and line rations in the bar-end region of M83 [4].

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Search for New Milky Way Satellites from the Subaru/HSC Survey: Discovery of Two More Candidates

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The standard Cold Dark Matter (CDM) paradigm predicts the presence of hundreds to thousands of subhalos, and thus potential satellite galaxies, around a Milky Way-sized galaxy. However, only about 60 Milky Way (MW) satellites have been identified to date—a discrepancy known as the missing satellites problem. While revised galaxy formation models and modifications to the CDM framework have been proposed as solutions, observational biases—such as the incompleteness in detecting faint or distant systems—may also play a role. Therefore, constraining the spatial distribution and total number of MW satellites through deep imaging surveys is crucial for testing these models.

In this context, we have conducted a dedicated search for MW satellites using Hyper Suprime-Cam (HSC) as part of the Subaru Strategic Program (SSP). Since 2015, our team has identified three satellite candidates [1,2,3], and in this work, we report the discovery of two additional candidates based on the latest internal data release [4]. These new satellites, Virgo III and Sextans II, are located at heliocentric distances of > 100 kpc and have absolute magnitudes of $M_V > -4.0$ mag (Figure 1). Including four previously known satellites within the HSC-SSP footprint (~1140 deg^2), all of which are recovered in our analysis, the total number of satellites identified reaches nine. This significantly exceeds the expected number (~3–5) predicted by the recent galaxy formation simulation for a Milky Way-sized host (Figure 2).

This apparent excess, indicating the "too many" satellites problem, may prompt a re-evaluation of satellite formation processes. However, given that the HSC-SSP footprint covers only ~2.8 % of the sky, the result is still limited by small-number statistics. Further confirmation from upcoming wide-area surveys is awaited. Nonetheless, our long-term project has made a significant contribution by alleviating the originally proposed missing satellites problem.

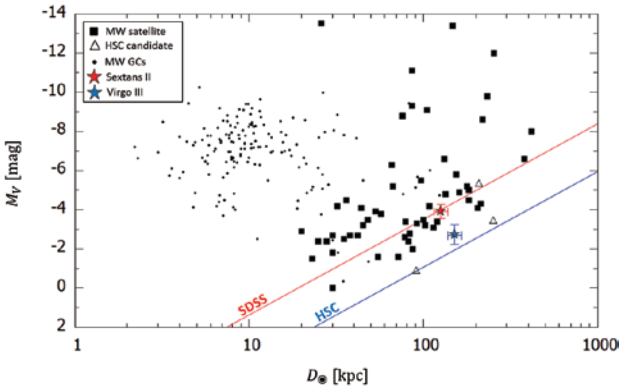

Figure 1: Relationship between absolute magnitude and heliocentric distance for Milky Way satellite galaxies (squares) and globular clusters (dots). The three satellite candidates discovered by Subaru/HSC by 2019 are shown as open triangles, and the two newly discovered candidates in this work are shown as stars. The blue and red lines indicate the detection limits of Subaru/HSC and the earlier large-scale survey (SDSS), respectively.

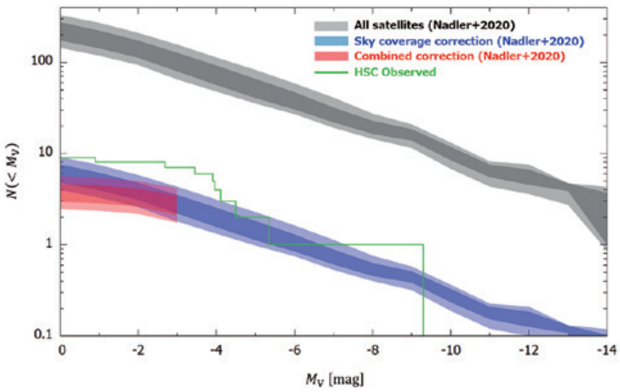

Figure 2: The black bands represent the cumulative luminosity function of satellite galaxies predicted by the recent galaxy formation simulation for a Milky Way-sized host. The blue bands correspond to the expected cumulative luminosity function for the HSC-SSP footprint (~1140 deg^2), while the red bands incorporate completeness corrections based on the detection limit of Subaru/HSC. The green line shows the observed cumulative luminosity function for the nine satellite candidates identified in the HSC-SSP survey.

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Spectroscopic Study of Heating Distributions and Mechanisms of Coronal Loops Using *Hinode*/EIS

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The solar corona is the outermost region of the solar atmosphere. Thermodynamically, it is expected that the temperature of the solar atmosphere decreases with distance from the core of the Sun (approximately 16 million K). However, in the actual Sun, the corona, located above the photosphere (the solar surface), is hotter than the photosphere (photosphere: 6,000 K, corona: over 1 million K). Therefore, it is believed that heating mechanisms exist in the corona, and various heating models have been proposed. In this study, we derive the relationship among the heating flux input into the coronal loops (structures where high-temperature plasma in the corona is confined within magnetic flux tubes connecting different magnetic poles; hereinafter referred to as 'loops') and their parameters determining the heating flux.

The electron temperature distribution $T_e(s)$ and the electron density distribution $n_e(s)$ along coronal loops are derived from spectroscopic observation data obtained by *Hinode*/EIS to estimate the heating distribution. We analyse eighteen loops, and their half-length L_{half} are 24–107 Mm. The coronal bottom magnetic field is approximated as a constant multiple of the average value of the photospheric magnetic field beneath the coronal loops obtained from the *SDO*/HMI data, averaged over a 5 Mm × 5 Mm region. From one-dimensional hydrostatic numerical calculations, which assume a heating distribution where the basal heating rate E_0 at the transition region height decreases toward the top of the loop with a scale length s_H, the approximate solutions for $T_e(s) \cdot n_e(s)$ are derived [1]. By comparing them with the observed $T_e(s) \cdot n_e(s)$, we estimate $s_H \cdot E_0$ using Bayesian analysis. Additionally, we investigate the heating mechanism using the power-law relationship $F_H \propto B_{\mathrm{base}}^{\beta} L_{\mathrm{half}}^{\lambda}$, where F_H is the heating flux obtained by integrating the heating distribution along the loop length, B_{base} is the magnetic field at the corona base which is the energy source for heating, and L_{half} is the loop half-length which determines the spatial scale where energy is input.

The results of the analysis show that the scale length of the heating distribution is $s_H = 10 \pm 4$ Mm, the base heating rate is $E_0 = 10^{-2.0\pm0.5}$ erg cm^{-3} s^{-1}, and the heating flux is $F_H = 10^{7.0\pm0.4}$ erg cm^{-2} s^{-1}. These loops show $s_H/L_{\mathrm{half}} = 0.21 \pm 0.07$, suggesting that heating is concentrated near the lower part of the loops. Compared to previous studies using imaging data [2,3], s_H is similar, but E_0 and F_H are about one order of magnitude larger. This is likely due to the electron density being underestimated when using imaging data, resulting in underestimation of E_0 and F_H. Additionally, we find $\beta = 1.04^{+0.18}_{-0.36}$ and $\lambda = -0.99^{+0.04}_{-0.05}$ which show that the reconnection heating model [4] is the most plausible [5].

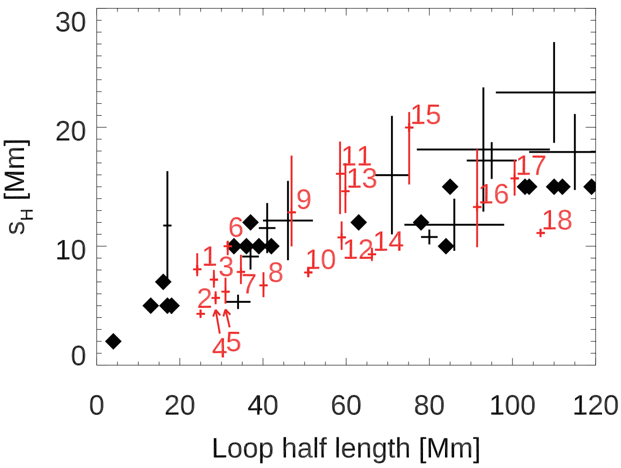

Figure 1: Relationship between s_H and L_{half}. The red vertical bars indicate the 95 % credible intervals of the probability distribution of s_H for the 18 loops indicated by numbers. The black crosses are s_H obtained from [2] with an error of 1σ. The diamonds are s_H obtained from [3].

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Cluster Candidates with Massive Quiescent Galaxies at $z \sim 2$

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In the local Universe, red galaxies are predominantly found in galaxy clusters, while blue galaxies are more commonly located in the field (e.g., [1]). This color–density relation suggests that the environment plays a significant role in galaxy formation. However, how and when the environment plays a role in galaxy formation (environmental effect) remains unclear. One approach to understanding the environmental effects is to search for galaxy clusters at high redshift Universe. Currently, the redshift records of confirmed mature clusters are at $z \sim 2$. In this study, we search for galaxy cluster candidates at the frontier redshift of $z \sim 2$ in the XMM-LSS field and investigate environmental effects at this epoch [2].

We construct a photometric redshift catalog based on deep multiwavelength imaging data ranging from the u^* to the K band, compiled from the Hyper Suprime-Cam Subaru Strategic Program [3], CLAUDS [4], and VIDEO [5] surveys. Photometric redshifts, stellar masses, and star formation rates are derived using a Bayesian spectral energy distribution fitting code ([6]). From this catalog, we select massive ($M_* > 3 \times 10^{10} M_\odot$) and quiescent (specific star formation rate $< 10^{-10}\,\mathrm{yr}^{-1}$) galaxies. We identify overdensities of such galaxies at $z \sim 2$ using a Gaussian kernel density estimation method. This analysis yields seven significant overdensities of massive quiescent galaxies, which we interpret as candidate galaxy clusters at this redshift. These candidates exhibit spatial and redshift concentrations within a projected radius of 0.5 physical Mpc and a redshift range of $\Delta z = \pm 0.2$. In addition, they show red sequences in the color–magnitude diagrams ($z - H$ versus H), consistent with the presence of evolved galaxies. One candidate (CL1; Figure 1) exhibits extended X-ray emission in the XMM-Newton data [7], suggesting that the system is evolved and virialized. The virial mass, estimated from the X-rays, is $M_{200} = (7.75 \pm 1.15) \times 10^{13} M_\odot$. We define r_{200} as the radius within which the mean interior density is 200 times the critical density of the Universe at the cluster redshift. M_{200} is the mass within r_{200}.

We investigate the environmental effects at $z \sim 2$ using the mature cluster candidates. We calculate the quiescent fraction and find that it is higher in the cluster candidates compared to that in the field. The excess of the quiescent fraction is higher for higher-mass galaxies, indicating the mass-dependent environmental quenching in the massive clusters even at this redshift of $z \sim 2$.

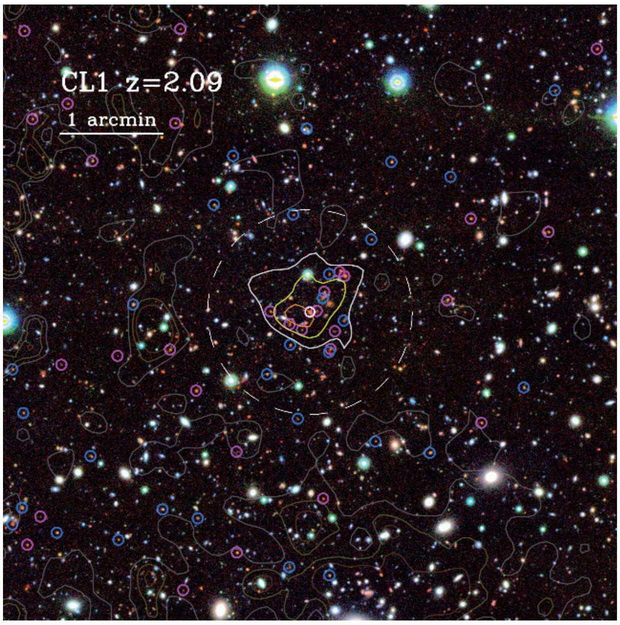

Figure 1: Pseudocolor image of CL1, one of the cluster candidates at $z = 2.09$ (blue: Hyper Suprime-Cam/z band, green: VIRCAM/J band, red: VIRCAM/K_s band). The spatial concentration of massive quiescent galaxies (red circles) is clearly shown. The blue circles show massive star-forming galaxies. The contours show the extended X-ray emission (0.5–2 keV of XMM-SERVS; [7]) at 1σ (white), 3σ (yellow), 5σ (orange). The white dashed line indicates a circle with 1 arcmin radius from the central galaxy of CL1 [2].

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Role of Magma Oceans in Controlling Carbon and Oxygen of Sub-Neptune Atmospheres

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Planets with radii between Earth and Neptune ("sub-Neptunes") are among the most common types of exoplanets [1]. Their sizes exceed those of bare-rock cores, implying substantial volatile contents. However, the mass–radius relation alone cannot distinguish between a thin atmosphere over an icy core and a rocky (magma) core with a thick H–He layer [2]. Atmospheric spectroscopy is essential to resolve this degeneracy.

Previous studies have shown that the chemical reactions between a molten silicate core (magma) and the atmosphere strongly affect the atmospheric composition [3], which implies the atmospheric feature can give the clues to the interior. However, the quantitative analyses of a wider range of elements (e.g., Carbon) and the dependence on planetary parameters are still underexplored. Motivated by this situation, we explored the dependence of atmospheric O/H-C/O ratio trend on various planetary parameters (e.g., magma properties) of magma-bearing sub-Neptune using atmosphere-magma chemical equilibrium model (Figure 1).

We confirmed that magma - atmospheric reactions drive atmospheric H_2O mole fractions to 1 % – 10 % when the magma is fully molten with Earth-like composition, which is consistent with the previous studies. Despite H_2O's much higher solubility in silicate melt compared to carbon species, we find that the atmospheric C/H ratio remains within only a few times the bulk (solar) value. As a result, a silicate core produces a strong negative O/H–C/O correlation, depleting C/O to below 10 % of the solar value if the magma is sufficiently oxidized (Figure 2). This feature can provide a piece of evidence of rocky core and endogenic water formation [4].

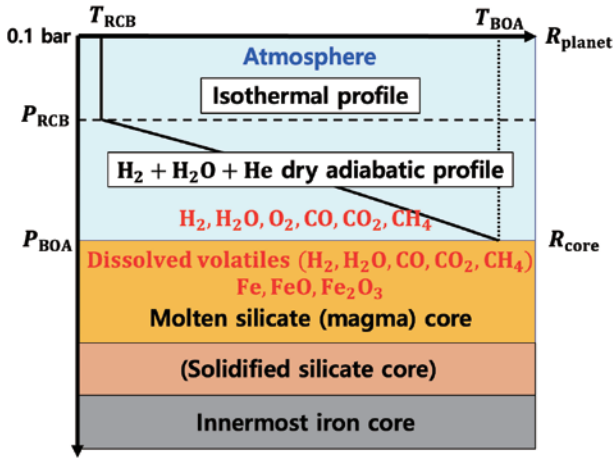

Figure 1: The schematic figure of our model. The black line illustrates the atmospheric temperature–pressure profile. Chemical species involved in reactions are written in red. The RCB stands for the Radiative-Convective Boundary, while the BOA denotes the bottom of the atmosphere.

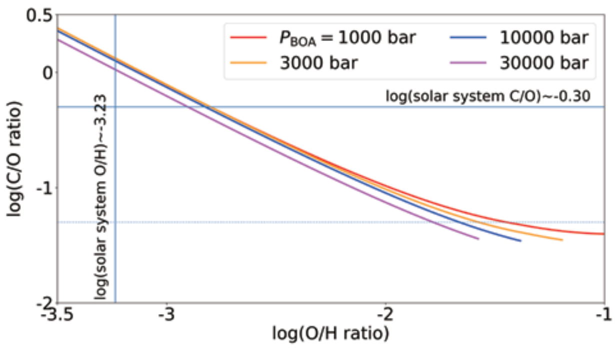

Figure 2: The trend between atmospheric O/H and C/O ratios. Different colors represent different surface pressures. The blue vertical and horizontal lines denote the solar values of O/H and C/O, which was used as input. A dotted horizontal line marks 10 % of the solar C/O.

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Analyses of Multiple Balmer Emission Lines from Accreting Brown Dwarfs and Very Low Mass Stars

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A planetary growth rate, i.e., the mass accretion rate, is a fundamental parameter in planet formation, as it determines a planet's final mass. We evaluated two models for the accretion flow model, which attributes hydrogen line emission to the accretion flow, and the accretion shock model, which links emission to the shock region [1]. These models can yield significantly different mass accretion estimates, especially for low accretion rates, making it crucial to determine the dominant mechanism for planetary-mass objects. One diagnostic for determining the emission mechanism is the hydrogen line ratio [2,3].

Applying both models to 96 archival data points for 76 accreting brown dwarfs and very low-mass stars (0.02–0.1 $M_\odot$), we analyzed 89 data points. Of these, 15 aligned with the shock model, 55 with the flow model, 13 showed characteristics of both, and 6 fit neither. For the 15 shock-model cases, estimated accretion rates were up to one to two orders of magnitude higher than those from the flow model, particularly for planetary-mass objects.

Additionally, while the accretion flow model shows increasing emission line luminosity with decreasing mass, the shock model shows the opposite trend. No clear boundaries between the two models were identified based on physical parameters like accretion rate or luminosity. High-resolution spectroscopy (R > 10,000) could help distinguish between the two mechanisms, though available data remain limited. Variability in emission mechanisms was also observed in some sources over time, though the cause remains unclear.

Overall, while the accretion flow model is more prevalent in brown dwarfs and very low-mass stars, the shock model is applicable in some cases, suggesting both models may also apply to planetary-mass objects. As a result, emission line fluxes can vary even for the same accretion luminosity, implying that the mass accretion rate depends on whether the accretion-flow or the shock model is used. Further observations are needed to better understand the accretion processes in planetary-mass objects.

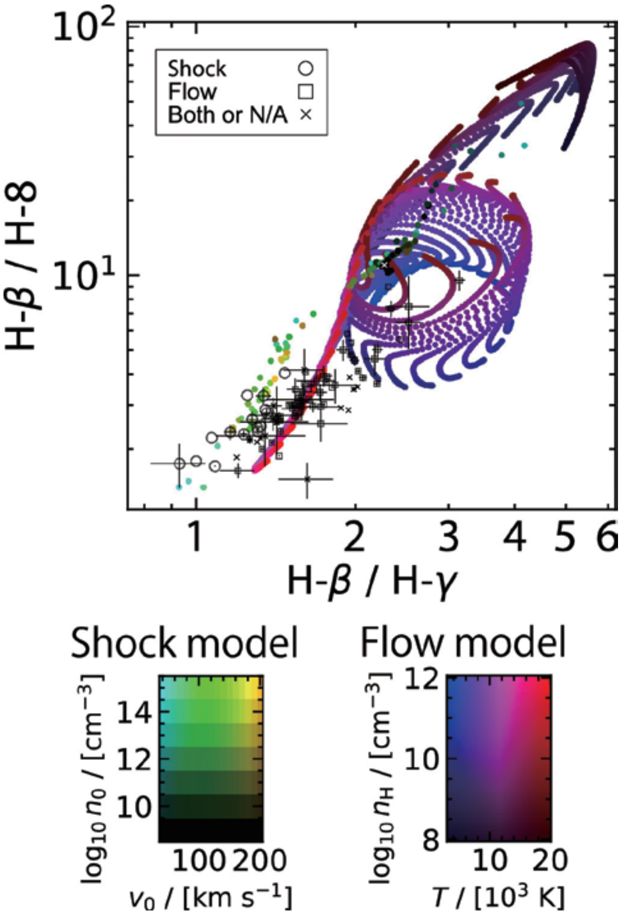

Figure 1: Out of the 96 data points, 89 were analyzed for line ratios in the H-β/H-γ vs. H-β/H-8 diagram, with 7 points excluded due to dominant contributions from stellar chromospheric activity. These 89 data points are plotted against the loci of the shock and flow models. The data are categorized as follows: 15 points are identified as shock-dominated emission (circles), 55 points as flow-dominated emission (squares), 13 points as fitting both models (crosses), and 6 points as not fitting either model (crosses).

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Carbon Isotope Fractionation of Complex Organic Molecules in Star-Forming Cores

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We investigated the carbon isotope fractionation of Complex Organic Molecules with six or more atoms (COMs) [1] from prestellar cores to protostellar cores by combining the chemical network model and the radiation hydrodynamical simulation [2]. The temporal variation of the molecular abundances and $^{12}C/^{13}C$ ratios were calculated by conducting calculations of a gas-grain chemical network within a single fluid parcel.

In the static prestellar phase, due to the carbon isotope exchange reactions, the molecules formed from atomic C and C^+ were depleted in ^{13}C, while the molecules formed from CO were around 10 % enriched in ^{13}C at the end of the static phase. COMs also showed carbon isotope fractionation depending on the fractionation of their reactants.

While in the collapse phase, after the protostar formation, where species are sublimated to the gas phase, the $^{12}C/^{13}C$ ratios of some sublimated species (e.g., CH_4 and CH_3OH) reflected those of their icy counterparts. On the other hand, the $^{12}C/^{13}C$ ratios of other species are affected by chemical reactions during the collapse phase. Some COMs (e.g., CH_3CHO) were formed on warm grain surfaces during the collapse phase as much as in the static phase. As a result, the $^{12}C/^{13}C$ ratios of these COMs were different from those of their icy counterparts formed in the static phase. In addition, some COMs (e.g., CH_3OCH_3) were formed in the warm gas phase after water ice sublimation, which also affects their carbon isotope ratios. Eventually, in our base model, some complex molecules (e.g., CH_3CHO and CH_3OCH_3) become more depleted in ^{13}C compared to the observations.

Additionally, we incorporated the direct C-atom addition reactions into our base model and investigated the effect of these reactions on the formation and the $^{12}C/^{13}C$ ratios of COMs (Figure 1).

The direct C-atom addition reactions suppressed the diversity of the carbon isotope fractionation and led to the production of molecules depleted in ^{13}C in the base model, exhibiting reduced fractionation. Our results reproduced the observations of the $^{12}C/^{13}C$ ratios of some complex molecules including COMs (CH_2CO, CH_3CHO, and HCOOH) in the Class 0 source, IRAS16293-2422B, which were comparable to the elemental $^{12}C/^{13}C$ ratio in the local Interstellar Medum [3]. However, CH_3OCH_3 in our results still shows depletion of ^{13}C compared to the observations. This study [4] demonstrates for the first time that the formation pathways of complex organic molecules, believed to be formed in the gas phase and on dust grain surfaces during the protostellar stage, can be constrained using carbon isotope ratios.

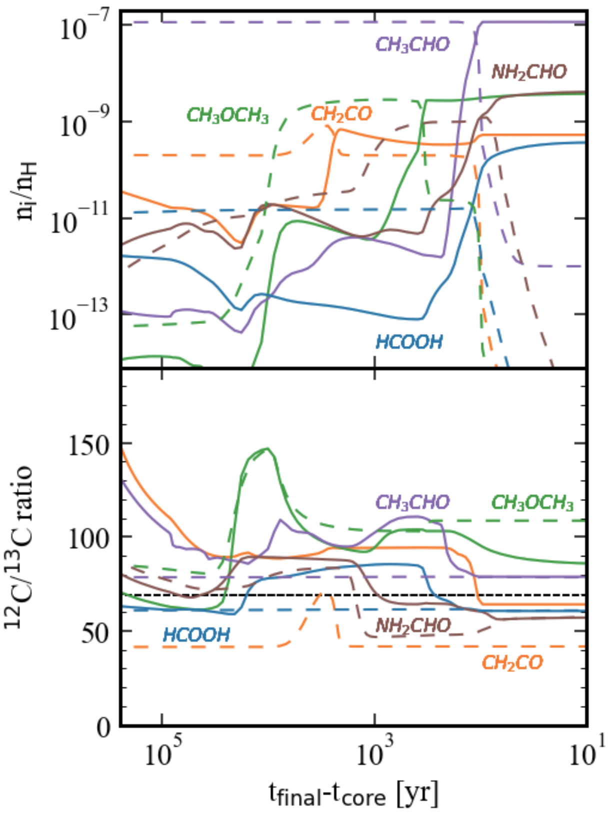

Figure 1: Temporal variation of the molecular abundances and $^{12}C/^{13}C$ ratios for gaseous species (solid lines) and icy species (dashed lines) during the collapse phase with the direct C-atom addition reactions. The horizontal black dashed line represents the average $^{12}C/^{13}C$ ratio of local ISM.

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Quantification of Propagation Modes in an Astronomical Instrument from Its Radiation Pattern

YAMASAKI, Yasumasa[1], IMADA, Hiroaki[1]

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A radio telescope consists of an antenna that collects radio waves from celestial objects, an optical system (mirrors and lenses) that guides the collected radio waves to a detector, a trumpet-shaped feed that couples the guided radio waves into a metal tube (waveguide) within the detector, and a detector that converts the radio waves into electrical signals (Figure 1). A wideband device refers to an instrument capable of observing a broad range of radio frequencies with a single receiver system. While such wideband capability is increasingly demanded in modern radio telescopes, it can also introduce instrumental effects that potentially degrade measurement accuracy. For example, it was reported that the instrument installed in MeerKAT —the precursor to the large-scale, next-generation centimeter-wave interferometer project SKA-Mid— had an error in its beam pattern (i.e., the spatial distribution of its sensitivity to radio waves) derived from the instrument itself [1]. These errors were attributed to misalignments at the junctions between the feed and the waveguide, which distorted the electromagnetic field distribution of radio waves within these components [2].

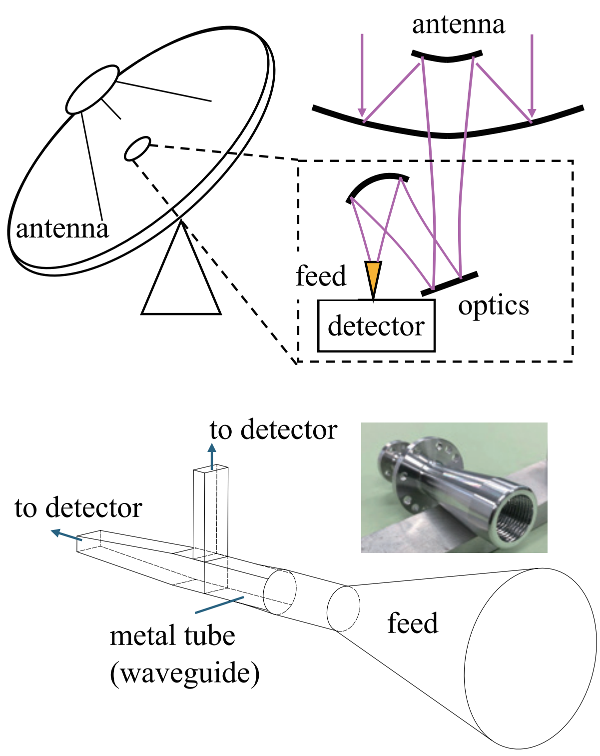

Figure 1: Conceptual drawing of a device for a radio telescope.

Reducing instrument-induced errors is crucial for ensuring observational data quality. However, directly measuring internal disturbances in feeds or waveguides is challenging, as their small size (millimeters to hundreds of micrometers) and the probes can alter the internal field. To address this, we developed a method to estimate the internal field distribution from externally measurable feed beam patterns [3]. Simulations showed that this method achieves an accuracy of 10^{-6} in amplitude and 10^{-3} degrees in phase.

This method is broadly applicable to radio telescope instruments as long as the system is linear. For instance, feed beam measurements can reveal misalignments at the feed?waveguide junction. Figure 2 shows how a positional offset dx at the interface excites unwanted waveguide modes, distorting the internal field and altering the beam pattern. Our method quantifies such distortions from beam measurements, enabling estimation of the misalignment's direction and displacement. This aids in alignment, ensures beam accuracy, and can also support feed design [3].

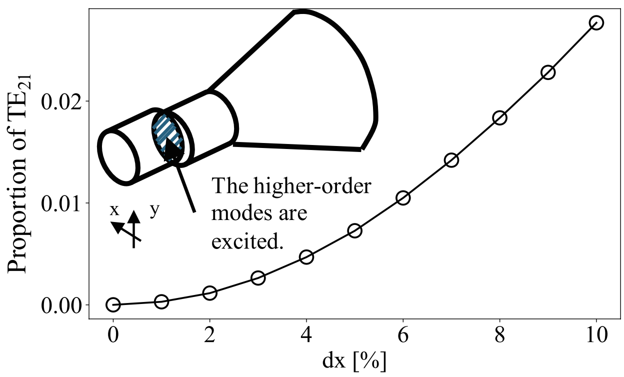

Figure 2: Simulation of the proportion of the higher-order waveguide mode TE_{21}. The dx represents the offset in the x-direction normalized by the waveguide diameter. ©2024 IEEE

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A Massive Quiescent Galaxy in a Group Environment at $z = 4.53$

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Massive quiescent galaxies at $z \sim 4$ are likely progenitors of massive elliptical galaxies in the local Universe [1]. They have been the subject of many recent papers to constrain the physical drivers to stop their star formation activities (quenching). To date, only a few massive quiescent galaxies at $z \sim 4$ are spectroscopically confirmed [2], and the detailed physics of their quenching mechanisms is still unclear. Especially, the connection between galaxy quenching and the environment at this frontier redshift remains completely unexplored.

The authors report on the spectroscopic confirmation of a massive quiescent galaxy at $z = 4.53$ in the COSMOS field [3]. The galaxy is first selected as a quiescent galaxy candidate at $z > 4$, which has ceased its star formation activity, based on the COSMOS2020 photometry catalog [4]. The spectroscopic follow-up observation with Keck/MOSFIRE reveals a strong Balmer break feature, indicating an evolved stellar population. In addition, faint [O II] emission line allows us to constrain the spectroscopic redshift of this galaxy ($z_{\mathrm{spec}} = 4.5313$, Figure 1).

We constrain the physical properties of this quiescent galaxy by fitting the spectral energy distribution (SED) using both photometry from COSMOS2020 and the spectrum from MOSFIRE. The obtained stellar mass is massive ($M_* \sim 10^{10.8} M_\odot$), and the current star formation rate (SFR) is more than 1 dex below the star-forming main sequence. The star formation history (SFH), which shows the relation between galaxy age and SFR, suggests that the galaxy experienced rapid quenching since $z \sim 5$ (200 million years before the observation). In this study, we utilize two models of SFH (Parametric SFH, which is called ‘Delayed-tau model’, assuming the SFR declines exponentially as a function of galaxy age, and Non-parametric SFH, which constrains the stellar mass as a function of galaxy age) to ensure consistency of SFH constraints. Based on these SFHs, this galaxy is one of the youngest quiescent galaxies confirmed so far at $z > 3$ with $z_{\mathrm{form}} \sim 5.2$.

The unique feature of this quiescent galaxy is that it is located in a dense region of galaxies on a very small scale. Based on the photo-z catalog in COSMOS2020, there are four massive star-forming galaxies within 150 kpc from the quiescent galaxy. Intriguingly, the virial radius of 3 of 4 galaxies strongly overlaps the virial radius of the quiescent galaxy. This suggests that the galaxy over-density is the highest-redshift galaxy group with a quiescent galaxy. Furthermore, the galaxy group and companion galaxy suggest that environmental effect has a role in quenching of massive galaxies at $z \sim 4$ and are important objects to understand the effect of the local environment for the formation of massive quiescent galaxies at this frontier redshift.

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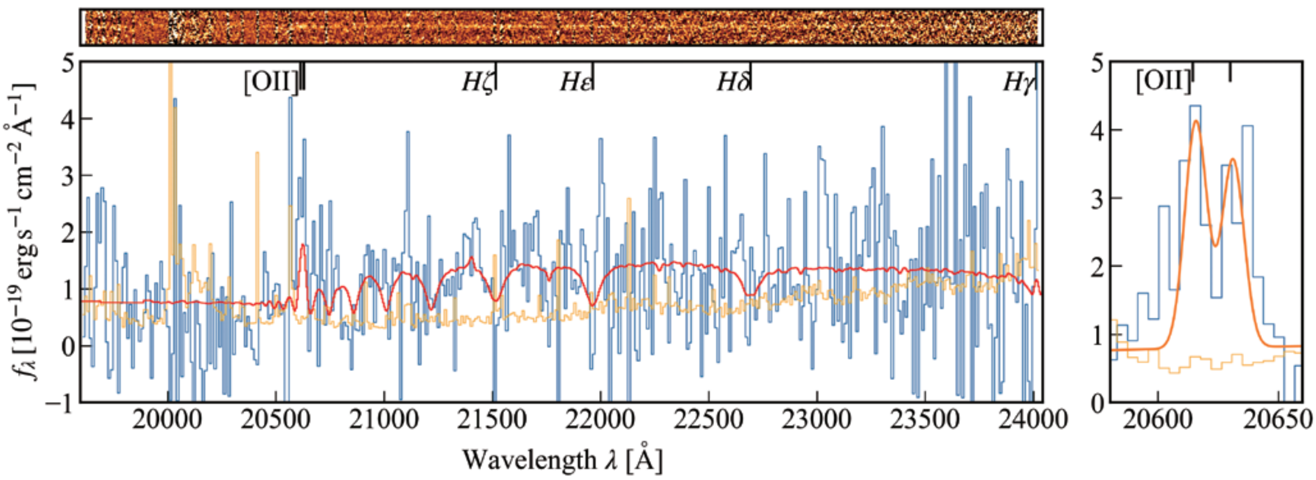

Figure 1: Keck/MOSFIRE *K*-band spectrum and [O II] emission profile. The blue line shows the 1-dimensional spectrum of the quiescent galaxy, and the yellow line is the error spectrum. The red line represents the best-fit model spectrum from the SED fitting analysis. The orange line shows the model by fitting the [O II] line doublet profile using a double Gaussian.

Aperture Efficiency Calculation of Multi-beam Axisymmetric Dual-Reflector Antenna of Cassegrain Type

NAGAI, Makoto[1], IMADA, Hiroaki[1]

1: NAOJ

Next-generation radio telescopes in the field of millimeter-wave to THz astronomy are desired to have high imaging capability with focal plane arrays, and to be a multi-beam antenna. As the number of beams of an antenna corresponds to the number of pixels of a camera, multi-beam antennas enable us to observe a wider field of view simultaneously. Since the design of traditional radio telescopes is based on methods to treat a single pencil beam, design of a multi-beam radio telescope is a new challenge. The aperture efficiency is one of the import figure-of-merits of such radio telescopes. For the ideal case where the incident plane wave perfectly couples with a receiver beam of the fundamental Gaussian mode at a circular aperture, an analytical expression of the aperture efficiency is well-known, even with a subreflector blockage [1]. The condition that the subreflector blockage becomes minimum is called the minimum blockage condition (MBC) for a single-beam system, but a corresponding condition for a multi-beam system was not clear. Thus, we derived a multi-beam MBC for a dual-reflector antenna, and proposed a design procedure to obtain a realistic and almost best configuration [2]. Using with the formalism of the aperture efficiency of a general dual-reflector antenna [3], we can calculated the aperture efficiency of the configuration. The efficiency factors of an axisymmetric dual-reflector antenna of Cassegrain type are explicitly derived in [2].

We consider an axisymmetric Cassegrain antenna (Figure 1). Its beam path is filled by several beams as shown in Figure 2 Multi-beam MBC is expressed with the filling factors k_{bm}, k_{s}, and k_{f}, the aperture efficiency of the whole antenna η_{ap}, and the aperture efficiency of the feed $\eta_{\mathrm{df,ap}}$, based on the fundamental relation of antenna. The minimum size of the subreflector of an efficienct telescope is almost determined by the telescope optics, given as

$$D_{\mathrm{s}}^{\mathrm{min}} \simeq \sqrt{\phi_{\mathrm{FoV}} L_{\mathrm{s}} D_{\mathrm{m}}} \qquad (1)$$

where φ_{FoV} is the FoV radius. We can calculate the ideal efficiencies of a system which satisfies the condition for a given φ_{FoV} value (Figure 3).

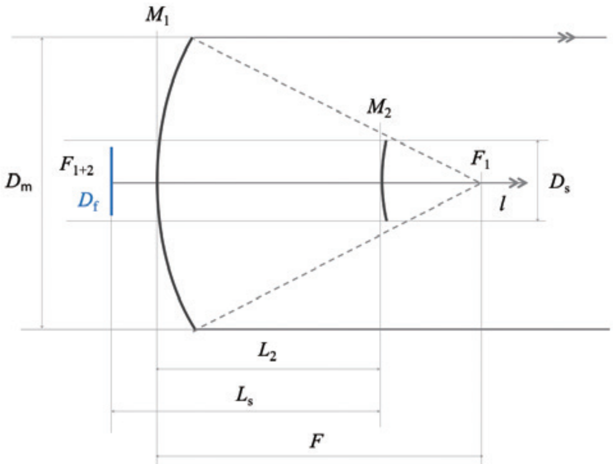

Figure 1: Antenna considered and its parameters. The main reflector and subreflector is denoted as M_1 and M_2, main reflector's focus F_1, the composite focus F_{1+2}, and the focal plane diameter D_{f}.

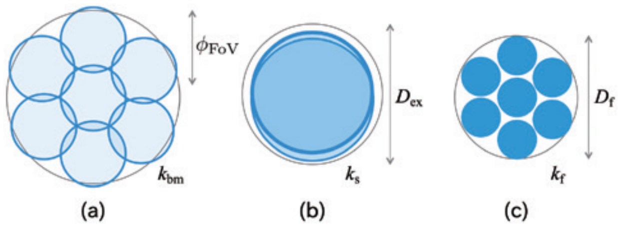

Figure 2: Beam cross sections of a multi-beam telescope. Left) On the sky. (Middle) On subreflector. (Right) Focal plane. Their filling factors are k_{bm}, k_{s}, and k_{f}, respectively.

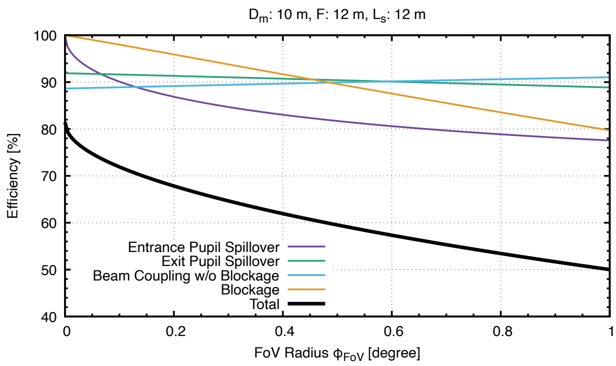

Figure 3: Plot of efficiency factors vs FoV radius as an example.

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High-Time-Cadence Spectroscopy and Photometry of Stellar Flares on M-dwarf YZ Canis Minoris with Seimei Telescope and TESS. I. Discovery of Rapid and Short-Duration Prominence Eruptions

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In recent years, M-dwarfs are considered as prime targets for the search for habitable planets. On the other hand, M-dwarfs show frequent flares. The XUV radiation from flares and coronal mass ejections (CMEs) associated with flares may significantly affect the habitability of close-in planets. Some M-dwarf flares show red or blue asymmetries in the Hα line profile, which are thought to be signatures of prominence eruptions—an early stage of CMEs (e.g., [1]). However, high-time-cadence spectroscopic observations of such phenomena are still limited.

We conducted spectroscopic monitoring of the active M-dwarf YZ Canis Minoris using the Seimei Telescope with an unprecedented cadence of approximately one minute over 12 nights, simultaneously with optical photometric observations by the Transiting Exoplanet Survey Satellite (TESS). We detected 27 Hα flares with Hα energies ranging from 1.7×10^{29} to 3.8×10^{32} erg and durations from 8 to 319 minutes. Among them, we identified 3 blue asymmetry and 5 red asymmetry events. The maximum velocity of the blue- and red-shifted components ranges from 250 to 450 km s^{-1} and 190 to 400 km s^{-1}, respectively. Figure 1 shows a representative blue asymmetry event showing the fastest velocity of 450 km s^{-1} observed in this study. The time evolution of blueshifted components is fast, occurring within ~5 minutes.

In particular, we discovered rapid, short-duration blue asymmetry events suggesting prominence eruptions, with durations of < 20 minutes and velocities of 300–500 km s^{-1}, as shown in Figure 2. These events are thought to be the shortest-duration stellar prominence eruption events ever reported, which could not have been detected with previous spectroscopic observations due to insufficient time resolution. Our discovery suggests that previous studies may have underestimated the frequency of prominence eruptions and CMEs on M-dwarfs, which are important for evaluating planetary habitability [2].

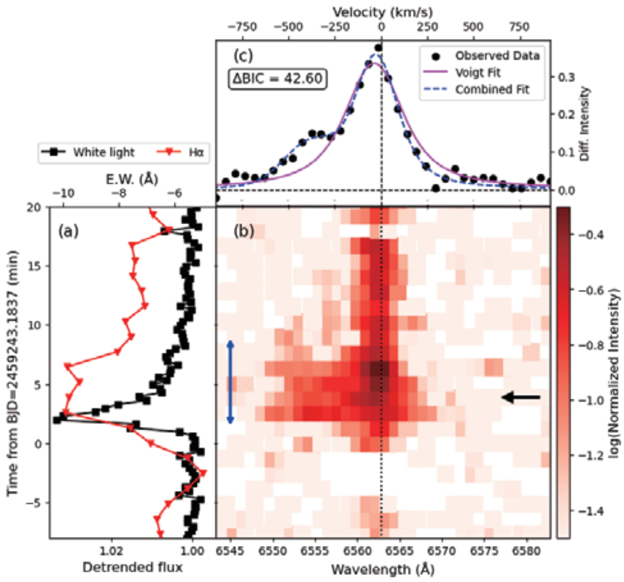

Figure 1: (a) Light curves of the flare. (b) Time evolution of the Hα line.(c) Pre-flare-subtracted Hα line profile at flare peak.

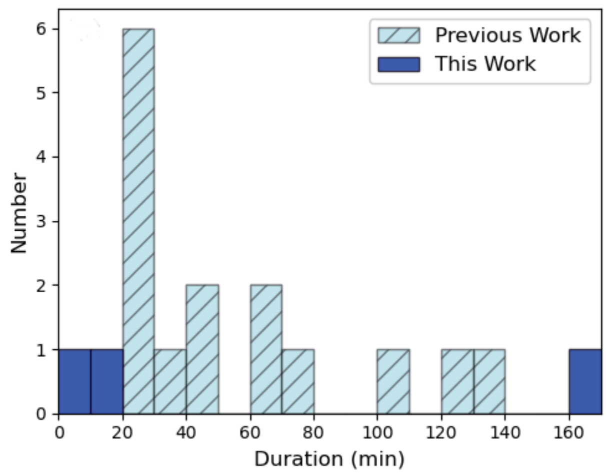

Figure 2: Event duration histogram of blue asymmetries.

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Detection of the Shallow Population in the Outskirts of the Triangulum Galaxy

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Galaxies are thought to grow through mergers and accretion events (e.g., [1]). The remnants of such interactions are preserved in the outer region as a stellar halo. In massive spiral galaxies such as the Milky Way and the Andromeda galaxy, the properties of stellar halos have been studied, so far (e.g., [2]). In contrast, for intermediate-mass galaxies even the detection of stellar halos remains largely unaccomplished.

One of the primary challenges in identifying stellar halos is their intrinsically faint and diffuse nature. Due to their low surface brightness, deep imaging is required to detect these structures. Furthermore, their faintness makes them highly susceptible to foreground contaminants and background sources.

In this study, we aim to detect and characterize the stellar halo of the nearby intermediate-mass spiral galaxy, M33 (Triangulum Galaxy), utilizing multi-band imaging data obtained with the Subaru Telescope/Hyper Suprime-Cam (HSC) [3]. The observations targeted the western region of M33 and employed three broad-band filters (g, r_2, i_2) and a surface gravity sensitive narrow-band filter (*NB515*). The combination of the three broad-band filters enabled the removal of background objects, while the addition of *NB515* facilitated the efficient elimination of foreground stars.

Using the stars selected as the M33 population, we construct a radial number density profile (see Figure 1) and perform model fitting. The selected population is found to include a component following a power-law with a relatively shallow slope of $\alpha > -3$ (blue line in Figure 1). Such a profile is observationally and theoretically known to describe stellar halos well, providing compelling evidence for the presence of a stellar halo in the outer regions of M33.

Although a halo-like outer structure has been identified in M33, the inferred power-law slope characterizing this component differs somewhat from those typically observed in the stellar halos of more massive galaxies such as the Milky Way. Stellar halos around large spiral galaxies generally exhibit steep radial density profiles with power-law indices of $\alpha < -3.5$. In contrast, the structure detected around M33 displays a significantly shallower gradient, suggesting the presence of an extended, diffuse stellar component - "shallow" halo.

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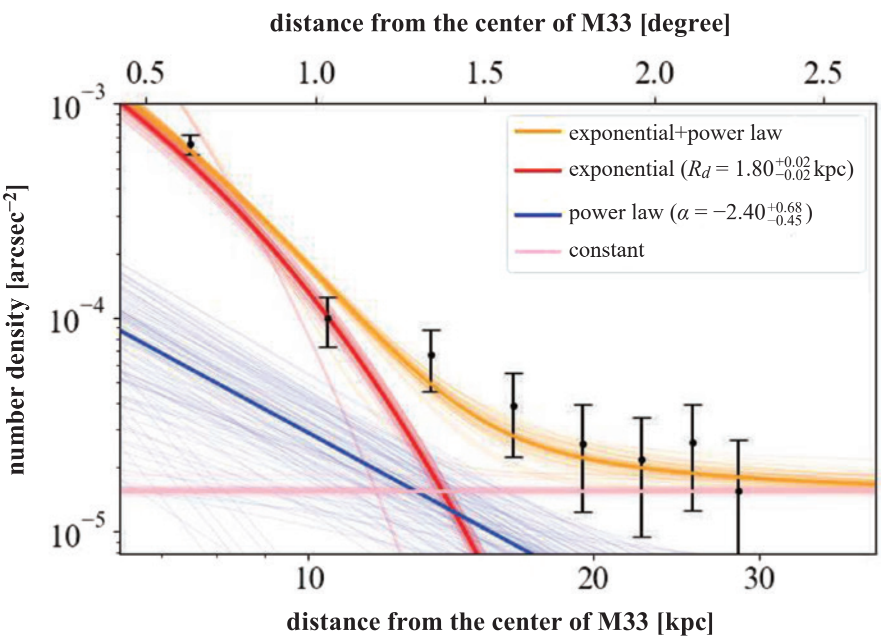

Figure 1: Radial number density profile of selected M33 halo stars. The black points represent the observed data. Colored lines indicate the best-fitting components derived via Markov Chain Monte Carlo (MCMC) modeling: an exponential profile for the galactic disk (red), a power-law profile for the stellar halo (blue), a constant background level accounting for residual contaminants (pink), and the sum of all components (orange).

The Nature of the Stellar Halo of the Andromeda Galaxy Explored by Subaru/HSC NB515. I.

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The stellar halo serves as valuable information for understanding galaxy formation. In the ΛCDM paradigm, massive galaxies are thought to grow through hierarchical mergers with small systems. Evidence for this process remains imprinted in the halo in the form of streams.

The Andromeda galaxy (M31), the nearest massive spiral galaxy, offers an exceptional laboratory for testing the galaxy formation theory. Owing to its proximity, M31 can be resolved into individual stars. Indeed, widefield imaging surveys revealed a wealth of substructures (e.g., [1]). However, deriving their properties has been challenging due to foreground contaminants, which overlap spatially with the M31 stars.

To mitigate this problem, a narrow-band filter sensitive to stellar surface gravity, NB515, was developed for use with the Hyper Suprime-Cam (HSC) on the Subaru Telescope. *NB515* enables efficient separation of M31 stars from foreground stars based on the *NB515* flux. As a result, M31 stars and foreground stars occupy distinct loci in the *NB515*-coporated color.color diagram (see left panel of Figure 1), allowing for accurate classification and analysis of halo populations.

We conducted a large-scale survey of the M31 halo using the HSC/*NB515*, with the aim of characterizing the structure and properties of the M31 halo in greater detail than previous studies [2]. By examining the spatial distribution of *NB515*-selected halo stars, we have identified three previously unknown substructures (see right panel of Figure 1).

An analysis of the distance gradients, luminosity functions, and metallicities of the newly discovered structures have revealed that they share similar metallicities with known giant tidal streams. Furthermore, the spatial configurations of these features are consistent with predictions from theoretical simulations [3], suggesting that a dwarf galaxy accretion event occurred within the past 2–3 Gyr. These findings imply that the inner regions of the present-day M31 halo are likely dominated by debris from such recent accretion events.

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† Affiliation at the time of publication: Johns Hopkins University

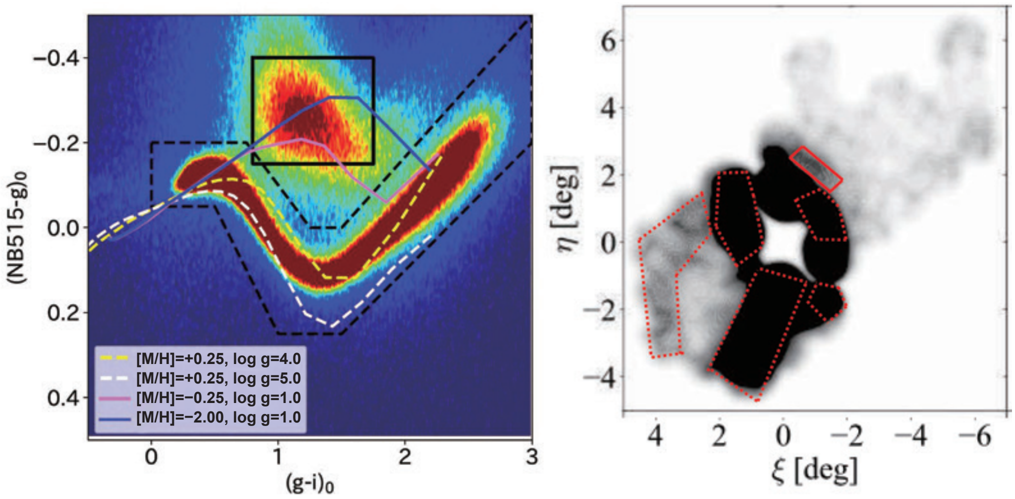

Figure 1: (Left): A color-color diagram with NB515. M31 halo stars (foreground stars) are distributed within the solid (dashed) black box. The solid blue and magenta (dashed yellow and white) lines represent the theoretical stellar loci with physical properties characteristic of M31 halo (foreground) stars. (Right): Spatial distribution of the metal-rich stars. M31 is located at the origin. Previously known halo substructures (one of the newly detected structures) are indicated by red dashed (solid) outlines.

Star Formation in the Extreme Outer Galaxy Revealed by JWST and Subaru

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1: NAOJ, 2: NASA-JPL, 3: NSF NOIRLab, 4: ASIAA, 5: SOKENDAI, 6: University of Tokyo

The extreme outer Galaxy (EOG) is known to have significantly different from the solar neighborhood. In particular, the metallicity of the EOG is about one-fifth to one-tenth that of the solar neighborhood. Such environments may have characteristics similar to those of dwarf galaxies, and to our Galaxy during the early phases of its formation, in particular, in the thick disk formation phase. To reveal star-formation mechanism in such primordial environments, we have been investigating the discovery and properties of star-forming regions in the EOG. In particular, near-infrared imaging observations using the Subaru Telescope have detected numerous young stars, with a detection limit mass of approximately 0.1 $M_\odot$ (e.g., [1]) The main findings from the Subaru Telescope data include that the slope of the initial mass function is consistent with values verified in the solar neighborhood, but the lifetime of protoplanetary disks is estimated to be shorter than previously thought in the solar neighborhood (e.g., [2]).

To investigate the properties of star formation in the EOG more in detail, we conducted near- to mid-infrared (1–21 μm) imaging observations toward 4 star-forming regions discovered by Subaru telescope using the James Webb Space Telescope (JWST). These observations were proposed by Michael E. Ressler of JPL, who was interested in the above research results, and conducted using GTO time allocated to him. The JWST observations achieved sensitivity 10–80 times higher than our Subaru Telescope observations in the near-infrared (NIR) and 6–13 times higher than previous Spitzer Space Telescope observations in the mid-infrared (MIR). The detection limits were approximately 0.01 $M_\odot$ in the NIR and 0.1 $M_\odot$ in the MIR (Figure 1). As a result, we successfully detected not only numerous low-mass stars but also Class 0 candidates, outflow/jet components, and distinctive nebular structures (Figure 2, [3]).

These data will enable us to investigate the properties of star formation in the EOG at the same depth of detail as previous observations of star formation in the solar neighborhood for the first time. We will continue our analysis to clarify the star formation mechanisms in the EOG.

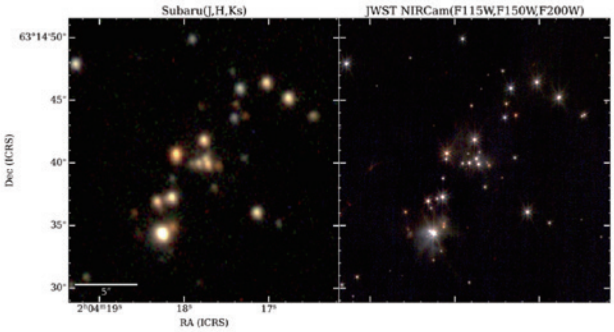

Figure 1: Example of IR pseudocolor image of star-forming region detected by Subaru (left: J, H, and K bands) and JWST (right: F115W, F150W, and F200W filters).

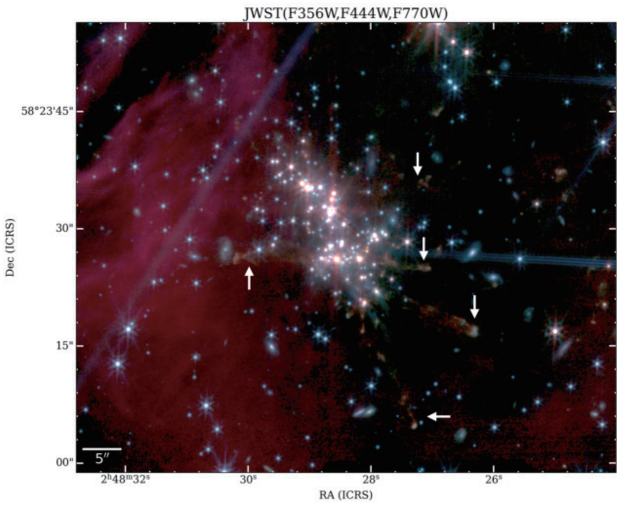

Figure 2: Example of IR pseudocolor image of outflow and jet components detected by JWST (F356W, F444W, and F770W filters). The white arrows indicate the positions of the possible outflow or jet components.

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HST/WFC Grism Observation Reveals Quiescent Galaxies in a Cosmic Noon Protocluster

NAUFAL, Abdurrahman[1/2], KOYAMA, Yusei[1/2]

1: The Graduate University for Advanced Studies, 2: NAOJ

We present deep *Hubble Space Telescope* (*HST*) WFC3 G141 grism slitless spectroscopy of the core region of the Spiderweb protocluster at $z = 2.16$, targeting a $2' \times 2'$ field to uncover and characterize its galaxy population in an unbiased manner [1]. Our analysis utilizes the full spectra of all detected objects with $H_{160} < 26$, applying a robust membership selection based on integrated redshift probability within $2.10 < z < 2.21$. This leads to the identification of 40 robust protocluster members, including 19 previously known Hα emitters (HAEs) [2] and 21 new members, along with 14 additional likely members.

A key result of our work is the spectroscopic identification of 11 quiescent galaxies within the protocluster, selected by their pronounced 4000 Å break. The median 4000 Å breaks of quiescent galaxies in our sample imply a recently quenched population (see Figure 1). Among these, three exhibit spectral features of quiescence but retain SED-inferred star formation rates near the main sequence, suggesting either residual or dust-obscured star formation. The overall fraction of quiescent galaxies with $M_* > 10^{11} M_\odot$ is found to be ~60 % in the core, about three times higher than that of the general field at comparable redshift and mass, highlighting accelerated galaxy evolution in the overdense environment.

Notably, approximately half of the quiescent population are found to host active galactic nuclei (AGN), identified through X-ray emission and/or [OIII]/Hα flux ratio. This high incidence of AGN among massive quiescent galaxies supports the role of AGN feedback as a dominant quenching mechanism in the protocluster.

We also investigated the structure of protocluster galaxies by fitting Sérsic profiles to the F160W imaging. Quiescent members are systematically more compact than star-forming galaxies at fixed stellar mass, lying below the late-type mass–size relation of field galaxies at $z = 2.2$. Their Sérsic indices are higher than star-forming galaxies but still in the intermediate range ($n \sim 1.5$–3), indicating the persistence of disk components and an incomplete morphological transition toward classical ellipticals. This suggests ongoing structural transformation, likely through minor mergers and secular processes, with the protocluster population representing progenitors of present-day cluster ellipticals. We note, however, that the observed structural difference between quiescent and star-forming galaxies may also be driven in part by stellar mass and progenitor bias, and caution is advised when interpreting the results.

In summary, our deep *HST* spectroscopy reveals a substantial population of massive, compact, quiescent galaxies in the Spiderweb protocluster at $z = 2.16$, many of which host AGN. The elevated quiescent fraction and AGN incidence underscore the accelerated assembly and transformation of galaxies in protocluster environments, offering a critical window onto the formation of cluster red sequences at cosmic noon.

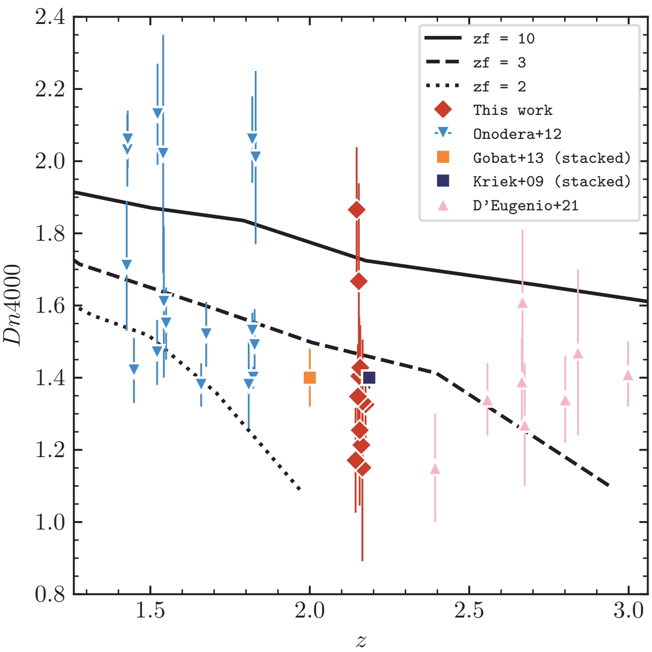

Figure 1: The 4000 Å break strengths of grism-selected quiescent galaxies in the Spiderweb protocluster (red diamonds) plotted as a function of the observed redshifts. Quiescent galaxies observed from other redshifts are also shown in this plot. Quiescent galaxies in our sample are consistent with a single stellar population model formed at redshift $z_f = 3$ indicating they are quenched recently.

References

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[2] Shimakawa, R., Koyama, Y., et al. 2018, *MINRAS*, **481**, 5630.

II Status Reports of Research Activities

01. Mizusawa VLBI Observatory

Mizusawa VLBI Observatory serves as Japan's national center for astronomical research using Very Long Baseline Interferometry (VLBI). In collaboration with Kagoshima University, it operates VERA, an array of four 20-meter radio telescopes. Additionally, Mizusawa VLBI Observatory integrates VERA and other domestic radio telescopes with observatories in the Republic of Korea and China to form the East Asian VLBI Network (EAVN), whose machine time is provided to the international community as an open-use facility. Through VLBI observations, the observatory conducts research on the structure of the Milky Way, maser sources, and active galactic nuclei. Furthermore, the observatory jointly operates the Yamaguchi 32-m radio telescope with Yamaguchi University and the Hitachi-Takahagi 32 m radio telescopes with Ibaraki University, contributing to JVN (Japanese VLBI Network) research activity. As a member institution of the Event Horizon Telescope (EHT) project, Mizusawa VLBI Observatory also contributes to promoting millimeter-wave VLBI, and is developing a future plan to participate in the Square Kilometre Array (SKA) project. Beyond these activities, the observatory engages in VLBI equipment development as well as geodetic and geophysical VLBI observations, demonstrating its broad contributions to the VLBI field

1. VERA and International VLBI Observations

(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 2024, a total of 282 sessions (2,159 hours) of VLBI observations were conducted using VERA. Mizusawa VLBI Observatory has started a new observational mode "VERA Large-scale COllaborative Program (VLCOP)" since September 2022. In FY 2024, 21 projects (15 are continuations from FY 2023) have been conducted since September 2024. A total of 114 sessions (643 hours) of VLBI observations were conducted for VLCOP projects such as monitoring of maser variability in star-forming regions; comparison of water and methanol maser distributions; astrometry observations of maser emission in OH/IR stars; and long-term monitoring and parallax measurements of Galactic center Sgr A*. In addition to VLBI observations, single-dish observations from AOC or at local stations have been conducted for a total of 2,158 hours to monitor the time-variation of maser sources in star-forming regions and survey maser sources associated with OH/IR stars and mira-variables. These observing times include commissioning observations for a newly developed receiver and correlator system, and geodetic observations (details of geodetic observations will be described in Section 4).

VERA is participating in the international observations of KaVA together with the KVN, which consists of four 21-m antennas. Furthermore, VERA is also a member of EAVN, utilizing VERA, KVN, Sejong 22-m in Korea; the Tianma 65-m, Sheshan 25-m, Nanshan 26-m, and Kunming 40-m, in China; and Nobeyama 45-m, Yamguchi, Hitachi, and Takahagi 32-m radio telescopes in Japan. For the common-use projects, commissioning and test observations with EAVN, a total of 152 sessions (1,198 hours) of observations were conducted in FY 2024. EAVN open-use calls for proposals for semesters 2024B (first half of FY 2024) and 2025A (second half of FY 2024) were released in June and November of 2024, respectively. In total, 48 proposals requesting a total time of 1,790 hours (c.f. 1,210 hours requested by 30 proposals in FY 2023) were submitted by researchers in Japan, Korea, China, Italy, Germany, and other countries and regions. Through the evaluations by anonymous referees nominated from scientists in related fields and the subsequent decision made by the EAVN combined Time Allocation Committee, a total of 31 proposals were accepted for a total observing time of 1,166 hours (c.f. 930 hours accepted for 29 proposals in FY 2023).

In FY 2024, Mizusawa station could not be operated in the first half of the fiscal year due to an antenna failure that occurred in FY 2023. After fixing the problem, the Mizusawa antenna restarted regular operation in September 2024 and the full four VERA stations have resumed. As a result, the total VLBI observation time was slightly increased to 110 % of that in FY 2023. As for the single-dish mode, total observing time was significantly increased to 142 % of that in FY 2023.

In addition, in FY 2024, test observations were conducted several times from September to November 2024 aiming to expand the bandwidth of the EAVN observations from 1 Gbps to 2 Gbps or larger, and to extend future collaboration between VERA and the international global VLBI network. VLBI test observations were successfully conducted between VERA and EAVN antennas in Korea and China, as well as those in the European VLBI network (EVN). High-speed data transfer over the internet was also achieved from VERA to EAVN and EVN.

The VLBI data, except for EAVN observations, were processed at the Mizusawa Correlation Center in NAOJ Mizusawa Campus. The correlated data were sent to the proposer or representative person of data analysis of each project. For some of the EAVN observations, the Mizusawa Correlator Center copied the recorded data to change frequency settings (digital filtering) and transfer the reprocessed data to the Korea-Japan Correlation Center in Daejeon in Korea for further data correlation.

The international millimeter wave VLBI observations of the Event Horizon Telescope (EHT), in which the Mizusawa VLBI Observatory also participates as one of core institutes, were conducted from April 4 to 11 in 2024 with the participation of ALMA, JCMT, and others.

(2) Science Research

In FY 2024, staff members of Mizusawa VLBI Observatory contributed to a total of 37 refereed journal papers, and 6 of them were published by the Mizusawa staff members as the first author.

As a result of VLBI observations by VERA alone, a refereed journal paper was published for the results of proper motion measurements of the H_2O masers tracing the outflow from the massive protostar NGC 6334I, which experienced a mass accretion burst event, to investigate the emission mechanism of masers in combination with submillimeter water maser observations with ALMA. In addition, a total of 11 peer-reviewed papers were published in FY 2024 for observational studies of various celestial objects using different VLBI networks, such as research on the collimation mechanism of AGN jets with KaVA, monitoring of the light curve of an extragalactic supernovae using the domestic Japanese VLBI network JVN and the Korean VLBI network KVN, pulsar observations with VLBA in US, and AGN observations with the Global VLBI Network, as well as related theoretical research. In addition, a review paper on the well-studied representative nearby AGN M87 has been published by a first author formerly affiliated with Mizusawa VLBI Observatory.

In relation to EHT, two papers were published as part of the series of papers reporting the observational results of the supermassive black hole at the center of the Milky Way, Sgr A*, at a wavelength of 1.3 mm. Five papers were also published for observational and theoretical work on other AGNs. Results of the first VLBI observations at 0.87 mm wavelength were also published in a refereed journal paper.

In addition, Mizusawa VLBI Observatory conducted radio observations with ALMA and the Nobeyama 45-m Radio Telescope, as well as observations from infrared to X-rays and gamma-rays, and related theoretical work, such as star formation and AGNs including Sgr A*. A total of 11 related peer-reviewed papers were published for such multi-wavelengths studies. Furthermore, a subproject at Mizusawa VLBI Observatory, SKA-J, is working with the domestic user community on preparatory research for the SKA. Six peer-reviewed papers were published in FY 2024 on the results of observational and theoretical research using the SKA precursors ASKAP in Australia and GMRT in India, and instrument development (described in Section 3).

2. The Japanese VLBI Network (JVN)

The University VLBI Collaborative Observation Projects have been conducted jointly by the National Astronomical Observatory of Japan (NAOJ) and six universities. By integrating the radio telescopes of VERA, the participating universities, and research institutes such as JAXA/ISAS, we established the Japanese VLBI Network (JVN). The JVN operates at three frequency bands: 6.7, 8, and 22 GHz. In FY 2024, a over 280 hours were dedicated to VLBI observations. The primary research targets included protostars, active galactic nuclei, and X-ray binary systems. Single dish observations related JVN research were carried out at Ibaraki, Gifu and Yamaguchi stations, with more than 4,000 hours of single-dish observations conducted at Ibaraki station.

In FY 2024, JVN focused on three major targets in time-domain VLBI astronomy:

1. (Periodic) flux variations in CH3OH masers
2. Radio jets from protostars
3. A water maser associated with a supernova remnant

Radio telescopes operated by the JVN-member universities were used for these observations. Over the year, four peer-reviewed papers related to JVN were published, including Tanabe et al. (2024) and Iwata et al. (2025), along with several conference proceedings.

Prof. Yonekura of Ibaraki University and Prof. Niinuma of Yamaguchi University led a development study aimed at upgrading the VLBI observation systems at the Ibaraki, Yamaguchi, and VERA stations. These works were supported by Grants-in-Aid for Scientific Research. Several students from Ibaraki and Yamaguchi Universities participated in the development under the supervision of Professor Ogawa at Osaka Metropolitan University. These activities highlight JVN's contributions to graduate student education.

3. SKA1 Japan Promotion Group

Phase 1 of the SKA project (SKA1), whose construction began in July 2021, reached a major turning point in Fiscal Year 2024. First, in the LOW array under construction in Australia, significant milestones were achieved: first light with a single station, first fringe with two stations, and first image with four stations. As a result, the initial array, AA0.5, is nearing completion. Meanwhile, construction and testing of four MID antennas are also progressing, albeit with slight delays. Another key development is the prospect of securing an additional investment of approximately 2.6 billion yen from the member countries, which has made the realization of array AA* a certainty. The number of SKAO member countries (those that have ratified the treaty) has reached 12, with three additional countries having secured budgets and currently in the process of treaty ratification or signing memoranda of understanding.

At NAOJ, a SKA1 study group was established under the Mizusawa VLBI Observatory for three years starting in Fiscal Year 2019. This group conducted preliminary research and made in-kind contributions to the construction of SKA1. Based on these efforts, a formal SKA1 project proposal was submitted in October 2021. In Fiscal Year 2022, the group continued its activities during the transitional period of project review. From Fiscal Year 2023, the SKA1 Promotion Group was launched under Mizusawa VLBI Observatory. Alongside addressing several scientific and technical issues, the promotion group faced its greatest challenge: securing the necessary budget and formulating a feasible plan to obtain it. The SKA1 Promotion Group was organized into four divisions—Planning, Science, SRC (Science Regional Centre), and Engineering—through which it carried out its activities.

In the Planning Division, participation as an observer in the SKAO Council allowed for the monitoring of SKA construction progress and the presentation of updates on Japan's research activities. The division also took part in deliberations as a member of several committees: the SKA Finance Committee, the SKA Tender Subcommittee, the SKA In-Kind Subcommittee, and the SRCNet Resource Board. Domestically, following the non-selection of SKA for the MEXT Roadmap 2023, ongoing dialogue with the research community and stakeholders was maintained, leading to the drafting of a new participation plan. Under this plan, Japan aims to officially join SKA1 by contributing approximately 2 % of the total SKA1 construction cost, beginning around 2028 during the expansion phase from array stage AA* to AA4. In the meantime, competitive research funding will serve as a bridge, and a framework is being developed in which Nagoya University takes the lead with support from NAOJ. Although proposals submitted in collaboration with the broader scientific community for a large-scale KAKENHI grant were unsuccessful, continued success has been achieved in securing multiple budgets from NINS. These funds are being used to promote scientific research through long-term overseas stays and to advance low-frequency radio technology development. Preparation is also underway to renew the Memorandum of Understanding (MoU) with SKAO regarding contributions to Assembly, Integration, and Verification (AIV), originally signed in January 2022. As an interim measure, the current MoU was extended for one additional year.

In the Science Division, research using SKA pathfinder instruments continues to be encouraged. In May 2024, an international conference on cosmic magnetism was hosted, centered around the ASKAP magnetic field research group POSSUM. With support from the Japan Tourism Agency and the City of Kagoshima, the conference attracted 77 in-person participants (over 90 including online attendees). In June 2024, a proposal workshop for MeerKAT was held, drawing 32 participants, and subsequently, three proposals submitted from that workshop were accepted. Analyses of MeerKAT observation proposals were also conducted. In November, a user tutorial was held for the sensitivity calculator provided by SKAO, encouraging its use in preparation for the international SKA Science Book scheduled for 2025. In December, a community meeting was convened to facilitate contributions to the Science Book and to energize proposal activities. In February 2025, a training workshop on long-wavelength radio data analysis was conducted, featuring two invited lecturers from abroad and attended by 15 early-career researchers from Japan. As part of efforts to foster young talent, budget secured from the research organization enabled deeper personnel exchanges with Australian institutions and the advancement of collaborative research projects.

In the SRC (Science Regional Centre) Division, contributions were made to international agile development by participating in the East Asia node team (Lavender), providing a total of 1 to 1.5 FTEs and supporting prototype development activities. The main goal for Fiscal Year 2024 was for the Japanese node, JPSRC, to officially join the initial release of SRCNet v0.1, with efforts focused on preparing the necessary hardware and software. The unique features of the JPSRC node include improved operational convenience and availability through implementation of a Kubernetes cluster in a virtual machine environment using OpenStack; acceleration of the astronomical data analysis software CASA through Japan's proprietary vector processor technology; and stable operation testing of the domestically developed Gfarm file system as part of the SRCNet system architecture. Alongside node development, JPSRC also contributed resources to SDC3, which has been recognized as a highly visible contribution on the international stage. To support these R&D activities, a specially appointed expert was employed in a dual role with the Astronomy Data Center, establishing a framework for enhanced information sharing and coordination.

In the Engineering Division, activities were conducted based on the Memorandum of Understanding (MoU) with SKAO regarding AIV (Assembly, Integration, and Verification), with a total contribution of 1.5 FTEs across both the LOW and MID arrays. For LOW, Japan played a leading international role as the coordinator responsible for planning the test content and creating test procedures for AA0.5. Following a change in personnel, a new representative participated directly in the actual testing activities, continuing the contribution. For MID, contributions included executing test observations, identifying issues, and exploring potential solutions. To enable remote contribution from Japan, discussions were held with on-site staff, laying the groundwork for university researchers to get involved. Based on this progress, Japan has set a goal to double its contribution to 3.0 FTEs starting in Fiscal Year 2025, and personnel have been secured to support this expansion. Regarding the low-frequency VLBI component within the scope of AA*, test observations were organized and conducted between the Iitate Observatory at Tohoku University and overseas facilities such as India's GMRT/Ooty and Australia's MWA. These efforts successfully resulted in fringe detection between Iitate and Ooty. In preparation for the SKA Observatory Development Program, development of a VLBI recording system continues. Software capable of receiving and recording data transmissions at 16 Gbps over 10GbE (equivalent to 128 Gbps in 100GbE-JF environments, handling 1.6 million packets per second) has been completed. Concerning the feasibility of incorporating the 15–29 GHz observation band for MID, a collaborative development plan has emerged in which Japan would provide the optics system and Switzerland the low-noise amplifiers. In the area of wideband digitizer development, discussions regarding the development of digitizers that meet SKA's technical requirements have begun with a domestic company that has a proven track record in high-speed samplers for radio astronomy.

4. Geodesy and Geophysics

To monitor the position and shape of the VERA network in the international reference frame, semi-regular geodetic VLBI observations were conducted during FY 2024, which include 7 times of VERA internal observations using the K-band and 5 times where the Mizusawa Station participated in IVS sessions using the S- and X-bands (IVS-T2P and AOV). In AOV and IVS-T2P sessions, wideband observations using OCTAD-OCTADISK2, and recorded data transfers to the IVS correlation center have been routinely conducted. The number of these sessions was half that of previous years, due to long-term operational outages caused by antenna failures at Mizusawa, and the execution of these observations resumed in October 2024. The final estimates of the VERA station positions were reconstructed based on ITRF2020 and supplied to the astronomical 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 was developed by NASA/JPL and Caltech is used in the analysis. We produce propagation delays (excess pass delays), which is essential correction 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.

An optical grid clock is being operated at the Mizusawa site as part of the JST-Mirai Program (Katori, H., Space-time information platform with a cloud of optical lattice clocks, JST-Mirai Program, 2018) to study relativistic geodesy. As one of the scientific applications of this optical lattice clock, VLBI observations using a reference signal created from the optical lattice clock were conducted in October 2024. As a result, it was confirmed that the solution is as accurate as or better than conventional VLBI.

5. System Development

As a development group, we are currently developing the dual-polarization and dual-frequency (K, Q) 32 Gbps receiver system for VERA in accordance with the next EAVN broadband observing mode. In 2024, we modified IF and BBC at the Ogasawara and Ishigakijima stations to improve the reduction in sensitivity due to inconsistencies with conventional observation systems. In addition, we investigated and modified the bit alignment problem of the high-speed A/D OCTAD to enable conducting observations at all stations. With the above improvements and the restoration of the antenna at the Mizusawa station, we have conducted various CSV observations using new observing modes of wideband (16 Gbps) and dual-polarization K/Q band simultaneous receiving using the function of K-band RF direct A/D with OCTAD at all stations for the first time.

Ten years have passed since the Mizusawa correlation center was established, and the time is approaching for replacement of the servers, including the VLBI recorder. In FY 2024, we have upgraded our recording software “VSREC” for a new OS (rocky linux 9.5) with a view to using it in SKA-VLBI. We succeeded in recording up to 32 Gbps for 8 hours without packet loss. Since packet loss occurs when recording at over 64 Gbps, we have been installing SR-IOV software that virtualizes the driver and reduces the security load to reduce packet loss.

We have verified the GPU correlator in normal mode, including wideband mode, which is now in regular operation by the operation group.

6. Public Outreach

(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 27, 2024 The 15th Open Observatory Event held by the Ibaraki University Center for Astronomy, and NAOJ Mizusawa VLBI Observatory, Ibaraki Station. <Total 616 people>
- On August 11, 2024 The special open house event at VERA Ishigakijima Station held together with “The Southern Island Star Festival.” <277 people>
- On October 12, 2024 Mizusawa district “Iwate Galaxy Festa 2024.” <Total 1154 people>
- On March 2, 2025 Lecture Ogasawara Visitor Center, Tokyo. <38 people>

At Ogasawara Station, the event was changed to a lecture due to the day of the week and shipping schedules.

For more details, please refer to Section VIII Public Access to Facilities.

(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) 12,679

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 924
c) VERA Ishigakijima Station 2,452
e) VERA Ogasawara Station 6,430

For more details, please refer to Section VIII Public Access to Facilities.

(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) The Iwate Marugoto Kagakukan (led by Iwate Prefecture), a science event for children and adults in Iwate Prefecture, is held every year and we participated in 2024 as well.

November 30, 2024 (Saturday) Iwate Marugoto Kagakukan in Morioka at Iwate Prefectural Citizens’ Information Exchange Center (Aiina) <Approximately 850 people>

b) In 2024, we held a “Kirari Oshu City Astronomical Class” for elementary and junior high schools in Oshu City.

September 9, 2024 (Monday) Mizusawa Minami Elementary School 5th grade joint / “What is a black hole?”
Lecturer: Mareki Honma <104 people>

October 7, 2024 (Monday) Maesawa Junior High School 3rd grade joint (1st, 2nd Class) / “What is a black hole?”
Lecturer: Yuhei Iwata <60 people>

October 7, 2024 (Monday) Maesawa Junior High School 3rd grade joint (3rd, 4th Class) / “What is a black hole?”
Lecturer: Yuhei Iwata <59 people>

October 15, 2024 (Tuesday) Higashi Mizusawa Junior High School 3rd grade joint / “Life of a Star”
Lecturer: Tomoya Hirota <128 people>

December 24, 2024 (Tuesday) Esashi First Junior High School Science faculty 1st and 2nd year students jointly / “Earth, Moon, and Solar System”
Lecturer: Koji Matsumoto <40 people>

c) Starting in Fiscal Year 2024, we began cooperation in creating children's spaces to support child-rearing in Oshu City.

June 22, 2024 (Saturday) Fujisato Promotion Association, Fujinoko Club (Fujisato Community Center)
Lecturer: Tomohiko Ozawa <12 people>

July 27, 2024 (Saturday) Fureai Shokudo Hanecchi no Kai (Haneda District Center)
Lecturers: Hirotomo Noda and Tomohiko Ozawa <15 people>

September 21, 2024 (Saturday) Food Nurturing Association Children's Square (Esashi Odaki Community Center)
Lecturers: Yuhei Iwata and Tomohiko Ozawa (Cancelled due to bad weather)

November 21, 2024 (Thursday) Kuroishi After-School Children's Club (Kuroishi Children's Center)
Lecturers: Mareki Honma and Tomohiko Ozawa <23 people>

December 22, 2024 (Sunday) Hirose After-School Children's Class (Hirose Community Center)
Lecturers: Tomoya Hirota <29 people>

7. Education

(1) University and Post-Graduate Education

Regarding postgraduate education, Mizusawa VLBI

Observatory assisted 4 doctoral and 3 master's course graduate students from the University of Tokyo with their research. One master's student and 2 doctor students are from foreign countries. Each of 1 master's student and 1 doctor student obtained their degrees in March 2025. In addition to students of the University of Tokyo, Mizusawa VLBI Observatory accepted a few graduate students and interns from domestic universities (Ibaraki University, University of Electro-Communications, Osaka Metropolitan University). A staff member of Mizusawa VLBI Observatory gave lectures at Tohoku University and the National Institute of Technology, Ichinoseki College as a visiting lecturer.

(2) Research Experience for High School Students

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 VERA Ishigakijima Station, Ishigakijima Astronomical Observatory, and Ishigaki Youth Center. Including 21 participants from outside Okinawa Prefecture, a total of 24 high school students experienced the lectures on astronomy, observatory tours, star watching, and observational studies with the VERA 20-m antenna to search for new maser sources.

02. Nobeyama Radio Observatory

1. Nobeyama 45-m Radio Telescope

(1) Charged Telescope Time

The 43rd term (charged telescope time) started on September 1, 2024. The statistics of the conducted programs are as follows. "General Programs": 31 programs, "CSV Programs": 2 programs, "Observation Tutorial Programs": 4 programs. The number of the successful proposals for "Students Programs", which are reviewed scientifically, is 3 proposals out of the 5 submitted proposals.

(2) Improvements and Developments

(a) Developments

A new focal plane array receiver system for observations at 72–116 GHz (named "7BEE") was conducting CSV measurements and test observations, but it was found that the cooled HEMT amplifiers (hereinafter referred to as CLNAs) had deteriorated. The CLNAs was repaired and resumed test observations in March 2025. 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 seven 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.
- Millimetric Adaptive Optics (MAO)
- 100-GHz, 109-element MKID camera.
- Research on noise reduction for a 100 GHz band SIS receiver equipped with a 45 m reflector using a waveguide-type variable frequency bandpass filter.
- Development of an ultra-wideband atmospheric spectral measurement system that opens up new horizons for space-time measurements of the Earth and space.

(c) Call for development proposals

The following two proposals were adopted.

- NOCTURNE (Nobeyama Octatonic-scale bands, Unitary-frame Receivers Nexus)
- Extending 7BEE with RFSoC Spectrometer

(d) 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.
- The following system problems occurred and were repaired:
  - Repair of antenna collimator shutter winding mechanism that broke last year.
  - A major failure occurred in the SAM45 radio spectrometer, causing observations to be suspended for about a month, but with the cooperation of the ALMA project, a board was replaced and operations were restored.
  - The hydrogen maser clock that broke last year was repaired under the leadership of Mizusawa VLBI Observatory, and VLBI observations are expected to resume soon.

(3) Scientific Results

A total of 41 refereed journal papers were published on the basis of research using the 45-m radio telescope.

Taniguchi, K., et al. conducted mapping observations toward the streamer and reservoir in the Per-emb-2 region which is one of the candidates for a class-0 protostellar object in the Perseus region. They revealed the distribution of the molecular gas and its dynamics, and found that molecular gas is provided to the streamer from the reservoir and the gas also may reach the central star. Yamamoto, H., et al. were the first to find a molecular cloud interacting with a relativistic jet in the Galaxy by comparing data for molecular gas, radio continuum, and X-ray emissions toward the microquasar SS433. Matsunaga, K., et al. showed that the SNR G359.0-0.9 is Mg-rich by using the XMM Newton data. In addition, they also used molecular gas data to identify the distance of the object and to estimate its mass. From the results, they concluded that the SNR has experienced a shell-merger. Murillo, N., et al. compared the physical properties of molecular gas and the multiplicities of protostars toward the star formation regions in the Perseus region, and found that the multiplicity is not correlated with the gas temperature or density but is correlated with gas mass. Takekawa, S., et al. investigated the Galactic Central Molecular Zone (CMZ) with SiO and CS lines, and found that the molecular line ratio of SiO/CS is lowest at the Galactic center and it increases as a function of distance from the Galactic center. Nakamura. F., et al. developed a new wide-band receiver named eQ which covers the 30-50 GHz frequency range. Results of their test observations show the good performance of the receiver, and they produced science results for multiline mapping of the Taurus molecular cloud and the line search of a high-z object.

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 2024, receiver, spectrometer and observation system development was performed with the aim of investigating high-mass star formation mechanisms by developing ultra-wide bandwidth mm- submm wavelength spectroscopic receiver systems.

3. Public Outreach

(1) PR activities at Nobeyama Campus

Nobeyama Campus received a cumulative total of 47,316 visitors throughout the year. Three press releases were published. Staff members conducted 46 requests for filming and interviews. No workplace visits by local high schools were conducted. An event where people can volunteer to paint the 45-m telescope was held on August 3, and 14 people in 7 groups participated. For the public lecture, the retirement lecture of Professor

Tatematsu “The Science of Zodiac Signs” was held on March 15 at Minamimaki Village “Vegetable With,” with 67 people in attendance.

The annual Nobeyama Special Open House was held as an on-sight and online event. The maximum number of connections for live streaming was about 200 and the total number of views for all content was about 17,000 in the nine months after the event. On the other hand, 1185 people joined the on-sight event.

Moreover, we received and answered about 89 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 with contributions by Minamimaki Village Shinko-kosha, Minamimaki Village, Minamimaki village society of commerce and industry, Nagano Prefecture, and Nagano Prefecture Board of Education. Moreover, the “Nagano Prefecture is Astro-Prefecture” liaison council promoted the activities such as monitoring night sky condition in the prefecture, and the 9th meeting was held on November 2.

4. Education

One doctoral course student from the University of Electro-Communications was 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 174 paid group tours and filmings.

(2) Staff Reassignment

NRO Director Ken’ichi Tatematsu (Professor) reached the end of his term and Atsushi Nishimura (Associate Professor) became the new NRO Director.

(3) NRO Conference Workshops and Users Meeting

- December 18–20, 2024, Hybrid (in-person and on-line)
  FY 2024 ALMA/45-m/ASTE Users Meeting (Organizing Committee: Akiko Kawamura, Bunyo Hatsukade, Takuma Izumi, Atsushi Nishimura, Ken Tatematsu, Tetsuhiro Minamidani (NAOJ))

- July 5, 2024 Hybrid (in-person and on-line)
  Nobeyama Development Program Meeting 2024 (Organizing Committee: Atsushi Nishimura, Chieko Miyazawa (NAOJ))

- December 2, 2024, Hybrid (in-person and on-line)
  Science workshop of NRO45 2024 (Organizing Committee: Atsushi Nishimura (NAOJ), Hidetoshi Sano (Gifu University), Kazuki Tokuda (Kyushu University/NAOJ), Shunya Takekawa (Kanagawa University), Fumiya Maeda (Osaka Electro-Communication University), Haruka Sakemi (Yamaguchi University))

03. Solar Science Observatory

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 Satellite

The scientific satellite Hinode is an Earth-orbiting satellite that was launched in 2006, by ISAS/JAXA and 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 detailed observations of the 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 scientific operation is carried out based on cooperation between ISAS/JAXA and NAOJ with international contributions by the US NASA and the UK STFC, the European Space Agency ESA, and the Norwegian Space Centre NSC. 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 J. Okamoto for SOT) join the SSC activity. The SSCs serve as a contact point for observation proposals from solar physics researchers world-wide to use Hinode and promote 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 ground-based telescopes, as well as long-term standalone observations by Hinode. The number of Hinode-related refereed papers published in FY 2024 is more than 50. The Hinode project has been shifted to a late-stage operations team within ISAS in FY 2024 to focus on the next solar mission SOLAR-C, and the results and lessons learned from Hinode will be transferred to SOLAR-C. We are continuously observing long-term variations in solar activity using polar magnetic fields and full-disk mosaic observations, while also conducting joint observations with rocket and balloon experiments promoted by the SOL project.

Solar Data Archive System (SDAS) in the Astronomy Data Center (ADC), which developed from the open-use data analysis system of Hinode, former NSRO (Nobeyama Solar Radio Observatory), and 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 the 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 the 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 in addition to full-disk Hα, Ca K, continuum, and G-band imaging observations with the Solar Flare Telescope (SFT). Relative sunspot number measurements also continue as a proxy of long-term solar magnetic activity. The solar activity has been increasing toward the solar maximum, and useful data such as active regions and flares have been obtained. The most advanced data accumulated are those for magnetic fields in the solar atmosphere. The current near-infrared Stokes polarimetric observations provide measurements of magnetic fields both in the photosphere and in the chromosphere. Calibration of their data is underway for the release of magnetic field data. 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. The past and new observational 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 and Ca K 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 the 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. The microwave observation conducted over 70 years since the time of the Research Institute of Atmospherics, Nagoya University 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. Stable operations have been achieved in all frequency bands in FY 2024, allowing us to observe many radio bursts associated with solar flares. On the other hand, some frequency bands required evaluation to address the deteriorating radio environment in Nobeyama, resulting in delays in the release of some data.

4. Rocket and Balloon Experiments

The SOL project is working to develop advanced technology for next-generation solar observations through 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 US and Europe, three successful flight experiments CLASP (2015), CLASP2 (2019), and CLASP2.1 (2021). In FY 2024, we worked on the analysis of the observation data acquired with CLASP 2.1 and published two peer-reviewed papers and submitted a new paper.

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 US, and Spain are participating. The SOL project developed the near-infrared spectro-polarimeter SCIP, which was installed on SUNRISE-3, and aimed to obtain three-dimensional magnetic field structures from the photosphere to the chromosphere by simultaneously observing many spectral lines with a resolution higher than that of the Hinode satellite. SUNRISE-3 successfully launched in July 2024, and during its approximately one-week flight, it obtained high spatial resolution and high polarimetric accuracy observational data of various solar structures and phenomena, including quiet regions, active regions, flares, and polar areas. Joint observations with Hinode were also successfully conducted. The observational data were delivered one month after the flight, and the calibration process is underway to release the data in 2025. In parallel, we are working on producing initial scientific outcomes.

FOXSI (Focusing Optics X-ray Solar Imager) 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. Aiming to understand plasma heating, energy transport, and particle acceleration in a solar flare, the fourth flight FOXSI-4 was launched on April 17, 2024 and successfully conducted the world's first focusing X-ray imaging spectroscopic observation of a solar flare. The Japanese group led by the project delivered 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. The launch was operated as NASA's first attempt to monitor solar activity in real time and trigger the launch just after a flare occurrence. The Japanese group contributed to the launch operation by providing predictions of the flare location and magnitude. Thanks to these careful preparations, FOXSI-4 successfully observed the decay phase of an M-class flare and detected X-rays up to around 20 keV. A joint observation with Hinode was also successfully carried out. Currently, calibration of the instrument and data is underway to produce scientific results. 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, and two doctoral thesis and four master's theses have been accomplished so far, demonstrating contribution to the development of young researchers. FOXSI-5, the reflight following FOXSI-4, has been selected by NASA with the highest rating of 'Excellent,' and preparations are underway for a launch in FY 2025.

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 its technical expertise in optomechanical design, UV observation technology, interface (IF) coordination with overseas institutions, and on-ground test techniques accumulated through the development of the rocket and balloon experiments.

6. Education

The SOL project accepted and supervised four Ph.D. students from SOKENDAI and three contract graduate students (two from the University of Tokyo and one from Ibaraki University). Two received a master's degree either at the University of Tokyo or Ibaraki University. The SOL project accepted two undergraduate students to experience solar research during the SOKENDAI Summer Student Program (August 2024) and participated in the Tour of Solar Research Frontiers (March 2025) to introduce 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 to deliver the latest solar activity and the results obtained through the scientific research of the Sun to the public: web releases, a homepage, social media, media appearances related to solar observations and space weather in response to requests for media interviews, providing materials to the media, etc.

8. Science and Community Meetings

To advance solar physics research with the Hinode satellite, the 17th Hinode science meeting (HINODE-17/IRIS-15/SPHERE-3) was held on July 23–27, 2024 at Montana State University, US. A meeting of the Hinode Science Working Group was held on July 22, 2024, 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 (JSPC) organized a symposium held during February 17–19, 2025 at ISAS/JAXA (co-hosted by NAOJ) where the latest solar physics research results were presented, and future plans for SOLAR-C and beyond were introduced and discussed.

9. Others

Observations using GREGOR in the Canary Islands and BBSO in the US were successfully carried out in collaboration with overseas researchers. For these observations, coordination with Hinode was also organized and efforts were made to establish a scheme for joint observations between ground-based telescopes and SOLAR-C. 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.

04. Subaru Telescope

1. Subaru Telescope Staff

As of the end of FY 2024, the Subaru Telescope research and academic staff consisted of 23 dedicated faculty members including seven stationed at Mitaka and two stationed at Okayama, five technicians, one specially appointed teacher, three senior specialists, and three administrative staff members. Additional staff members include two specially appointed teachers, nine project research staff members, eight senior specialists, one administrative expert, five administrative supporters, one public outreach staff member, and one re-employment staff member, all of whom are stationed at Mitaka; as well as one specially appointed teacher, and two administration associates, all of whom are stationed at Okayama. Moreover, there are 13 research and acadmeic staff members, 12 of whom are stationed at Mitaka. And, one engineer who is stationed at Mitaka, is posted concurrently. The project also has 61 local staff members dispatched from the Research Corporation of the University of Hawaiʻi (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 2024, Subaru Telescope produced many outstanding scientific outcomes, which were published in major international journals. Below are some examples:

(1) A new extrasolar planet named Gliese 12b was discovered through a collaboration between the Subaru Strategic Program (SSP) with the InfraRed Doppler (IRD) instrument and NASA's TESS campaign. The planet may still retain a certain amount of atmosphere, making it one of the most suitable targets out of all of the planets discovered so far to investigate the atmosphere of a planet like Venus. In the near future, NASA's JWST and extremely large telescopes, such as TMT, will be used to characterize the atmosphere of Gliese 12b in detail, greatly improving our understanding of the conditions necessary for habitability.

(2) The earliest pair of black holes was found in the Hyper Suprime-Cam Subaru Strategic Program (HSC-SSP) data. The follow-up observations using the Faint Object Camera And Spectrograph (FOCAS) on the Subaru Telescope and GNIRS on the Gemini-North Telescope confirmed that they are 12.9 billion light-years away. This is the record for the farthest pair of merging black holes, and the only pair found during the “Cosmic Dawn.”

(3) Hyper Suprime-Cam's wide and deep imaging observations contribute to NASA's New Horizons mission. Subaru Telescope began helping to find Kuiper Belt objects for the spacecraft to fly-by and/or observe. By applying a unique analysis method to HSC images targeting Kuiper Belt objects, seven new objects have been discovered. While previous observations have shown that the number of Kuiper Belt objects decreases dramatically beyond about 50 au, the determined orbits of two of the seven new objects show the semi-major axes to be greater than 50 au. If such discoveries continue, we may conclude that the Kuiper Belt extends even further.

(4) In the Hyper Suprime-Cam Subaru Strategic Program (HSC-SSP) data, two new satellite galaxies were found around the Milky Way. This discovery raised the estimates for the total number of satellites expected to exist around the Milky Way. This solves the “missing satellite problem,” but now the estimates are too high for the standard dark matter model to explain.

3. Open-use

The Open Use Program is conducted semiannually through an open call for proposals. The application 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 will be accepted at the Subaru Mitaka Office of the National Astronomical Observatory of Japan. The Subaru Program Time Allocation Committee (TAC) will review and select proposals based on the domestic and international referee evaluations. We accepted 56 proposals (107.6 nights including 16 nights of ToO proposals) {out of 108 proposals (263.9 nights)} in S24A and 55 proposals (89.95 nights including 6 nights of ToO proposals) {out of 134 proposals (301.6 nights)} in S24B. For the Intensive Proposals beyond the semester, 9.7 nights (2 proposals) in S24A and 6 nights (1 proposal) in S24B were allocated. In addition, observations of the Service Program, a short-time assignment, were also conducted. Of the proposals selected for Open Use in S24A and S24B (excluding University of Hawaiʻi time), 4 (1 in S24A and 3 in S24B) were foreign PI proposals. The total number of applicants, including co-researchers, was 734 foreign researchers compared to 1,948 domestic applicants, and the total number of researchers in the accepted proposals was 375 foreign researchers compared to 1,106 domestic applicants.

The total number of observers using Open Use in S24A and S24B was 407 (including 98 foreign and 147 remote observers from Mitaka Campus). The Mitaka side handled the applications and review of observation proposals, travel procedures for domestic researchers to observe, and travel expense payment administration, while the Hawaiʻi side prepared the observation schedule and provided support for observers' accommodations, transportation, and observations in Hawaiʻi. Open Use observations during S24A and S24B, including University of Hawaiʻi time, averaged 84.07 % of available observation time, excluding weather factors and downtime due to scheduled maintenance such as the primary mirror coating. There was about 1.25 % downtime due to instrument troubles, 0.19 % due to communication system troubles, 14.26 % due to telescope troubles, and 0.24 % due to operation troubles.

Remote observations from the Hilo base facility were made on 66.8 nights (46 programs) during S24A and S24B. Remote observations from NAOJ Mitaka Campus were conducted for 35 nights (28 proposals including IRD Subaru Strategic Programs) with the participation of both summit observers and remote side observers, or only Mitaka remote side observers. Telescope time exchanges with Gemini and W. M. Keck Observatories, driven to make the best use of the telescope resources at the summit of Maunakea. With W. M. Keck Observatory, the exchange time was 5.0 nights in S24A and 2.5 nights in S24B. Regarding the exchange time with Gemini Observatory, Subaru Telescope users used Gemini observing time for 5.0 nights in S24A and 3.6 nights in S24B (excluding Fast-Track proposals), and Gemini users used Subaru Telescope observing time for 3.8 nights in S24A and 4.0 nights in S24B.

4. Telescope Maintenance and Performance Improvement

In FY 2024, a simplification of normal maintenance work and continuous remote monitoring were planned and performed for the planning and implementation of the summit unmanned observations. To accommodate a stricter visa issuance period by the U.S. Department of State, a human resource rotation in the telescope maintenance has been planned. Constant monitoring has started for the following items for these situations.

(1) Hydrostatic bearing system
- Oil supply rate
- Oil pressure

(2) Coolant chiller system
- Amount of water supply
- Water temperature

In addition, surveillance cameras have been added to strengthen remote monitoring. Electrical and mechanical maintenance was performed as routine maintenance to confirm the telescope integrity. Troubleshooting and countermeasures regarding unexpected events during operation were performed. We are also promoting cooperation among telescope maintenance groups and cooperating with each observatory in NAOJ to perform maintenance in cooperation with each other.

As part of the aging countermeasures, we carried out improvements to the main shutter sensor system, replaced the cracked drive sprocket on the top screen, and refurbished the equipment related to the primary mirror coating.

5. Instrumentation

The following seven facility instruments were provided for the open-use observations in FY 2024: Hyper Suprime-Cam (HSC), Prime Focus Spectrograph (PFS), Faint Object Camera And Spectrograph (FOCAS), High Dispersion Spectrograph (HDS), Infrared Camera and Spectrograph (IRCS), Multi-Object Infrared Camera and Spectrograph (MOIRCS), and the facility Laser Guide Star Adaptive Optics system (LGSAO). As for the carry-in instruments, Infrared Doppler (IRD) and Subaru Coronagraphic Extreme Adaptive Optics (SCExAO) were provided for the open-use observations. In addition, the following instruments/devices have been used in combination with SCExAO: Coronagraphic High Angular Resolution Imaging Spectrograph (CHARIS), Fast Near-Infrared Polarization Differential Imaging (FastPDI), MKID Exoplanet Camera (MEC), Rigorous Exoplanetary Atmosphere Characterization with High dispersion coronography (REACH), and Visible Aperture Masking Polarimetric Imager for Resolved Exoplanetary Structures (VAMPIRES). As carry-in devices, the WavePlate Unit (WPU) at the Infrared Nasmyth Focus and the Near Infrared WaveFront Sensor (NIR-WFS) have been used for the open-use observations.

One major activity in FY 2024 was the upgrade of the Deformable Mirror (DM) for the facility AO system from the original 188 element bimorph mirror to an approximately 3,000 element mirror. The 188-element wavefront sensor is still used in the visible wavelength, and the correction performance in this case has not changed significantly. But, when the new DM is combined with the carry-in device NIR-WFS, it allows higher-order wavefront correction and a Strehl ratio of ~90 % has been achieved in K-band with bright guide stars.

To enable remote switching of instruments/devices downstream of this AO188/AO3k system, the Nasmyth Beam Switcher (NBS) has been under development. In FY 2024, the final design and fabrication of the NsIR common platform was completed, which is to mount NBS, IRCS, and other instruments. The NsIR common platform will be transported to Hawaiʻi in the next FY, and the summit installation is planned in the summer after the mechanical assembly and optical alignment of the NBS.

For the carry-in instruments, a review meeting was held for SCExAO and the instruments/devices to be used in combination with SCExAO. Discussions continue on their operations and development, as well as the possibility of transferring part of the functions to the facility instruments.

In addition to the many instruments/devices in operation as listed above, proposals for new instruments are also increasing. The number of instruments/devices, which have completed submission of the Letter of Intent and are in the process of developing a more concrete plan in cooperation with the observatory (Phase II), has gone up to 9 as of the end of FY 2024. We are following the carry-in procedure which was revised in FY 2023, and continuing the discussions with the instrument development teams with careful attention to the workload of the observatory.

6. Computers and Networks

Subaru Telescope's computing and network systems core systems remained stable. We continued support for the PFS ICS infrastructure, and PFS Analysis environment. The Computer and Network division has been working to migrate the PFS IPMU servers to the STN environment (Web, Jira, Bugzilla, Blog and other services). This should be completed by the end of August, 2025. We implemented license server software for GLAO.

Major upgrades in the base firewall and end user VPN devices were implemented. Both of these were to address end-of-life and support, plus security vulnerabilities. Other network upgrades include:

- PFS-ICS Core network upgrade to 100 G redundant links
- HSC Network network upgrade to 100 G redundant links
- Upgrade on NS-IR to 40 G connections
- Deployment of POE switch for Telescope and Safety
  - ○camera support
  - ○New bullhorns, strobe lights
- Consolidation of CDM network equipment at the summit
- Increase continued usage of Hi-speed (Hilo-Summit 100 G)
  - ○Snapshots of Summit VM for backup purposes

○Real-time data exchange for PFS-ICS to PFS Analysis during observation
○Working to use the UH-Data Transfer Nodes to move SCEXAO science data to remote support scientist

7. Education (Under-graduate and Graduate Courses)

In FY 2024, Subaru Telescope had 16 staff members jointly affiliated to SOKENDAI. These staff members, including those jointly affiliated to other divisions, are the primary supervisors of 7 students, which comprise 1/5 of all the SOKENDAI students. Among the 7 students, 5 are supervised by staff members primarily affiliated to Subaru Telescope. There were 5 graduate students who had long-term stays (longer than 2 weeks) in Hilo, and 7 SOKENDAI students visited the telescope as part of SOKENDAI class. It should be noted that 2 graduate students from OISTER universities stayed in Hilo as part of a student intern program for the first time. Also, 8 students gave a talk in the Subaru Telescope Hilo facility, taking advantage of their visit for open-use observations.

Subaru Telescope hosted 4 students through the Akamai Internship Program. As part of Akamai Space Grant Consortium activities, Subaru Telescope hosted 1 intern student. In addition, Subaru Telescope hosted 1 undergraduate student of UH Hilo. As part of the SOKENDAI summer student program, Subaru Telescope staff members supervised 1 student in Mitaka and 2 students in Hilo. This is the first time to host summer students in Hilo after the COVID pandemic.

Turning to Subaru Telescope's contributions to the larger Japanese community, 11 and 12 graduate students (including 1 student supervised by a Subaru-affiliated staff member) defended their PhD and Master's theses, respectively, using data from the Subaru Telescope. The HSC data reduction school was not held in FY 2024 due to the absence of HSC helpdesk, and we are now trying to reactivate it from FY 2025.

8. Public Information and Outreach Activities

In FY 2024, various projects and events were organized to commemorate the 25th anniversary of the Subaru Telescope since its first light in 1999, in addition to the usual annual activities.

(1) Public Information

(a) Website

The main channel for public information is the official website (https://subarutelescope.org). The homepage was redesigned to enhance accessibility to various digital content for the public, including a virtual tour, citizen science projects, a 24/7 live streaming from Maunakea, and the Subaru Kids website. Additionally, in FY 2024 (April 2024 – March 2025), the homepage was updated with a special design to commemorate the 25th anniversary, and two new images per month of celestial objects were published on the Subaru Gallery.

- Science results from the Subaru Telescope: 5 Japanese and 5 English articles
- Announcements and topics of special activities and events: 33 Japanese and 27 English articles
- New images on the Subaru Gallery: 25 Japanese and 25 English pages

(b) Social Media

- X accounts:
  SubaruTelescope (Japanese)
  SubaruTel_Eng (English)
- Facebook accounts:
  国立天文台 (Japanese)
  Subaru Telescope Hawaii Outreach (English)
  National Astronomical Observatory of Japan (English)
- Instagram account: subaru_telescope (English)
- YouTube channels:
  SubaruTelescopeNAOJ (Japanese)
  SubaruTelescopeNAOJe (English)
  subarutel_starcamadmin (bilingual subchannel)

The English X account targets international followers from any country, whereas Facebook and Instagram focus on the local community in Hawaiʻi. The Japanese X account exceeded 100,000 followers in June 2024 and reached 120,000 by March 2025.

(c) Original Press Release to the Local Media of Hawaiʻi: 4 English Releases
(Main Contents)

- Science results from the Subaru Telescope
- Field trips by a local elementary school to the Hilo Base Facility
- Prime Focus Spectrograph (PFS) to begin science operations

(d) Contribution to the Maunakea Observatories' Public Information

- Providing photos for the new official website (https://www.maunakeaobservatories.org)
- Contribution to the renewal of the Maunakea Coin Contest page on the official site
- Receiving interviews for the "Stories" articles featured on the official site (5 interviews in total)
- Posting articles and photos on the official social media (X: maunakeaobs, Facebook: Maunakea Observatories, Instagram: maunakeaobs)

(2) Public Outreach

(a) Activities in Hawaiʻi

1) In-Person Lectures and Presentations, Workshops, etc., on the Island of Hawaiʻi: 27 cases, about 900 people in total
(Main Activities)

- Classroom visits through the annual Journey Through the Universe (JTTU) program
- Other classroom visits at nearby schools
- Judges at a series of VEX robotics competitions for elementary, middle, and high school teams
- Lecture for a university group at Halepōhaku, the mid-elevation facilities of Maunakea

2) Online Lectures and Presentations: 7 cases, about 2,500 people in total
(Main Activities)

- Presentations for Japanese junior and senior high school students
- "100 Years of the Planetarium × 25 Years of the Subaru Telescope" Online Events (see (d) 4) and 5))

3) Other Activities, Including Science Booths and Local Events: 14 cases, about 10,000 people in total
(Main Activities)
- Merrie Monarch Parade
- AstroDay
- AstroDay West
- Series of science events at elementary schools, like Science Day, and Family Science Night
- Series of career events, like Career Fair, and Career EXPO for high school students
- AstroBash at Waimea Public Library
- Christmas in the Park at Liliʻuokalani Gardens (as a member of MKAOC: Maunakea Astronomy Outreach Committee)
- Maunakea Coin Contest (led by Subaru Telescope as an MKAOC project)

4) YouTube Live Streaming: 13 cases, about 174,600 views in total
(Main Activities)
- Live streaming of the NAOJ citizen science project GALAXY CRUISE
- Live streaming commemorating the 3rd anniversary of the Subaru-Asahi StarCam and the 25th anniversary of the Subaru Telescope (*)
- Live streaming of Lyrids meteor shower (*)
- Live streaming of Eta Aquarids meteor shower (*)
- Live streaming of Comet Tsuchinshan-ATLAS (*)
- First Japanese session of Shadow the Scientists (StS) (**)
- Live streaming of the total lunar eclipse

(*) Streamed from the Asahi Shimbun Astro LIVE YouTube Channel (9 out of 13 cases). The Eta Aquarids meteor shower was captured by a camera installed at the Canada-France-Hawaii Telescope (CFHT), and Comet Tsuchinshan-ATLAS was captured by a temporarily installed camera at the Subaru Telescope pointed toward the western sky. Additionally, a 24/7 live stream from the Subaru-Asahi StarCam is available in collaboration with The Asahi Shimbun Company. In January 2025, the CFHT-Asahi StarCam, a second live camera operated by CFHT and The Asahi Shimbun Company in collaboration with Subaru Telescope, began streaming live.

(**) Streamed from the Shadow the Scientists YouTube Channel (1 out of 13 cases).

5) Volunteer Activity: 1 case
(Main Activity)
- Invasive Species Weed Pulls at Halepōhaku, the mid-elevation facilities of Maunakea

(b) Activities in Japan

1) In-Person Lectures and Presentations: 3 cases, about 300 people in total
(Main Activities)
- Astronomy pub (Mitaka, Tokyo)
- Public lecture at an international conference (Beppu, Oita, as part of a nationwide simultaneous Tanabata lecture series)
- Public lecture at SPIE Astronomical Telescopes + Instrumentation 2024 (Yokohama, Kanagawa)

2) Mitaka Open House Day: about 800 visitors to the Subaru Building
(Main Activities)
- Spectroscopy workshops
- The Subaru Telescope virtual tours
- Guided tours at the remote observation room

3) Other Activities, Including NAOJ Booths: 4 cases, about 3,000 people in total
- SPIE Astronomical Telescopes + Instrumentation 2024 (*)(**)
- IAU GA 2024 (*)
- Exhibition commemorating the 100th anniversary of the relocation of "Tokyo Astronomical Observatory" to Mitaka City (provided images captured by the Subaru Telescope) (*)
- NINS Symposium (*)(**)

(*) Activities at the NAOJ booth
(**) Subaru Telescope led the NAOJ booth

See the "VIII Public Access to Facilities" chapter, "4. Subaru Telescope" section about facility tours in Hawaiʻi and Mitaka.

(c) Media Interview/Filming: 19 cases (15 Japanese, 4 English)
- About 150 articles were published in newspapers in Japan
- 13 articles were published in media in Hawaiʻi (including newspapers and online news websites)

(d) Subaru Telescope 25th Anniversary Projects
1) Creation of a commemorative logo and special website design
2) Production of a commemorative movie "The Subaru Telescope in Hawaiʻi -25 Years of Achievements and Beyond-" (in Japanese and English)
3) Special exhibition at the Information Space of Astronomy and Science (Mitaka, Tokyo)
From July 5 to August 25, 2024, 2,332 visitors
(Including 4 workshops and 2 gallery talks)
4) Tanabata Block Party
Joint open house for the Maunakea Observatories' base facilities in Hilo, Hawaiʻi
hosted by MKAOC
August 17, 2024 (in Hawaiʻi)
About 600 visitors in total, about 300 visitors to the Subaru Telescope Base Facility
5) The "100 Years of the Planetarium × 25 Years of the Subaru Telescope" nationwide online event, co-hosted with the Japan Planetarium Association (JPA)
October 18, 2024 (in Hawaiʻi) or October 19, 2024 (in Japan)
25 planetaria and science facilities all over Japan, with about 1,900 participants in total
6) The "100 Years of the Planetarium × 25 Years of the Subaru Telescope" lecture series, co-hosted with JPA
From November 24, 2024 to March 2, 2025
10 planetaria and science facilities all over Japan, with 792 participants in total
(Including 2 online lectures from Hawaiʻi with 107 participants)
7) Publication of the "25 Years of Cosmic Discovery with the Subaru Telescope" image collection (edited by Subaru Telescope, published by Crevis inc.)
8) Contributions of feature articles on the 25th anniversary of the Subaru Telescope to Monthly Hoshi-Navi (published by KADOKAWA), NAOJ NEWS (published by NAOJ), and THE ASTRONOMICAL HERALD (published by the Astronomical Society of Japan) journals, receiving interviews at an FM FUJI radio program, and by The Research Corporation of the University of Hawaiʻi (RCUH), etc.

Subaru Telescope Okayama Branch

The Okayama Branch was established in FY 2018 primarily to provide half of the observation time of the 3.8 m New Technology Optical-Infrared Telescope (commonly known as “Seimei Telescope”) at the Okayama Observatory, Graduate School of Science, Kyoto University, for national university open use. Additionally, it collaborates with universities and the local municipality in the use of the telescopes at the former Okayama Astrophysical Observatory. As of the end of FY 2024, the Okayama Branch has two research and academic staff members, one specially appointed teacher, and two administrative support staff.

1. Seimei Telescope

(1) Open use (calendar year)

In the first half of 2024 (January-June), 65 nights were provided. There were 37 applications consisting of 15 Classical, 3 Classical+ToO, and 19 ToO requests, with the requested nights totaling 182.83 (110.52 for Classical, 72.31 for ToO). Of these, 32 applications were accepted (13 Classical, 3 Classical+ToO, and 16 ToO), with the allocated nights totaling 96.7 (52.25 for Classical, 44.55 for ToO). The term "Classical" refers to observations conducted on pre-assigned dates, while "ToO" refers to observations scheduled by proposers upon the occurrence of specific events. The total loss of time during this period was 2.3 nights. In the second half of 2024 (August-December), 63 nights were provided. There were 43 applications, comprising 24 Classical, 2 Classical+ToO, and 17 ToO requests, with the requested nights totaling 240.35 (170.0 for Classical, 70.35 for ToO). Of these, 32 applications were accepted (14 Classical, 2 Classical+ToO, and 16 ToO), with the allocated nights totaling 89.8 (51.5 for Classical, 38.3 for ToO). The total loss of time during this period was 0.7 nights.

(2) Observing instruments

Three instruments—the Kyoto-Okayama Optical Low-dispersion Spectrograph with the optical-fiber Integral Field Unit (KOOLS-IFU), the TriColor CMOS Camera and Spectrograph (TriCCS), and the high-dispersion optical spectrograph for precise radial velocity measurements (GAOES-RV)—were made available for open use. In the case of TriCCS, in addition to its imaging mode, the long-slit spectroscopic mode became available from the latter half of 2024. Various activities were conducted, including the management and operation of environmental monitors, storage of acquired data, maintenance of computer systems and networks, and upkeep of the facility. In addition, the development of a medium-dispersion spectroscopic module for simultaneous observation of the Hα and Ca II HK lines with GAOES-RV is being led by Kyoto University.

(3) Development of remote and queue observations

Since January 2024, remote observations without on-site observers, in collaboration with the Okayama Observatory of Kyoto University, have been made available for open use. Testing of the queue observation system is currently underway.

(4) Research results

The following example of significant research results from observations with the Seimei Telescope was published in a paper during FY 2024.

Spectroscopic monitoring observations of the active M-dwarf YZ CMi were conducted with a time resolution of approximately one minute, accompanied by simultaneous photometric observations by TESS. A total of 27 Hα flares were detected, with blue asymmetries observed in three events and red asymmetries in five. These asymmetric components showed velocity ranges of 200–450 km/s and exhibited diverse temporal variations. Notably, asymmetric events occurring over short durations of 6–8 minutes were newly identified, some of which were interpreted as prominence eruptions. Based on this result, the occurrence rate of prominence eruptions is estimated to be approximately 1.1 times per day. These short-duration events were likely overlooked in previous observations with lower time resolution and provide important insights into the impact of stellar activity on the environments of habitable planets around M-dwarfs.

(5) Meetings

(a) Seimei Users Meeting

The sixth Users Meeting was held on September 9-10, 2024, at Kurashiki Geibunkan in Okayama, in an online hybrid style. The organizing committee consisted of: Kodai Yamamoto (Kyoto University) as the Chair, Akito Tajitsu (NAOJ), Katsuhiro Murata (Kyoto University), Yuu Niino (The University of Tokyo), and Kento Masuda (Osaka University). The total number of participants was approximately 80.

(b) Seimei Subcommittee

The subcommittee held five meetings in Fiscal Year 2024, primarily dedicated to the time allocation for open use observation programs for the latter half of 2024 and the first half of 2025. The committee members in FY 2024 were chaired by Fumihide Iwamuro (Kyoto University), with members including Miho Konishi (Oita University), Yoichi Ito (University of Hyogo), Megumi Shidatsu (Ehime University), Masaomi Tanaka (Tohoku University), and Yoshiki Toba (NAOJ).

(c) Kyoto University 3.8-m Telescope Council

On September 27, 2024, the Graduate School of Science at Kyoto University and NAOJ held the seventh Kyoto University 3.8 m Telescope Council meeting in the Okayama Branch. The purpose of the meeting was to discuss the operation of the Seimei Telescope. It was attended by the Dean of the Graduate School of Science at Kyoto University, the Director General of NAOJ, and numerous others. The meeting included discussions on the operational status and presentation of research outcomes.

2. Telescopes of the former Okayama Astrophysical Observatory

(1) 188-cm reflecting telescope

(a) Although the 188-cm telescope had remained out of operation due to the dome shutter collapse accident that occurred on September 29, 2022, steady progress in recovery planning led to a decision at the end of FY 2023 to proceed with the restoration work, to be undertaken by Yokogawa System Building Co., Ltd. (currently Yokogawa Bridge Corp.). The repair work was conducted from September to December 2024 and was successfully completed. The newly adopted horizontally sliding shutter system significantly improved functionality, reducing the opening and closing time from 11 minutes to approximately 80 seconds.

(b) Alongside the completion of the dome repair, restoration efforts were carried out for the telescope and observation instruments, which had been inactive for approximately two and a half years. As a result, regular observations resumed in March 2025.

(c) On October 11, 2024, a meeting of the 188-cm Telescope Operation Council was held at Asakuchi City Hall. At this meeting, the contents and progress of the ongoing dome shutter restoration were presented and discussed with council members, including representatives from Asakuchi City and Institute of Science Tokyo.

(2) Other telescopes

Okayama Branch also cooperated in the operation of several telescopes, including the 91-cm reflecting telescope, the 50-cm reflecting telescope known as MITSuME, and the Thirty Milli-Meter Telescope (TMMT) in the 4-m dome.

(3) Study of Next-Generation Observation Instruments

As part of efforts to develop next-generation observation instruments for the 188-cm telescope and the Seimei Telescope, plans for a super-high spectral resolution spectrograph were under consideration. In recent years, the search for extrasolar planets using the radial velocity method has advanced significantly through the use of high-dispersion spectrographs with a resolving power of approximately 100,000 in highly stable environments. These instruments can achieve wavelength precision down to several tens of cm/s, enabling the detection of Earth-like planets. However, despite improvements in instrumental precision, the observed radial velocity variations induced by planets remain limited to around 1 m/s, showing signs of stagnation. This limitation is believed to result from the inability to fully eliminate stellar surface activity signals. To overcome this challenge, a new spectrograph with a resolving power of 300,000 is being planned. In order to maintain high spectral resolution without sacrificing efficiency, the implementation of an image slicer is being considered. For improving wavelength calibration accuracy, the project will utilize the laser frequency comb (optical frequency comb) that has been developed at the Okayama Branch. Additionally, the use of a large CMOS detector is planned to allow for high-frequency alternation between reference light sources and celestial light. This project has been selected for funding under the Grants-in-Aid for Specially Promoted Research, and the development is scheduled to begin in FY 2025.

3. Public Outreach

Since the Okayama Branch lacks staff assigned to public relations and dissemination activities, only essential tasks are performed.

(1) The Asakuchi City Okayama Astronomical Museum, in collaboration with Kyoto University and NAOJ, organized public stargazing events using the Seimei Telescope through general applications. In FY 2024, these events were held four times, with approximately 40 participants each time.

(2) On October 26, 2024, the third “Asakuchi Observatory Festival” 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 operation of the supercomputer ATERUI II (Cray XC50) installed in 2018 was terminated in August, and the new supercomputer ATERUI III (HPE Cray XD2000) began operation in December. Efforts in visualizing astronomical data also continue.

2. Open Use of Computers

(1) General Status

This year marked the seventh year of operation of the supercomputer (Cray XC50), which is the core of the joint-use computing facility operated by the center (the lease period was six years, but was extended to 6.5 years), and also the first year of operation of a new supercomputer (Cray XD2000). Both supercomputers were installed in Mizusawa VLBI Observatory and have been operated with the full cooperation of the observatory. XD2000, which replaced XC50, which has achieved significant scientific results, began operation in December 2024, and is also continuing to operate smoothly.

While XC50 is leased for six years from Hewlett-Packard Enterprise (which acquired Cray. Note that the lease period was extended from six years to six and a half years), 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 113 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 (operation ended on September 2, 2024)
- Operating hours
  Annual operating hours: 3653.1 hours
  Annual core operation ratio by users' PBS jobs: 96.91 %
- Number of users
  Category A: 14
  Category B+: 14
  Category B: 121
  Category MD: 27
  Category Trial: 40

Cray XD2000 (operation started in December 2024)
- Operating hours:
  Annual operating hours: 2831.4 hours
  Annual core operation ratio by users' Slurm jobs: 80.87 %
- Number of users
  Category A: 15
  Category B+: 19
  Category B: 125
  Category MD: 27
  Category Trial: 47

GPU System
- Operating hours
  Annual operating GPU hours: 96,040
- Number of users
  21 (at the end of the fiscal year)

General-Purpose PC farm
- Operating hours (Ryzen nodes)
  Annual operating hours: 7900 (a ballpark figure)
  Total number of submitted PBS jobs: 831,871
  Annual core operation ratio by users' PBS jobs: 92 % (a ballpark figure)
- Operating hours (EPYC nodes)
  Annual operating hours: 2491 (a ballpark figure)
  Total number of submitted PBS jobs: 326
  Annual node operation ratio by users' PBS jobs: 41 % (a ballpark figure)
- Number of users
  68 (at the end of the fiscal year)

Small Parallel Computers
- Operating hours
  Annual operating hours: 5159 (a ballpark figure)
  Total number of submitted PBS jobs: 3256
  Annual node operation ratio of each queue by users' PBS jobs (a ballpark figure):
    Small queue node: 24 %
    Single queue node: 86 %
    Single-debug queue node: 0.1 %

(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 iSALE shock physics code (medium-level tutorial)
  January 7–28, 2025
  11 attendees (+ 2 lecturers from outside NAOJ + 1 lecturer from inside NAOJ)
- Cray XD2000 workshop for novice users (zoom)
  Introduction to the basic usage of XD2000 system, which started operation in December 2024
  December 10, 2024
  75 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
  November 25–26, 2024
  November 25: 49 attendees (Onsite) + 44 attendees (Online),
  November 26: 51 attendees (Onsite) + 29 attendees (Online)
- Early spring school for N-body numerical simulations (Onsite + zoom)
  Lectures on N-body simulations, and programming practice using GPU and GRAPE-Library
  February 4–6, 2025
  13 attendees (for hands-on training and lectures), 2 attendees (for lectures only)
- School for numerical hydrodynamics (Onsite+zoom+Slack)
  Lectures on the basics and applications of Smoothed Particle Hydrodynamics, with practical exercise using NanoASURA.
  March 24–26, 2025
  15 attendees (for hands-on training and lecture)

3. PR Activity

In FY 2024, the following press releases were issued from the center:

"Simulations Yield New Intermediate Mass Black Holes Recipe"
May 31, 2024, Michiko Fujii (The University of Tokyo) et al.

"Supercomputer "ATERUI III" Opens New Era of Simulation Astronomy"
December 2, 2024, Center for Computational Astrophysics, NAOJ

In addition, the following research results and news appeared on the CfCA website:

"A New Horizon for the Kuiper Belt: Subaru Telescope's Wide-Field Observations"
June 26, 2024, Fumi Yoshida (Chiba Institute of Technology), Takashi Ito (CfCA/NAOJ) et al.

"Supercomputer simulations reveal the nature of turbulence in black hole accretion disks"
August 29, 2024, Yohei Kawazura (Utsunomiya University, Tohoku University), Shigeo Kimura (Tohoku University)

"Structure of the Outer Solar System Revealed - The Subaru Telescope and New Horizons' 20-Year Challenge"
September 5, 2024, Fumi Yoshida (Chiba Institute of Technology), Takashi Ito (CfCA/NAOJ) et al.

"Influence of a Black Hole's Spin: First Evidence of Precession in Ultraluminous Accretion Disks"
October 11, 2024, Yuta Asahina, Ken Ohsuga (University of Tsukuba)

"M87's Powerful Jet Unleashes Rare Gamma-Ray Outburst"
December 13, 2024, EHT Multi-wavelength Science Working Group, EHT Collaboration et al.

In December 2024, we held a press conference at Mizusawa Campus to announce the renewal of the supercomputer system and to unveil the actual system. In January 2025, we held a "Lecture on Astronomy for Science Journalists" for media representatives to introduce the new supercomputer system "ATERUI III," its expected science, and the results obtained from the supercomputer "ATERUI II."

At the Mitaka Open House Day 2024 held in October 2024, the CfCA computer room was open for tours and about 100 visitors were guided. A Twitter/X account @CfCA_NAOJ and YouTube channel have been operated to provide the information on CfCA.

4. 4D2U Project

In FY 2024, the 4D2U project continued to develop and provide movie content and software. In February 2025, we started to publish HD and VR versions of "Star Cluster Formation in Molecular Clouds" and to distribute the dome master file. We also continue to provide 4D2U content produced so far to TV programs, books, science museum exhibitions, planetarium programs, etc.

In FY 2024, the projection system of the 4D2U Dome Theater was updated in cooperation with the Public Relation Center of NAOJ. In October 2024, we held a "Lecture on Astronomy for Science journalists" to unveil the new 4D2U Dome Theater projection system to the media. At the unveiling, Associate Professor Michiko Fujii of the University of Tokyo and 4D2U Senior Specialist Takaaki Takeda showed and introduced a new movie, "Star Cluster Formation in Molecular Clouds."

At the Japan Planetarium Association meeting held in June 2024, 4D2U gave an oral presentation introducing the recent activities and latest contents of the 4D2U project, introduced applications currently under development through a booth exhibit, and actively exchanged information with planetarium personnel.

For the 2024 Mitaka Open House Day, CfCA staff members introduced their research on simulated astronomy at the 4D2U dome theater by showing 4D2U videos. Approximately 100 people attended the three screenings. Continuing from the previous year, 4D2U also operated a Twitter/X and YouTube channel to provide information on 4D2U contents, related events, and media coverage.

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 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 several programs: Programs for Promoting Research on the Supercomputer Fugaku. Of which the newest one is Structure and Evolution of the Universe Unraveled by Fusion of Simulation and AI. CfCA joins this project.

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 and Tomoya Takiwaki conducted research on "black hole accretion disks and relativistic jets," and "Elucidation of the mechanism of 3D supernova explosions by first-principles calculations of neutrino radiation transport" using a magnetohydrodynamics code and a mesh-type fluid code, respectively. We obtained funds for this project. 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. The technical investigation of what the architecture of the next generation flagship of Fugaku should be is also in full swing.

6. Other Activities

(1) Hosting internships
n/a

(2) Committee members at international organizations
IAU Commission F2 Organizing Committee (Eiichiro Kokubo)

(3) Support activity for Super Science Highschools
Hibiya Highschool, Tokyo, 2024 January 14 (Eiichiro Kokubo)

(4) List of major visitors

- Yixian Chen (Princeton University, USA, PhD student, host: Eiichiro Kokubo) 2024/5/22–2024/5/22 seminar
- Bin Cheng (Tsinghua University, China, Assistant Professor, host: Eiichiro Kokubo) 2024/7/5–2024/7/5 seminar
- Wen-Han Zhou (Observatoire de la Côte d'Azur, France, PhD student, host: Eiichiro Kokubo) 2024/9/4–2024/9/4 seminar
- Chris Ormel (Tsinghua University, China Professor, host: Eiichiro Kokubo) 2024/11/19–2024/11/22 seminar
- Shuo Huang (Tsinghua University China, PhD student, host: Eiichiro Kokubo) 2024/11/22–2024/11/22 seminar
- Helong Huang (Tsinghua University, China, PhD student, host: Eiichiro Kokubo) 2024/11/22–2024/11/22 seminar
- Hanno Rein (University of Toronto, Canada, Associate Professor, host: Eiichiro Kokubo) 2024/12/20–2024/12/20 seminar

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 ALMA2 project, launched in FY 2023, represents Japan's strategic framework for the next decade. By continuing scientific observations and upgrading its observational capabilities, ALMA is expected to remain at the forefront of global astronomy in the years ahead. This report highlights the key developments and manufacturing of new instruments in the ALMA2 project, as well as the progress of open-use scientific observations, which are supported by the daily operational work, 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 provide a stably operational telescope, maximize the availability of observing time, and make the operations user-friendly to facilitate science for broader communities; to collect and deliver high-quality data sets to the scientific community by operating, maintaining, and further developing a state-of-the-art observatory; to produce outcomes to meet the scientific requirements from broader fields of research and obtain fair evaluation from the scientific community; and to dramatically improve the capabilities of the ALMA telescope during ALMA2 to provide the international academic community with unparalleled radio observation capabilities to explore the birthplace of planets and the evolution of matter in the Universe, including elemental components for life. 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; to provide the interface in Chile with the Joint ALMA Observatory (JAO), the other ALMA Executives, and Chilean institutions; and to 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. The ngVLA Study Group has been assessing, together with the scientific community, unique and compelling science cases, as well as the technical feasibility of Japan contributing to the ngVLA project. The ngVLA Study Group has been leading various development studies, which will allow NAOJ to contribute to the construction of the telescope array in a timely manner, if supported by the Japanese scientific community and the necessary budget processes.

1. Progress of the ALMA Project

ALMA has long been working to establish the framework for implementing the Wideband Sensitivity Upgrade (WSU). In Japan, the WSU is carried out as part of the ALMA2 project. East Asia is responsible for the development of several key components of the WSU: the upgraded Band 8 receivers to expand the frequency ranges that can be simultaneously covered in observations (Band 8v2); the Data Transmission System (DTS) capable of high data rate and high-capacity data transfer; and the Total Power GPU Spectrometer (TPGS), a next-generation spectrometer for the Total Power Array. The proposal for the first phase of the Band 8v2 project was approved by the ALMA Board in 2023 and development is underway (see the chapter of the Advanced Technology Center for details). Development of DTS and TPGS is also progressing. In addition, the integrated WSU system and its implementation are being extensively discussed and designed across the entire ALMA Partnership, with many ALMA staff contributing from the perspectives of science, development, engineering, computing, and science operations. For this WSU system, the delta System Requirements Review and the Initial Program Plan Review were conducted between May and July 2024, with the review meeting held in July. The following paragraphs describe the progress of DTS and TPGS.

As one of the WSU development projects, NAOJ is leading the upgrade of the DTS in collaboration with NRAO, with technical support from the Photonic Network Laboratory of the National Institute of Information and Communications Technology (NICT). The DTS is designed to transmit four 400 G optical data streams from each antenna to ATAC at OSF, which is the new correlator for the WSU, over a distance of up to 120 km using Dense Wavelength Division Multiplexing (DWDM) technology. In FY 2024, the third year of the DTS project, development activities in the preliminary design phase continued to advance. In addition to the previous proof-of-concept testing, we expanded system design and evaluation by testing DTS configurations with 400G-ZR optical transceivers from multiple vendors and by selecting key components such as EDFAs and 4-channel MUX/DEMUX units for DWDM. Based on these results, the Preliminary Design was compiled, and an international Preliminary Design Review (PDR) meeting was conducted in October 2024. The DTS design proposed by the team, along with the system demonstrations performed during the review, were highly praised by the review panel, leading to a successful completion of the PDR. Following this achievement, the DTS team has begun the prototyping of DTS units and their monitor and control software, proceeding to the Critical Design phase. These prototypes are planned to be used for end-to-end integration tests with other WSU subsystems at NRAO scheduled for 2025.

The design of a new GPU-based spectrometer for the Total Power Array was initiated by KASI (Korea Astronomy and

Space Science Institute) in close collaboration with NAOJ. This new spectrometer, named TPGS, has been designed to meet the science requirements for the WSU era. The design team successfully passed the Conceptual Design Review and Subsystem Requirements Review in November 2024.

2. ALMA Open-Use and Scientific Achievements

The 11th round of ALMA open-use observations (Cycle 10) finished on September 30, 2024. It is remarkable that an impressive total of 4,250 hours of science-quality data were successfully acquired on the 12-m Array during Cycle 10, which significantly exceeds the previous record of 3,787 hours. Record numbers were also achieved on the 7-m (3,769 hours) and Total Power (2,723 hours) Arrays. The subsequent transition to Cycle 11 on October 1 was completed on schedule. For Cycle 11, a total of 1,712 proposals were submitted requesting 31,608 hours of time on the 12-m Array, which is the highest amount of time ever requested in a single Cycle. This resulted in an oversubscription rate of 7.4. The main capabilities of Cycle 11 include interferometric observations using at least forty-three 12-m antennas; ACA observations (interferometric observations with at least ten 7-m antennas and single-dish observations with at least three 12-m antennas); 9 frequency bands (Bands 1, 3, 4, 5, 6, 7, 8, 9, 10) and maximum baselines of 13.6 km. Band 1 receivers developed in EA are available for all time in the Cycle, for the first time. Several new observation capabilities are introduced; Full polarization in Band 1 on the 12-m Array, Band 1 on the 7-m Array (Stokes-I only), High-frequency (Bands 8, 9, 10) long-baseline observations, 4x4-bit spectral mode on the 7-m Array that allows spectral setups fully compatible with those of the 12-m Array.

As was also in the case of Cycle 10, a Joint Proposals framework has been available in Cycle 11 with three other facilities: the Space Telescope Science Institute's James Webb Space Telescope (JWST), the National Radio Astronomy Observatory's Karl G. Jansky Very Large Array (VLA), and the European Southern Observatory's Very Large Telescope (VLT).

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.

A team led by Kazuki Tokuda, an astronomer affiliated with NAOJ and Kyushu University, studied a group of young stars called Taurus Dense Core MC 27. This stellar nursery is located approximately 450 light-years from Earth in the direction of the constellation Taurus. The team discovered the remnants of powerful 'sneezes' expelling gas, dust, and electromagnetic energy from around stars in the process of forming. The team believes that these sneezes help the baby star expel excess magnetic flux, and as such may play a vital role in enabling the star to form.

Observations reveal that in the early Universe, high-luminosity quasars powered by billion-solar-mass black holes coincide with intense starbursts. To probe their progenitors, a research team led by Associate Professor Yoshiki Matsuoka of Ehime University used Subaru Telescope's Hyper Suprime-Cam to detect the faintest "pair quasars" at 12.8 billion light-years, marking the earliest pre-merger stage. ALMA observations by a research team led by Associate Professor Takuma Izumi of NAOJ then confirmed that these two host galaxies, bridged by gas and totaling around 100 billion times the mass of the Sun, are indeed interacting and destined to merge, supplying fuel for future quasar brightness and starbursts. This breakthrough identifies true ancestors of early high-luminosity quasars and starburst galaxies.

ALMA successfully observed a site of planet formation by detecting a high concentration of dust grains, a planet-formation material, outside the orbits of just-formed planets. An international research team led by Kiyoaki Doi, who was a Ph.D. student at NAOJ/the Graduate University for Advanced Studies (SOKENDAI) at the time and is currently a postdoctoral fellow at the Max Planck Institute for Astronomy, performed high-resolution observations of a protoplanetary disk around a young star called PDS 70 at a wavelength of 3 mm with ALMA. The object hosts two known planets, and the new observations revealed a localized accumulation of dust grains outside the planetary orbits. This finding suggests that already-formed planets accumulate the material for a planet and facilitate the potential formation of the next planet. This work contributes to revealing the formation process of planetary systems consisting of multiple planets, like the Solar System.

Based on ALMA multi-band observations of dust polarization, the magnetic field structure in a protoplanetary disk has been measured for the first time. A research team led by Project Assistant Professor Satoshi Ohashi at NAOJ investigated the dust polarization in the protoplanetary disk around a young star: HD 142527, by analyzing ALMA 0.9, 1, 2, and 3 mm observation data. As a result, they discovered strong dust polarization primarily due to the magnetic field. Furthermore, they successfully estimated the strength and the three-dimensional structure of the magnetic field. This research can help to understand the role of magnetic fields in planet formation.

An international team led by Project Assistant Professor Jorge Zavala from NAOJ observed the distant galaxy GHZ2 (GLASS-z12), detecting emission from excited Hydrogen and Oxygen atoms at redshift $z = 12.333$—about 13.4 billion light-years away. This marks ALMA's first detection at $z > 10$ with multiple spectral lines. This in-depth study offers the first direct insights into the properties of the earliest galaxies in the Universe, a glimpse into the distant past.

An international research team led by Professor Ken-ichi Tadaki of Hokkai-Gakuen University observed a supermassive black hole from 12.9 billion years ago, revealing its surrounding gas heated by intense X-rays from its accretion disk and corona, as well as quasar-driven winds and shocks. By detecting high-energy CO emissions, they probed gas only hundreds of light-years from the black hole—conditions too extreme for stellar heating alone. This method also uncovers obscured quasars hidden by dust, since radio waves penetrate dust unlike visible light or X-rays. Applying ultra-high-resolution CO observations broadly promises a fuller census of early, "hidden" supermassive black holes and insights into their formation and evolution.

3. Education and Public Outreach Activities

In FY 2024, the achievements with ALMA continued to be covered by the media, such as newspapers, magazines and TV. They included research on planet formation led by a graduate student. The NAOJ ALMA website posted 25 news articles and 10 press releases. Mailing-list-based newsletters with approximately 2,000 subscribers have been issued 4 times per year. Day-to-day information is posted in a timely manner on X (formerly Twitter) (@ALMA_Japan) with nearly 74,000 followers as of the end of FY 2024. Impressive images are often posted on Instagram with 11,000 followers.

Twelve public lectures were given in FY 2024. In May, the NAOJ ALMA Project exhibited a joint booth with the NAOJ TMT Project at the Japan Geoscience Union Meeting. The open house of Nobeyama Radio Observatory was held in August, and posters and video contents of ALMA were also presented. NAOJ held the Mitaka Open House Day on site in October, where the ALMA Project displayed posters, models of an antenna and the Atacama Desert, gave short-lectures, and so on. In March, NAOJ Chile Observatory joined the Open Day of the Joint ALMA Observatory (JAO) and provided NAOJ leaflets and traditional origami activities.

The NAOJ ALMA Project continues to collaborate with the JAO to 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 the ALMA telescope and its scientific results in a fun way. The NAOJ ALMA Project provided scientific news information for Universe Awareness (UNAWE) for kids, maintained by the IAU Office for Astronomy Outreach.

4. International Collaboration (Committees, etc.)

Meetings for the international ALMA project are held frequently by various committees and groups. The ALMA Board meeting took place in Washington D.C. in April and at the JAO in November. The ALMA Scientific Advisory Committee (ASAC) held online meetings as needed, while the ALMA East Asian Science Advisory Committee (EASAC) held online meetings twice. Groups in charge of specific tasks of the ALMA operations and development also held frequent meetings, both in-person and online, to implement the international projects in close cooperation.

5. Workshops

- July 22–26, 2024: EA ALMA Science Workshop & ALMA Data Analysis Workshop, Korea Seoul National University
- October 8–9, 2024: ALMA Development Workshop, NAOJ Mitaka Campus and online
- November 11–13, 2024: ALMA Workshop "AGN Feeding and Feedback in Massive Galaxies at the Centers of Galaxy Clusters", Kagoshima University
- November 25, 2024: ALMA Workshop "Exploring Hierarchical Interstellar Matter with High-Spatial Dynamic Range and Multi-Line Observations", online
- December 18–20, 2024: ALMA/45m/ASTE Users Meeting 2024, NAOJ Mitaka Campus and online
- December 27, 2024: Atacama Submillimeter Telescope Experiment (ASTE) Science and Development Workshop 2024, NAOJ Mitaka Campus and online
- February 18–20, 2025: KASI-NAOJ F2F meeting, NAOJ Mitaka Campus and online
- March 3–4, 2025: ALMA Workshop "Exploring Hierarchical Interstellar Matter with High-Spatial Dynamic Range and Multi-Line Observations", Nagoya University (+online)
- March 10–12, 2025: ALMA Workshop "Revealing the Nature of Supermassive Black Hole Coronae with Synergy of XRISM and ALMA", Osaka University Nakanoshima Center
- March 21, 2025: ALMA Cycle 12 Proposal Preparation Meeting, NAOJ Mitaka Campus and online
- March 26–27, 2025: ALMA Workshop: "Multi-scale Perspectives in Galaxy Evolution", Osaka Electro-Communication University (+online)

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

- Satoru Iguchi: funded by the research support program of the National Institutes of Natural Sciences (NINS) (OPEN MIX LAB (OML) Program, PI: Toshikazu Onishi (Osaka Metropolitan University)

7. Main Visitors

- May 2, 2024: Takako Ito, Ambassador of Japan to Chile, visited the operation site facilities and the observatory close to San Pedro de Atacama in Chile.
- May 4, 2024: United Nations Secretary-General António Guterres visited the ALMA telescope site in the Atacama Desert, Chile.
- March 3, 2025: Takako Ito, Ambassador of Japan to Chile, visited NAOJ Mitaka Campus.

8. Progress of the ASTE Telescope

After the recovery of the subreflector drive mechanism in May 2024, test observations of the integrated superconducting spectrometer, DESHIMA 2.0 (PIs: Akira Endo (Delft University of Technology) and Yoichi Tamura (Nagoya University)), resumed in June 2024. Its observations were continued until the end of November. During this period, the telescope site in Chile suffered several power outages due to power generator faults and several communication breakdowns with the antenna control unit rack. Still, the planned data acquisition was fully completed through prompt recovery efforts.

In Japan, the project proceeded with the maintenance of the heterodyne receivers returned from Chile. Specifically, the cryocooler maintenance was carried out. For the DASH345 receiver covering the 345 GHz band and the CAT8W receiver covering the 460 GHz band, the root causes of their faults were addressed, and their original performances were recovered. In addition, the project replaced parts to solve the phenomenon in which the output of the IFDC (intermediate frequency down converter) fluctuates significantly when the antenna is tilted.

On December 27, 2024, the ASTE Science and Development Workshop was held at NAOJ Mitaka. Despite the end of the year, there were many participants both on-site and remotely, and a lively discussion was held on the future of the ASTE telescope.

In Chile, the telescope operation was temporarily suspended after December 2024. After the February-March maintenance period in 2025, the operation was resumed to complete the AZ torque limiter replacement, the annual antenna maintenance by NAOJ staff, and the installation of the heterodyne receivers and the spectrometer.

In addition, the project has addressed the major issues raised in the international external review conducted in March 2024, namely, the update of a website to share information with the user community, the strengthening of the human resources, and preparations for the release of observation data such as demonstration science data through the Japanese Virtual Observatory (JVO), etc.

9. Progress of the ngVLA

Over the past decade, ALMA has significantly advanced many areas of astronomy: it has revealed gaps in protoplanetary disks, detected heavy elements in distant galaxies, and imaged a black hole's shadow via the EHT collaboration. While ALMA will continue to yield groundbreaking results, some key questions require higher resolution at lower frequencies—where dust opacity is lower and non-thermal radiation dominates. Our motivation is to explore this regime with a resolution and sensitivity far beyond ALMA and the JVLA. The ngVLA, led by NRAO, is the only facility capable of this, offering >10× the resolution and 10× the sensitivity of current instruments at comparable frequencies. The ngVLA will address these specific challenges through its three complementary components: (1) the Main Array (MA) = 214×18-meter antennas, (2) the Short Baseline Array (SBA) = 19×6-meter antennas and 4 additional 18-meter antennas used as single-dish telescopes, and (3) the Long Baseline Array (LBA) = 30×18-meter antennas operating in VLBI mode. The ngVLA will be equipped with six receiver bands, covering a wide frequency range from 1.2 GHz to 116.0 GHz.

The ultimate goal of the ngVLA Study Group in NAOJ is to realize the aforementioned scientific objectives—as well as a broad range of PI-driven research topics—by (i) participating as a major partner (~10–20 % level of the total construction + operation cost) in the ngVLA project and (ii) securing guaranteed observing time for the Japanese community in the post-2030 era. Leveraging its exceptional angular resolution and sensitivity at cm and mm wavelengths, the ngVLA will probe astronomical sources emitting synchrotron, free-free, and thermal dust continuum emissions, as well as a rich array of spectral lines.

Key contributions from Japan include strengthening Japanese compelling science cases by the five Science Working Groups (SWGs) led by the community, as well as in-kind technical contributions led by NAOJ, which cover (1) Construction of ultra-low cost antennae, (2) Time/frequency reference signal transfer systems development, and (3) Receiver development. (2) and (3) are led by NAOJ/ATC.

Regarding the SWG-led activity, we held multiple domestic science workshops in FY 2024 to foster collaboration, understand recent major progresses provided by ALMA and JWST, and to update our compelling science cases as necessary. We also decided to have a joint-SWG workshop in FY 2025, and then an international science conference in Japan in FY 2026.

Major examples of technical progress in FY 2024 are as follows.

(1) Ultra-low cost antenna: The initial design phase of the 18-m antenna was completed. But we also identified some items that will potentially further improve the accuracy and the cost of the Japanese antennas. We will then continue the designing and initiate the experiment phase in FY 2025.

(2) Time/frequency reference signal distribution systems: The key technologies developed in NAOJ/ATC successfully passed the ngVLA Conceptual Design Review in September 2024. Now is a pivotal moment to advance this technology for application in large-scale interferometric arrays such as the ngVLA. We plan to prototype the system in close collaboration with industrial partners and Japanese universities, and conduct on-site experiments in FY 2025.

(3) Receivers: The base-designs of the waveguide components (horn, OMT) of the ngVLA Band 6 became available in 2024. Component-level performance tests will be done in ATC in FY 2025. We will continue to explore the possibility to collaborate with Japanese universities to complete a full-design of the Band 6 receiver.

We will continue to work on these items to obtain a more realistic estimate of Japan's cost and a strategic contribution plan.

07. Gravitational Wave Science Project

The large-scale cryogenic gravitational wave telescope KAGRA, promoted by the National Astronomical Observatory of Japan (NAOJ) in collaboration with the Institute for Cosmic Ray Research (ICRR) at the University of Tokyo and the High Energy Accelerator Research Organization (KEK), suffered major damage due to the Noto Peninsula Earthquake on January 1, 2024. Recovery was completed in September 2024, and efforts continued to improve sensitivity in preparation for the third phase (O4c) of the 4th international gravitational wave observation run (O4).

On Mitaka Campus, R&D progressed through international collaborations with Taiwan and the Republic of Korea, including the design of a quantum optics source for KAGRA and improved efficiency of frequency-dependent squeezing using TAMA300. Joint research with France on high-quality sapphire mirrors also advanced. New international collaborations began with Australia, the UK, Germany, and Italy.

1. Gravitational Wave Telescope KAGRA

NAOJ is primarily responsible for vibration isolation systems, auxiliary optics, mirror characterization, and the main interferometer of KAGRA. It also plays a central role in signal calibration and noise evaluation and contributes to operations through the Executive Office, System Engineering Office, and KAGRA Scientific Congress.

(1) **Main Interferometer & Commissioning**

Continuing from the previous year, efforts were focused on repairing damage to the KAGRA interferometer caused by the Noto earthquake and implementing countermeasures. Restoration took over nine months. Investigations and improvements were also made on several areas potentially limiting sensitivity. As a result, sensitivity increased by a factor of 2.5 by the end of FY 2024. Efforts continue to improve sensitivity and operational stability toward rejoining O4c around June 2025.

(2) **Vibration Isolation System**

The stacked vibration isolation system for the Output Mode Cleaner (OMC) was reconstructed due to direct contact between upper and lower stages. The number of stack stages was optimized based on performance evaluation. In addition to the previously used displacement (LVDT) and velocity (geophone) sensors in Type-A systems, control using a folded pendulum accelerometer was introduced.

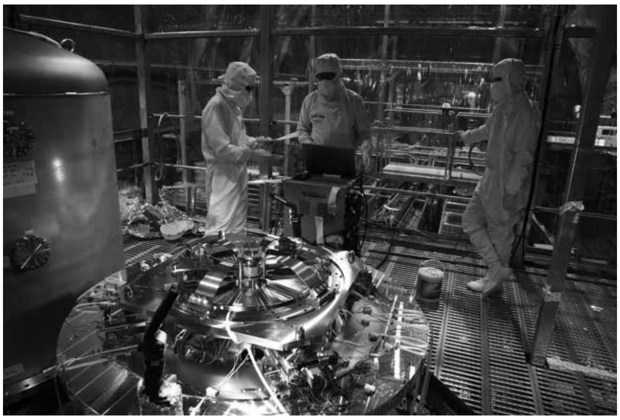

Figure 1: Adjusting the Vibration Isolation System.

(3) **Auxiliary Optics**

Preparations for the O4c upgrade and new devices for O5 were studied by incorporating knowledge from LIGO and other international sources. Specifically, design, fabrication, and installation of the OMC shroud—a stray light mitigation structure around the OMC—were completed. A conceptual design of the OMC vibration isolation table for O5 was also developed.

(4) **Mirror Characterization**

To replace the two input sapphire mirrors (ITMs) with higher performance versions for O5, new ITMs are being fabricated. Two crystals were selected at NAOJ after quality assessment and are undergoing pre-polishing and final polishing. Development of a high-speed birefringence measurement system and joint research with France on high-quality sapphire crystals were also conducted.

(5) **Signal Calibration**

Contamination found in the Pcal-Y (Photon Calibration System-Y) was cleaned and the system was restored. Regular calibration of two Pcal systems continued for O4c, and calibration statistics have been accumulated. At University of Toyama, automation of the calibration system improved reproducibility and efficiency. For Ncal (Newtonian Calibration System), testing preparations were carried out at KEK, and design and component fabrication were completed for post-O4 KAGRA deployment. For O4a data, uncertainty in the gravitational wave strain signal h(t), including Pcal uncertainty, was evaluated and shared with the analysis group. The Pcal paper written within LVK was published in Metrologia.

(6) **Noise Evaluation**

Environmental noise in the KAGRA interferometer was assessed through vibration and acoustic injection tests. Detailed studies were conducted in the OMC and IFI chambers to guide improvements. A large magnetic injection coil (6 m × 2 m, 96 turns) was constructed and tested in the central KAGRA lab. For the Einstein Telescope, acoustic noise at a mine in Sardinia, Italy—one of the candidate construction sites—was analyzed jointly with Polish institutions (University of Warsaw and Copernicus Science Centre).

(7) **Other**

Thermal noise in the sapphire suspension system was evaluated in collaboration with KEK. Results indicated that the bonding between fibers and end blocks determined the mechanical Q factor, and improvements were made accordingly.

2. Fundamental Research Using TAMA300

At Mitaka Campus, advanced technologies for future gravitational wave telescopes are being developed using the first-generation TAMA300 interferometer and ATC laboratory, with an eye toward KAGRA upgrades and third-generation telescopes. NAOJ also supported stress measurement in bio-cells using a gravitational wave detection technology through a matching fund with the University of Electro-Communications (UEC).

(1) **Squeezing Technology**

Development of squeezing technology to improve broadband sensitivity continues. At TAMA300's filter cavity, fast quantum state tomography using machine learning is under study. Joint development of a squeezer for KAGRA with Taiwan and the Republic of Korea also progressed.

(2) **Detector R&D**

To significantly improve detector sensitivity in the future, a new control method for the speedmeter-type interferometer was developed and demonstrated. Plans for next-generation experiments at TAMA300 were discussed, exploring possibilities such as EPR entanglement squeezing and tunable-bandwidth filter cavities.

3. Education

Four students from the University of Tokyo's Department of Astronomy and one UEC contract student were enrolled, while one Institute of Science Tokyo student received research guidance at TAMA300. One graduate student each from Maastricht University (Netherlands), Claude Bernard Lyon 1 University (France), and University of Angers (France) participated in internships. NAOJ members lectured at graduate and undergraduate levels at the University of Tokyo and Hosei University. Outreach lectures were also conducted for high school students and during the Fureai “Friendly” Astronomy events.

4. Outreach Activities

During “Mitaka Open House 2024” (October 19, 2024), a guided tour of the TAMA300 facility was held.

5. International Collaboration & Visitors

There were 20 international visitors. Joint research progressed with institutions such as National Tsing Hua University (Taiwan), KASI (Korea), and UWA (Australia). Active exchanges, including a TAMA Strategy Meeting, were conducted. NAOJ members also visited ANU (Australia) and UWA for joint research under Institute of Science Tokyo’s ASPIRE program.

6. Publications, Presentations & Workshops

Project members co-authored 21 peer-reviewed papers in international journals. Additionally, there was one non-peer-reviewed English paper, one English publication report, and one Japanese-language report. There were 27 oral presentations at international conferences and 34 other conference presentations.

7. External Funding (Non-KAKENHI)

No external funding outside of KAKENHI was acquired.

08. Thirty Meter Telescope (TMT)

The Thirty Meter Telescope (TMT) Project is a project to build an extremely large 30-meter telescope under international collaboration. For Japan's part, the National Institutes of Natural Sciences (NINS) is the ultimately responsible body, and NAOJ is the executing institute. In 2014, an agreement was executed among the 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 fabrication of the telescope primary mirror; the design and fabrication 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 established at NAOJ.

In Hawai‘i where TMT is slated to be built, with the State of Hawai‘i's approval of a new Conservation District Use Permit (CDUP) for TMT construction on Maunakea in 2017, on-site construction was planned in 2019. However, protests and road blockades prevented full-fledged construction of TMT. Currently, as a TIO member, NAOJ provides assistance for TIO's continued efforts for building trust in Hawai‘i through direct dialogue, educational programs, and other community engagement activities together with relevant organizations, considerably improving the situation surrounding the project. In the State of Hawai‘i, the transfer of management from the University of Hawai‘i to the newly established Maunakea Stewardship and Oversight Authority (MKSOA), formed in 2022, is currently underway. In the U.S., the National Science Foundation (NSF) is preparing for participation in the TMT project by getting ready to enter the Final Design Phase. It has been also engaging in the environmental review process to evaluate environmental effects of the TMT project on the construction site, and has been assessing impacts on historic properties by consultation with the local communities under Section 106 of the National Historic Preservation Act. Seeing major progress in the situation in Hawai‘i and NSF's procedures for its possible investment in the project, TIO, NAOJ, and the other members continue to focus on essential activities in the overall process, including those that will lead the way to full-fledged construction once on-site construction restarts, while minimizing their expenditures.

1. Progress in the Project and Status of the Site

NINS and the other participating countries and institutes, as well as TIO which was established in 2014, are constructing TMT. In addition, the U.S. Association of Universities for Research in Astronomy (AURA) is participating as an Associate Member, while the NSF is preparing for possible participation.

TIO, operated according to deliberations and decisions made by the TIO Board of Governors, is overseeing the construction work performed at the institutes, as well as developing the on-site infrastructure. In FY 2024, the Board convened eight meetings, including extraordinary meetings, to deliberate on the progress in NSF's process and issues surrounding the restart of on-site construction. Those meetings saw Japan represented through attendance by NINS Project Professor Tsuneta, Vice-Director General Yoshida, and Director of the NAOJ TMT Project Usuda. Project Professor Tsuneta co-chaired the meetings.

The project is enforced as part of the Project to Promote Large Scientific Frontiers by the Ministry of Education, Culture, Sports, Science and Technology (MEXT). In December 2023, the Working Group on Large Scientific Research Projects, under the Research Environment Infrastructure Subcommittee of the Science Committee of MEXT's Council for Science and Technology, released the “Roadmap 2023” which outlines the fundamental concepts for promoting large-scale scientific research projects. The promotion of the TMT project is listed in the Roadmap. In addition, the Science Council of Japan listed TMT as No. 161 in the Grand Vision No. 18 for the Revelation of Birth and Co-evolution of Celestial Objects and Life.

In the U.S., in 2021, a decadal survey by the National Academies of Sciences, Engineering, and Medicine, which identifies priority projects every 10 years, recommended as a top priority of ground-based astronomy the US Extremely Large Telescope Program (the US ELT Program) which will allow all-sky observing access to TMT and the Giant Magellan Telescope (GMT, a telescope with an aperture of 24 m currently under construction in Chile). In response, in FY 2022, NSF conducted the Preliminary Design Review (PDR) of the US ELT Program jointly proposed by TIO, the National Optical-Infrared Astronomy Research Laboratory (the NSF NOIRLab), and the GMTO Corporation. The review panel produced a very positive review of the TMT project. In July 2024, the NSF established an external review panel to determine whether the US-ELT Program could proceed to the Final Design Phase (FDP), and the panel's report was published in December. The report emphasized the significance of the US-ELT Program for the advancement of U.S. science and concluded that both the TMT and GMT projects are ready to move forward to the FDP. In FY 2024, following the allocation in FY 2023, NSF provided a fund for design and development of TMT. NSF's Major Research Equipment and Facilities Construction (MREFC) funding is essential to complete TMT. NSF will release a Record of Decision that will state NSF's decision after conducting a final design review, the environmental review process, and the community consultation process under National Historic Preservation Act (NHPA) Section 106 explained below.

In Hawai‘i where TMT is slated to be built, with the State of Hawai‘i's approval of a new Conservation District Use Permit (CDUP) for TMT construction on Maunakea in September 2017, on-site construction was planned in July 2019. However protests, including road blockades, prevented the start of construction. TIO reflected on its past activities that lacked an understanding of social issues behind the protest movement and failed to communicate more broadly with local communities, thus not being able to fully build trust with them. The TIO Board decided to relocate TIO's headquarters from Pasadena, California, to Hawai‘i in a phased way. The TIO Project Manager and the NAOJ TMT Project Director moved to the Island of Hawai‘i in 2021, and engaged in community-based activities along with indigenous staff in Hawai‘i. NAOJ's Senior Specialist Kakazu who was in charge of outreach activities for the Subaru Telescope for a long time, has also joined the team, leading the TIO's education, outreach, and broader impact program and providing vocational opportunities for indigenous children and those in rural areas who have not benefited from astronomy on Maunakea. This program is well received by the NSF who advocates for activities that reach underrepresented groups (the Missing Millions).

The long-standing issue of decommissioning obsolete telescopes was addressed with the decommissioning of the Caltech Submillimeter Observatory (CSO) and the University of Hawai‘i at Hilo’s Hōkū Ke‘a, both of which were completed in 2024.

The Mauna Kea Stewardship and Oversight Authority (MKSOA) was established in 2022, and in July 2023, a transition period started to transfer the management from the University of Hawai‘i to MKSOA. In 2024, John De Fries was selected as Executive Director of the MKSOA. In December 2024, Kimo Alameda, a Native Hawaiian who supports the construction of TMT, assumed office as the new mayor of Hawai‘i County and joined the MKSOA as a member.

In 2022, NSF commenced a consultation process under NHPA Section 106, followed by scoping meetings at multiple venues in Hawai‘i Island and solicitation of comments. Based on the many comments received, NSF is conducting the Section 106 process under NHPA, and is preparing for a draft environmental impact statement. In 2024, participants were identified for the consultation party meetings under Section 106 of the NHPA to facilitate the consultation process.

As for the island of La Palma of the Canary Islands in Spain, which was selected as an alternative site in 2016, the process for all permits needed for construction was completed in 2019, including an environmental impact assessment. 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, concentrating its efforts on essential work for the overall process instead of production. In FY 2024, 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 processes, 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. NAOJ’s primary mirror team identified manufacturing of a blank in a renewed furnace as necessary development work that would facilitate smooth production upon the restart of production. This work is now completed in FY 2024. This furnace was used for the past production, but went through measures due to replacement of its heat-resistant bricks. In FY 2023, in order to verify that blanks manufactured by this furnace meet TMT’s specifications, the team conducted a process of melting raw materials and cooling and solidifying them, and manufacturing blanks. In FY 2024, mirror blanks were fabricated again, and residual stress as well as the coefficient of thermal expansion were measured for samples gained from this work and it was confirmed that they meet the specifications. Continuing on from FY 2023, studies on mirror surface protection during the hexagonal shaping process were further advanced. In FY 2024, four types of protective coatings, both individually and in combination, were applied to small mirror blanks samples, which then underwent the hexagonal shaping process to evaluate their durability. In addition, various holes and engraved characters were ground into small samples using candidate machining tools, and the processed features were examined to determine whether they met the TMT specification requirements (Figure 1). Furthermore, at a candidate facility for hexagonal shaping, a full-scale mock-up of the mirror material was used to identify potential issues related to handling and mounting the mirror on the machining equipment.

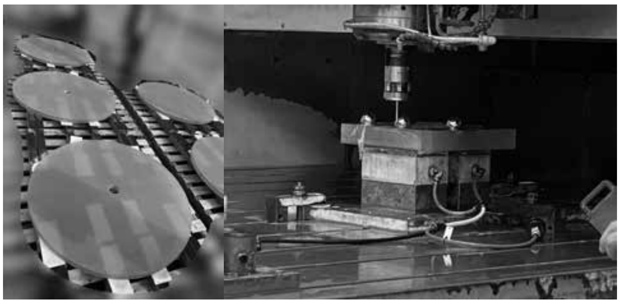

Figure 1: (Left) Prototype of the mirror blanks. (Right) Measurement of a hexagonal-shaped small sample mirror to evaluate the durability.

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

The TMT telescope structure supports the primary mirror, other key optical systems, and science instruments, and functions as a high-precision mechanism to point the telescope toward target astronomical objects. Japan is responsible for the design and production of both the mechanical and control systems of this telescope structure. The baseline and detailed designs have been completed. From FY 2021 to FY 2022, three separate Production Readiness Reviews were conducted, covering the main rotating mechanical structures for the azimuth and elevation axes, as well as the Nasmyth structures that support the science instruments and related systems. The team successfully passed all reviews with favorable evaluations. In FY 2023–2024, the team supported TIO in coordinating interface definitions between the telescope structure and other subsystems as part of preparations for upcoming NSF reviews. In parallel, efforts continued to finalize the interface documentation for the telescope structure and to revise implementation schedules and verification plans in preparation for the remaining three reviews. Additionally, following the withdrawal of the company previously responsible for designing the TMT hydrostatic bearings, the team evaluated and narrowed down potential replacement manufacturers. Working with the most promising candidate, they defined the scope of future tasks required to meet the TMT specifications and to ensure a smooth transfer of existing design assets.

(3) Science Instruments

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

Japan is responsible for the imager of IRIS, and has been developing it in cooperation with the Advanced Technology Center, including design and prototyping activities. In FY 2024, the team continued addressing the action items identified in the imager's final design review held in FY 2021 and carried out preparation toward the final design review of the full IRIS instrument scheduled for September 2025. Regarding the former, the vibration analysis, which was deemed the highest risk item in the review, was completed for the integrated NFIRAOS and IRIS system, successfully mitigating the risk. The thermal-structural-optical analysis of the imager has also made steady progress and is expected to be completed by the time of the review. For the latter, in collaboration with TIO systems engineers, the team completed key system engineering documents including the Verification Planning Matrix outlining validation methods at each development milestone, a Failure Modes and Effects Analysis (FMEA), a reliability analysis to estimate downtime and maintenance time required to prevent failures, and a hazard analysis/risk assessment. The team also finalized the astrometry capability, one of IRIS's unique features, and demonstrated that the design meets the required performance. The preliminary design of the optical simulator's mechanical system, which will be used to evaluate the imager and integral field spectrograph, and the redesign of the imager's mechanical structure in response to a detector change in FY 2022, are both nearing completion. In addition, the team investigated adhesive delamination found in the mirror substrate mounting process during the final design phase. Through failure analysis and re-prototyping using an improved bonding process, the delamination issue was resolved.

A Wide Field Optical Spectrometer (WFOS) continued to be developed as part of Subphase 1 of the preliminary design phase since FY 2023. As part of this phase, a report summarizing the study results on a future upgrade option involving an integral field spectroscopy unit was compiled and submitted to the WFOS management team. In November, Subphase 2 commenced, during which a trade study was initiated to assess whether the integral field spectroscopy unit should be included as a baseline function. To support this study, a cost estimate for the development of the spectroscopy unit was conducted.

3. Planning of TMT Science, Instrumentation, and Operation with Science 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 2024, three meetings were held online, attended by four university researchers and the Director of the NAOJ TMT Project on behalf of Japan, including the Committee Chair Masayuki Akiyama (Tohoku University). An updated version of the TMT Detailed Science Case, reflecting the latest scientific results from JWST, ALMA, LIGO, and other observatories, was compiled primarily by members of the TIO Science Advisory Committee in close collaboration with the broader community, and was released in October 2024. There were also changes among the Japanese committee members. Masayuki Akiyama (Tohoku University: Chair until 2024) and Mitsuhiko Honda (Okayama University of Science), who had served on the committee for many years, stepped down. In their place, Norio Narita (University of Tokyo) was appointed as Co-Chair, while Masaomi Tanaka (Tohoku University) continues to serve on the committee. In addition, Chikako Yasui from the TMT Project newly joined as a committee member.

The Science Advisory Committee for the NAOJ TMT project, which is a domestic committee consisting of fifteen researchers from universities and other institutes, reviewed issues of science programs, instrumentation, and operations. In FY 2024, there were six meetings in total, including one which was held jointly with the Subaru Science Advisory Committee. The FY 2024 NAOJ's funding program for research and development of TMT science instruments was granted for five proposals to carry out research for development by thirty-three researchers at twelve universities and research institutions.

Meetings were actively organized to explain the status of the project and engage in discussions for larger communities of astronomy in Japan. In addition to the Astronomical Society of Japan's annual meetings, NAOJ's TMT Project provided a progress report at meetings organized by the Group of Optical and Infrared Astronomers in September 2024, ALMA/45m/ASTE Users Meeting in December 2024, NAOJ Future Symposium in December 2024, and the Japan Radio Astronomy Forum in January 2025. In addition, a TMT session was held at the Subaru Users Meeting, where the latest progress of the TMT project was reported and discussions were held on future operations and instrument development. 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.

As for the scientific activities related to TMT, a workshop titled "The Scientific Landscape for Extremely Large Telescopes in Light of JWST. Part II: Asia" was held at Tohoku University from June 3 to 7, 2024, to discuss the science enabled by next-generation extremely large telescopes (ELTs) such as TMT and GMT in the 2030s. The workshop attracted more than 100 participants, primarily from Asia. Topics presented included atmospheric characterization of exoplanets using high-resolution spectroscopy with JWST, Gemini/IGRINS, and Subaru Telescope/IRD; chemical composition studies of high-redshift galaxies with JWST; and the detection of individual stars in a lensed galaxy at redshift 0.7 affected by microlensing. The workshop also featured discussions on the synergies between JWST and ELTs in the context of multi-messenger astronomy, including future programs related to gravitational waves, neutrinos, gamma rays, X-rays, and other optical/infrared telescopes. Furthermore, the second TMT-ACCESS workshop, aimed at fostering new science cases for TMT, was held at Tohoku University from June 10 to 12, 2024 (Figure 2). A total of 38 participants, mainly graduate students, early-career researchers, and engineers, attended. Lectures were given by invited speakers across a broad range of fields where ELTs will be particularly powerful. The program also included interdisciplinary group discussions and lab tours of the Astronomical Institute and Department of Geophysics at Tohoku University, where TMT-related instrument development is underway. These activities facilitated wide-

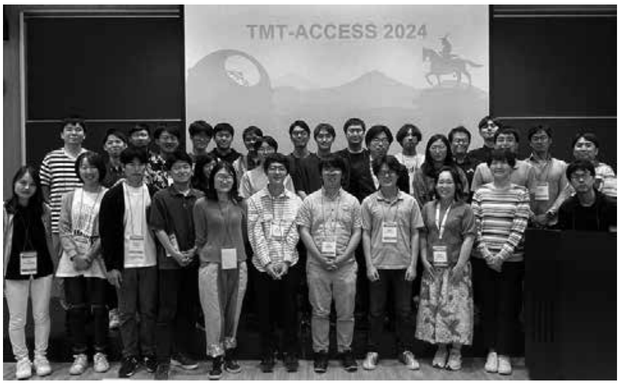

Figure 2: The second TMT-ACCESS workshop, organized primarily by early-career researchers in Japan, was held at Tohoku University in June 2024. A total of 38 participants, mainly early-career scientists and engineers, gathered to engage in active discussions on future science opportunities with TMT.

ranging discussions on future science cases and instrumentation plans for TMT. In addition, on June 15, just prior to the SPIE Astronomical Telescopes + Instrumentation conference, a TMT Instrumentation Community Workshop was held, bringing together about 50 researchers and engineers involved in TMT instrument development. The participants shared progress updates and discussed future plans related to instrumentation for the observatory.

4. Public Relations, Outreach, and Education

Updates on the TMT project, including the status of the construction site at Maunakea and progress on Japan's contributions, are regularly shared on the official TMT project website. In addition, TMT newsletters No. 82 through No. 86 were published. Outreach efforts were actively pursued through public lectures, exhibitions, and other events. A total of 28 public engagement activities were conducted in FY 2024, including school programs in Japan and abroad through the "Fureai Astronomy" initiative, delivered in various formats such as in-person, online, and hybrid sessions.

In the U.S., particularly on Hawai‘i Island, the Senior Specialist from NAOJ stationed at TIO has taken a leading role in educational and public outreach activities. Working with Native Hawaiian and local community advisors, the team has developed over 20 pilot programs to date tailored to local needs. In FY 2024, TIO collaborated with Maunakea observatories and various organizations to implement public education events such as "Journey Through the Universe" outreach classes, Astro Day (Figure 3), and career fairs. TIO also focused on educational support and workforce development in partnership with local institutions. Activities included weekly tutoring sessions at local middle schools, science workshops for 37 local teachers, distribution of educational materials to approximately 1,600 students, and the launch of a STEM education and vocational training program in partnership with Hawai‘i Community College to support local industry. In addition, TIO, in collaboration with Hawai‘i County and Hawaiian cultural leaders, organized the second edition of "Alele Lau Loa," a cultural exchange and experiential learning program. As part of the program, high school students from Hawai‘i Island visited Indigenous communities in Canada (First Nations), deepening cross-cultural understanding and engagement (Figure 3).

Moreover, in September, a U.S.-Japan conference on the

Figure 3: (Left) Astro Day held at a shopping mall in Hilo, featuring the TMT outreach booth (May 2024). (Right) Cultural exchange with students and community members of the Penticton Indian Band, an Indigenous group in British Columbia, Canada (September 2024).

Figure 4: US-Japan Conference on Life on Exoplanets – Insights and Future Prospects, held in Washington, D.C., in collaboration with the Japan Aerospace Exploration Agency (JAXA) and the Japan Society for the Promotion of Science (JSPS) (September 2024).

search for life on exoplanets was co-hosted by NAOJ, JSPS, and JAXA in Washington, D.C. The meeting served as an opportunity to promote the US-ELT program and engage with U.S. policymakers (Figure 4). Seven researchers from both Japan and the United States took the stage to discuss the complementary roles of the US-ELT and the Habitable Worlds Observatory (HWO). The discussion highlighted the essential collaboration between the two projects, particularly in the exploration of exoplanets and the search for extraterrestrial life. The meeting was attended by 86 participants, including Ambassador Shigeo Yamada, as well as senior officials from NASA and NSF, government representatives, and influential policy makers. The event received high praise from many attendees.

5. Organization

By the end of the fiscal year, three Professors, five Associate Professors, two Assistant Professors, one Research Engineers, and five Senior Specialists (one of whom is seconded to TIO) held positions in the NAOJ TMT Project (one Professor will retire at the end of FY 2024). In addition, from the Advanced Technology Center and Subaru Telescope, one Professor, two Associate Professors, two Assistant Professors, one Project Assistant Professor, three Senior Specialists, and one Engineer 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 (two Senior Specialists will retire at the end of FY 2024).

With the aim of strengthening the close partnership with TIO, two members are stationed in Hawai‘i working for TMT, one of whom is the Director of the NAOJ TMT Project, and the other is the Senior Specialist who is 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 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.

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 and time-series photometric data of candidate stars for exoplanetary systems, 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. The mission definition review was held in July 2024, and the scientific goals and objectives were approved by ISAS/JAXA. According to the current progress schedule in the Basic Plan on Space Policy established by the Cabinet Office in Japan, the launch of JASMINE is scheduled for 2032. We are promoting JASMINE with the aim of improving the development stage at JAXA step-by-step. JASMINE has the following two primary scientific objectives.

1) To explore the Galactic nuclear region, which plays a key role in the formation of the Galaxy, by measuring the distances and the motions of stars.

2) To search for Earth-like exoplanets that are located in habitable zones and whose atmospheres can be observed, as promising targets for future life exploration.

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 (wavelength band: 0.9–1.6 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 and dark matter distribution 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; stellar physics; 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 2024

1) Organization of the JASMINE Project

The JASMINE Project, NAOJ, is composed of two Professors, one Associate Professor, one Project Associate Professor, six Assistant Professors, and one Project Researcher. Significant contributions were also made by members of the following organizations: ISAS/JAXA, Kyoto University, the University of Tokyo, 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 August 2024, a consortium meeting was held that also served as an open science workshop for JASMINE. We were able to listen to the opinions of many researchers and lectures in a wide range of fields. In addition, regarding astrometry, we have established a science core team, which holds regular meetings to discuss issues such as examining and expanding scientific results, collaboration with other observation projects, and training young researchers.

The JASMINE Joint Scientific Research Program is conducted for researchers at Japanese universities, to promote preparatory research for scientific studies related to the Galactic center region using JASMINE's astrometric data. In 2024, we selected one research project, and the selection of one Project Researcher to support the project is underway.

Regarding the development of satellite and observation instruments, we are working with candidate manufacturers on conceptual studies, especially how to maintain high stability of the optical performance on orbit, which is important for astrometric observations in JASMINE. We have advanced the confirmation of stability based on structural, thermal, and optical analyses. In addition, we are developing a domestic infrared camera for space in collaboration with the NAOJ Advanced Technology Center, ISAS/JAXA, and candidate manufacturers. We have advanced conceptual studies on the structure/thermal design of the detector box unit and the electronics design to control the camera, as well as performance evaluation tests on prototype detectors. We have also completed the development of a prototype of large-format detectors in a package designed to be installed in JASMINE.

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. By constructing a simplified and reduced simulation (mock observation survey) of the mission, we have succeeded in reproducing stellar proper motions and annual parallaxes with the anticipated precisions. We are progressing with analysis considering more realistic and complex noise sources. In international cooperation, we have continued discussions with researchers in the University of Heidelberg on the analysis methods of astrometric data based on their knowledge of the Gaia data analysis. We also had a discussion with researchers in Lund University on a global design of astrometric data analysis. Additionally, we have continued discussions on cooperation with the NAOJ Astronomy Data Center for the creation of an archive of observational data.

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

1. Project Overview

The Martian Moons eXploration (MMX) launch was postponed until FY 2026. Accordingly, the schedule of the tests and trainings was delayed. The Landing Site Selection (LSS) training was also temporarily suspended. To compensate for this delay, the Geodesy Science Strategy Team (G-SST), led by the RISE Project, reconsidered and refined operation plans, maintained software, and advanced the laser altimeter (LIDAR) ground tests as explained below. First, we contributed to discussing the Mission Operation Working Team (MOWT) reforming mid to long-term operation plans. Based on a 2026 launch orbit, the scan observation plan for shape modeling from high-altitude Quasi-Satellite Orbits (QSO-H) was revised. Given the unavoidable uncertainty of orbit prediction, the number of images sufficient to cover candidate landing sites was examined. Under a limit on the number of commands, feasible procedures to control spacecraft attitude were investigated. Second, the steps to construct the shape model were confirmed using Hayabusa2 ONC images. Third, we regularly held online meetings with the development team of the orbit/gravity field estimation software (GINS), produced by the Centre national d'études spatiales (CNES) in France. We appended a new function to estimate the scale factor of the shape model to GINS and confirmed the interface of the spacecraft attitude information. To prepare for LSS training, we conducted simulations in which the spacecraft gradually lowered its altitude, obtaining multiple types of remote-sensing data, and estimated the gravity field of Phobos. In addition, our new paper, based on research work from FY 2023, was published to evaluate the accuracy of the gravity field and internal structure estimated from remote-sensing observations at different QSO altitudes and during the ascent operation of the spacecraft. Fourth, RISE members participated in the integration tests of the LIDAR flight model attached to the spacecraft two times and confirmed their interfaces. As for LIDAR telemetry, the members contributed to revising the Spacecraft Information Base version 2 (SIB2) and PI’s Quick Look.

Regarding Hayabusa2/LIDAR, first, we released the level-4 albedo data of the asteroid Ryugu surface from LIDAR observations via JAXA’s Data Archives and Transmission System as well as NASA’s Planetary Data System, together with a user's manual. Second, for the Hayabusa2 extended mission operation in the proximity of asteroid 1998 KY26, we investigated the use of solar radiation pressure to stabilize the spacecraft's orbit, aiming for long-period science observations under the microgravity environment and with the limited fuel resource. The result of this investigation was reported at an international science conference and submitted to a scientific journal for review. Third, we analyzed the data obtained from the artificial impact experiment on Ryugu in preparation for a similar impact experiment on 1998 KY26 using a projectile. After preprocessing the data, such as image calibration, a new method was developed to reproduce the temporal variation of the 3-dimensional structure of impact ejecta. A part of this work has been published as a peer-reviewed paper. Fourth, one RISE project member hosted five research meetings for the community to advance the fundamental studies of orbital dynamics.

For the Jupiter Icy Moons Exploration (JUICE) and its Ganymede Laser Altimeter (GALA), the RISE project members attended the GALA-JAPAN team meeting every month. They also attended the online team meeting held in Berlin on October 24 and 25 to discuss the range measurements carried out on August 19 and 20 between JUICE and the Moon and the future plan. One RISE member published a non-refereed paper describing the GALA performance model in Yu-Sei-Jin, the journal of the Japanese Society of Planetary Sciences.

2. Educational Activities

The RISE Project also accepted one undergraduate student from Michigan State University into the NAOJ/SOKENDAI Summer Student Program and supervised his work on the albedo data analysis of the asteroid Ryugu.

3. Outreach/PR

In FY 2023, the Project members volunteered once for Kirari Oshu City Astronomy School and three times for FUREAI (Friendly) Astronomy classes. In addition, RISE members provided eight special lectures for the public.

11. SOLAR-C Project

1. SOLAR-C Project Overview

SOLAR-C is a JAXA project scheduled for launch in FY 2028 and will become Japan's fourth solar observation satellite after Hinotori, Yohkoh, and Hinode. This project aims to elucidate the following mechanisms of solar magnetic plasma activities, which are significant problems in solar physics and impact 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.

Since the establishment of the JAXA SOLAR-C project WG, many Japanese and foreign researchers and specialists have participated in the project. Japan will be responsible for the launch vehicle, satellite bus, and telescope section of the science instrument. The development of the sub-assemblies of the spectrograph has proceeded through international collaborations with the U.S. and European space agencies and institutions. NAOJ plays a leading role in the development of the telescope section.

The SOLAR-C project was proposed as the Solar-C_EUVST satellite project in the JAXA Competitively-chosen Middle-class satellite solicitation opportunity in January 2018. This proposal was nominated as a candidate for the 3rd or 4th Middle-class mission 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 4th JAXA Middile-class satellite 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, followed by completion of the System Requirement Review in Decmber 2022. Afterward, we passed the System Definition Review in December 2023, and the JAXA SOLAR-C Project has started since March 2024.

2. Progress of the SOLAR-C Project Activity in FY 2024

In the basic design of the science payload EUVST, which has been continued since last fiscal year, the preliminary design reviews (PDRs) have been conducted at each organization responsible for the development. In Japan, the PDR was conducted by domestic manufacturers from April to June, and the development of the engineering models (EMs) began. For sub-assemblies provided by overseas organizations, PDRs were conducted by each responsible organization, starting with NASA in the United States in April. The PDR for the entire science payload is scheduled for 2025.

The SOLAR-C Project proceeded with the following development activities in FY 2024 with JAXA and the manufacturers:

(1) The EM primary mirror has undergone lightweighting and shape processing in France and has completed the reflective coating process in Germany. An acoustic test was conducted in JAXA to confirm the vibration response of the primary mirror support structure and the mechanism responsible for scanning and image stabilization.

(2) The interface design between the numerous overseas devices and the EUVST telescope structure has progressed, and manufacturing of the structure has begun. Based on this design, we have proceeded to prepare for the coming activities: integration, the optical alignment and adjustment, and environmental testing and measurement.

(3) We have worked with the system manufacturer to design the structural, thermal, and electrical interfaces, as well as the attitude control design, including pointing control and attitude stability, to achieve the target observation performance of the satellite system.

The design meetings with overseas partner organizations were primarily conducted via online conferences, while an on-site design meeting was held in September 2024 at MPS in Germany, which has facilities for the thermal vacuum test and sensitivity calibration of the EUVST flight model.

3. SUNRISE-3 Project Support

The re-flight experiment of the balloon project SUNRISE-3, in which many project members contributed to developing the science payload, was executed in 2024. The successful experiment has returned high-precision polarimetric data containing information about magnetic fields in the photosphere and chromosphere. For details please refer to the report from the Solar Science Observatory.

4. Educational and Publicity Outreach Activity

The project staff has supervised two SOKENDAI graduate students and two from other universities. The project also participated in the Tour of the Solar Research Frontline to introduce domestic solar physics research to undergraduate students. The project activities in research and development have been introduced through the web. The project provided SOLAR-C-related materials to NHK's TV program “Science Zero,” and the ongoing SOLAR-C mission was introduced in a program on the latest solar research broadcast in mid-November.

5. Others

While NAOJ reimbursed the NAOJ SOLAR-C project activity for its general operation and contingencies, JAXA funds the expenses for designing and developing the science payload. There are no changes in the project team members.

12. The Subaru Prime Focus Spectrograph (PFS) Project

1. Overview of the PFS A project

The Prime Focus Spectrograph (PFS) is a next generation large-scale facility instrument of the Subaru Telescope. PFS enables simultaneous observation of approximately 2400 objects across wavelengths ranging from 0.38 μm to 1.26 μm with spectral resolutions of R=2000~5000.

PFS was developed through an international collaboration led by Kavli IPMU at the University of Tokyo. The collaboration includes the National Astronomical Observatory of Japan (NAOJ) and numerous research institutions across Japan, Taiwan, the United States, Brazil, France, Germany, and China.

The PFS A-project started in FY 2019 at NAOJ and has focused on the design and construction of the telescope infrastructure for PFS, as well as the integration, commissioning, and performance verification of PFS. The PFS A-project also plays a critical role in the operation and maintenance of the instrument and the development of its data reduction pipeline and science database.

Accordingly, the A-project will be dissolved once PFS is fully transitioned into a Subaru Telescope facility instrument.

2. Progress in FY 2024

(1) Subsystems Delivery and Integration

PFS is comprised of several subsystems. The Prime Focus Instrument (PFI) equips ~2400 science fiber optics and positioners. It is installed at the prime focus of the telescope during operations. CableB consists of four science fiber bundles running along the telescope. They transmit light from celestial objects captured by PFI to the Spectrograph System (SpS). SpS consists of four identical Spectrograph Modules (SMs) located in the Spectrograph Clean Room (SCR) on the fourth floor of the observatory enclosure. Each SM is equipped with 3 cameras covering the blue, red, and near infrared (NIR) channels. The Metrology Camera System (MCS), mounted at the Cassegrain focus of the telescope, takes images of fibers in PFI to measure their positions precisely and provides feedback to the fiber positioning system.

At the beginning of FY 2024, PFI, MCS, four CableB units, and four SMs were installed at the Subaru Telescope summit facility and were undergoing the operational testing. However, the NIR camera for SM4 was not yet delivered, and the one for SM1 has been returned to Johns Hopkins University to recover the degraded detector quantum efficiency.

The NIR cameras for SM4 and SM1 were delivered and integrated with the Subaru Telescope in June 2024 and August after the recovery at the manufacturer. At this point, PFS was fully equipped with all subsystems operating at Subaru Telescope. Following full installation, several repairs were required. The fiber connector of SM2 was repaired in May 2024 with Brazilian members because a few ferrules had been broken. A hexapod responsible for fiber slit positioning in SM1 malfunctioned in September 2024 and was repaired by replacing damaged parts in collaboration with a developer from France in January 2025. The shutter was removed from 3 out of 6 AG cameras to mitigate the risk of motion resistance. This work caused an unexpected focus shift of more than

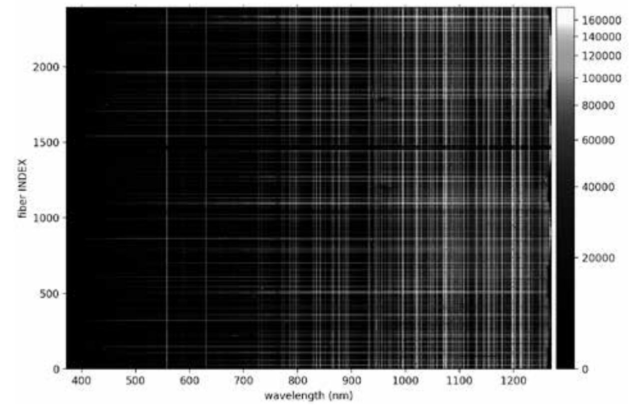

Figure 1: An example of spectra in one exposure with the fully equipped PFS. The horizontal axis is for wavelength and each horizontal stripe is the spectrum of one of the 2400 fibers in 0.38–1.26 μm. The spectra are taken without a cavity along all the wavelengths and fiber optics.

100 μm. Corrective work is ongoing. Also in October, one of the cryocoolers for the SM2 NIR camera exhibited overload failure and ceased operation. This issue was resolved by replacing the unit with a spare in February 2025. After several additional repairs, the system operates stably.

(2) Engineering Observation Runs

There were 6 engineering observations with 36 nights in total scheduled in FY 2024. Among them, 2 nights were cancelled due to telescope trouble or bad weather, but the on-sky tests and calibrations were carried out on most of the allocated nights. We achieved the best fiber configuration accuracy to date (20–30 μm for 95 % of allocated fibers) and observed its repeatability over the observation runs. We are aiming at further improvement of the accuracy. The system throughput was verified to be comparable to the prediction. In this FY, we newly found that the relative throughput among the fibers changes by a few % on a short time scale (a few hours). This affected the accuracy of sky subtraction. Various investigations revealed that the variation was caused by tiny (<1 μm) changes in the air gap at the fiber connection surface. By utilizing a gel whose reflection index is the same as fiber glass, we succeeded in suppressing the variation. We also found that the spectral flux was fainter than expected. We are investigating the root causes.

(3) Observation Procedures and Policies

PFS science operations finally started in FY 2024. In the first half of FY 2024, we held a PFS community meeting to discuss filler categories and collected feedback through a dedicated webform. With further discussions with TAC and SAC, the science operation framework has been established. We passed the open-use readiness review in July 2024, and the first call for proposals for PFS was issued in August. The online Exposure Time Calculator (ETC) and target uploader were fully operational, and we successfully made the first PFS time allocation. The first PFS observing run was in March 2025 and we used all of the observing modes (queue, classical, and ToO). There is a lot of room for improvement in our operations, and we continue to explore more efficient and more stable operations.

Figure 2: A scene from when the first open-use exposure with PFS was being taken (March 22, 2025, HAST).

(4) Data Reduction Pipeline

The PFS team at NAOJ has been continuously contributing to the development of the data reduction pipeline (DRP) in close collaboration with Princeton University and other PFS collaborators. The main contributions of the NAOJ team are the overall development of flux calibration and quality assessment of processed data. In this fiscal year, we made significant updates to the middleware used by the DRP and performed adaptation work on the DRP side. Regarding quality assessment, we developed tools to monitor changes in the fiber efficiency (mentioned previously) and the accuracy of flux calibration, and conducted comprehensive tests using data obtained in the engineering observations. For data processing of near-infrared detectors, the entire team is identifying problems and implementing solutions to improve quality. Additionally, in anticipation of distributing processed data for open-use observations, we are currently working on transferring knowledge and experience related to construction of calibration data and processing of science data, which has been done by the team in Hawai`i until now, to the team in Mitaka.

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 started its activities. The GLAO project completed the preliminary design of the GLAO system in FY 2022 and started prototyping the key subsystems and final design in FY 2023. The GLAO project aims to complete the final design phase in FY 2025, followed by production, assembly, integration, and test phases to start the commissioning observation in FY 2028.

2. Staff

The GLAO project consists mainly of members from the Subaru Telescope. At the end of FY 2023, there were 1 associate professor and 1 research fellow dedicated to the GLAO project. There were also 1 associate professor, 1 senior specialist, 2 assistant professors, 1 research engineer, and 2 RCUH employees (engineering staff) appointed concurrently. There was also 1 associate professor at the Advanced Technology Center (ATC) who participated in the GLAO project in FY 2023. In addition, the GLAO project received support from the instrument division technicians, day crews, and administration staff at Subaru Telescope and engineers at ATC. During FY 2024, four Hawai`i-based scientists who participated in the GLAO project, including the project manager, moved from Hawai`i to Mitaka Campus.

3. Major Progress in FY 2024

In the GLAO project, we are conducting technology demonstrations using prototypes of major GLAO subsystems, as well as performing final design work. In FY 2024, in collaboration with the Australian National University, we completed the fabrication of prototype components for the wavefront sensor (WFS) optical system and opto-mechanical system, which had been underway since the previous fiscal year, as well as for the pointing module used in the laser guide star generation system (LGSF). We have started assembly, alignment, and performance evaluation.

In addition, as part of the development of laser tomography adaptive optics (LTAO) being carried out in collaboration with Tohoku University as a GLAO technology demonstration, we continued optical alignment and performance evaluation of the wavefront sensor in the laboratory at the Subaru Telescope base facility. We also completed a four-beam laser guide star generation system (4LGSF) using diffractive optical elements and conducted engineering observations at the Subaru Telescope.

At ATC, we continued the detailed design of the thermally insulated cabinet to hold the electrical components for the WFS and LGSF, the platform for mounting the LGSF on the telescope, and the cooling system for the LGSF. We also fabricated opto-mechanical components for the Star Simulator, which is used in the calibration tests of the WFS prototype.

Regarding the adaptive secondary mirror, for which fabrication had started earlier, we continued the production of major optical components and conducted assembly and evaluation of mechanical and electrical parts. Furthermore, we completed interface studies with the telescope and the final design of the Optical Test Tower, which will be used for optical testing of the adaptive secondary mirror and calibration tests in combination with the GLAO WFS.

As for the wide-field infrared imager (WFI) to be used together with GLAO, we conducted the final design of the optical system and the vacuum cryogenic system. We also compiled the results of detailed sensitivity calculations for observations using GLAO and WFI, and presented the expected performance at the bi-annual meeting of SPIE.

4. Education Activities and Internships

In FY 2024, the research staff of the GLAO project supervised two students from the University of Tokyo and Saitama University through the SOKENDAI Summer Student Program and the short-term training program of “OISTER” (The Optical and Infrared Synergetic Telescopes for Education and Research). The students received research guidance related to the development and system design of adaptive optics systems and science instruments. In addition, we hosted four graduate students from Tohoku University and one from Kwansei Gakuin University at the Subaru Telescope to conduct research related to the LTAO development.

5. Outreach

GLAO project activities are reported not only at academic conferences, workshops, and community meetings in Japan and abroad, but also shared widely with the general public beyond the astronomical community. To communicate the scientific significance and progress of the project in real time, updates are regularly posted on the official website of the Subaru GLAO Project (https://sites.google.com/naoj.org/ultimate-subaru).

In July 2024, as part of public outreach efforts, the ULTIMATE-Subaru Project Scientist participated in a public lecture titled “The Mysteries of the Universe Unveiled by Cutting-Edge Astronomy,” held at J:COM HorutoHall OITA in collaboration with Oita University. Since the official launch of the “Subaru Telescope 2.0” project in FY 2022, a dedicated “Subaru Telescope 2.0” page was established on the official Subaru Telescope website, where the ULTIMATE-Subaru project is introduced.

6. International Collaboration

Since Fiscal Year 2021, the ULTIMATE science team has been leading efforts in the Japan Society for the Promotion of Science (JSPS) Core-to-Core Program titled “International research network toward the era of deep and wide near-infrared survey of the universe with space and ground-based telescopes" (known as "SUPER-IRNET"). This program, with collaboration from Japan, the United States, France, Australia, and Taiwan, aims to significantly advance next-generation wide-field near-infrared observation projects, including ULTIMATE.

In July 2024, the program hosted an international workshop titled "The Second SUPER-IRNET Workshop: Sparkling Our Collaboration at the Cosmic Gate" in Beppu, Oita Prefecture in Japan, which attracted about 120 participants.

Within the GLAO project, collaboration with the Australian National University (ANU) has been ongoing. To further strengthen this partnership, the Australia-Japan Foundation Grant has been awarded to support a two-year initiative from FY 2024 to FY 2025. As part of this effort, a kick-off meeting to discuss Japan-Australia scientific collaboration was held in May 2024 at Macquarie University in Sydney, Australia.

In March 2025, a workshop titled "Wide-field Adaptive Optics for Astronomy and Astrophysics," focusing on the development of wide-field adaptive optics, was held at the National Astronomical Observatory of Japan (NAOJ) in Mitaka, with around 60 participants.

In FY 2024, we also accepted two researchers from the Australian National University to stay at the Subaru Telescope for 1–2 months to collaborate on the development of real-time control algorithms and a laser guide star generation system related to LTAO and GLAO.

14. Astronomy Data Center

The Astronomy Data Center (ADC) works with observatories and universities to consolidate, organize, and permanently archive astronomical observation data. ADC provides these data to the community alongside a computing environment for data utilization. In addition, we conduct research and development to maintain and improve these research platforms. This includes operating computer systems for data analysis and data archives primarily covering optical, infrared, and radio wavelengths. It also includes developing JVO, HSC, and high-speed databases. This fiscal year, we renewed the computer rental contract and devoted considerable effort to migrating the systems and setting up the environment. Regular operations for open-use services with the updated system began in July 2024. In February 2025, we held the ADC Users Meeting (UM), which had not been held since FY 2021 due to preparations for updating the rental system. We explained the status of various ADC open-use services and the updated systems after the transition to users and exchanged ideas of how to improve the services. The following sections describe individual ADC activities.

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 from the Subaru Telescope, the Okayama 188-cm Telescope, the Kiso 105-cm Schmidt Telescope (the University of Tokyo), two MITSuME 50-cm telescopes (jointly operated by Science Tokyo and Kyoto University), the Kanata 150-cm Telescope (Hiroshima University), the NAYUTA 2-m Telescope (University of Hyogo), and the 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 enables the revalidation of research results and supports the credibility of research results. SMOKA also serves as the framework to open Subaru Telescope data to the public.

The total amount of opened raw observational data in SMOKA is about 42 million frames (595 TB) as of early May 2025. SMOKA has contributed to many astronomical publications. The total number of refereed papers using SMOKA data is 303 including 13 new publications in FY 2024 as of early May 2025. A significant number of papers have recently listed “SMOKA” as a source of “Data Availability.” In FY 2024, we started the release of data from GAOES-RV on the Seimei Telescope. Preparatory work to receive data from PFS on the Subaru Telescope is underway.

The following supplementary services also have updates. 1) We are developing and operating a system that makes all-sky monitor images at Higashi-Hiroshima, Okayama, Akeno, Kiso, and Subaru Telescope available to the public (https://ozskymon.nao.ac.jp/ ; 42 TB as of early May 2025). Data from the Subaru All-Sky Camera started to be released this fiscal year. 2) A system for publishing digitized data from photographic plates taken at Kiso Observatory has also continued to operate (https://pplate.nao.ac.jp/ ; 4 TB). This fiscal year, we prepared for the release of digitized data from photographic plates taken at Okayama Observatory using this system. 3) Tomo-e Gozen data archive service also continued to operate (https://archive.nao.ac.jp/tomoe ; 384 TB as of early May 2025) and raw data, in addition to stacked data, have newly become available in the service.

2. MASTARS

MASTARS, a data archive system in Mitaka for the Subaru Telescope observers, continued to operate working closely with the STARS data archive system at Subaru Telescope. The hardware was replaced in July 2024, and the service continued without troubles. The data storage was increased to handle the increasing data production rate. We also constructed a new backup system based on a Linear Tape File System (LTFS), which is compatible with the SMOKA system.

3. Next-generation Archive System

Based on the concept of the next-generation optical and infrared data archive including the next version of STARS (STARS3), and SMOKA, we have begun to consider its implementation. We have introduced and constructed a new computing environment for the development and testing of this next-generation data archive, and have begun the conceptual design of the archive system.

4. JVO (Japanese Virtual Observatory)

The JVO portal and the Virtual Observatory (VO) service for various data, etc. were operated and their functionality was updated. Data obtained from the open-use observations of the Nobeyama 45-m Radio Telescope were made public through the VO interface and a dedicated user interface of the JVO portal. This allows the Nobeyama data, which are already available at the Nobeyama/ASTE science archive, to be easily viewed using the FITS WebQL which is operated on the JVO portal. All the public data obtained with HDS on the Subaru Telescope were processed through a data reduction pipeline developed by the JVO group. These data are also available through the VO interface and a dedicated user interface of the JVO portal. In addition to data processing and its distribution, FITS WebQL has been extended to visualize the HDS spectrum. This allows HDS data to be easily visualized on a web browser. Another extension is ongoing on the FITS WebQL to display event data taken by X-ray satellite telescopes. The above developments of the Nobeyama and HDS FITS data archive were presented at the annual Autumn and Spring meetings of the Astronomical Society of Japan, respectively. The access counts to all the JVO services in FY 2024 was 32 million and the total download volume was 9.9 TB.

5. HSC Data Analysis and Science Archive

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), a multi-band optical survey covering >1100 square degrees with HSC (survey period: March 2014–January 2022), we have been analyzing the data with the developed pipeline and producing databases to store the processed results for researchers. We continued to work together with Subaru Telescope to update the data analysis for the entire data set from the survey. In July 2024, the 11th internal data release (S23B) was made available to the SSP collaborators. In February 2025, a revised release with further improvements in some analysis issues was made to build a more reliable and scientifically valuable data set. Preparations are also underway to make the pipeline version used for this release available for open-use users. We have continued to develop an archiving and analysis environment (science platform) for efficient use of the HSC images and catalogs, and supported the data evaluation system during the HSC observations.

The new multi-object spectrograph PFS began its observations. To ensure stable operation, we continued to investigate the data format and a science platform for the PFS with the observatory to enable future joint use with HSC public data.

The application of next-generation database technology for the HSC-SSP and other large object catalogs continued through joint research through industry-academia collaboration. We continued to improve the detection system for Solar-System objects using conventional databases and proceeded with scientific analysis and publication using the resulting catalogs, and preparation for their release to the public. After the high-speed database becomes general-purpose, it is expected to enable faster and more diverse data analysis by serving as a backend.

6. Open-use Computer Systems and Services

ADC provides data analysis computer systems for astronomical research as one of the key open-use services. “The Multi-Wavelength Data Analysis System (MDAS)” is a system component optimized for interactive tasks and it was operated under a rental contract system from March 2018. The system was replaced and began operating as a new system in July 2024. In the new MDAS, some of the functions are handled by new rental equipment, while most functions have largely transitioned to an in-house system built on a group of computers procured under a separate lease contract and purchased computer equipment. At the end of FY 2024, there were a total of 338 MDAS users, both within and outside NAOJ.

“The Large-scale Data Analysis System (LSC)” is a cluster computer system dedicated for analyzing large astronomical observation data. It began operating for Subaru Telescope/HSC observers in 2019. While enhancing the system, e.g., by adding computation nodes, we sequentially expanded the target users and the types of data to be processed. Preparations were also made to accept PFS data analysis in 2024. Although most of the equipment has been in use for over five years, we keep operating the system with the necessary updates and maintenance.

These open-use computer systems are used in various workshops and are provided as a computing environment for data analysis training, with the aim of promoting the use of astronomical data, archive systems, and astronomical software. The dates and numbers of participants for the workshops using MDAS held in FY 2024 are as follows:

- SOKENDAI Summer Student Program
  August 1–30, 2024
  4 users (used MDAS)

- Long Wavelength Radio Waves Analysis Workshop
  February 17–18, 2025
  18 users
  (These workshops were all held at NAOJ's Mitaka Campus.)

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 center for advanced astronomical observation instruments, from radio waves to visible and ultraviolet light, both on the ground and in space. In FY 2024, as in FY 2023, we supported instrument development for many projects including Subaru Telescope, ALMA, TMT, Large-scale Cryogenic Gravitational Wave Telescope KAGRA, High-sensitivity Solar Ultraviolet Spectroscopic Satellite SOLAR-C, and Infrared Astrometric Observation Satellite JASMINE, and actively engaged in joint development research and facility utilization.

In the operation of the matrix organization (see Figure 1), regular resource coordination meetings were held four times to bring together representatives of each project who wished to request work from ATC and the ATC Steering Committee. The meeting has become an important opportunity not only for communication between ATC and the projects but also for communication and information sharing among the attending projects.

The number of facility tours was the highest since 2016, when we began compiling statistics, and we welcomed about 550 people on 44 occasions. We were able to stress the importance of ATC in NAOJ for National Astronomical Research Institute of Thailand; University of Hawai`i; Embassy of the United Mexican States in Japan; Embassy of Italy in Japan; Minister of MEXT; Parliamentary Vice-Minister for MEXT; Research Promotion Bureau of MEXT; Diet members; local assembly members; domestic institutes; private companies; students; etc. In cooperation with the Industry Liaison Office, ATC exhibited a general-purpose AO test system at OPIE'24; the University Trade Show ~Innovation Japan; and interOpto2024 -Science Photonics Fair-; and exhibited dielectric constant measurement techniques using the free space method at the Microwave Workshops & Exhibition 2024, thus widely promoting ATC's technology to the industrial world.

A particularly notable achievement in the industry collaboration activities aimed at applying technologies developed at ATC to industrial use is the selection of two major proposals. In January 2025, NAOJ had its proposal, “NAOJ Space Innovation Center Initiative,” accepted under the “SX Research and Development Site” theme of the Space Strategy Fund. In February 2025, a separate proposal, in which ATC participated as a cooperating institution, was selected under a different government funding program. ATC played a pivotal role in the preparation of both proposals. Going forward, these projects will be carried out based on ATC’s personnel and facilities.

Details of the activities in FY 2024 are described below.

2. Developments for Prioritized Projects

(1) TMT Instruments

1) Infrared Imaging Spectrograph (IRIS)

The IRIS team continued to work on the homework raised at the final design review for the IRIS imager held in June

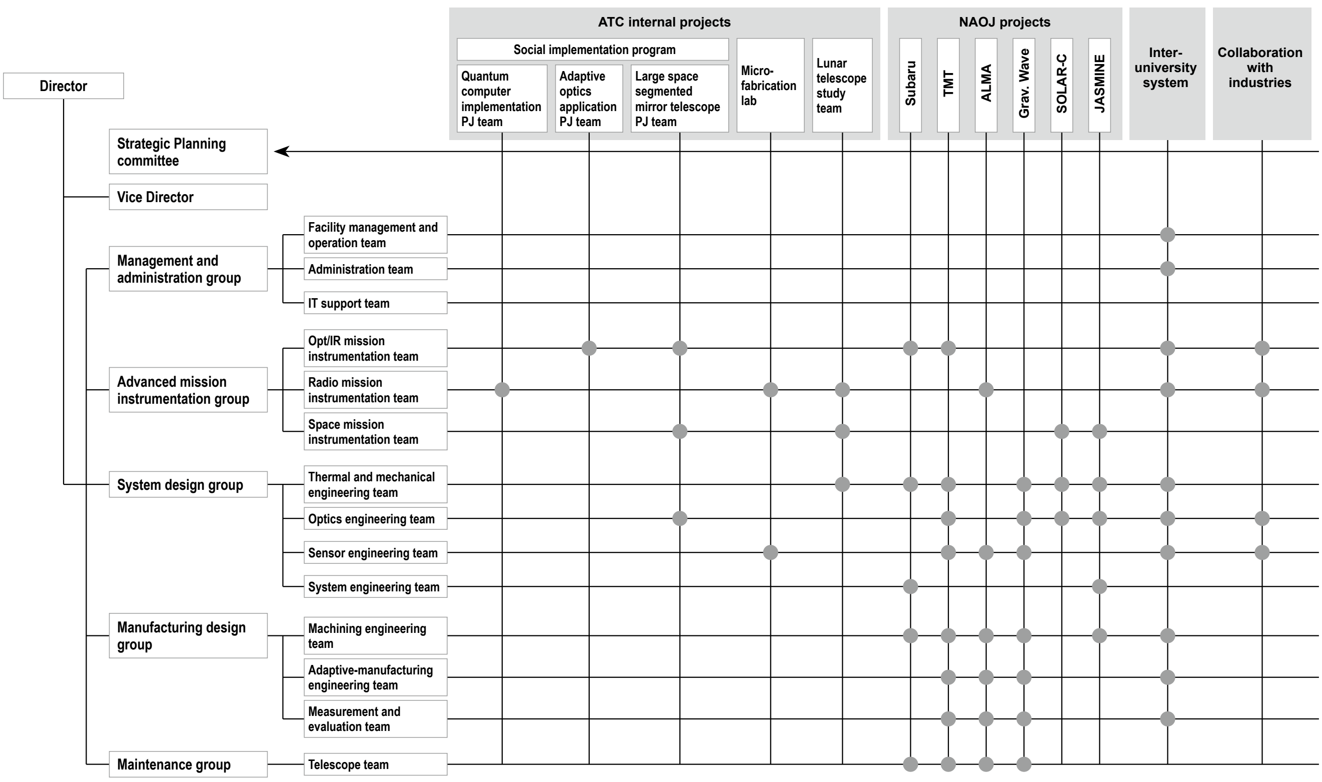

Figure 1: Matrix organization structure of ATC.

2021. The system-level analysis and documentation have been conducted in preparation for the system-level IRIS final design review scheduled for September 2025. For the former, a vibration analysis has been completed with the adaptive optics NFIRAOS and IRIS combined, and we've demonstrated compliance with the vibration-induced wavefront error requirement. The analytical/FEA models were constructed for the structural thermal optical analysis, dealing with liquid nitrogen re-fill, cooling, changes in ambient temperature, and heat dissipation of the detector readout circuit as sources of thermal disturbance. For the latter, the preliminary design of the mechanical part of the optical simulator is almost completed with the documentation remaining. The optical simulator is used to evaluate the performance of the imager and the integral field spectrograph subsystems. The redesign of the imager mechanisms is nearing completion after the detectors were re-baselined in FY 2022. The adhesive process was established to prevent delamination of the adhesive used to hold the mirror substrate, which was found in the final design phase, through failure analysis and prototype testing.

2) Wide Field Optical Spectrometer (WFOS)

WFOS started the second subphase of the preliminary design phase (PDP2) from FY 2024. NAOJ has studied the integral field unit (IFU) for WFOS as an optional future upgrade. The WFOS international development team started studying the inclusion of the IFU in the necessary functions. NAOJ estimated the development cost of the IFU and reported it to the WFOS international development team.

(2) ALMA

1) ALMA receiver development and upgrades

With the start of ALMA2 in FY 2023, the project continued the development of the initiated upgrade of the Band 8 receiver. We also supported the development of Band 2 receivers.

1-1) Band 8 version 2 receiver upgrade

NAOJ has developed an upgrade plan for the current ALMA Band 8 receiver to improve its intermediate frequency and sensitivity and has initiated the upgrade of the receiver. This is called the ALMA Band 8 version 2 receiver upgrade project (hereafter Band 8v2) and is a part of the Wideband Sensitivity Upgrade (WSU) to be conducted in ALMA2. This project is divided into Phase 1 to conduct the preliminary and detailed design of the receiver and Phase 2 for the receiver production and integration on the antennas. The Phase 1 project proposal was documented in NAOJ and approved at the ALMA Board meeting held in November 2023. Within NAOJ, in addition to keeping the development framework with the ALMA project, a development collaboration has been established including domestic and overseas research institutes and universities.

In FY 2024, the design of the Band 8v2 receiver continued from FY 2023 with the aim of satisfying the performance requirements for WSU. In the relay optics and optics components, individual performance verification for the prototype components designed in FY 2023 was performed, and we proceeded to prepare for evaluation of the optical system sub-assembly. In preparation for optical system evaluation, the configuration design was carried out in collaboration with Osaka Metropolitan University. The beam measurement system improvement and measurement software program updating were carried out in collaboration with the Korea Astronomy and Space Science Institute (KASI) under the agreement. In the collaboration with KASI, in addition to the optical system, the effect of noise induced on the mixer by the input local signal was evaluated at the laboratory in KASI. In the development of the Orth-mode Transducer and a waveguide component for the sideband separating mixer, detailed performance was checked, including the effect of the component material and final surface treatment/plating on the transmission loss. For broadband cryogenic low-noise amplifiers, which have a significant impact on the performance of the intermediate frequency band, we conducted comparative evaluation of several configuration candidates and down selected for the receiver configuration. As for the wideband cryogenic isolator, we worked to evaluate its performance and to identify issues to be addressed when installed on the receiver with the cooperation of a domestic company and external institute. For the wideband hybrid coupler, we proceeded using superconducting technology aiming to reduce transmission loss under a collaboration with the University of Electro-Communications. In addition, for the development of a superconductor-insulator-superconductor (SIS) mixer, which is critical for wideband and low-noise receivers, significant progress has been made for the second prototype, which was modified based on the evaluation results of the first prototype; it achieved the target noise performance in the 2SB configuration by combining waveguide components designed for evaluation. Based on these results, preparations are underway to test the configuration combined with the components designed for the receiver. In addition, based on the results of the above component design and subsystem studies, one receiver system configuration was extracted, and the mechanical design of the receiver cartridge was advanced. We also obtained a practically viable conceptual design solution that takes into account structural and thermal aspects and assembly while ensuring receiver performance.

The development of Band8v2 receivers has proceeded through cooperation between ATC and the ALMA Project, especially the fabrication of superconducting devices such as the SIS mixer and their electrical characterization in collaboration with the Micro Fabrication Lab. However, in the current phase, it is necessary for NAOJ to separate the development from ATC's supporting functions for universities and to promote strong development on its own initiative. For this reason, the receiver development and SIS device development team centered on ALMA receivers were placed under the direct control of the ALMA Project from January 1, 2025.

1-2) Receiver development for Band 2

For the Band 2 (67–116 GHz) receivers led by the European Southern Observatory (ESO), NAOJ has been contributing to the design of the optics system and the design, manufacturing, and testing of optical components. Band 2 passed the manufacturing readiness review (MRR) in September 2023 and advanced to the production phase. Among the optical components for which NAOJ is responsible, the fabrication was completed for the feed-OMT assembly to be used under cryogenic temperatures which consists of the corrugated horn, waveguide transition, and Ortho-mode Transducer (OMT). Acceptance inspection and performance evaluation for each component individually and assembled units were completed for 65 sets, and 49 sets were shipped to ESO. For the warm optics assembly, which consists of the dielectric lens and metal holder used at room temperature, we found a design solution for eliminating the noise level from the optical system by the end of FY 2023 by changing the shape of the lens, and conducted demonstrations in the first half of FY 2024 at laboratories in ESO and NAOJ, and later, the new lens design was tested at OSF by installing it on an antenna. Based on these results, the change request (CRE) for design modification was submitted by ESO to ALMA and approved.

Evaluation of the receiver optical performance, and manufacturing and evaluation of the prototype OMT were carried out as technical contributions to the Band 6 receiver upgrade (Band 6v2) led by the National Radio Astronomy Observatory (NRAO) under the agreement. The reported test results were used for NRAO's own internal review as technical contributions.

2) ALMA Receiver Maintenance

2-1) Band 4, 8, 10 receiver maintenance

NAOJ has been responsible for 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. Since more than 10 years have already passed since 2011, when ALMA started its initial scientific operation, it is undeniable that the failure rate of the receivers will increase in the near future when they enter the wear failure phase according to the characteristic life 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 (JAO) for solving the problems for smooth operation of ALMA. A Band 8 receiver tends to have a gradual and slight fluctuation in receiving power immediately after startup, and has conventionally been used after stabilization over an extended period of time. The cause of the fluctuation was identified through the investigation, and an adjustment procedure to stabilize in a short time was established together with the JAO and introduced into the observation operation. The same phenomenon was observed in Band 3 receivers, so this countermeasure was deployed. Verification tests on a number of ALMA antennas by the JAO confirmed that the same short-time stabilization effect was obtained.

2-2) Band 1 receiver maintenance

The Band 1 (35–50 GHz) receiver development project, which was led by Taiwan's Academia Sinica Institute of Astronomy and Astrophysics (ASIAA), in collaboration with NAOJ, etc., as a contribution to East Asia ALMA, completed its production phase. The production and performance verification of the Band 1 cartridge receivers in Taiwan has proceeded as planned, and the shipment of all receivers including spares, was completed within FY 2022. The integration of the receivers in the telescope in Chile is still ongoing, but some of the receivers are available for common-use observations in FY 2024.

NAOJ has taken responsibility for the maintenance of the Band 1 receivers in the operation phase, in addition to the Band 4, 8, and 10 receivers. In FY 2023, the test equipment for the maintenance of the Band 1 receivers was transferred to ATC, taking over the responsibility from ASIAA. In FY 2024, we diagnosed and repaired five Band 1 warm cartridge assemblies that were found to be defective during the integration procedure in the telescope. After passing the post-repair evaluation tests, these receivers were safely returned to the ALMA site.

(3) ULTIMATE-Subaru/Ground-Layer Adaptive Optics (GLAO)

GLAO is a wide-field adaptive optics instrument being developed at Subaru Telescope. The GLAO development is currently in the final design phase through collaboration between Subaru Telescope, ATC, and the Australian National University (ANU). In the final design, ATC is responsible for the design of the thermally insulated electric cabinet that holds the electronics of the wavefront sensor (WFS) and laser guide star facility (LGSF), the platform for attaching the LGSF components to the telescope, the cooling system for the LGSF, and systems engineering for the entire GLAO system. In FY 2024, two members from the Thermal and Mechanical Engineering team visited the summit facility of the Subaru Telescope to investigate the interface with the thermally insulated electric cabinet, platform, and cooling system, and proceeded with their final design. The team also completed the design of the interface plate on the platform for the laser guide star-acquisition camera, which was purchased by the GLAO project in FY 2024. The Manufacturing Design Group investigated the procedures to manufacture and measure the mechanical components of the artificial light source (StarSimulator) for calibrating the WFS. After updating the design from manufacturing and measurement perspectives, manufacturing of the prototype of the StarSimulator was started and is expected to be completed in early FY 2025.

(4) Large-scale Cryogenic Gravitational Wave Telescope: KAGRA

In collaboration with the gravitational Wave project, we are developing the vibration isolation system (VIS) and auxiliary optical system (AOS) of the KAGRA interferometer, and also evaluating its new mirror's performance. At KAGRA, recovery work following the Noto Peninsula Earthquake in January 2024 continued until early October. In response to an urgent request from the gravitational wave project, ATC contributed to the recovery effort by assigning one dedicated staff member with expertise in the VIS and AOS systems. At the same time, we contributed to the upgrade of equipment for the upcoming international joint observation run (O4c), scheduled to begin in June 2025. Specifically, we designed and assembled a black-coated structure (OMC shroud) to suppress stray light noise in the Output Mode Cleaner (OMC), a key optical component for extracting gravitational wave signals, and successfully installed it in KAGRA. In addition, by analyzing the interferometer's output noise behavior, we identified mechanical weaknesses in the steering mirrors and proposed effective improvements, significantly contributing to noise reduction. As of the end of FY 2024, the detector's sensitivity has reached approximately 2.5 times that of the O4a period. Other activities included the development of technologies required for upgrades beyond the fifth observation run (O5). This involved fabrication and evaluation of folded pendulums (core components of accelerometers for VIS) as well as the design of a new compact vibration isolation system, prototyping of this isolation system's core component (mini-GAS filter), and conceptual design of a new vibration isolation table for the OMC. We also continued efforts to develop and maintain systems for mirror performance evaluation.

(5) High-sensitivity Solar Ultraviolet Spectroscopic Satellite: SOLAR-C

ATC has contributed to the SOLAR-C telescope development by drafting the development specifications, designing the mechanical and thermal interfaces for the optical and electrical assemblies provided by overseas partner organizations, designing the optics for the spectrograph, and providing equipment for contamination control. In FY 2024, the contributions to the mechanical interface design were reflected in the Mechanical Interface Control Drawing of the telescope structure. In the optical design activity, the spectrograph's optical design for the flight model was reported at the SPIE meeting. ATC has also conducted an investigation clarifying the locations of the telescope structure illuminated by the converging beam from the primary mirror at oblique solar incidence and a stray light analysis at the instrument level, providing fundamental materials for revising the telescope structure and pointing control design.

(6) Infrared Astrometric Observation Satellite: JASMINE

ATC has performed the conceptual study of the JASMINE payload instrument together with the JASMINE Project. The Thermal and Mechanical Design Team of the System Design Group is in charge of studying a detector box unit (DBU) that holds detectors in focus and cools them down to ~170 K with a radiator and Peltier devices. In FY 2024, the team contributed the re-investigation of the DBU interface to the radiator, the evaluation of the thermal performance of thermal straps consisting of a bundle of graphite-sheets in the low-temperature environment (~200 K), and the DBU thermal and structural design based on the evaluated performance. The group also supported the conceptual study of the JASMINE telescope, and in particular discussed the structural thermal and optical performance (STOP) analysis to estimate image distortion due to thermal deformation of the telescope. The Advanced Mission Instrumentation Group studied the development of an electric system for detector driving and onboard data processing.

3. Advanced Technology Development

(1) Near-infrared Image Sensor

Near-infrared wavelengths between 1 μm and 2.5 μm are widely used in astronomical observations next to visible light. In the near infrared, sensitive observations can be made with high spatial resolution comparable to that of visible light for star-forming regions which are difficult to observe in visible light due to extinction by dust, and for high-redshift objects that cannot be detected in visible light. Until now, detectors available for the near-infrared wavelength range were only provided by a company in the U.S., making them difficult to obtain due to cost and export regulations. Our group has developed detectors sensitive to wavelengths from 1 μm to 1.7 μm in collaboration with a domestic manufacturer, enabling near-infrared observations by small university groups. In FY 2024, in collaboration with Kagoshima University, we developed a newly optimized CMOS circuit for astronomical observations to scale up extended-wavelength detectors with sensitivity up to the more challenging wavelength of 2.5 μm. In FY 2025, there are plans to combine this new CMOS circuit with long-wavelength sensors.

(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 such as manufacturing technology of an image slicer which is a key device of the IFU. In FY 2024, we conducted a coating test of high reflectivity multilayer dielectric coating (HR coating) and a manufacturing test of slicing mirrors with the HR coating. In parallel, ATC is now developing an IFU for technology verification. In FY 2024, we finished the conceptual mechanical design.

(3) Adaptive Optics Technology

Adaptive optics systems, which improve the accuracy of imaging and spectroscopy by correcting turbulent wave-fronts, are becoming an important technique in optical and infrared astronomy.

In ATC, the instruments for actual implementation of adaptive optics are developed (status of the recent GLAO system for Subaru Telescope is detailed in the separate part of this document). To develop a new analysis method for atmospheric turbulence profiling, observational data gathering has been started. On the other hand, reaffirming adaptive optics in and of itself as fundamental technology or basic science, the basic studies are being developed to establish the working principles of adaptive optics, starting from the basic elements such as optical devices, system designing, and physical characteristics of atmospheric turbulence. As a part of such basic studies, a general purpose experimental adaptive optics system is in development and is utilized for such experimental studies. In particular, studies to experimentally realize a phase contrast wave front sensor based on Zernike's phase contrast interferometry are continuing.

(4) Terahertz Technology

The terahertz experiment group supports developments in superconducting detectors, cryogenic electronics, and cryogenic systems. In FY 2024, although we suffered failures of a 4-K mechanical cooler and cooling water supply, we obtained achievements on superconducting detectors and cryogenic electronics. Evaluations on 1.5-THz SIS photon detectors, Cooper pair breaking detectors on aluminum film fabricated in the ATC clean room, show low-enough leakage current at 0.8 K. Development of the cryogenic electronics showed about 10 MHz bandwidth in a cryostat for terahertz experiments.

In collaboration with the University of Tsukuba, a Microwave Kinetic Inductance Detector (MKID) camera with French-made lumped elements kinetic inductance detectors (LEKIDs) was installed in the Nobeyama 45-m telescope to evaluate its performance.

To support Antarctic astronomy to deploy the 30-cm submillimeter-wave telescope of the University of Tsukuba, activities for on-site operation and cooling test of the telescope were made. Also related, proposals were submitted to the NAOJ science roadmap including the Antarctic terahertz telescope and FIR/THz intensity interferometry.

(5) Solar Observation Technology

5-1) Sounding rocket experiment: 4th flight of Focusing Optics X-ray Solar Imager (FOXSI-4)

FOXSI is a series of US-Japan joint sounding rocket experiments to demonstrate focusing imaging spectroscopic observation in X-rays emitted from the solar corona. The fourth flight of FOXSI (FOXSI-4) was launched at 22:13 on April 17, 2024 (UTC) and successfully performed the world's first solar flare X-ray focusing imaging spectroscopic observation. The Machining Engineering Team at ATC fabricated the “electronics boxes for the soft X-ray high-speed CMOS cameras” and the “mounting tube for the optical blocking filter” aboard FOXSI-4.

5-2) Balloon-borne Solar Observatory: SUNRISE-3

The SUNRISE-3 balloon telescope, equipped with the Sunrise Chromospheric Infrared spectroPolarimeter (SCIP) developed at ATC, was successfully flown in July 2024 and observed various features of the Sun during the 1-week flight with expected spatial resolution and polarization accuracy. We are working to generate initial science results along with the publication of a SCIP instrument paper.

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 four teams: thermal and mechanical engineering, optics engineering, sensor engineering, and systems engineering. In FY 2024, as in FY 2023, we continued to respond to requests from projects both inside and outside NAOJ, and worked on instrument development, focusing on design work.

(1) Thermal and Mechanical Engineering Team

The team continued the mechanical design and related tests of IRIS, TMT telescope structure (STR), KAGRA, SOLAR-C, JASMINE, Tricolor CMOS Camera and Spectrograph (TriCCS), and GLAO from FY 2023.

TMT: For IRIS, we continued to address the issues raised at the final design review meeting (FDR1). In preparation for FDR2, we conducted thermal and structural analysis using the imager finite element model, mirror deformation measurement at cryogenic temperature, construction of the mirror finite element model, design of the NFIRAOS simulator, and optimization of the mechanical design to accommodate the updated optical design. For STR, the external interface assessment/negotiation with TMT International Observatory (TIO) and the STR contractor has been made for the telescope key subsystems such as the secondary mirror (M2S) and the tertiary mirror (M3S) whose designs evolved significantly toward the US National Science Foundation review and we found a reasonable solution which will not affect the established STR design. Also, the final design of the support structures for the Telescope Utility Service (TUS) was refined for facilitating the smooth restart of the STR fabrication by the STR contractor. In addition, the effort was continued to realize the full’ resolution of the remaining action items from the previous STR Reviews.

SUBARU: For GLAO, the detailed design of the LGSF platform and cooling system and the LGSF/WFS electrical cabinet continued. Discussions with development partners and the Subaru Telescope summit facility visits clarified requirements and constraints, and additional requirements such as a laser safety equipment interface and Laser Launch Telescope (LLT) wind shield were flexibly accommodated.

KAGRA: On-site recovery work related to the Noto Peninsula Earthquake, which had continued since January 2024, was completed in June. In terms of equipment development, the OMC shroud was designed, followed by a trial assembly check at ATC and subsequent installation work at KAGRA. Additionally, a conceptual study of the OMC vibration isolation table was conducted.

Spaceborne Instrumentation: For SOLAR-C, the team made further coordination of a detailed mechanical interface for the telescope Engineering Flight Model (EFM) fabrication. The team contributed to the revision of various specifications, including consensus establishment with overseas institutions, and to the estimation of instrument performance through on-orbit alignment analysis. For JASMINE, the conceptual study of the detector box unit and the experiments with technology components were continued. The organization of the work assignment with the manufacturer and updating the requirements and thermal mechanical design was done for the next phase after the mission definition review. The report was prepared on the characterization of the Peltier device and the thermal strap.

Other projects: For TriCCS, the surface spectrograph system developed in FY 2023 was mounted on TriCCS for test observations, which revealed brightness variations due to changes in the gravity direction and an issue where the system could not be sufficiently retracted from the optical path. In response, brightness variation measurements and a stage upgrade were carried out by the end of FY 2024.

(2) Optics Engineering Team

The Optics Engineering Team is responsible for the development of optical systems for astronomical observation instruments, as well as for specialized optical coating. The team has participated in numerous astronomical instrument development projects led by NAOJ, universities, and research institutes, taking charge of optical design, analysis, measurement and assembly, as well as the development of optical element technologies. In FY 2024, the team continued its involvement in NAOJ-led development projects, including SOLAR-C (EUVST), KAGRA, and JASMINE, contributing to the development of optical systems and providing technical support. In addition, the team engaged in several collaborative research efforts, including: the development of an integral field spectroscopy system for the TriCCS instrument on the Seimei Telescope; a feasibility study on a large space telescope utilizing a formation of small satellites equipped with diffractive optical elements; development support for the formation-flying technology demonstration satellite SILVIA (IFO); optical design studies for a wide-field submillimeter-wave camera for the Greenland Telescope; optical design support for a three-band simultaneous imaging instrument for a New Zealand telescope; optical design support for the wide-field imager MuSaSHI; and optical design support for an integral field spectrograph for the TAO telescope. The team also cooperated in the operation of the Optical Shop managed by the Facilities Management and Operation Team. Furthermore, as a member of the Large Space Segmented Mirror Telescope Project Team, the team contributed to technical studies aimed at realizing future large space telescopes.

(3) Sensor Engineering Team

The sensor engineering team has contributed to the development and maintenance of ALMA receivers and Subaru Telescope instruments (Prime Focus Spectrograph (PFS), Hyper Suprime-Cam (HSC)). For the ALMA receiver development, mechanical design and thermo-structural analysis were conducted for the ALMA2 Band 8 receiver cartridge, and it was confirmed that the current design meets the required specifications. For the development of superconducting devices, the team has fabricated SIS devices for a mixer in a Band 8 receiver, and evaluation of the devices is underway. In the development of a visible-light detector, the team is working on the development of a CMOS camera to be installed on the Bok Telescope in Arizona, in preparation for test observations.

(4) Systems Engineering Team

In FY 2024, we worked on three projects (GLAO, JASMINE, and IRIS). For GLAO, we worked on modeling two subsystems (the wavefront sensor and the laser guide star generation system) and their interfaces using a systems engineering software program (MagicDraw). Discussions on the integration of subsystems shared between NAOJ and ANU are ongoing. We also aim to model the manufacturing, assembling, and evaluation plans for these subsystems in MagicDraw. We also prepared a cloud document management system to maintain the Configuration Item Data List (CIDL). For JASMINE, we joined the detector box unit team after the mission definition review in July 2024 and updated the requirements specification confirmation document. For IRIS, we participated in systems engineering meetings, confirmed the traceability matrix, and supported managing comments etc. from the Preliminary Design Review.

5. Manufacturing Design Group

The Manufacturing Design Group is responsible for the “manufacturing” of experimental and observational equipment. Its three teams, Additive Manufacturing (AM) Engineering Team, Machining Engineering Team, and Measurement and Evaluation Team, utilize their respective expertise to support equipment development. The group also collaborates with the Thermal Structure Team of the System Design Group to conduct complex development projects.

The number of requests responded to in FY 2024 is as follows.

Table 1: The number of requests in FY 2024.

Breakdown	Number
From FY 2023	4
FY 2024	
Advanced Technology Center	23
ALMA	13
Subaru Telescope, IRIS	15
KAGRA	17
Others	
Internal organizations	13
External organizations	9
Total	90
To FY 2025	4

(1) Machining Engineering Team

The machining team responded to fabrication requests and consultations from major projects, ATC groups, and other joint users. The team performs machine finishing on key parts of the shapes produced by the Additive Manufacturing (AM) Engineering Team. Additionally, the team provides guidance to individuals who wish to create their own products.

The main correspondence is as follows.

i. IRIS related
- Gears made of Ti-6Al-4V

ii. Subaru Telescope related
- Ultimate Subaru GLAO (Continued in FY 2025)

iii. ALMA related
- Band8 ver.2 C2R 2step shim
- Band8 ver.2 Cooling optics (Continued in FY 2025)

iv. Others, open use
- Mechanical finishing of molded parts using a metal 3D printer
  - Blank flange NW40 (Advanced Technology Center)
  - QRFH (Osaka Metropolitan University)
- Machining
  - Marionette recoil mass (KAGRA)
  - THz cryostat (NAOJ)
  - CMOS camera parts set (Advanced Technology Center)(Continued in FY 2025)

(2) Additive Manufacturing (AM) Engineering Team

In FY 2024, while utilizing the molding technology with aluminum material that has been accumulated so far, the team responded to various requests, further developed applications, and prepared for molding titanium material, which had not been attempted since its introduction.

As a new initiative, the team began taking on the challenge of modeling with a topology optimization method. This is aimed at realizing an optimized support structure for some parts of the ALMA Band 8 optical system using additive manufacturing technology. Currently, the team is working with an external vendor to create an optimized model, and is also studying the finishing process for the mirror surface in cooperation with the machining team. In addition, the team is also planning to utilize the hybrid modeling method that it has been developing for some time.

In collaboration with external organizations, four parties, including JAXA, have continued joint research, including the use of an infrared camera to measure temperatures during fabrication. Currently, we are analyzing the acquired data and identifying issues.

We responded to requests from Iwate University for the modeling of various lattice structures, and from Osaka Metropolitan University for the production of quad-ridge antennas. The Turnstile OMT, jointly developed at the request of Osaka Metropolitan University, was mounted on a receiver for a 32-m radio telescope owned by Yamaguchi University in July 2024, and began operation in September. In addition, the automatic grass-cutting robot shown at the open day was equipped with an antenna made by resin molding, which also contributed to publicity activities.

Furthermore, the team is continuing its internal study and technological accumulation by taking advantage of the ability to operate the equipment by itself, including the investigation of the effects of changing parameters during modeling and the modeling of Gyroid structures using n-Top, which was introduced in FY 2023.

(3) Measurement and Evaluation Team

The Measurement and Evaluation Team is in charge of accuracy verification and evaluation measurement of parts produced by the Machining and Modeling Team using various measuring instruments. In particular, the team utilizes the LEGEX 910 large CMM to respond to measurement requests from co-users.

In FY 2024, the team made significant contributions in verifying the accuracy of machine tools that are being considered for new introduction, as well as in the fabrication of GLAO-related parts.

Through these tasks, the team also makes active use of on-the-job training for team members.

6. Management and Administration Group

The Management and Administration Group ensures the smooth operation of projects both within ATC and outside the institute, including open-use. In FY 2024, the Administrative Support Team also contributed to a wide range of operations, including routine administrative tasks, support for open-use, guided tours, and public relations activities. In particular, the number of guided tours continued to increase, with 44 tours conducted and a total of 548 visitors. This represents an increase of 3 tours and 143 people compared to FY 2023, indicating a growing interest in ATC.

Meanwhile, due to the development of ALMA2 for the ALMA Project and associated security considerations, it has become difficult to guide non-project personnel into the deeper areas of the building. In response, preparations have begun to convert the first-floor lobby of Instrument Development Building No.1 into a new exhibition space. The IT Support Team continued its efforts to register information assets and ensure compliance with information security policies. The team also developed, maintained, and operated the "ATC Entry Pre-registration" system.

In January 2025, personnel involved in ALMA receivers and SIS technology were transferred from ATC to the ALMA Project. In response, mailing lists and Microsoft Teams environments were reorganized, and administrative coordination between ATC and the ALMA Project was carried out.

In the Facilities Management and Operations Team, the simultaneous transfer of key members to the ALMA Project and other retirements led to a significant staffing shortage. As a result, reviewing and streamlining operations have become an urgent priority. Meanwhile, the operation for open-use has continued as usual.

The summary of activities for FY 2024 is as follows:

(1) Optical Shop

The Optical Shop continued to provide shared access to measurement instruments, performing daily inspections, equipment maintenance, and on-demand consultation for measurement-related inquiries. In FY 2024, repair and replacement work was carried out on the vibration isolation table legs used in interferometers, and the shop responded to 14 technical inquiries related to measurements.

The usage statistics for measurement instruments from April 2024 to March 2025 are as follows:

• Total number of users for open use: 362
  -Internal users: 236 (including 76 by ATC staff)
  -External users: 50
• Use of LEGEX (large 3-D measurement machine): 11 (Number of operating days:19)

(2) Space Chamber

As part of our support for the development of project experiments, we assisted with outgassing measurements conducted using vacuum chambers for the SOLAR-C project, and assisted the Institute of Industrial Science at the University of Tokyo with evaluation experiments on ionic liquids. In terms of facility management, □e investigated the malfunction of the baking heater in the medium-sized vacuum chamber and identified the cause. The heater will be replaced in FY 2025. Additionally, we repaired the faulty outgassing sensor. To enhance safety during the operation of the large vacuum chamber, we introduced an additional aerial work platform. We have been continuously developing and operating software for measuring instruments used by users.

(3) Facility Management and Operation Team

The Facilities Management and Operations Team is responsible for the overall building maintenance, as well as the statutory inspections and renovations of auxiliary equipment such as cranes and forklifts, and construction support for laboratories.

In FY 2024, a major renovation of the circulation cooling system in Instrument Development Buildings No.1 and 2 was carried out. In addition to renewal of rooftop facilities and replacement of piping, the systems in Buildings No.1 and No.2 were separated to operate independently, resulting in significant functional improvements.

The handling of chemicals was changed to comply with relevant laws and regulations and the "Observatory Mitaka Campus Chemicals Handling Guidelines." As a result, the provision of chemicals to external users has been discontinued, and prior application and risk assessment are required for use at ATC. In addition, the individual, group, or organization that brought in the chemicals is responsible for the disposal of the liquid waste including the costs.

The team is actively pursuing certifications and strengthening the division of roles in inspections and equipment operation. However, staff shortages have led to some operational issues, which remain a concern.

The team also provides safety and health training as needed to ensure compliance and maintain a safe environment. On the other hand, insufficient communication with facility users has been identified as an issue that needs improvement moving forward.

7. Maintenance Group

The ATC Maintenance Group was established on February 1, 2024 to centrally manage the resources allocated to each observatory for telescope maintenance and operation, and to make effective use of resources within NAOJ. In FY 2024, with support from the Engineering Promotion Office, the group conducted site visits to the ASTE telescope, VERA Ishigakijima Station, Nobeyama Radio Observatory, and Mizusawa VLBI Observatory in order to explore potential job rotation schemes.

8. Microfabrication Lab

(1) SIS Clean Room

In the SIS Clean Room, efforts continued to address aging facilities and equipment, enhance device performance toward ALMA2, stabilize equipment for future development, and improve device yield. This year, an ECR milling system was introduced to handle materials that are difficult to process with reactive etching, such as gold and palladium, and a sacrificial layer etching system for silicon was installed to enable low-energy processing of silicon. From FY 2025 onward, to strengthen the production of Band 8v2 devices, we are expanding the team, establishing a dedicated device fabrication team and an infrastructure team, clearly defining responsibilities, and preparing a structure that enables mass production. The introduction of new equipment has also revealed limitations in utilities such as air conditioning, drainage systems, and compressed air for equipment operation. Therefore, we have identified issues and begun preparing for facility upgrades in FY 2025.

(2) Parallelization of SIS Device Fabrication Lines and Development of Peripheral Circuits

For the future mass production of Band 8v2 devices, it is essential to ensure the reliability of the SIS device fabrication lines, avoiding downtime due to equipment failure. Furthermore, the development of devices that truly surpass existing performance requires not only enhanced development equipment but also new materials and novel processes that go beyond the current Band 8 devices—thus demanding a new platform. To address these challenges, a new cleanroom concept has been implemented, establishing two parallel fabrication lines capable of producing Band 8v2 devices. This system ensures continued production even if one line stops due to equipment trouble. When both lines are operational, the system allows for stable production while also enabling the development of new devices for the future. In addition to producing Band 8v2 devices, we have also started developing peripheral components such as bias-Ts and couplers. Moreover, significant progress has been made in advanced processes such as planarization for superconducting devices with multilayer films, enabling the demonstration of 1,000-junction amplifiers and the development of superconducting 3D integration devices using flip-chip technology.

9. 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 2024, we accepted 15/4 Joint Research Development programs in the first/last calls, and 19/4 Open Facility programs in the first/last calls.

10. Social Implementation Program

The Advanced Technology Center, in cooperation with the Industry Liaison Office, established a new organization in FY 2023 called the Social Implementation Program, which aims to apply the technology of astronomical instruments developed at the Center to society. This program is externally funded. The activities of the three projects are described below.

(1) Quantum Computer Implementation Project Team

In this project team, we proposed a new concept of superconducting microwave amplifier that uses a superconductor-insulator-superconductor (SIS) mixer, which has been widely used in radio wave observations in astronomy, as an amplification element. Our goal is to achieve operation with power consumption more than three orders of magnitude lower than semiconductor amplifiers. This amplifier utilizes the quantum noise performance and frequency conversion gain of the SIS mixer. The microwave signal is up-converted to millimeter waves using the SIS mixer, and then down-converted back to microwaves with another SIS mixer, thereby achieving amplification. The local oscillator (LO) signal required for mixing is generated by a superconducting Josephson junction array oscillator, enabling complete integration of the system. This approach is expected to contribute to the development of large-scale multi-element radio observation systems and fault-tolerant quantum computers. To date, we have demonstrated not only the principle of amplifier operation but also the ability to induce non-reciprocal behavior, such as isolators, by controlling the phase between the two converters and the LO. In FY 2024, we advanced the development of a compact, integrable Josephson junction array oscillator and successfully obtained a micro-watts-level output power sufficient to serve as an LO source for pumping two SIS mixers. Building on these results, we have begun designing an integrated amplifier chip that monolithically combines the SIS mixers and Josephson oscillator.

Furthermore, regarding the utilization of ultra-high-frequency technology cultivated through the development of radio wave observation receivers, we are developing high-precision material characterization technology for millimeter-wave/submillimeter-wave bands, which are expected to be used in Beyond 5G/6G mobile communication systems. In FY 2024, to improve the convenience of material characterization, we designed and prototyped an optical system capable of measuring small dielectric samples. In cooperation with the Industry Liaison Office of NAOJ, we exhibited a poster of the material characterization technology in the booth of the "Terahertz Systems Consortium" at the Microwave Workshops & Exhibition (November 27 to 29, 2024, at Pacifico Yokohama).

(2) Adaptive Optics Application Project Team

Adaptive optics is a technology developed to correct phase aberrations in optical wavefronts, thereby restoring the diffraction-limited performance of optical systems. In ground-based astronomical observations, AO technology is employed to compensate for distortions caused by atmospheric turbulence, enabling high-resolution imaging and spectroscopy. The team worked to extend the applicability of the AO technology beyond the field of astronomy, with the objective of realizing high-quality data acquisition through the correction of wavefront phase distortions in various domains.

One field of application is satellite optical communications. By integrating adaptive optics into ground-stations that receive optical signals from communication satellites, the coupling efficiency of optical links can be significantly enhanced, facilitating high-speed and high-capacity data transmission. For this purpose, a contract research-and-development program by the Ministry of Internal Affairs and Communications entitled "Research and Development of Next-Generation Adaptive Optics Devices for Satellite Optical Communications" has been performed. In FY 2024, the optical and mechanical designs of the wavefront sensor (WFS) subsystem, which detects phase distortions caused by the atmospheric turbulence, and the deformable mirror (DM) subsystem, which corrects these distortions, were completed.

The necessary parts were procured based on the design to conduct preliminary assembly and performance evaluations of each subsystem. Furthermore, for the control subsystem that interfaces between the WFS and DM, computational and device control software was developed, and necessary hardware components were procured.

Simulations and measurement were performed to evaluate computational throughput. In parallel, measurement testing was initiated using a white-light interferometer to characterize the performance of the MEMS-based deformable mirror.

In addition to these developments, applications of the AO technology in biological microscopy for the observation of cellular structures have also been pursued. A functional demonstration unit fabricated to disseminate the AO technology, was exhibited at events such as OPIE'24 and during facility tours at the Advanced Technology Center.

(3) Large Space Segmented Mirror Telescope Project Team

In recent years, space astronomy in the visible-infrared wavelength range has advanced through projects like the James Webb Space Telescope (JWST) and the Roman Space Telescope (ROMAN). The largest space telescope using visible light is the Hubble Space Telescope, which has a single primary mirror with a diameter of 2.4 meters. However, larger space telescopes that use segmented primary mirrors are currently being planned, such as the HWO. For Japan to realize large-scale optical (and infrared) astronomy projects, either independently or in collaboration with the international community, it is crucial to develop its own capabilities for large-scale optical telescopes, particularly those with segmented mirror technology. Therefore, the NAOJ formed the Large Space Segmented Mirror Telescope Study Group at ATC in FY 2023.

In FY 2024, the group is participating in a project to develop technology for a large-aperture optical space telescope. The group is advancing technology to evaluate the optical performance of large-aperture space telescopes.

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. In FY 2024, the Public Relations Center was comprised of 9 offices, 1 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, the General Affairs Office, and the Office of Historical Archives added on November 1.

2. Personnel

In FY 2024, the Public Relations Center was composed of Director Hitoshi Yamaoka changing to Director Watanabe Junichi on October 1, and the following staff members: 2 associate professors, 2 associate professors (senior lecturers), 2 assistant professors (3 as of November, two of whom hold concurrent posts), 2 Associate Senior Research Engineers, 1 research engineer, 1 engineer, 1 unit leader, 1 project professor, 4 senior specialists (3 as of May), 1 project researchers (2 as of May, and 4 as of February), 2 research experts, 2 administrative experts, 2 research supporters (including KAKENHI funded members), 14 public outreach staff members (15 starting from May), and 1 re-employment staff member.

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 articles to widely disseminate information about topics at the forefront of astronomy and astronomical phenomena, and promoting the use of social networking services. 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) Information Sharing through Various Means

The Public Relations Office runs the NAOJ website (https://www.nao.ac.jp/en/), disseminating information via the internet. In Fiscal Year 2024, the total access count for the NAOJ website was approximately 10.08 million page views.

The Office opened X (formerly 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 2025, the Japanese X account has nearly 299,000 followers (an increase of 22,000 compared to the previous fiscal year), and the English version of the X account has more than 9,700 followers. The release of visual images on Instagram and Flickr have been conducted continuously this year.

NAOJ e-mail newsletters No.250–252 were issued, introducing research results and NAOJ hosted events. A total of about 11,100 subscription addresses have been registered (almost unchanged from the previous year).

We continued to produce videos explaining astronomical phenomena and research results, and videos introducing outreach activities, producing 15 original videos. In addition, a total of 5 livestreams were held, including astronomical phenomena such as Comet Tsuchinshan-ATLAS and the occultation of Saturn; Special Open House Day lectures; and livestreams of celestial objects using the 50-cm Telescope for Public Outreach. In particular, the YouTube livestream of Comet Tsuchinshan-ATLAS attracted a lot of attention, with 56 thousand live views and a total of 140 thousand 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. On September 20, 2024, we conducted an international online stargazing event in cooperation with JAXA's Space Education Center. Subaru Telescope, Ishigakijima Astronomical Observatory, and various overseas observatories cooperated for this event in which a total of 422 people, primarily elementary and junior-high school students in over 9 countries and regions, participated.

(2) Research Result PR

There were 16 research result announcements (compared to 30 in FY 2023 and 30 in FY 2022). We released all the research releases in both English and Japanese. Press conferences were held in connection with 2 of these releases. All releases were sent to reporters via e-mail press releases to an original media list in addition to being published online.

The 29th "Astronomy Lecture for Science Journalists" was held on October 2, 2024 on the theme of "Technological Development in NAOJ and Collaboration with Industry 2," featuring lectures and tours of ATC and the 4D2U Dome Theater with 15 guests participating in each. In addition, the 30th "Astronomy Lecture for Science Journalists" was held on January 24, 2025 on the theme of "The Universe Depicted by Supercomputers – from ATEURI II to ATERUI III" with 13 guests in attendance.

(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 IAU General Assembly (August 6–15, 2024, Cape Town, Republic of South Africa), the American Association for the Advancement of Science Annual Meeting (AAAS2025, February 13–15, 2025, Boston). As public outreach activities for the whole of NAOJ, we produced the NAOJ leaflet and established the foundation for the NAOJ donations website. To support outreach efforts of other projects, we contributed to the construction of the EAMA11 website.

The Citizens Astronomy project "GALAXY CRUISE" conducted with the support of Subaru Telescope, is continuing its second season, which targets fainter galaxies, and also ran the "2023 Special Campaign" until the end of March 2024 to classify simulated galaxies. A live stream broadcast was held in July to report on the status of the classification results analysis. In addition, we established the "Simulation Review Course" where you can compare your impressions with the "correct answers" from the simulations. The highlight for 2024 was "The Violent Universe," a GALAXY CRUISE tie-up science meeting about galaxy mergers held in September with science sessions (2 days) aimed at researchers and, for the first time at an NAOJ Research Assembly, a social event was held for researchers and citizen astronomers. Special limited time campaigns were held corresponding to summer vacation and the year-end. During the latter, the second season which has been ongoing since 2022 reached the statistical target number of classifications for all of the galaxies. As of the end of March 2025, a total of 14,300 people from 110 countries and regions (including 9,703 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 23 reports including confirmation requests for new celestial object candidates and other reports. The contents were: 22 novae/supernovae/transient objects, and 1 moving object. From these reports there were no discoveries of novae, supernovae, or comets, but there were 8 discoveries of dwarf-novae/flare-stars.

4. Outreach and Education Office

(1) Public Visits

A total of 20,606 people participated in Mitaka Campus Public Visits in FY 2024. In addition, the group tours in 2024 consisted of 95 general tours (2,943 guests), for a total of 23,549 guests visiting Mitaka Campus. In efforts to maintain and open Cultural Property buildings and facilities, 359 guests participated in the Spring opening of the Solar Tower Telescope.

Regular stargazing parties were held twice a month (the day before the 2nd Saturday [online] and the 4th Saturday [onsite/advance registration, limited capacity]). Based on the celestial object to be explained, the parties were divided into (1) online sessions broadcast on YouTube and (2) onsite sessions (advanced reservations, limited capacity, observation by eye or digital observation). The former (1) were held 8 times, and accumulated 11,801 views as of the end of March 2025. Onsite events (2) were held 14 times, and a total of 1,129 people participated.

Except for a 2 month closure from August to September for renovations to aging equipment, regular public screenings at the 4D2U Dome Theater were scheduled to be held three times a month (1st, 3rd Saturday, and the day before the 2nd Saturday) on a reservation basis. Screenings were held on 28 days during the year, and 2,921 people participated. Group screenings were also held on Tuesdays or Wednesdays for a total of 45 screenings and 1,085 guests. There were also 60 inspection group tours, etc. (887 people) organized and a total of 4,893 guests watched the 4D2U movies.

(2) Telephone Inquiries

Telephone inquiries are accepted from 9:30 to 17:00 on normal business days, with 1 person assigned to this duty. With the introduction of the Working from Home System, the duty is also being appropriately handed from home in some cases. The number of telephone inquiries to which we responded this fiscal year totaled 2,987, of which 323 were from the media. The topics (and number) of the inquiries were: Solar Ephemeris (289), Lunar Ephemeris (157), Ephemeris (98), Time (16), Solar System (692), Universe (261), Astronomy (261), and Other (1,213).

We accepted questions in letters from elementary/junior-high/high students and others enrolled in an educational curriculum and official documents. The number of letter inquiries totaled 19, of which 15 were official documents.

(3) Media Reception

We received 122 interview and filming requests from various media, out of which the following filmings were conducted: 23 newspaper articles; 29 TV programs (7 news programs, 22 others); 18 publications; 15 websites and contents; 1 radio program; 2 others. We accepted 2 requests for charged commercial filming or photography.

(4) Educational and Outreach Activities

The "FUREAI (Friendly) Astronomy" project, now in its 15th year, continued to provide classroom visits and online lectures as in the previous year. These lectures were delivered at 123 schools, 88 in Japan and 35 overseas, by 80 instructors and attended by 9,212 pupils, with the number of attendees per lecture ranging from 3 to 450. In 15 years, 107,737 students in total have attended the lectures in 1,253 schools inside and outside Japan. For more details please refer to Section X Social Contributions.

"Mitaka Open House Day" was held as a non-reserved open facilities event. We participated as part of the secretariat under the direction of the steering committee, and contributed to some of the displays and content. 3,183 people participated in the hands-on exhibits, mini-lectures, and tours of research facilities usually inaccessible to the public. It was a lively Open House Day. For more details please refer to Section VIII Public Access to Facilities.

(5) Community Activities

The "Mitaka Picture Book House in the Astronomical Observatory Forest" welcomed 33,815 visitors in FY 2024. The Office supervised an exhibition, "In the Beginning" (July 2024 to June 2025). We also cooperated with an opening ceremony, traditional Tanabata event, 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 in FY 2023, 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" which held its 200th event in March 2024.

Nine years have passed since the opening of the "Information Space of Astronomy and Science," jointly established with Mitaka City, Mitaka NETWORK University Organization, and Mitaka Town Management Organization in September 2015. In FY 2024, a total of seven exhibitions were held at this facility. NAOJ planned and produced "The Evolving Subaru Telescope – 25 years of progress and the future" (July 5 to August 25) and "100 Years of Mitaka and the Observatory Walking Together" (August 30 to October 13). The permanent display panel, "Gazing into space, NAOJ Challenges the Mysteries of the Universe" was displayed from June 21 to June 30. The total number of visitors was 12,769 in 2023, an increase from the previous year.

(6) Content Creation

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 Tsuchinshan-ATLAS C/2023 A3 which then brightened in October. Documents detailing the remarkable astronomical phenomenon of the year (Perseid meteor shower in mid-August) were created and posted on "Astronomical Events Information," intended particularly for people like the media who want to obtain detailed information. In addition, in the "basic knowledge" which collects fundamental information about astronomical phenomena, the meteor shower information was updated. Also there was one case of a correction with renewed information in the "FAQ" which provides answer to the more frequently asked questions.

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 three members, of which two are dedicated members (Head and a research supporter) and one affiliated member. SMO members participated in 3 international meetings and 47 domestic meetings this year. In addition to these, the SMO also participated in email discussions and responded to requests from the Ministry of Internal Affairs and Communications (MIC) to study frequency sharing with experimental radio transmitters and requests from individual wireless operators for frequency utilization adjustments. In addition, the Radio Astronomy Frequency Committee met two times where parties involved in radio astronomy in Japan engaged in the exchange of information and opinions.

(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. WP7D meetings were held from September 17 to 26, 2024 in a hybrid format online and at the Novotel Almaty City Center in Kazakhstan and from March 17 to 26, 2025 in hybrid format online and at the ITU headquarters. The main topics on the agenda were World Radiocommunication Conference (WRC-27) agenda item 1.16 (coexistence of satellite constellations and radio astronomy), agenda item 1.18 (protection of the radio astronomy service in certain frequency bands above 76 GHz from unwanted emissions of active services), agenda item 1.15 (communications on the lunar surface and between lunar orbit and the lunar surface). A proposal was agreed upon to include information regarding Japan's TSUKUYOMI plan in the ITU-R report on future lunar surface radio observation facilities. In response to recent changes in societal conditions, such as the rapid increase in artificial satellites and chances for lunar surface development, the SMO participated in international discussion to establish a framework to protect the radio astronomy observation environment in the future.

(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 growth of transmission traffic, discussions continued regarding the frequency expansion of the 6 GHz band. Radio astronomy is protected in the frequency band 6.650–6.6752 GHz where the CH_3OH maser emission line is located. An investigation of system technical specifications, etc. advanced with the goal of introducing a mechanism (Automated Frequency Coordination) to prohibit radio emissions or adjust the output power of wireless LANs only in areas around radio telescopes and other users' radio stations.

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. Both radar and radio astronomy are allocated in this frequency band. The MIC working group meetings for this study have not convened since April 2022, but radar manufacturers and radio astronomers met 6 times in 2024 to discuss the study methods for frequency sharing.

3) Discussion on reassignment of 22/26/40 GHz bands: Discussion continued for assigning additional frequencies to the 5 G cellular telephones. Parallel discussions were held regarding the additional assignment of the 26/40 GHz bands and the relocation to 22 GHz and upgrade of the fixed communication system currently using 26 GHz. The SMO participated in the discussion because there are frequency bands allocated to radio astronomy in the 22 and 40 GHz bands. In FY 2024 a joint study was conducted with radio astronomers working in these bands.

4) Sharing Study with High Altitude Platform Stations (HAPS): A technical study was implemented for HAPS deployed as communication base stations in the stratosphere near an altitude of 20 km. Because the link to ground stations is near a frequency band allocated to radio astronomy, a sharing study was implemented and the SMO participated in discussions in the study group.

(3) 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. In response to these concerns, the International Astronomical Union established the Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference (CPS) in 2022 and in August 2023, the SMO submitted an application to participate on behalf of NAOJ. The application was approved in early FY 2024.

As for the light pollution on the ground, the SMO continued to participate in the night sky brightness survey using digital cameras conducted by the Ministry of the Environment and submitted the results of measurements in Mitaka City and Chichijima Island in the Ogasawara Islands. In addition, a dedicated camera was installed on the roof of the South Building in NAOJ Mitaka Campus, and a continuous survey of night sky brightness was commenced starting from June 2024.

(4) Activities for Raising Awareness of Frequency Resource Management

To make more people aware of frequency resource management, the SMO participated in the online Special Open House Day of Nobeyama Radio Observatory and Mitaka Open House Day 2024, explaining our activities to the guests. In FY 2024, there were 4 media interviews about negative impacts on astronomy by light pollution from ground-based sources or mega-constellations, and those situations were covered by newspapers, web articles, etc. The leaflet to raise awareness about light pollution countermeasures was newly produced and started to be distributed.

6. Ephemeris Computation Office

(1) ECO published the “Calendar and Ephemeris 2025” and compiled the ephemeris section and several parts of the astronomy section from the “Rika Nenpyo 2025” (Chronological Scientific Tables). ECO also posted the “Reki Yoko 2026” in the official gazette on February 3, 2025. In addition to those paper-oriented products, ECO maintains web versions of the “Calendar and Ephemeris” and updated their data simultaneously with the release of “Reki Yoko.” On May 1, ECO posted a PDF version of the “Calendar and Ephemeris 2025” on its website. Also, in cooperation with the Office of International Relations, we promoted the “Handbook of Scientific Tables” -The international edition of Rika Nenpyo- through leaflet distribution and sample presentations at the IAU General Assembly 2024.

(2) ECO featured the lunar occultation of Saturn; and the 1st sunrise of the year on its website. In cooperation with the “Astronomical Events Information” by the Outreach and Education Office, ECO displayed the radiant points of the Perseid and Geminid meteor showers; and the locations of Comet Tsuchinshan-ATLAS and Comet ATLAS in the Sky Viewer. In FY 2024, there were over 40 million page views for the ECO website, an all-time high.
https://eco.mtk.nao.ac.jp/koyomi/index.html.en

(3) The Japan Association for Calendars and Culture Promotion hosted Mini Forum, its 14th General Meeting, and the Calendar Presentation Ceremony. These were also delivered via a remote conference service.

(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 62nd regular exhibition was “Seigaku Shukan - the National Important Cultural Property II.” Past exhibitions are available at the following site.
https://eco.mtk.nao.ac.jp/koyomi/exhibition/

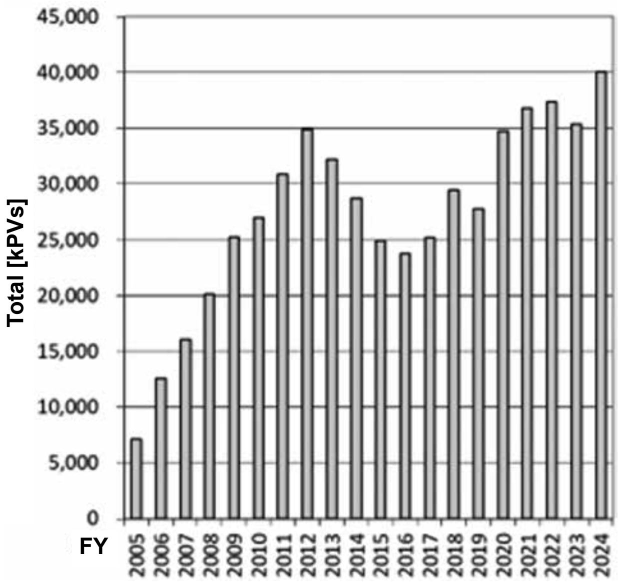

Figure 1: Pageviews for ECO Website.

7. Office of Historical Archives

The Office of Historical Archives was newly established on November 1, 2024. This fiscal year, the office digitalized approximately 9,000 historical photographic plates held by NAOJ. Among these, 5,000 photographic plates were digitized using a dedicated digitizer at Shanghai Astronomical Observatory, as part of a joint project with the observatory. The contents include 2,500 frames taken with the 188-cm telescope of the former Okayama Astrophysical Observatory and 2,500 frames taken with the 50-cm Schmidt telescope of the former Dodaira Observatory. After digitalization, two years of joint research and a public release are planned. Using a domestically produced flatbed scanner at NAOJ, 4,000 spectroscopic plates were digitized. The contents were spectroscopic plates taken from the Coude focus of the 188-cm telescope of the former Okayama Astrophysical Observatory.

8. Library Unit

The Library Unit collects, sorts, and preserves scientific journals, books, and electronic journals in order to make them available for use by NAOJ researchers and students.

The Mitaka Library is open to non-NAOJ affiliated users on weekdays. The library also 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, 87 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 2024 in October, held onsite for the first time in 4 years, the Library Unit prepared a special shelf of books related to the theme of this year's lectures and other materials housed in the library.

The Library home page was renewed at the end of March, designed for improved user convenience. The number of books and journals owned by Mitaka Library and each observatory are published in Section XI Library, Publications.

9. Publications Office

The Publications Office continued its activities in planning, editing, and printing NAOJ's original materials for education and outreach. For details please refer to Section XI Library, Publications.

Copies of NAOJ News 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. Website development is continuing for the shift to digital publication.

10. 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). It is primarily responsible for managing global astronomy communication and accessibility initiatives, which are mediated through our international network of IAU Outreach National Coordinators (NOCs), located in over 120 nations. Through supporting and growing the NOCs network, we work toward our mission of ensuring astronomy is accessible to everyone.

During the 2024–2025 fiscal year (FY), we have worked alongside IAU leadership and the NAOJ Office of International Relations to develop an IAU-NAOJ Agreement to maintain the Office for Astronomy Outreach for another six years, in alignment with a recommendation from the External Review that took place in 2023. This Agreement has been signed and is in effect.

Due to the low staffing at the OAO, we were forced to prioritize. For example, to allow growth in other areas we deprioritized our social media; responses to public inquiries and FAQs; newsletter; Meet the IAU Astronomers!; Telescopes for All; IAU Outreach Visitors Program; and the IAU Themes, as outlined below.

This FY, we grew the network of National Outreach Coordinators to include 66 new members (not including their Team and Committee members). The NOCs Funding Scheme for 2025 received four proposals of which three were funded, bringing together NOCs from 6 countries. This FY, we also began microfunding for the NOCs, providing our network with an opportunity to gain small amounts of funding to facilitate their astronomy communications work. Through this initiative, we supported 17 NOCs.

In the middle of this fiscal year, we published one issue of the Communicating Astronomy with the Public Journal. Articles were solicited through an open call for peer-reviewed submissions, but with two important feature articles: one related to the outreach strategy of the XXXII IAU GA in Cape Town, South Africa, and another dedicated to the works of the NOCs across the African continent.

Throughout 2023 and 2024, we co-organized the Communicating Astronomy with the Public Conference, which took place in person at Cité de l'espace in Toulouse, France and online in June 2024. This conference received 299 participants, 95 of whom were online, with 204 in person. Based on our pre-registration data, these delegates represented 52 nations. In addition to the financial support from the IAU (5,000 EUR) for travel grants and fee waivers, we were gifted a special grant from a Japanese donor (~600,000 JPY) for additional travel and registration support. In total, we were able to support seven travel grants and 17 fee waivers, not including those waivers provided by the LOC. The virtual experience we developed for this edition of the CAP Conference (based in the Discord online platform) will be reused as the foundation for a community of practice for all those interested in the CAP mission. Taking advantage of the CAP Conference in Europe, we also had informal visits with Lina Canas (IAU Central, Paris), the OAE Team and MPIA (Heidelberg, Germany), and Pedro Russo (Leiden, The Netherlands).

In addition to the CAP Conference, and as a manifestation of our dedication to supporting NAOJ in its international efforts, the OAO represented NAOJ at several other conferences in this fiscal year. More locally, the OAO continues to support NAOJ in its Open House Day and GALAXY CRUISE initiatives, and through Space Scoop.

At the XXXII IAU General Assembly, we hosted an institutional meeting with three sessions featuring talks and posters. We additionally helped to organize two plenary sessions, participated in the IAU booth, and attended several scientific sessions as presenters and participants.

Some highlights from this year include: 150 initiatives engaging people in 41 countries and regions; tens of thousands of people reached through the OAO social media and communication networks; and annual projects such as Women and Girls in Astronomy, Dark and Quiet Skies, and 100 Hours of Astronomy. Our 100 Hours of Astronomy events were supported by members of the IAU Office of Astronomy for Development. In 2024, the OAO assisted with the organization and implementation of two Special Projects on behalf of the IAU: one with The LEGO Group toy company and another with the US-based podcast Radiolab.

11. Timekeeping Office Operations

The Time Keeping Office operates 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. Three of the cesium atomic clocks continued stable operation at Mizusawa Campus throughout this fiscal year. Site preparations continued in order to move the atomic clocks to Mitaka Campus and one cesium atomic clock was established and maintained. The NTP (Network Time Protocol) server at the Time Keeping Office provides standard time on a network.

12. Ishigakijima Astronomical Observatory

Ishigakijima Astronomical Observatory is a unique observatory operated through cooperation between six entities including Ishigaki City, NPO Yaeyama Hoshinokai, and the University of the Ryukyus. Astronomy education and outreach activities in cooperation with the local community and research activities utilizing the highly versatile telescope are expanding.

(1) Public Outreach Activities

[Guided Tours, Space 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. The annual number of visitors was 6,569, and the cumulative number of visitors was 166,167.

[Online Outreach and Education Events, Co-sponsorships, Cooperative Events, etc.]

We were involved in online activities including photography and streaming videos with the "Southern Cross Monitor" and "Milky Way Monitor;" photography and streaming videos of Comet Tsuchinshan-ATLAS; and international online astronomical telescope events. The "Southern Island Star Festival" we co-hosted in August had approximately 3,000 participants. We cooperated in a joint broadcast during August 12~13, live-streaming the Perseid meteor shower from Ishigakijima Astronomical Observatory. There were 18 articles in newspapers and other media, and there were 16 cases of assistance with news gathering. The 3,200 km "Stamp Rally" held with Nayoro Observatory KITASUBARU had 42 people complete it, an all-time high.

(2) Educational Activities

There were 3 inspections (20 guests) and 30 educational group tours (459 guests) held in cooperation with Ishigaki City, Ishigaki City Education Committee, Specified Nonprofit Corporation Yaeyama Hoshinokai, and the Ishigaki Youth House. The Chura-boshi Research Team Workshop for high school students in August hosted 28 participants from across Japan, and the results were reported at the Junior Session of the Astronomical Society of Japan. We also worked for local education activities, including lectures at the University of the Ryukyus (53 attendees).

(3) Research Activities

Two refereed papers in western journals were published in FY 2024. The total number of papers including results based on Ishigakijima Astronomical Observatory observational data reached 34. There was 1 presentation at a domestic scientific conference. In addition, we replaced the control PC for the 3-color camera and supported Nihon University Department of Aerospace Engineering observations of the Taurid meteor shower by providing infrastructure.

13. Commemoration of the 100th Anniversary of the Relocation to Mitaka

We celebrated the 100th anniversary since NAOJ (formerly Tokyo Astronomical Observatory) relocated to Mitaka, and conducted various activities in cooperation with the Administration Department and others. A commemoration ceremony and commemorative lecture were held on September 1, at Mitaka City Public Hall with approximately 400 citizens and guests in attendance. The commemorative display, "From Mitaka to Outer Space, 100 Years of Mitaka and the Observatory Walking Together" was held from October 30 to November 3 at the Mitaka City Arts Center, and welcomed 711 guests. On November 3, "100 years of the Universe as observed by mankind. The ongoing story of the Universe woven by eyes and voices." was held. This performance about astronomy 100 years ago, today, and leading towards the future was presented by voice artists and NAOJ astronomers using the Observatory History Museum (65-cm Telescope Dome) as a stage. Additionally as mentioned in the section about cooperation with the local community, a related event, "100 Years of Mitaka and the Observatory Walking Together" (August 30 to October 13) was held at the "Information Space of Astronomy and Science." A display with almost the same content has been established in the Mitaka Campus Resting Room.

17. Division of Science

1. Overview

We will report on the FY 2024 research activities in the Division of Science based on the following vision and philosophy of the division:

- Promote fruitful research results through liberal ideas of individuals and achieve world-leading scientific results. Expand astronomical knowledge by developing new fields, such as effective collaborations between theory and observations, multi-wavelength astronomy, and multi-messenger astronomy. In addition to developing important research, we nurture creative ideas that can lead to new fields.

- Utilize large telescopes and supercomputers at NAOJ to achieve top-level research results as a world-leading research division. Contribute to promoting future plans of NAOJ from a scientific perspective.

- Actively promote the education of young researchers, including graduate students, to attract both Japanese and international researchers in the next generation who will lead worldwide research activities. Become a career path center for astronomical researchers worldwide.

- Foster collaborations with domestic and international researchers, including those in other NAOJ projects, to advance astronomy research and create new scientific breakthroughs. Play an important role in promoting internationalization in Japan's astronomical field.

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 – including dynamics and material evolution. Taking advantage of the facilities of NAOJ, such as the supercomputers of NAOJ, the Subaru Telescope, ALMA, and the Nobeyama radio telescope, the division fosters collaborations among theoretical and observational astronomers working across different wavelength ranges. We conduct interdisciplinary astronomical research with the physics of neutrinos, gravitational waves, elementary particles, atomic nuclei, and planetary science. The division members are also actively involved in developing scientific projects for future observational missions.

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 have arranged opportunities for interaction among members with an all-member science colloquium with external invited speakers, workshop, and social events in a hybrid format. The division actively organizes international and domestic workshops to promote research activities in various related fields of astronomy and astrophysics.

2. Current Members

The dedicated faculty members of the Division of Science included five Professors, three Associate Professors, one Project Associate Professor (cross appointment), and seven Assistant Professors, in addition to one affiliated Professor, one affiliated Associate Professor, and one affiliated Assistant Professor, who concurrently held a primary position at the Center for Computation Astrophysics (CfCA). In addition to these faculty members, the division was served by seven Project Assistant Professors including NAOJ Fellows, four Japan Society for the Promotion of Science (JSPS) Postdoctoral Fellows, two JSPS Foreign Research Fellows, one East Asia Core Observatories Association (EACOA) fellow, one NINS Project Researcher and three Research Supporters. Three Administrative Supporters gave full support to all activities of the division. (March 2025)

3. Research Output

There were 325 refereed research papers published by the division members as authors. The research highlights listed at the beginning of this report include some of the research results. Research in which division members took leading roles includes the following:

• Diversity in Hydrogen-rich Envelope Mass of Type II Supernovae. I. Plateau Phase Light-curve modeling
• Characterization of Supernovae Interacting with Dense Circumstellar Matter with a Flat Density Profile
• Carbon Isotope Fractionation of Complex Organic Molecules in Star-forming Cores

Research highlights on the division's website (https://sci.nao.ac.jp/main/articles-en/) include the following results:

• Discovery of the origin of the streamer feeding the material of the young star Per-emb-2 (Taniguchi et al.)
• Radio Emission from a Supernova Observed with Japanese and Korean Telescopes (Iwata et al. incl. Tominaga, Moriya)
• Diamonds in Exoplanetary Skies? New Insights on Photochemical Hazes of Exoplanetary Atmospheres (Ohno)

4. International and Domestic Collaborations and Cooperation

(1) International and Domestic Workshops

The division members organized or co-organized the following international and domestic workshops, serving as a hub for scientific activities, collaborating with international and domestic colleagues. This contributed to stimulating research activities in astronomy and related fields.

International Meetings:
• Elucidating the Material Circulation in the Early Universe (March 10–14, 2025, at Komaba Campus, the University of Tokyo and at Mitaka NAOJ, Japan)
• Astrochemistry workshop (May 23–24, 2024, Mitaka NAOJ)

Domestic Meetings:
• 37th "RIRON-KON" symposium - (December 24–26, 2024, Mitaka NAOJ)

(2) International Organization Committees and Reviews of International Funds

• JWST Cycle 4 External Panel (Ouchi)
• APCosPA Counsil Meeting (Kohri)
• KAGRA Collaboration Scientific Congress(KSC) meeting (Kohri)
• LiteBIRD Editorial Committee (Kohri)
• Next-generation Neutrino Science Organization(NNSO) (Kohri)

(3) International and Domestic Observation Projects

To proceed with efficient collaborations between theory and observations, and multi-wavelength astronomy, the members of the division contributed to the following observational projects. Additionally, the members contributed to promoting international and domestic future astronomy plans, including those for large telescopes at NAOJ from a scientific perspective.

• Asia Pacific Organization for Cosmology and Particle Astrophysics (APCosPA)(council member: Kohri)
• Association of Asia Pacific Physical Societies (AAPPS) Division of Astrophysics, Cosmology and Gravitation (DACG) (EXCO: Kohri)
• Euclid Supernova and Transient Science Working Group (Lead: Moriya)
• GREX-PLUS (Nomura; Ouchi; Moriya)
• HETDEX Publication Internal Reviewer (Ouchi)
• Habtable Worlds Obseravtory 2025 Technology and Science Organizing Committee(Ouchi)
• JWST Cycle 4 Review (External Panel member: Ouchi)
• KAGRA Collaboration Scientific Congress (KSC) (Kohri)
• KAGRA Committee of Publication Control (CPC) (Kohri)
• LAPYUTA (Science goal 3 Chief: Ouchi)
• LiteBIRD Collaboration (Kohri)
• Mizusawa VLBI SAC (Machida)
• ngVLA(Nomura)
• NINJA (Project Scientist: Moriya)
• NSF Panel for Multi-messenger Astrophysics Call (reviewer: Dainotti)
• Next-generation Neutrino Science and Multi-messenger Astronomy Organization (NNSO) (Kohri)
• PRIMA(Nomura)
• Roman Space Telescope High Latitude Time Domain Core Community Survey Definition Committee (Moriya)
• Roman Space Telescope SPQR Project (Member: Ouchi)
• SKA1 subproject (Head of Science: Machida)
• Subaru PFS survey Galaxy Evolution Team (co-chairman: Ouchi)
• Subaru SAC (Tominaga, Moriya)
• Subaru-Roman White Paper (Ouchi)
• ULTIMATE-Subaru (Moriya)
• Roman International paper (author: Dainotti)

5. Educational and Outreach Activities

The division actively promotes the education of young researchers, including graduate students. In FY 2024, the graduate students in the Division of Science included twenty SOKENDAI students (thirteen doctoral and seven master's course students) and nine students in the University of Tokyo (three doctoral and six master's course students), and one student in University of Hyogo (doctor course student). The members of the division delivered lectures at the University of Tokyo and several other institutions and universities. In addition, a spring school organized by the Division of Science for undergraduate and master's students was held in February 2025.

The members also engaged in outreach activities through public lectures.

6. Visitors

2024 0826 (National Chin-Yi University of Technology, Taiwan) Dr. Chia-Min Lin
2024 0716 (SISSA, Italy) Takeshi Kobayashi
2024 05 (Queen's University Belfast, UK) Tom J. Millar
2024 05 (NASA GSFC, USA) Martin Cordiner
2024 05 (Universite Grenoble Alpes, France) Pierre Hily-Blant
2024 07 (Copenhagen University, Denmark) Ayumu Kuwahara

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 the 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 Ephemeris 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 094 for details on the activities of the Library Section in FY 2024, and Chapter XI Library, Publications for the library collection.

19. IT Security Office

The IT Security Office (ITSO) has the following missions to ensure information security at NAOJ and to operate and protect information assets at NAOJ.

A) Managing 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.
I) Build and operate zero-trust and integrated communications services based on Microsoft 365 services.
II) Build, migrate, and operate network and telephony services.
III) Provide information service infrastructure such as virtualization and bare metal public servers.
IV) Operate cost-effective external and internal network services in cooperation with various R&D networks, etc.
V) Conduct security-related operations (CSIRT) in cooperation with the Administrative Division, NINS, and MEXT.
VI) Collect information and collaborate with other organizations.

The highlights of our actions in FY 2025 are as follows.

(1) Promotion of Security Measures and International Collaboration

ITSO has assigned dedicated personnel to promote information security, compliance, and international collaboration. It is enhancing CSIRT and collaborating with APIDT (Australia) (an organization that provides funding for Internet technology in the Asia-Pacific region) and the University of Hawai`i to improve the international network.

(2) Network equipment replacement plan

The NAOJ information network service replacement scheduled for 2026-2027 requires maintaining the scope of the network and implementing technical security features, while at the same time reducing operating costs due to the severe financial situation. To achieve this, the current contract has been extended; the installation and the scope of replacement are under revision; and low-cost equipment is being evaluated.

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 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. In terms of finance, the financial controller played a crucial role in budget planning through annual interviews with various projects, centers, a division, etc. Additionally, he contributed as a corresponding financial committee member to the East Asian Observatory, ALMA Project, and TMT Project. 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 2024 are as follows.

1. Research Assessment Support Office

(1) International External Evaluation

As the secretariat of the NAOJ Project Review Committee[1)], together with the General Affairs Unit of the General Affairs Group, we prepared for the FY 2024 project review, i.e., the international external evaluation of the Center for Computational Astrophysics (CfCA), based on the Committee's discussion. Subsequently, we supported the implementation of the review by the External Evaluation Committee (consisting of three overseas and three domestic members) conducted at Mitaka Campus in February 2025. Additionally, we assisted in finalizing the FY 2023 project evaluation reports for the three projects.

(2) Participation in NINS Activities Related to Evaluation and Enhancement of Research Capabilities

We attended the "NINS Task Force on Evaluation" (Evaluation TF) and supported the preparation of institutional evaluation materials (NINS's FY 2023 Self-Assessment Report[2)] and the progress confirmation table for the fourth mid-term plan) together with the NAOJ Evaluation TF (consisting of the Director of the Research Assessment Support Office Saito, Director of Research Coordination Ikoma, and Associate Professor Koyama) and the General Affairs Unit of the General Affairs Group.

In order to collect the results of NAOJ's joint use and joint research and to promote the use of open data within and outside NAOJ, we conducted the following activities as members of two NINS working groups (WGs) established sequentially under the NINS Research Collaboration and Liaison Committee. At the "Institutional Repository Development WG", we compiled opinions within NAOJ and prepared for application to the "Open Access (OA) Acceleration Project" of MEXT (Ministry of Education, Culture, Sports, Science and Technology). After the application was accepted in July 2024, at the "OA Promotion WG," we managed the progress of budget execution within NAOJ, supported the implementation of NINS projects, and prepared report materials for MEXT, with the cooperation of the Research Promotion Group.

As members of the NINS "Collaborative Research Team" and the "Research and Management Strategy Team," we regularly exchanged information on initiatives and achievements to enhance universities' research capabilities.

(3) Enhancement of Research Infrastructure

We conducted a survey of research papers published at NAOJ in FY 2023 and reported them to NINS and the NAOJ directorate. We also provided support for the preparation of materials and acquisition of external funding, mainly in response to requests from within NAOJ.

Based on discussions by the Science Advisory Committee and the Science Roadmap Committee, we supported the organization of the "NAOJ Future Symposium 2024 - Science Roadmap of NAOJ" (December 3–6, 2024)[3)] as a member of the LOC, in collaboration with the Research Promotion Group.

The Library and we set up the prototype of the "NAOJ Repository for Academic Resources" to be opened in the next fiscal year and drafted its policy.

2. Industry Liaison Office

(1) Collaboration with private companies

Three cases of joint research and three cases of commissioned business were contracted with private companies. These include joint research on superconductivity technology, which NAOJ has advanced as part of the development of receivers for radio telescopes, and supervision of science books, etc.

(2) Participation in exhibitions

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

- OPIE 24 (April 24–26, 2024): Demonstration of adaptive optics technology
- Innovation Japan 2024 (August 22–23, 2024): Demonstration of adaptive optics technology
- InterOpto2024(October 29–31, 2024): Demonstration of adaptive optics technology
- MWE 2024 (November 27–29, 2024): Permittivity measurement technology

(3) Outreach

Aiming to gain media exposure and to disseminate our activities to companies that are interested in collaborations with NAOJ, we hosted a lecture for journalists to explain NAOJ's advanced technology development and industrial collaboration "Astronomy Lecture for Science Journalists: Technology Development in NAOJ and Collaboration with Industry 2" on October 2, 2024 in collaboration with the Public Relations Center, Advanced Technology Center, and the Center for Computational Astrophysics. We provided lectures on the overview of NAOJ's technology development and industrial collaboration, adaptive optics technology (AO), and additive manufacturing, as well as visits to the AO and metal 3D printer laboratories. The number of participants was 15. Nikkan Kogyo Shimbun published an article on the industry collaboration of NAOJ.

In order to disseminate NAOJ's advanced technology, we revised the pamphlet of the Industry Liaison Office.

1) https://www.nao.ac.jp/recommend/project-review-committee/
2) https://www.nins.jp/about/assets/R5jikotenken.pdf
3) https://www.nao.ac.jp/for-researchers/naoj-symposium2024/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 for cooperative engagement in research and education by multicultural researchers and students. Specifically, the OIR's main activities include promoting international research collaboration, supporting visiting international researchers and students, and disseminating information at international conferences.

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 the EAO/EACOA budgets within NAOJ. The EACOA consists of four core observatories representing the East Asian regions: 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 FY 2024, following NAOJ's decision to withdraw from the EAO as of the end of February 2025, the OIR handled necessary adjustments and procedures for this process. In parallel, the OIR provided comprehensive support to four post-doctoral young researchers (EACOA Fellows) hosted by NAOJ through the EACOA Fellowship Program. Furthermore, as secretariat of the local organizing committee, the OIR initiated FY 2024 preparations for NAOJ to host EACOA's 11th East-Asian Meeting on Astronomy (EAMA 11) in Niigata in December 2025.

Alongside these duties, the OIR also handles legal document review, such as agreements and memoranda for international collaboration between NAOJ and overseas institutions. In FY 2024, the office conducted legal reviews and drafted texts for a total of 60 new or revised international agreements.

2. Support Services for International Researchers and Students

The annual number of international researchers and students visiting NAOJ recovered after COVID-19 was downgraded to a Category 5 infectious disease, and in FY 2024, it increased to approximately 1.5 times that of the pre-pandemic level. Consequently, the Support Desk (SD) of the OIR, which supports international researchers and students with daily life in Japan, has seen an increase in the number of accompaniment requests for various municipal procedures and general inquiries. The "NAOJ Support Desk Registration Form," first introduced in FY 2021 and now fully established, has enabled the development of a more efficient support system by streamlining the process for SD staff to gather information from incoming international visitors and ensuring prompt assistance.

Since its launch in July 2021, the OIR website has provided information to international researchers and students and their NAOJ hosts. The website offers bilingual support, providing practical information on immigration procedures, various Japanese systems such as medical care and social security, accommodations, campus neighborhoods, daily life, and reference information in both Japanese and English. In FY 2024, in addition to continued updates to the information posted on the website, information regarding the My Number Card insurance system, which started in December 2024, was added and organized by type of insurance coverage and registration status to make it easily understandable for international researchers and students. This update, along with active internal and external publicity, led to a further increase in the number of viewers from both within and outside Japan and expanded the website's utilization.

The OIR continues to collaborate with a specialized company to offer Japanese language classes to help international researchers and students quickly adjust to life in Japan. In FY 2024, in addition to the beginner and intermediate courses, an advanced course was newly established. All courses offer lessons that have been developed in response to the requests of 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 responsiveness, students were given the freedom to study at their convenience. The courses were well received by the students, who remained highly motivated to learn.

3. Information Dissemination at International Conferences

The OIR has been exhibiting booths at international conferences to recruit international researchers by presenting information about NAOJ's research activities and invitational programs. In August 2024, at the XXXII International Astronomical Union General Assembly (IAU GA) held in Cape Town, South Africa, the NAOJ booth provided information on its research activities and international invitation programs, with a focus on introducing "Subaru Telescope 2.0," which aims to acquire international joint operation partners.

4. Others

In addition to its regular duties, during FY 2024, the OIR reorganized its meeting space to promote staff internationalization through internal exchange and training. With the goal of starting utilization of this space within FY 2025, possibilities for exchange activities and language training for Japanese staff and international researchers and students are currently being explored.

22. Human Resources Planning Office

The Human Resources Planning Office works closely with the Directorate to formulate and implement the organization's overall human resources strategy and is expected to make the best use of the organization's human resources and contribute to the continuity and development of business at the National Astronomical Observatory of Japan (NAOJ). Specifically, the scope of its work includes the operation of the Objective Sharing and Talent Development System; planning and implementation of the training programs for leaders; management of fixed-term employees; improvement of the work environment including harassment prevention; and handling individual labor matters and consultations from employees. Through these, we strive to strategically and effectively promote human resource strategies to achieve organizational goals.

1. Objective Sharing and Talent Development System

The Objective Sharing and Talent Development System was operated for Research and Academic Staff, Research Engineer Staff, Engineering Staff, and Employees on Annual Salary System/URA Staff (Specially Appointed Teachers, Project Researchers, and Senior Specialists), with the overall flow of setting annual objectives, mid-term review, and year-end review. The evaluation results were reflected in the bonuses (June and December) and January salary increases for Research and Academic Staff and Engineering Staff, and in the annual salary amount from April for Employees on Annual Salary System. In each process, the transfer of related documents was conducted using SharePoint, to enhance security and efficiency as well as convenience for the staff involved. In FY 2024, we proposed a revision of the requested alphabetical grading terminology and prepared new guidelines and forms for the application of the new terminology beginning in FY 2025.

2. General Employment Management for Fixed-term Staff

Appropriate employment measures (e.g., operation of the Fixed-Term Employee Review Committee, operation of employment measures for employees transitioning to the mandatory retirement system, etc.) were implemented for fixed-term contract employees with various employment statuses, including Employees on Annual Salary System. This year, in particular, we were more cautious, as it was the first review since the retirement age for transitional employees was extended to 65. Sufficient time was taken to inform all parties concerned of the eligible employees, conditions, and procedural schedule for transitioning to the mandatory retirement system. Effective employment management that meets the needs of the organization is being practiced.

3. Training Program for Leaders

In FY 2024, the training theme continued to be “Strengthening Interpersonal Communication Skills.” We had three full-day face-to-face training sessions with a total of 67 participants.

As for the “Internal Communication Training” by an external instructor, which started in FY 2023, all members of the Directorate and more than 90 % of department heads have completed the course. The “Cross-Cultural Communication Training - Practical Version” customized for NAOJ was newly planned and implemented. The training provided an opportunity for diverse participants, transcending job types, positions, ages, and nationalities, to exchange opinions and learn collaborative skills through group work. The periodic training also provides an opportunity for personnel exchange across divisions.

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

We responded promptly and courteously to consultations regarding harassment (consultations with the external consultation service, internal counselors, or the Human Resources Planning Office), and took appropriate measures based on the fact-finding process. In addition, measures to prevent harassment such as e-learning training and promotion of the use of external consultation services were undertaken in cooperation with the Employee Affairs Unit of the Administration Department and the external consultation service vendor.

5. Contribution to International Projects

The Human Resources Manager participated in the ALMA HRAG (Human Resource Advisory Group) as a member of NAOJ and actively built relationships and exchanged opinions at the meeting held in Charlottesville in September 2024. In addition, we proceeded with a series of recruitment processes for the International Staff Members (ISM) of the Joint ALMA Observatory (JAO) in cooperation with the relevant departments. In FY 2024, four open positions were advertised, and one was hired through NAOJ.

6. Others

In addition to responding to special assignments, various information was provided to members of the Directorate such as stress check results and the 360-degree feedback program.

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.

In FY 2024, one of the two health officers (Safety and Health Management Office Staff) was replaced by a publicly recruited (experienced) person, but the handover was completed within one year without any major impacts from this change.

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, Hawaii, 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 2024, 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. During 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, 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.

The heat stroke alert was used to raise awareness.

At the middle of October 2024, the Mitaka district (Gravitational Wave Project, Advanced Technology Center / ME shop and Clean Room) 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 the Kamioka Branch in late June 2024, Mizusawa VLBI Observatory in late August 2024, Subaru Telescope Okayama Branch in early September 2024, and Nobeyama Radio Observatory in early October 2024 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 13, 2024.

Course Content:

□ Industrial Safety and Health Act
(New chemical substance management)
□ Chemical substance manager
□ Protective equipment wearing manager
□ Industrial accident cases
□ Hazardous risks
□ High Pressure Gas Safety Law

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: 189 (74 for NAOJ staff, 115 for students / external staff, etc.)
Other: No one participated in CE handling practical training.

In addition, a course on "Overview of Chemical Substance Management under the Revised Industrial Safety and Health Act" was held on September 3 and 11, 2024, and a Q&A MTG was held on September 30, 2024, with a total of 78 attendees.

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
□ Health Consultation with Occupational Physicians in the Mitaka district
□ General Lifesaving Course

5. Development of Rules and Manuals

The following guideline, in accordance with the partial revision of the Ordinance on Industrial Safety and Health etc., is prepared and requires business operators to establish and operate a system to appropriately implement exposure control measures based on the results of risk assessment, mainly for hazardous chemical substances.

□ Handling Guidelines for Chemicals at NAOJ (Mitaka Campus)

24. Engineering Promotion Office

1. Outline

The Engineering Promotion Office (EPO) aims to enhance NAOJ's overall engineering development and operational capabilities by coordinating efforts to develop the skills of the engineering staff. Specifically, the EPO engages in the assignment of the engineering staff, human resource development, and other activities essential for improving NAOJ's engineering capabilities.

2. Assignment of the Engineering Staff

The engineering staff at NAOJ consists of Engineering Staff, Executive Engineers, Senior Research Engineers, Associate Senior Research Engineers, and Research Engineers. They are regarded as "a group of professionals who tackle NAOJ's technical challenges with advanced expertise and a strong sense of responsibility, creating new value for current and future astronomy, and contributing to the advancement of science, technology, and society."

Staff assignments require balancing long-term human resource development and technology succession with the efficient execution of individual technical projects and initiatives. In FY 2024, to explore the potential for job rotations, we conducted site visits to observe work at the ASTE Telescope, VERA Ishigakijima Station, Nobeyama Radio Observatory, and Mizusawa VLBI Observatory.

Based on requests from each project and center, as well as proposals for medium- and long-term personnel promotion, the following promotions and hires were made: two Senior Research Engineers, one Associate Senior Research Engineer, two Research Engineers, and four Engineers.

3. Engineering Staff Human Resource Development

Human resource development was carried out based on a set of documents compiled in FY 2020. In FY 2024, two of those documents were revised with input from the engineering staff. Additionally, a career development system was implemented and is being operated through FY 2025, aiming to support staff career paths over the medium to long term in collaboration with their supervisors.

Regarding training, eight engineering staff members participated in an English e-learning course, and two took part in a lecture-style English course hosted by the Administration Department. Nine staff members also enrolled in a commercial business e-learning course. While participants responded positively, the impact across the engineering staff was limited; therefore, the EPO has decided not to solicit participants for this program in future years.

As an effort to apply systems engineering to actual operations, we organized a hands-on training workshop using a game-based system development exercise. A total of 21 participants, including those from outside NAOJ, joined the program.

The "Symposium on Engineering in Astronomy" was postponed due to prolonged discussions regarding the format of the symposium and the selection of organizing members. Preparations are now underway for its rescheduled launch in April 2025.

4. Other Areas Needed to Improve the Engineering Capabilities

To address safety and product development assurance at NAOJ, a Safety and Product Assurance (S&PA) Office was established on July 1, 2024.

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 Astronomical Science Program, the Graduate Institute for Advanced Studies at SOKENDAI. In FY 2024, which is the second year after SOKENDAI's reorganization, the Graduate Education Office continued to oversee the transition. For graduate students, individual meetings between SOKENDAI students and members of the Graduate Education Office, which have been conducted since 2022, were arranged for all students to further enhance support for graduate students.

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

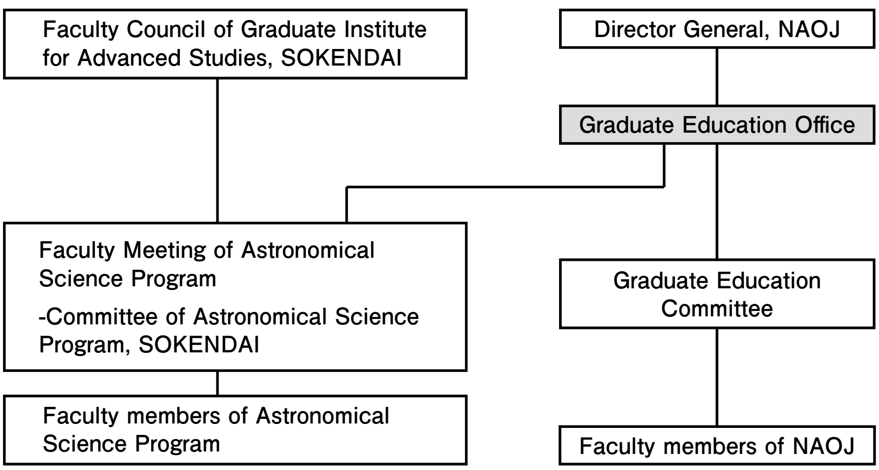

Figure 1: Organizational chart showing the position of the Graduate Education Office within NAOJ.

26. Safety and Product Assurance Promotion Office

1. Outline

Safety and Product Assurance Promotion Office was established on July 1, 2024 to collect and analyze information and issues related to system safety, reliability, and quality assurance activities (S&PA, Safety and Product Assurance activities) in a centralized manner, and to contribute to S&PA activities of various operations, including maintenance conducted by NAOJ project offices, in order to improve the level of safety, reliability, and quality of products provided by them.

Specifically, the S&PA Office prepares, maintains, and implements standards and procedures for S&PA activities, provides support to each project office, and performs other activities necessary for NAOJ's system safety, reliability, and quality assurance.

2. Establish, Maintain, and Implement Standards and Procedures for System Safety, Reliability, and Quality Assurance Activities

NAOJ develops, manufactures, and maintains various types of telescopes; collaborates with research institutes around the world; and provides observational data to researchers worldwide. Telescopes and other equipment that produce observational data require advanced technology and maintenance, and these activities must be supported by system safety, reliability, and quality assurance. While individual efforts have been made by our predecessors to achieve these goals, NAOJ needs to establish standards and procedures that can be used in a common way to systematically address these issues.

In FY 2024, the Safety and Product Assurance Promotion Office developed a draft of standards and reviewed the content of related procedures.

3. Support for Project Offices, etc.

In support of each project office, etc., we prepare necessary documents for the start of S&PA activities and provide comments from the viewpoint of S&PA in meetings with contractors.

In FY 2023, as the entity in charge of safety and quality assurance in the Engineering Promotion Office, the project office supported the preparation of a program plan for S&PA for the GLAO project. In FY 2024, as the Safety and Product Assurance Promotion Office, the Office is providing S&PA support to the JASMINE project by participating in meetings with contractors for the preliminary design review (PDR) of the JASMINE project.

4. Ensure NAOJ’s System Safety, Reliability, and Quality

NAOJ's projects have achieved results so far thanks to the efforts of our predecessors. In the future, as international cooperation continues to advance and the maintenance of existing facilities becomes more important, it will be necessary to establish a system for S&PA for NAOJ as a whole to ensure more results like these. In order to establish this system, it is necessary to gain the understanding and cooperation of NAOJ staff regarding S&PA.

Therefore, in FY 2024, we visited and observed two private companies (November 13, 2024 and February 17, 2025) and exchanged opinions with them in order to observe the efforts of other companies and confirm what is needed. (28 people in total)

In an effort to establish an ongoing exchange of opinions, facility use and collaborative development, The companies we visited were invited to tour the NAOJ Mitaka Campus facilities and a meeting was held for exchanging opinions.

In addition, we decided to hold a meeting in April after the end of the fiscal year to learn about the efforts of other companies and discuss what lessons to incorporate and how to incorporate them into NAOJ as a way forward.

III Organization

1. Organization

- Director General
  - Advisory Committee for Research and Management
    - Project Review Committee
    - Research Coordination Committee
    - Scientific Advisory Committee
    - External Council
    - Science Roadmap Committee
  - Vice-Director General (on General Affairs)
  - Vice-Director General (on Finance)
  - Director of Engineering
  - Director of Research Coordination
  - Executive Advisors to the Director General
  - Projects
    - (C Projects)
    - Mizusawa VLBI Observatory
      - Square Kilometer Array 1 (SKA1) Promotion Group
    - Nobeyama Radio Observatory
    - Solar Science Observatory
    - Subaru Telescope
    - Center for Computational Astrophysics
    - NAOJ Chile
    - ALMA Project
      - Next generation Very Long Array (ngVLA) Study Group
    - (B Projects)
    - Gravitational Wave Science Project
    - Thirty Meter Telescope (TMT) Project
    - (A Projects)
    - JASMINE Project
    - RISE Project
    - SOLAR-C Project
    - Subaru Prime Focus Spectrograph (PFS) Project
    - Subaru Ground Layer Adaptive Optics (GLAO) Project
    - ASTE Project
  - Centers
    - Astronomy Data Center
    - Advanced Technology Center
    - Public Relations Center
  - Division of Science
  - Collaborative Projects
    - Inter-university Collaboration: Optical and Infrared Synergetic Telescopes for Education and Research (OISTER)
    - Inter-university Collaboration: Japanese VLBI Network (JVN)
  - Library
  - IT Security Office
  - Research Enhancement Strategy Office
    - Research Assessment Support Office
    - Industry Liaison Office
  - Office of International Relations
  - Human Resources Planning Office
  - Safety and Health Management Office
  - Engineering Promotion Office
  - Graduate Education Office
  - Safety and Product Assurance Promotion Office
  - Administration Department

2. Number of Staff Members

	(2025/3/31)
Director General	1
Research and Academic Staff	161
Professor	28
Executive Engineer	1
Associate Professor	41
Senior Research Engineer	10
Associate Professor (Senior Lecturer)	8
Associate Senior Research Engineer	6
Assistant Professor	54
Research Associate	0
Research Engineer	13
Engineering Staff	36
Administrative Staff	59
Research Administrator Staff	1
Employees on Annual Salary System	136
Research Administrator Staff Transferring to the Mandatory Retirement System	2
Employees on Annual Salary System Transferring to the Mandatory Retirement System	14
Full-time Contract Employees	20
Full-time Contract Employees Transferring to the Mandatory Retirement System	4
Part-time Contract Employees	90
Part-time Contract Employees Transferring to the Mandatory Retirement System	14
Full-time Re-employment Staff	3
Part-time Re-employment Staff	1

3. Executives

Director General	Doi, Mamoru
Vice-Director General	
on General Affairs	Yoshida, Michitoshi
on Finance	Saito, Masao
Director of Engineering	Uzawa, Yoshinori
Director of Research Coordination	Ikoma, Masahiro
Executive Advisor to the Director General	Sakamoto, Seiichi
Executive Advisor to the Director General	Honma, Mareki
Executive Advisor to the Director General	Motohara, Kentaro
Executive Advisor to the Director General	Ishikawa, Ryoko

4. Research Departments

Projects

C Projects

Mizusawa VLBI Observatory

Director	Honma, Mareki
Professor	Honma, Mareki
Associate Professor	Hirota, Tomoya
Assistant Professor	Iwata, Yuhei
Assistant Professor	Kono, Yusuke
Assistant Professor	Jike, Takaaki
Assistant Professor	Sunada, Kazuyoshi
Engineer (Gishi)	1
Engineer (Shunin Gijutsuin)	2
Project Researcher	Akahori, Takuya
Project Researcher	Kurahara, Kohei
Project Researcher	Yoshiura, Shintaro
Senior Specialist (Tokuninsenmonin)	3
Technical Experts	5
Research Supporters	2
Administrative Supporters	2
SKA1 Promotion Group	
Group Leader	Akahori, Takuya
Administration Office	
Head of Administration Office	Onuma, Toru
General Affairs Unit	
Leader	1
Re-employment Staff	1
Administrative Supporters	3
Accounting Unit	
Leader	1
Re-employment Staff	1

Nobeyama Radio Observatory

Director	Nishimura, Atsushi
Professor	Tatematsu, Kenichi
Associate Professor	Nishimura, Atsushi
Senior Engineer	1
Engineer (Gishi)	3
Full-time Re-employment Staff	1
Administration Office	
Acting Head of Administration Office	Nishimura, Atsushi
General Affairs Unit	
Senior Staff	1
Administrative Supporters	2
Accounting Unit	
Senior Staff	1
Administrative Supporters	2

Solar Science Observatory

Director	Katsukawa, Yukio
Professor	Katsukawa, Yukio
Associate Professor	Ishikawa, Ryoko
Associate Professor	Hanaoka, Yoichiro
Assistant Professor	Narukage, Noriyuki
Posdoctoral Researcher	Tei, Akiko
Senior Specialist (Tokuninsenmonin)	2
Part-time Re-employment Staff	1
Administrative Supporter	1

Subaru Telescope

Director	Miyazaki, Satoshi
Vice-Director	Hayano, Yutaka
Professor	Tamura, Naoyuki
Professor	Hayano, Yutaka
Professor	Miyazaki, Satoshi
Project Professor *	Tamura, Motohide
Project Professor	Yoshida, Michitoshi
Associate Professor *	Kotani, Takayuki
Associate Professor	Koyama, Yusei
Associate Professor	Tanaka, Masayuki
Associate Professor	Pyo, Tae-Soo
Associate Professor *	Hirano, Teruyuki
Associate Professor	Minowa, Yosuke
Project Associate Professor	Kambe, Eiji
Senior Research Engineer	Iwashita, Hiroyuki
Senior Research Engineer	Kumura, Yoshinori
Associate Professor (Senior Lecturer) *	Murakami, Naoshi
Assistant Professor	Ishigaki, Miho
Assistant Professor	Imanishi, Masatoshi
Assistant Professor	Ono, Yoshito
Assistant Professor	Okamoto, Sakurako
Assistant Professor	Okita, Hirofumi
Assistant Professor	Onodera, Masato
Assistant Professor *	Suto, Hiroshi
Assistant Professor	Maehara, Hiroyuki
Assistant Professor	Moritani, Yuki
Assistant Professor	Yanagisawa, Kenshi
Assistant Professor	Yabe, Kiyoto
Project Assistant Professor *	Kuzuhara, Masayuki
Project Assistant Professor	Toba, Yoshiki
Project Assistant Professor *	Hashimoto, Jun
Project Assistant Professor *	Hori, Yasunori
Project Assistant Professor *	Livingston John Henry
Research Engineer	Omiya, Jun
Research Engineer	Bando, Takamasa
Senior Engineer	1

Engineer (Shunin Gijutsuin)	4
Project Researcher	Ali, Sadman Shariar
Project Researcher	Ando, Makoto
Project Researcher *	Urago, Riku
Project Researcher	Onozato, Hiroki
Project Researcher	Kawanomoto, Satoshi
Project Researcher *	Kono, Masaru
Project Researcher *	Komatsu, Yu
Project Researcher	Takahashi, Ayumi
Project Researcher *	Takarada, Takuya
Project Researcher	Nakata, Fumiaki
Project Researcher *	Nugroho Stevanus Kristianto
Project Researcher	Fitriana, Itsna Khoirul
Project Researcher	He, Wanqiu
Project Researcher *	Mizuki, Toshiyuki
Project Researcher	Laishram, Ronaldo
Project Researcher	Liang, Yongming
Senior Specialist (Tokuninsenmonin)	10
Senior Specialist (Tokuninsenmonin) *	2
Posdoctoral Researcher	Taniguchi, Daisuke
Posdoctoral Researcher	Mori, Mayuko
Administrative Expert	1
Re-employment Staff	1
Public Outreach Staff	1
Administrative Supporters	5

*concurrently appointed in NINS

Administration Department

Manager	Furuhata, Tomoyuki
General Affairs Unit	
Staff	1
Accounting Unit	
Staff	1

RCUH

RCUH Staff Members	58

Okayama Branch Office

Director	Tajitsu, Akito
Associate Professor	Izumiura, Hideyuki
Project Associate Professor	Tajitsu, Akito
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	Huang, Yukun
Project Researcher	Matsumoto, Yuji
Project Researcher	Misugi, Yoshiaki
Senior Specialist (Tokuninsenmonin)	3
Research Expert	1
Administrative Expert	1
Research Supporters	3

NAOJ Chile

Director	Watanabe, Teruyuki
Vice-Director	Mizuno, Norikazu
Associate Professor	Utsumi, Yosuke
Associate Professor	Minamidani, Tetsuhiro
Project Associate Professor	Enokiya, Rei
Engineer (Shunin Gijutsuin)	1
Senior Specialist (Tokuninsenmonin)	1
Full-time Re-employment Staff	1
Chile Employee	
Chile Employees	6

Administration Department

Manager	Seto, Yoji
General Affairs Unit	
Staff	1
Accounting Unit	
Senior Staff	1

ALMA Project

Director	Iguchi, Satoru
Professor	Iguchi, Satoru
Professor	Kameno, Seiji
Professor	Sakamoto, Seiichi
Professor	Fukagawa, Misato
Professor	Mizuno, Norikazu
Associate Professor	Asaki, Yoshiharu
Associate Professor	Ishii, Shun
Associate Professor	Izumi, Takuma
Associate Professor	Okuda, Takeshi
Associate Professor	Kojima, Takafumi
Associate Professor	Kosugi, George
Associate Professor	Sawada, Tsuyoshi
Associate Professor	Shimojo, Masumi
Associate Professor	Takahashi, Satoko
Associate Professor	Nagai, Hiroshi
Associate Professor	Hatsukade, Bunyo
Senior Research Engineer	Kikuchi, Kenichi
Senior Research Engineer	Sugimoto, Kanako
Senior Research Engineer	Nakazato, Takeshi
Senior Research Engineer	Nakamoto, Takashi
Senior Research Engineer	Watanabe, Manabu
Associate Professor (Senior Lecturer)	Nakanishi, Koichiro
Associate Senior Research Engineer	Morita, Eisuke
Assistant Professor	Ezawa, Hajime
Assistant Professor	Kamazaki, Takeshi
Assistant Professor	Hsieh, Pei-Ying
Assistant Professor	Taniguchi, Kotomi
Assistant Professor	Hirota, Akihiko
Assistant Professor	Masui, Sho
Assistant Professor	Matsuda, Yuichi
Research Engineer	Ezaki, Shohei
Research Engineer	Shizugami, Makoto
Research Engineer	Yamada, Masumi
Project Assistant Professor	Izumi, Natsuko

Project Assistant Professor	Imada, Hiroaki
Project Assistant Professor	Ohashi, Satoshi
Project Assistant Professor	Olguin Choupay, Fernando Andres
Project Assistant Professor	Cataldi, Gianni
Project Assistant Professor	Tokuda, Kazuki
Engineer (Gishi)	3
Engineer (Shunin Gijutsuin)	1
Engineer (Gijutsuin)	3
Project Researcher	Kawanaka, Norita
Project Researcher	Kang, Haoran
Project Researcher	Huang, Shuo
Project Researcher	Shibaike, Yuhito
Project Researcher	Silva Bustamante, Andrea Ludovina
Project Researcher	Chen, Zhengyi
Project Researcher	Chen, Xiaoyang
Project Researcher	Desmet, Pascale Heather
Project Researcher	Nagai, Makoto
Project Researcher	Harrington, Kevin Corneilus
Project Researcher	Mallick, Kshitiz Kumar
Project Researcher	Lee, Kianhong
Senior Specialist (Tokuninsenmonin)	23
Posdoctoral Researcher	Yamasaki, Yasumasa
Technical Expert	1
Public Outreach Staff	1
Technical Supporters	7
Administrative Supporters	3

ngVLA Study Group

Group Leader	Izumi, Takuma

B Projects

Gravitational Wave Science Project

Director	Tomaru, Takayuki
Professor	Tomaru, Takayuki
Associate Professor	Aso, Yoichi
Associate Professor (Senior Lecturer)	Takahashi, Ryutaro
Assistant Professor	Akutsu, Tomotada
Engineer (Shunin Gijutsuin)	1
Project Researcher	Eisenmann, Marc
Project Researcher	Page, Michael Anthony
Administrative Supporter	1

Kamioka Branch Office

Director	Tomaru, Takayuki
Assistant Professor	Chen, Dan
Assistant Professor	Washimi, Tatsuki
Senior Specialist (Tokuninsenmonin)	1
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
Associate Professor	Iono, Daisuke
Associate Professor	Sugimoto, Masahiro
Associate Professor	Suzuki, Ryuji
Associate Professor	Terada, Hiroshi
Associate Professor	Noumaru, Junichi
Assistant Professor	Nishikawa, Jun
Assistant Professor	Yasui, Chikako
Research Engineer	Tazawa, Seiichi
Senior Specialist (Tokuninsenmonin)	4
Senior Specialist (Tokumeisenmonin)	2

A Projects

JASMINE Project

Director	Kano, Ryohei
Professor	Kano, Ryohei
Professor	Goda, Naoteru
Associate Professor	Wada, Takehiko
Assistant Professor	Ueda, Akitoshi
Assistant Professor	Ohsawa, Ryou
Assistant Professor	Tsujimoto, Takuji
Assistant Professor	Miyoshi, Makoto
Assistant Professor	Yano, Taihei
Project Researcher	Ramos Ramirez, Pau

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
Re-employment Staff	1
Public Outreach Staff	1

SOLAR-C Project

Director	Hara, Hirohisa
Professor	Hara, Hirohisa
Assistant Professor	Okamoto, Takenori
Assistant Professor	Kawabata, Yusuke
Assistant Professor	Kubo, Masahito
Engineer (Gishi)	1
Senior Specialist (Tokuninsenmonin)	1
Administrative Supporter	1

Subaru Prime Focus Spectrograph (PFS) Project

Director	Koshida, Shintaro

Subaru Ground Layer Adaptive Optics (GLAO) Project

Director	Minowa, Yosuke

ASTE Project

Acting Director	Saito, Masao

Centers

Astronomy Data Center

Director	Furusawa, Hisanori
Vice-Director	Takada, Tadafumi
Associate Professor	Takada, Tadafumi
Associate Professor	Furusawa, Hisanori
Assistant Professor	Shirasaki, Yuji
Assistant Professor	Yagi, Masafumi
Research Engineer	Koike, Michitaro
Research Engineer	Mineo, Sogo
Project Researcher	Uchiyama, Hisakazu
Project Researcher	Kasuga, Toshihiro
Project Researcher	Koyama, Shuhei
Project Researcher	Zhang, Tianfang
Senior Specialist (Tokuninsenmonin)	8
Research Supporters	2
Administrative Supporter	1

Advanced Technology Center

Director	Hirabayashi, Masayuki
Vice-Director	Ozaki, Masanobu
Vice-Director	Fukushima, Mitsuhiro
Professor	Uzawa, Yoshinori
Professor	Ozaki, Masanobu
Executive Engineer	Hirabayashi, Masayuki
Associate Professor	Oya, Shin
Associate Professor	Shan, Wenlei
Associate Professor	Matsuo, Hiroshi
Senior Research Engineer	Kanzawa, Tomio
Senior Research Engineer	Fukushima, Mitsuhiro
Associate Professor (Senior Lecturer)	Ozaki, Shinobu
Associate Professor (Senior Lecturer)	Nakaya, Hidehiko
Associate Senior Research Engineer	Uraguchi, Fumihiro
Associate Senior Research Engineer	Obuchi, Yoshiyuki
Assistant Professor	Oshima, Tai
Assistant Professor	Kushibiki, Kosuke
Project Assistant Professor	Hattori, Masayuki
Research Engineer	Kohara, Naoki
Research Engineer	Sato, Naohisa
Research Engineer	Tsuzuki, Toshihiro
Research Engineer	Tokoku, Chihiro
Engineer (Gishi)	6
Engineer (Shunin Gijutsuin)	5
Engineer (Gijutsuin)	1
Project Researcher	Terao, Koki
Project Researcher	Murayama, Yosuke
Project Researcher	Yoneta, Kenta
Senior Specialist (Tokuninsenmonin)	2
Technical Experts	2
Technical Supporter	1
Administrative Supporters	3
Research Assistant Staff	1
Senior Specialist (Tokumeisenmonin)	3
Full-time Re-employment Staff	1

Public Relations Center

Director	Watanabe, Junichi
Vice-Director	Hiramatsu, Masaaki
Vice-Director	Fuse, Tetsuharu
Project Professor	Watanabe, Junichi
Associate Professor	Agata, Hidehiko
Associate Professor	Yamaoka, Hitoshi
Associate Professor (Senior Lecturer)	Hiramatsu, Masaaki
Associate Senior Research Engineer	Katayama, Masato
Associate Senior Research Engineer	Fuse, Tetsuharu
Assistant Professor	Umemoto, Tomofumi
Research Engineer	Shibata, Takashi
Engineer (Shunin Gijutsuin)	1
Project Researcher	Asabre Frimpong, Naomi
Project Researcher	Duran Carrillo, Cintia
Project Researcher	Blumenthal, Kelly Anne
Senior Specialist (Tokuninsenmonin)	3
Research Experts	2
Administrative Expert	1
Re-employment Staff	1
Research Supporters	2
Public Outreach Staff Members	15
Senior Specialist (Tokumeisenmonin)	1

Public Relations Office

Director	Yamaoka, Hitoshi

Outreach and Education Office

Acting Director	Agata, Hidehiko

Ephemeris Computation Office

Director	Katayama, Masato

Spectrum Management Office

Director	Hiramatsu, Masaaki

Administration Office

Library Leader	1

Publications Office

Director	Yamaoka, Hitoshi

The Office for Astronomy Outreach of the IAU

Director	Blumenthal Kelly Anne

Administration Office

Director	Fuse, Tetsuharu

Ishigakijima Astronomical Observatory

Director	Hanayama, Hidekazu

Associate Professor (Senior Lecturer)	Hanayama, Hidekazu
Project Researcher	Hayatsu, Natsuki
Administrative Expert	1

Time Keeping Office

Director	Fuse, Tetsuharu

Office of Historical Archives

Director	Watanabe, Junichi
Assistant Professor	Yanagisawa, Kenshi

Division of Science

Division Head	Tominaga, Nozomu
Professor	Ikoma, Masahiro
Professor	Ouchi, Masami
Professor	Kohri, Kazunori
Professor	Tominaga, Nozomu
Professor	Nomura, Hideko
Associate Professor	Fujii, Yuka
Associate Professor	Nakamura, Fumitaka
Associate Professor	Machida, Mami
Assistant Professor	Kataoka, Akimasa
Assistant Professor	Dainotti, Maria Giovanna
Assistant Professor	Takahashi, Ko
Assistant Professor	Hamana, Takashi
Assistant Professor	Harada, Nanase
Assistant Professor	Morino, Junichi
Assistant Professor	Moriya, Takashi
Project Assistant Professor	Arzoumanian, Doris
Project Assistant Professor	Ito, Yuichi
Project Assistant Professor	Ono, Kazumasa
Project Assistant Professor	Kashino, Daichi
Project Assistant Professor	Kokubo, Mitsuru
Project Assistant Professor	Sugiyama, Naonori
Project Assistant Professor	Nagakura, Hiroki
Project Researcher	Escriva Manas, Alberto
Project Researcher	Kashiwagi, Raiga
Project Researcher	Zhang, Haibin
Project Researcher	Tran, Thi Thai
Project Researcher	Dorozsmai, Andras
Project Researcher	Liu, Junhao
Posdoctoral Researcher	Kusakabe, Haruka
Posdoctoral Researcher	Mori, Masamitsu
Research Supporters	3
Administrative Supporters	3
Research Assistants	5

5. Research Support Departments

IT Security Office

Director	Yoshida, Michitoshi
Vice Director	Oe, Masafumi
Associate Professor (Senior Lecturer)	Oe, Masafumi
Associate Senior Research Engineer	Tomine, Takashi
Engineer (Shunin Gijutsuin)	1
Senior Specialist (Tokuninsenmonin)	1
Re-employment Staff	1

Research Enhancement Strategy Office

Director	Saito, Masao
Vice Director	Iguchi, Satoru
Assistant Professor	Ishizuki, Sumio
Assistant Professor	Shirasaki, Masato
Assistant Professor	Hattori, Kohei
Senior Specialist (Tokuninsenmonin)	3

Research Assessment Support Office

Director	Saito, Masao
Assistant Professor	Ishizuki, Sumio
Senior Specialist (Tokuninsenmonin)	1

Industry Liaison Office

Director	Hiramatsu, Masaaki

Office of International Relations

Director	Chapman, Junko
Senior Specialist (Tokuninsenmonin)	1
Senior Specialist (Tokuninsenmonin)	2

Support Desk

Research Supporters	2

Human Resources Planning Office

Director	Yoshida, Michitoshi
Senior Specialist (Tokuninsenmonin)	1

Safety and Health Management Office

Director	Mori, Yasushi
Senior Specialist (Tokuninsenmonin)	2

Engineering Promotion Office

Director	Uzawa, Yoshinori
Senior Research Engineer	Fujii, Yasunori

Graduate Education Office

Director	Sekii, Takashi
Project Professor	Sekii, Takashi

Safety and Product Assurance Promotion Office

Director	Uzawa, Yoshinori

Administration Department

General Manager	Fujita, Hisashi
Senior Specialist (Tokuninsenmonin)	1

General Affairs Group

Manager	Tanaka, Aiko
Deputy Manager	1
Specialist (Information Technology)	1
Specialist (Personnel Relations)	1
Senior Specialist (Tokuninsenmonin)	3
Administrative Supporter	1
General Affairs Unit	
Leader	1
Staff Members	2
Administrative Expert	1
Administrative Supporter	1
Personnel Unit	
Leader	1
Staff Members	2
Administrative Expert	1
Payroll Unit	
Leader	1
Senior Staff Members	2
Senior Specialist (Tokuninsenmonin)	1
Administrative Supporter	1
Employee Affairs Unit	
Leader	1
Staff Members	2
Administrative Expert	1

Research Promotion Group

Manager	Kaneko Osamu
Deputy Manager	1
Senior Specialist (International Relations)	1
Senior Specialist (Tokuninsenmonin)	1
Administrative Supporter	1
Research Support Unit	
Leader	1
Administrative Experts	2
Administrative Supporter	1
External Funding Unit	
Specialist (External Funding)	1
Staff	1
Graduate Student Affairs Unit	
Leader	1
Administrative Experts	2
International Academic Affairs Unit	
Leader	1

Financial Affairs Group

Manager	Hirose, Yoshikazu
Deputy Manager	1
General Affairs Unit	

Leader	1
Senior Staff	1
Staff	1
Administrative Supporter	1
Budget Unit	
Leader	1
Senior Staff	1
Administrative Supporter	1
Asset Management Unit	
Leader	1
Receiving Unit	
Leader	1
Administrative Supporters	3
Accounting Group	
Manager	Hosoya, Akio
Accounting Unit	
Leader	1
Senior Staff	1
Administrative Supporters	3
Procurement Unit	
Leader	1
Senior Staff	1
Staff	1
Administrative Expert	1
Administrative Supporter	1
Facilities Group	
Manager	Ogawa, Masayoshi
Deputy Manager	1
Specialist (Accounting)	1
General Affairs Unit	
Leader	1
Administrative Supporter	1
Facilities Direction Unit	
Leader	1
Administrative Supporters	2
Maintenance Unit	
Leader	1
Staff Members	2

6. Advisory Committee for Research and Management

Members

From universities and related institutes

	Arai, Tomoko	Director of the Planetary Exploration Research Center, Chiba Institute of Technology
	Omukai, Kazuyuki	Professor at the Graduate School of Science, Tohoku University
	Kobayashi, Kaori	Professor at the Graduate School of Science and Engineering, University of Toyama
○	Kodama, Tadayuki	Professor at the Graduate School of Science, Tohoku University
	Kohno, Kotaro	Director at the Institute of Astronomy, Graduate School of Science, The University of Tokyo
	Kuriki, Satoshi	Professor at Department of Fundamental Statistical Mathematics, The Institute of Statistical Mathematics
	Sumi, Takahiro	Professor at the Graduate School of Science, Osaka University
	Tagoshi, Hideyuki	Professor at the Institute for Cosmic Ray Research, The University of Tokyo
	Yamada, Toru	Professor at the Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency
	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 at ALMA Project
	Honma, Mareki	Project Professor at the Mizusawa VLBI Observatory
	Ikoma, Masahiro	Director of Research Coordination
	Miyazaki, Satoshi	Professor at Subaru Telescope
	Nomura, Hideko	Professor at the Division of Science
	Saito, Masao	Vice-Director General(on Finance)
	Usuda, Tomonori	Professor at TMT Project
	Uzawa, Yoshinori	Director of Engineering
	Watanabe, Junichi	Project Professor at Public Relations Center
●	Yoshida, Michitoshi	Vice-Director General(on General Affairs)

● Chairperson ○ Vise-Chairperson
Period: April 1, 2024 – March 31, 2026

IV Finance

Revenue and Expenses (FY 2024)

(Unit: ¥1,000)

Revenue	Budget	Final Account	Budget − Final Account
Management Expenses Grants	9,664,702	10,508,425	−843,723
Facilities Maintenance Grants	2,324,024	2,058,106	265,918
Subsidy Income	745,663	942,107	−196,444
Facilities Maintenance Grants (NIAD-QE)	0	12,000	−12,000
Miscellaneous Income	19,658	70,389	−50,731
Industry-Academia Research Income and Donation Income	616,013	576,504	39,509
Reversals of Reserves for Specific Purposes	0	0	0
Reversals of Specific Assets Set Aside	295,193	288,800	6,393
Total	13,665,253	14,456,331	−791,078
Expenses	Budget	Final Account	Budget − Final Account
Management Expenses	9,979,553	10,423,462	−443,909
Employee Personnel Expenses	3,801,872	4,124,506	−322,634
Operating Expenses	6,177,681	6,298,956	−121,275
Facilities Maintenance Expenses	2,324,024	2,070,106	253,918
Subsidy Expenses	745,663	942,107	−196,444
Industry-Academia Research Expenses and Donation Expenses	616,013	708,594	−92,581
Total	13,665,253	14,144,269	−479,016
Revenue-Expenses	Budget	Final Account	Budget − Final Account
	0	312,062	−312,062

V KAKENHI (Grants-in-Aid for Scientific Research)

1. Series of Single-year Grants for FY 2024

Research Categories	Number of Selected Projects	Budget (Unit: ¥1,000)		
		Direct Funding	Indirect Funding	Total
Transformative Research Areas (A)	4	25,000	7,500	32,500
Scientific Research (S)	7	146,500	43,950	190,450
Scientific Research (A)	6	42,000	12,600	54,600
Publication of Scientific Research Results	1	490	0	490
Total	18	213,990	64,050	278,040

2. Series of Multi-year Fund for FY 2024

Research Categories	Number of Selected Projects	Budget (Unit: ¥1,000)		
		Direct Funding	Indirect Funding	Total
Scientific Research (B)	25	115,900	34,770	150,670
Scientific Research (C)	18	21,200	6,360	27,560
Early-Career Scientists	23	25,200	7,560	32,760
Challenging Research (Exploratory)	3	8,100	2,430	10,530
Research Activity Start-up	7	7,900	2,370	10,270
Fund for the Promotion of Joint International Research (International Leading Research)	1	59,920	17,976	77,896
Fund for the Promotion of Joint International Research (Fostering Joint International Research (B))	2	7,700	2,310	10,010
JSPS Research Fellows	8	13,700	4,110	17,810
JSPS International Research Fellow	4	3,200	0	3,200
Total	91	262,820	77,886	340,706

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	111	402 (80)	57 Institutes, 12 Countries
	Subaru Telescope Okayama Branch	SEIMEI Telescope	64	220	22 Institutes, 2 Countries
	Solar Science Observatory	Ground-based Solar Observatory	*	*	*
		Sun-observing satellite “Hinode”	**	**	**
	Mizusawa VLBI Observatory	VERA	31	126 (89)	51 Institutes, 13 Countries
	Astronomy Data Center		338	338 (21)	90 Institutes, 12 Countries
	Center for Computational Astrophysics		340	340 (28)	78 Institutes, 9 Countries
	Advanced Technology Center	Facility Use	26	86	33 Institutes
		Joint Research and Development	19	144	30 Institutes
	ALMA Project	ALMA (Cycle 10)	240	3213 (2693)	377 Institutes, 36 Countries
		ASTE	***	***	***
Paid Telescope Time System	Nobeyama Radio Observatory	45-m telescope	36	–	–
Large-scale Collaborative-Program	Mizusawa VLBI Observatory	VERA	21	82 (7)	30 Institutes, 4 Countries
Joint Development Research			6		5 Institutes
Research Assembly			15		12 Institutes
NAOJ Symposium			0		0 Institutes

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 10) is from October 2023 to September 2024.

* The observation data are 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 had no instruments available for Open-Use Observations in this fiscal year, and there were no calls for proposals and no accepted proposals.

2. Commissioned Research Fellows

Visiting Scholars (Domestic)

Name	Position at NAOJ	Affiliated Institute	Period	Host Project/Center/Division
Komiyama, Yutaka	Visiting Professor	Hosei University	April 1, 2024 – March 31, 2025	Subaru Telescope
Tsuchiya, Fuminori	Visiting Professor	Tohoku University	April 1, 2024 – March 31, 2025	Mizusawa VLBI Observatory
Shimoikura, Tomomi	Visiting Associate Professor	Otsuma Women's University	April 1, 2024 – March 31, 2025	Division of Science
Nakanishi, Hiroyuki	Visiting Associate Professor	Kagoshima University	June 13, 2024 – March 31, 2025	Mizusawa VLBI Observatory
Nishimura, Nobuya	Visiting Research Fellow	The University of Tokyo	April 1, 2024 – March 31, 2025	JASMINE Project
Inami, Hanae	Visiting Research Fellow	Hiroshima University	July 1, 2024 – March 31, 2025	Advanced Technology Center

Visiting Scholars (Foreign)

Not Applicable. Declined due to schedule conflicts.

JSPS (Japan Society for the Promotion of Science) Postdoctoral Research Fellows

Name	Research Subject	Acceptance Period	Host Researcher
Niwano, Masafumi	Study of Be X-ray binaries by simultaneous multi-wavelength observations with TESS	2025/1/1 – 2025/3/31	Furusawa, Hisanori
Yamasaki, Yasumasa	Development of a low frequency telescope system on the Lunar Surface to explore the Dark Ages	2024/4/1 – 2027/3/31	Iguchi, Satoru
Zhang, Yechi	Formation and Evolution of Supermassive Black Holes Probed by High-Redshift Active Galactic Nuclei	2023/10/1 – 2024/8/31	Ouchi, Masami
Mori, Kanji	Investigating Signatures of Axions from Core-collapse Supernova Events with Three-dimensional Simulations	2023/4/1 – 2026/3/31	Takiwaki, Tomoya
Kusakabe, Haruka	Kinematics and ionization state of the circumgalactic medium around extremely-metal poor galaxies investigated with wide-field integral field spectroscopy	2023/4/1 – 2025/3/31	Ouchi, Masami
Taniguchi, Daisuke	Metallicity distribution and formation history of nearby galaxies investigated using red supergiants	2023/4/1 – 2026/3/31	Ishigaki, Miho
Mori, Masamitsu	Calculation of black holes from supernovae for the multi-messenger astronomy	2023/4/1 – 2025/3/31	Takiwaki, Tomoya
Tei, Akiko	Exploring the nature of the solar chromosphere jets with high-resolution spectroscopic observations	2023/4/1 – 2026/3/31	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

JSPS (Japan Society for the Promotion of Science) Foreign Research Fellows

Name	Period	Host Researcher
Bajpai, Rishabh	2023/5/1 – 2024/10/31	Tomaru, Takayuki
Kuzma, Pete Bryson	2023/10/17 – 2025/10/16	Ishigaki, Miho
Chaudhuri, Arnab	2023/11/14 – 2025/11/13	Kohri, Kazunori
Fang, Qiliang	2024/4/1 – 2026/3/31	Moriya, Takashi
Martinez Rey, Noelia	2025/1/6 – 2025/3/5	Minowa, Yosuke

VII Graduate Education

1. Astronomical Science Program, Graduate Institute for Advanced Studies, 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. Since FY 2004 SOKENDAI had six schools: Cultural and Social Studies, Physical Sciences, High Energy Accelerator Science, Multidisciplinary Sciences, Life Science, and Advanced Sciences, 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 reorganized 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 has been reorganized into Astronomical Science Program.

(1) Astronomical Science Program

Astronomical Science Program 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 accepted annually:
Around 5 (for the five-year doctoral course)
Around 1 (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

Astronomical Science Program 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) Program Details

Optical and Near 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 program 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 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 an economical basis upon which they can develop into young researchers skilled in conducting research effectively, the program has set up the Associate Researcher program in addition to the Research Assistant system. In addition, the program 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 program.

In FY 2024 there were 10 NAOJ Junior Fellows, 18 Associate Researchers, and 5 Research Assistants.

To further improve the research environment for the students, the program 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 the SOKENDAI Summer Students Program, Spring School, and Asian Winter School to offer chances to experience research at the Astronomical Science Program. Admission Guidance also targets undergraduate students.

In FY 2024, a total of 25 students participated in the SOKENDAI Summer Students program, of which 23 students conducted research activities at Mitaka Campus and two at the Subaru Telescope in Hawai`i. The Asian Winter School, conducted online, received 249 applications, and of these 134 students from 21 countries and regions participated in the program. In addition, 41 students participated in the Spring School, which was held onsite in Mitaka Campus.

(7) Number of Affiliated Staff (2025/3/31)

Optical and Infrared Astronomy	
Professors	10
Associate Professors	11
Associate Professor (Senior Lecturer)	1
Assistant Professors	11
Radio Astronomy	
Professors	8
Associate Professors	12
Associate Professor (Senior Lecturer)	2
Assistant Professors	14
General Astronomy and Astrophysics	
Professors	12
Associate Professors	14
Associate Professors (Senior Lecturers)	2
Assistant Professors	17
Total	114

(8) Graduate Students (38 students)

Five-year doctoral program

1st year (7 students)

Name	Principal Supervisor	Supervisor	Title of research project
Kitade, Naoya	Kataoka, Akimasa	Nomura, Hideko/ Fujii, Yuka	Unveiling planet formation by ALMA polarization observations of protoplanetary disks
Kiyota, Tomokazu	Ouchi, Masami	Iono, daisuke	Exploring Early Galaxy Formation with JWST
Takeda, Yui	Ouchi, Masami	Ishigaki, Miho	Uncovering the Chemical Enrichment of the Early Universe with JWST
Chiba, Ryotaro	Moriya,Takashi	Tominaga, Nozomu	Interaction between supernovae and their surrounding environments
Hirose, Tadasshi	Narukage, Noriyuki	Shimojo, Masumi/ Sekii, Takashi	Observational study of energy release and propagation processes in the solar atmosphere
Budi Bakuh Danang Setyo	Aoki, Wako	Ishigaki, Miho	Spectroscopic study of stellar and chemical evolution
Matsuno, Nana	Machida, Mami	Tominaga, Nozomu/ Fujii, Yuka	Magnetohydrodynamics simulations about galaxy clusters

2nd year (4 students)

Name	Principal Supervisor	Supervisor	Title of research project
Imai, Seiya	Tanaka, Masayuki	Koyama, Yusei	Statistical properties of extreme emission line galaxies
Tan, Miho	Machida, Mami	Takiwaki, Tomoya	Clarifying the Collimation Mechanism of Astrophysical Jets
Hatami, Ryota	Tominaga, Nozomu	Takiwaki, Tomoya	Supernova nucleosynthesis
Watanabe, Kazuki	Oshima, Tai	Uzawa, Yoshinori/ Kojima, Takafumi	Development of a sub-THz MKID Camera for Deep Space Observation

3rd year (5 students)

Name	Principal Supervisor	Supervisor	Title of research project
Kakimoto, Takumi	Tanaka, Masayuki	Iono, daisuke	The formation mechanism of massive elliptical galaxies
Sato, Yoshiaki	Narukage, Noriyuki	Shimojo, Masumi/ Sekii, Takashi	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	Moriya,Takashi	Koyama, Yusei/ Nagai, Hiroshi	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

4th year (5 students)

Name	Principal Supervisor	Supervisor	Title of research project
Ikeda, Ryota	Iono, Daisuke	Tanaka, Masayuki/ Izumi, Takuma	Observational Studies of Distant Galaxies using ALMA
Ishigami, Shun	Hara, Hirohisa	Katsukawa, Yukio	Observational approach to reveal heating properties of coronal loops
Suzuki, Toya	Kohri, Kazunori	Tominaga, Nozomu/ Takiwaki, Tomoya	New Physics with Gravitational Waves from Black Hole Binaries
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 Physical and Chemical Structure of Planet-Forming Regions by ALMA Observations of Molecular Lines

5th year (12 students)

Name	Principal Supervisor	Supervisor	Title of research project
Ishihara, Kousuke	Saito, Masao	Nakamura, Fumitaka	Study of high-mass star formation process, focusing on hierarchical fragmentation
Ogami, Itsuki	Aoki, Wako	Furusawa, Hisanori	The Nature of the Stellar Halo and Substructures in the Local Group Galaxies Explored with Subaru Telescope
Kobayashi, Umi	Tanaka, Masayuki	Nakanishi, Koichiro	Influence of galaxy interactions and mergers on AGN activities
Sasaki, Shunsuke	Takiwaki, Tomoya	Machida, Mami	Turbulent-driven mechanism of core-collapse supernovae
Sato, Masato	Tominaga, Nozomu	Takiwaki, Tomoya	Supernova light curve and observation
Seo, Chanoul	Fujii, Yuka	Nomura, Hideko/ Ikoma, Masahiro	Modeling atmospheres of super-Earth/sub-Neptune-sized planets in contact with magma ocean
Tashima, Yuta	Machida, Mami	Nakamura, Fumitaka/ Takiwaki, Tomoya	Study of the galactic magnetic fields using MHD simulation and observational visualization
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
Naufal, Abdurrahman	Koyama, Yusei	Tanaka, Masayuki	Morphological Evolution of Galaxies across Cosmic Environment
Bhardwaj, Shubham	Tominaga, Nozomu	Iwasaki, Kazunari	Transient search using Subaru/HSC SSP data
Hosokawa, Ko	Kotani, Takayuki	Minowa, Yosuke/ Fujii, Yuka	Development of high-contrast and high-spectral resolution spectrometer for the Subaru Telescope and characterization of exoplanet atmospheres

Three-year doctoral program

1st year (4 students)

Name	Principal Supervisor	Supervisor	Title of research project
Azhari, Ainun Nahdhia	Aoki, Wako	Tominaga, Nozomu	Investigating the Origin and Chemical Evolution of R-Process Elements in The Universe
Sato, Kyosuke	Tanaka, Masayuki	Ishigaki, Miho	The formation mechanisms of local dwarf galaxies with Subaru/ HSC and PFS wide-field data
Duffy, Seamus Edward	Kotani, Takayuki	Hirano, Teruyuki/ Oya, Shin	Development of the PSF calibration method by using deep learning techniques
Teixeira Guimaraes, Gabriel	Nomura, Hideko	Kokubo, Eiichiro	Theoretical study of planetary dynamics

2nd year (1 students)

Name	Principal Supervisor	Supervisor	Title of research project
Ichimura, Ryota	Nomura, Hideko	Kataoka, Akimasa	Research on Chemical Evolution from Star- and Planet-Forming Regions to Planetary Systems by Chemical Reaction Network Calculations

2. Education and Research Collaboration with Graduate Schools

Name	Affiliated Institute	Supervisor	Title of Research Project
Ishida, Yuichiro	The University of Tokyo	Kokubo, Eiichiro	Theoretical study of planet formation
Kojima, Ryoya	The University of Tokyo	Okuda, Takeshi	Probing cold molecular gas near the super massive black hole in NGC 1275 using ALMA data
Sakamoto, Yuji	The University of Tokyo	Kano, Ryohei	Research and Development on the JASMINE instrument
Tanaka, Kensho	The University of Tokyo	Motohara, Kentaro	Development and Performance Evaluation of a NIR Array Detector System
Nakamura, Kenta	The University of Tokyo	Honma, Mareki	The study of super fast optical downlink for the realization of millimeter-wave space VLBI
Nishida, Akimasa	The University of Tokyo	Fukagawa, Misato	Observational Study on Exoplanet Formation
Fujii, Misato	The University of Tokyo	Motohara, Kentaro	Development of a NIR Imager/MOS spectrograph SWIMS
Ye, Yuheng	The University of Tokyo	Tomaru, Takayuki	Study of Detection Technologies for Gravitational Wave Telescopes
Oshida, Keisuke	The University of Tokyo	Ikoma, Masahiro	Research on formation and evolution of exoplanet atmospheres
Liu, Meizhi	The University of Tokyo	Nakamura, Fumitaka	Study of the internal structure of turbulent molecular clouds
Ma, Minghui	The University of Tokyo	Honma, Mareki	Research on M87 and Sgr A* based on VLBI
Otsuka, Munetake	The University of Tokyo	Tomaru, Takayuki	Research on Improving the Sensitivity of Gravitational Wave Telescopes in the kHz Band
Kitamura, Ryota	The University of Tokyo	Kokubo, Eiichiro	Theoretical study of planet formation
Sawamura, Mahoshi	The University of Tokyo	Okuda, Takeshi	Observational studies on high-z galaxies
Zhuang, Rui	The University of Tokyo	Fukagawa, Misato	Observational Study on Exoplanet Formation
Fujimori, Arisa	The University of Tokyo	Katsukawa, Yukio	Study of magentic structures in the solar polar regions
Masaoka, Hiroto	The University of Tokyo	Honma, Mareki	Probing the Origin and Mechanism of Fast Radio Burst (FRB) with Low-Frequency Expansion of Domestic Radio Telescopes
Yukino, Tomoya	The University of Tokyo	Motohara, Kentaro	Development of a NIR spectrograph NINJA and observational study of nearby LIRGs
Yoshino, Aoto	The University of Tokyo	Nakamura, Fumitaka	Formation of streamers by dense core collisions
Li, Xinru	The University of Tokyo	Hatsukade, Bunyo	Extraction of peculiar velocity structures in molecular clouds using machine learning
Matsumura, Akifumi	The University of Tokyo	Ikoma, Masahiro	Research on atmospheric formation and interior differentiation for rocky planets
Ozawa, Yoshiki	The University of Tokyo	Fukagawa, Misato	Observational Study on Exoplanet Formation
Cha, Chaenae	The University of Tokyo	Motohara, Kentaro	Observational Study of Molecular Gas Properties and Morphology of Nearby LIRGs
Oki, Aika	The University of Tokyo	Honma, Mareki	Measuring potential heat content of galaxy clusters and devising a galaxy cluster evolution map based on observations of AGN using VLBI
Kambara, Yuki	The University of Tokyo	Kokubo, Eiichiro	Theoretical study of planet formation
Nakajima, Takeru	The University of Tokyo	Fukagawa, Misato	Development of instruments for exoplanet observations
Narita, Kanako	The University of Tokyo	Hatsukade, Bunyo	Evolution of CO and [CII] luminosity functions explored by unbiased search and intensity mapping of millimeter-wave line emitters
Mitsuhashi, Kohei	The University of Tokyo	Tomaru, Takayuki	The calibration of gravitational wave telescopes using gravity field and photon pressure
Fariyanto, Elika Prameswari	The University of Tokyo	Honma, Mareki	The Jet Collimation Profile Analysis and Core-Shift Measurement of M84
Yun, Jeung	The University of Tokyo	Motohara, Kentaro	Spectroscopic Study of H-alpha Emitters at z~2 and development of SWIMS
Moritsuka, Akie	The University of Tokyo	Katsukawa, Yukio	Study of magneto-convection on the solar surface with spectro-polarimetric observations
Nishino, Yohei	The University of Tokyo	Tomaru, Takayuki	Development of quantum-noise reduction technique for gravitational-wave detectors
Hafieduddin, Mohammad	The University of Tokyo	Honma, Mareki	Observational Studies of High Mass Star Formation in G354.61+0.47 using VLBI
Kofuji, Yutaro	The University of Tokyo	Honma, Mareki	Time Variations of Supermassive Black Holes Probed by cm and 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	Revealing the inflow of gas around cores in the early stages of high-mass star formation
Liang, Zhuoxi	The University of Tokyo	Doi, Mamoru	Properties of supernova host galaxies
Zhang, Tianfang	The University of Tokyo	Doi, Mamoru	A study on the correlation between Photon Indices and Accretion Disk Dominance in FSRQ Blazers

3. Commissioned Graduate Students

Doctoral Course	Affiliated Institute	Period	Supervisor	Title of Research Project
Inoue, Shuhei	The University of Tokyo	2024/4/1 – 2025/3/31	Uzawa, Yoshinori	Development of an ultra-wideband and easy-to-array planar Magic-T for millimeter-submillimeter continuum imaging
Kameyama, Akira	Osaka Metropolitan University	2024/4/1 – 2025/3/31	Honma, Mareki	Development of low noise and wideband receiver for VERA
Okada, Hiroko	University of Hyogo	2024/4/1 – 2025/3/31	Tominaga, Nozomu	Study of metal-poor stars
Kagetani, Taiki	The University of Tokyo	2024/4/1 – 2025/3/31	Ikoma, Masahiro	Research on the structure of the atmosphere and interior of gas giant planets
Koseki, Tomohiro	University of Tsukuba	2024/4/1 – 2025/3/31	Matsuo, Hiroshi	Realizing Synthesis Imaging Using Intensity Interferometry
Katsuki, Riku	The University of Electro-Communications	2024/4/1 – 2025/3/31	Tomaru, Takayuki	Real-time imaging of cell traction force with 3D birefringence measurement
Watanabe, Yumi	Fukushima University	2024/4/1 – 2025/3/31	Nakanishi, Koichiro	Dense molecular gas studies in the nearby Seyfert galaxy NGC 1068 using HCN/CO line ratio
Niwa, Ayako	University of Tsukuba	2024/4/1 – 2025/3/31	Matsuo, Hiroshi	Development of 1.5 THz photon counting detectors for Antarctic Terahertz Intensity Interferometry
Miyato, Ken	The University of Electro-Communications	2024/4/1 – 2025/3/31	Nishimura, Atsushi	Study on distribution of molecular clouds in the Galaxy
Takiguchi, Futa	University of Tsukuba	2025/1/1 – 2025/9/30	Kojima, Takafumi	Development of a 500-GHz receiver for the 30-cm Antarctic Telescope

Master's Course	Affiliated Institute	Period	Supervisor	Title of Research Project
Ichikawa, Ryota	Ibaraki University	2024/4/1 – 2025/3/31	Katsukawa, Yukio	Multi-height analysis of Ellerman bomb based on the multi-line spectroscopy
Okami, Junpei	Shizuoka University	2024/4/1 – 2024/9/30	Kojima, Takafumi	Study on microwave cryogenic low-noise amplifier with ultra-low-power consumption
Kondo, Shoki	Osaka Metropolitan University	2024/4/1 – 2024/9/30	Honma, Mareki	86 GHz band observation using VERA telescope
Sato, Riku	Waseda University	2024/4/1 – 2025/3/31	Motohara, Kentaro	Development of a NIR spectrograph for Subaru Telescope
Nagashima, Yuzuki	Fukushima University	2024/4/1 – 2024/9/30	Iono, Daisuke	Star Formation Rate Distirbution Map of the Nearby Spiral Galaxy NGC 1068 and Related Studies
Nishikawa, Yuma	Osaka Metropolitan University	2024/4/1 – 2024/9/30	Kojima, Takafumi	Development of wideband optics for radio telescope
Kawamura, Kenzo	The University of Electro-Communications	2024/5/1 – 2025/3/31	Honma, Mareki	Observational studies of a super-luminal jet of radio-loud AGN 3C111
Takahashi, Mihiro	Hosei University	2024/10/1 – 2025/9/30	Motohara, Kentaro	Research and development of a CMOS camera for test observations in Arizona
Yamazaki, Go	University of Tsukuba	2025/1/1 – 2025/12/31	Kojima, Takafumi	Development of a 500-GHz receiver for the 30-cm Antarctic Telescope
Hayashi, Urumi	Kagoshima University	2025/2/1 – 2026/1/31	Kotani, Takayuki	Installation and evaluation of the detector for the Near-Infrared spectrometer SAND

4. Degrees Achieved with NAOJ Facilities

Name	Degree	Title of Research Project
Doi, Kiyoaki	Doctor of Philosophy, SOKENDAI	Constraining Physical Properties of Protoplanetary Disks from Spatial Distributions of Dust Millimeter Continuum Observations
Fukagawa, Nao	Doctor of Philosophy, SOKENDAI	Chemical Evolution of Dwarf Galaxies
Sasaki, Shunsuke	Doctor of Philosophy, SOKENDAI	Phenomenological Turbulent Modeling of Core-Collapse Supernovae
Tada, Shotaro	Doctor of Philosophy, SOKENDAI	Probing Inhomogeneity in an Exoplanet Atmosphere through Chromatic Transit Variation
Ogami, Itsuki	Doctor of Philosophy, SOKENDAI	The Nature of the Stellar Halo in the Andromeda Galaxy Explored with the Subaru/HSC
Sato, Masato	Doctor of Philosophy, SOKENDAI	Theoretical and Observational Investigations of Electron-capture Supernova Light Curves
Hosokawa, Ko	Doctor of Philosophy, SOKENDAI	Experimental Study of Hot CH_4 Spectral Line Broadening in H_2 and He Environment for the Atmospheres of Substellar Objects

VIII Public Access to Facilities

1. Mitaka Campus

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 (6 days in total): October 19 (for Mitaka Open House Day, open to participants only), November 9 (due to equipment inspection), and August 16, August 30–September 1 (due to storm warnings).
Visitors: 23,549 (of which 2,943 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
The Exhibit Room and Astronomical Instruments Museum reopened on May 8, and the Theater Room reponed on August 26.

[Regular Star Gazing Party]
Dates: Friday before second Saturday, fourth Saturday (held either on-site or online based on the objects to be observed)

(Online): Held 8 times
Maximum number of simultaneous connections: 860
Total Views: 7,162 (As of March 31, 2025)

(On-site): Held 14 times
Total Visitors: 1,129 guests

Online events were broadcasted via Zoom to YouTube Live.

[4D2U Theater Showings]
Dates: Friday before second Saturday; first and third Saturdays
Capacity: 120 people per day
Visitors: 4,893 (28 events held including special group tours, closed August-September for equipment renovation.)

[Special Open-House Event] Mitaka Open House Day
Dates: October 19 (Saturday), 2024, 10:00–19:00
Topic: Exploring the Formation and Evolution of Galaxies
Onsite Attendees: 3,183
NAOJ Main Lectures: 2, Onsite Attendees: 208
Total YouTube Maximum Simultaneous Connections: 336
Total Views on YouTube: 13,647 (in the first 3 weeks)
Total Views on niconico Live: 6,006

This event is jointly sponsored by NAOJ, the University of Tokyo Graduate School of Science Institute of Astronomy; Astronomical Science Program at the Graduate Institute for Advanced Studies; and the NINS Astrobiology Center. In FY 2023, taking preventative measures against the COVID-19 pandemic into consideration, the event was held with a limited capacity, but from this year the event was held on-site without restrictions. The main lectures were held onsite and also broadcast through niconico Live streaming.

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 is a national holiday, the facility is closed on the following Tuesday/Wednesday)
Stargazing Sessions: Evenings on Saturdays, Sundays, and Holidays, (20:00–21:00), one 45-minute session per evening
Space Theater: 15:30–16:15, from Wednesdays to Sundays and on Holidays
Visitors: 6,569
Open Facilities: Murikabushi 105-cm optical/infrared telescope, Hoshizora Manabi no Heya (Starry Sky Study Room) (featuring exhibits of astronomical images, screenings of celestial body videos and 4D2U "four-dimensional digital universe," and stargazing sessions with the 40-cm telescope), interior of observation dome, and corridors (including exhibits of astronomical images)

[Special Open Day]
[Southern Island Star Festival 2024] (co-sponsored)
Dates: August 3 (Saturday) – 12 (Monday), 2024
Cool Evening Live Performance & Stargazing Party:
Held on August 10 (Saturday) at Painuhama-machi Green Park with 3,000 onsite guests in attendance
Star Festival Lecture: Held on August 11 (Sunday) at Ishigaki City Hall with 80 visitors
Total for Star Festival Week: August 3 (Saturday) – 12 (Monday), Ishigakijima Astronomical Observatory, Total Guests: 545

2. Mizusawa Campus

Mizusawa Campus
[Open year-round]
Dates: April to March (except for New Year's season), 9:00–17:00 daily
Visitors: 12,679
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.

[Special Open Day] Held as Part of Iwate Galaxy Festival 2024
Dates: August 12 (Saturday), 2024
Visitors: 1,154
We consulted with Oshu City and the Oshu Space and Astronomy Museum (OSAM: Yugakukan), and this year, the event was held in the fall to avoid the summer heat.

Iriki: VERA Iriki Station
[Open year-round]
Dates: April to March (except for New Year's season)
Visitors: 924

[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, due to a change in the implementation format, the event was not held again as last year.

Ogasawara: VERA Ogasawara Station
[Open year-round]
Dates: April to March (except for New Year's season)
Visitors: 6,430

[Special Open Day]
The decision was made to cancel the special open house in January and February, when the vessels' sailing schedule for Saturdays and Sundays was discontinued and after the possibility of holding the open house in other months was explored, but no researchers were found who could handle it.
As an alternative, a "Space Lecture Meeting" was held.

Ishigaki Island: VERA Ishigaki-jima Station
[Open year-round]
Dates: April to March (Excluding weekends, holidays, year-end/New Year holidays, and irregular closures)
Visits are permitted from 9:00 AM to 5:00 PM for free viewing of the antenna from outside the fence.
The observation building is not open to visitors.
Visitors: 2,452

[Special Open day] The Special Open Day was held as a part of the Southern Island Star Festival.
Dates: August 11 (Sunday), 2024
Visitors: 277

3. Nobeyama Campus

Nobeyama Campus

[Open year-round]

Open Time: 8:30–17:00 (every day except around New Year’s Day, December 29 to January 3)

Visitors: 47,316

Open Facilities: 45-m Radio Telescope, Nobeyama Millimeter Array, Nobeyama Radioheliograph, etc. (just viewing)

[Open House Day]

(Online)

Date: July 20 (Saturday), 2024, 10:00–16:00 (available for video access after the day)

Participants:

Public lectures:

- ~229 (maximum viewers for live streaming)
- ~16,000 (total number of views as of 2025/5/26)

Virtual space (poster session): 122

(On-site)

Date: August 24 (Saturday), 2024, 9:30–16:00

Participants: 1,185

Nobeyama Open Campus Day 2024 was held onsite and online. Three observatory users gave public online lectures regarding their research topics, including Professor Tomoharu Oka (Keio University) and Assistant Professor Hiroaki Yamamoto (Nagoya University). We also held a poster session using a virtual space where 10 posters introducing individual research and 21 posters introducing laboratories were presented. For on-site open-day, several events were conducted such as 45-m antenna-touch, DIY paper-fan-antenna by observatory OBs, exhibition booths by ALMA Project/Solar Science Observatory/ Spectrum Management Office/Osaka Metropolitan University, and public lectures by observatory users (six talks and nine posters were presented).

4. Subaru Telescope

Subaru Telescope

[Summit Facility Tours in Hawai‘i]

The public tour program has officially ended due to various circumstances.

Special tours: 39 groups, 131 visitors

[Base Facility Tours in Hawai‘i]

Special tours visitors: 24 groups, 514 visitors

* This number includes 4 school field trips and 1 teacher training workshop from local schools (total 5 groups, 389 visitors), visits by Japanese high school groups (6 groups, 67 visitors), and a visit by a Japanese high school teacher group through the MEXT Tobitate! (Leap for Tomorrow) Study Abroad Initiative program (1 group, 5 visitors).

[Special Open House Day at the Base Facility]

Tanabata Block Party

Joint open house for the Maunakea Observatories’ base facilities in Hilo, Hawai‘i hosted by the Maunakea Astronomy Outreach Committee (MKAOC)

Date: August 17, 2024 (in Hawai‘i)

About 300 visitors to the Subaru Telescope Base Facility

[Headquarters Tours by Subaru Telescope in Mitaka]

Special tours visitors: 4 groups, 190 visitors

* This number includes visitors who attended the Subaru Telescope Virtual Tours and the Remote Observation Room Tours at the Mitaka Open House Day (counted as 1 group, 130 visitors)

Please see the “04. Subaru Telescope” section in the “II Status Reports of Research Activities” chapter for more details of public information and outreach activities in Hawai‘i and Mitaka by the Subaru Telescope Project.

IX Overseas Travel

Research and Academic Staff Overseas Travel
(Including employees on annual salary system.)

category / country/area	Business Trip	Training	Total
Republic of Korea	32	0	32
China	11	0	11
Thailand	4	0	4
Taiwan	17	0	17
Hong Kong	1	0	1
Singapore	0	0	0
Indonesia	6	0	6
Philippines	0	0	0
Other areas in Asia	11	0	11
Hawai`i	29	0	29
U.S.A.	65	0	65
Australia	17	0	17
Italy	21	0	21
U.K.	5	0	5
France	19	0	19
Canada	1	0	1
Guam, Saipan	0	0	0
Germany	26	0	26
Other areas in Europe and Oceania	41	0	41
Mexico	3	0	3
Brazil	1	0	1
Africa	17	0	17
Other areas in South and Central America *	46	0	46
Total	373	0	373

* In typical years, most travelers to South and Central America go to Chile.

X Award Winners

Award Recipients	Affiliated Division	Job Title	Award	Date
Iguchi, Satoru	ALMA Project	Professor	The University of Electro-Communications Alumni Award for 2024	2024/4/4
Kikuchi, Shota	RISE Project	Assistant Professor	NAOJ Young Researchers Award, FY 2024	2024/6/26
Nakajima, Kimihiko	Division of Science	Project Assistant Professor	The 13th NINS Young Researcher's Award	2024/7/24
Mizuno, Norikazu	ALMA Project	Professor	The Foreign Minister's Commendation, FY 2024	2024/8/8
Yoneta, Kenta	Advanced Technology Center	Project Researcher	Visible Infrared Observatory Technology Workshop 2024, Young Presenter Award, Silver Prize	2024/11/26
Akutsu, Tomotada	Gravitational Wave Science Project	Assistant Professor	Highlighted as an Editor's Pick	2025/3/13

XI Library, Publications

1. Library

Number of books in each library (2025/3/31)

	Japanese Books	Foreign Books	Total
Mitaka	19,389	50,451	69,840
Nobeyama	1,128	5,891	7,019
Mizusawa	4,986	18,113	23,099
Hawai‘i	1,699	4,683	6,382
Total	27,202	79,138	106,340

Number of journal titles in each library (2025/3/31)

	Japanese Journals	Foreign Journals	Total
Mitaka	404	1,737	2,141
Nobeyama	16	82	98
Mizusawa	659	828	1,487
Hawai‘i	15	9	24
Total	1,094	2,656	3,750

2. Publications

Here we list continuing publications produced by NAOJ in FY 2024.

(Mitaka)
01) Annual Report of the National Astronomical Observatory of Japan (Japanese), no. 36, Fiscal Year 2023: 1 issue
02) Annual Report of the National Astronomical Observatory of Japan (English), vol. 26, Fiscal Year 2023: 1 issue
03) Calendar and Ephemeris, 2025: 1 issue
04) NAOJ News, No. 343–345: 3 issues
05) NAOJ Pamphlet 2024 (Japanese): 1 issue
06) NAOJ Pamphlet 2024 (English): 1 issue
07) Rika Nenpyo (Chronological Scientific Tables), 2025: 1 issue

3. Publication Support

In FY 2024, the NAOJ Reprints were replaced by publication support.
National Astronomical Observatory publication support, No. 3744–3778: 35 issues.

XII Important Dates

2024

2024/4/2	Fifth graders from Hilo Union School visited the Subaru Telescope Hilo Base Facility for an immersive field trip.
2024/4/3 ~ 2024/4/6	Subaru Telescope live streamed from Maunakea, Hawai‘i, for 3 consecutive nights, commemorating the 3rd anniversary of the Subaru-Asahi StarCam and the 25th anniversary of the Subaru Telescope with the cooperation of The Asahi Shimbun Company.
2024/4/6	Subaru Telescope and TMT Project participated in Merrie Monarch Parade held in Hilo, Hawai‘i, as Maunakea Observatories members.
2024/4/16, 23, 30	As a part of the Subaru Stars program, Subaru Telescope invited grades 2–5 students from Kea‘au Elementary School to the Hilo Base Facility for an immersive field trip.
2024/4/24 ~ 2024/4/26	TMT Project set up the NAOJ booth at OPIE SPACE & ASTRONOMICAL OPTICS EXPO 2024 held at Pacifico Yokohama and showcased TMT, Division of Science, Industry Liaison Office, and OISTER.
2024/4/29 ~ 2024/4/30	Director General Doi made courtesy visits to Ministry of Foreign Affairs and others in Chile.
2024/5/2	Takako Ito, Ambassador of Japan to Chile, visited the operation site facilities and the observatory close to San Pedro de Atacama in Chile.
2024/5/4	United Nations Secretary-General António Guterres visited the ALMA telescope site in the Atacama Desert, Chile.
2024/5/4	Subaru Telescope, its internal citizen science project PANOPTES, and TMT Project participated in the annual AstroDay event, in Hilo, Hawai‘i, and provided fun science activities at their booths to the local community.
2024/5/21	A special exhibition, “After the War, Back to the Central Bureau of International Projects” was held at the Kimura Hisashi Memorial Museum until around the fall term.
2024/5/26 ~ 2024/5/31	TMT Project set up the NAOJ booth at the hybrid Japan Geoscience Union (JpGU) Meeting 2024 at Makuhari Messe and online, and showcased TMT and ALMA.
2024/6/3 ~ 2024/6/4	Dignitaries from the National Astronomical Research Institute of Thailand (NARIT) visited the Subaru Telescope summit facility and the Hilo Base Facility, and discussed with the Subaru Telescope directorate.
2024/6/10	Decision to hold the Churaboshi Research Team Workshop, abbreviated as “Churaken,” for short, on Ishigaki Island (August 7 (Wednesday) to August 9 (Friday), 2024).
2024/6/12	Minister of Education, Culture, Sports, Science and Technology Masahito Moriyama visited Mitaka Campus.
2024/6/18 ~ 2024/6/20	The first SPIE Astronomical Telescopes + Instrumentation in Asia was held at Pacifico Yokohama, and Satoshi Miyazaki, Director of Subaru Telescope, co-chaired the symposium. The NAOJ booth showcased the Subaru Telescope, TMT, ALMA, ATC, and Solar Science Observatory.
2024/6/24 ~ 2024/6/28	OAO (IAU Office for Astronomical Outreach) organized CAP Conference (Cite de l’espace, Toulouse).
2024/7/5 ~ 2024/8/25	Subaru Telescope provided a special exhibition commemorating its 25th anniversary, including additional workshops and gallery talks, at the Information Space of Astronomy and Science in Mitaka City.
2024/7/20	Subaru Telescope scientists gave a talk at an Astronomy Pub entitled “25 Years of the Subaru Telescope - The Birth of the Milky Way Galaxy Explored by Cosmic Fossil Stars” held at Mitaka Network University.
2024/7/20	Open House Day of Nobeyama Radio Observatory was held on-line.
2024/7/22 ~ 2024/7/26	EA ALMA Science workshop and data analysis workshop was held at Seoul National University, Seoul, Korea.
2024/7/28	Subaru Telescope scientists gave a talk at the public lecture series “Mysteries of the Universe Revealed by the Latest Astronomy” at J:COM Horuto Hall OITA.
2024/7/29	45-m telescope painting event was held under the joint organization of Nobeyama Radio Observatory and 45 Supporters Club (voluntary group).
2024/8/1	Professor Norikazu Mizuno received the 2024 Foreign Minister’s Commendation. The award presentation ceremony was held on October 25 at the official residence of the Japanese Ambassador in Chile.
2024/8/1 ~ 2024/10/31	Subaru Telescope supervised two graduate students at the Hilo Base Facility as part of the OISTER (Optical and Infrared Synergetic Telescopes for Education and Research) short-term residency training program.
2023/8/2	Four Undergraduate interns of the Akamai Workforce Initiative program, supervised by Subaru Telescope mentors, presented at the Akamai Internship Symposium held at University of Hawai‘i at Hilo.
2024/8/3 ~ 2024/8/5	OAO Organized ASTRO ACCEL Summit (Cape Town, South Africa).
2024/8/3 ~ 2024/8/12	The “Southern Island Star Festival” was held for the 23st time this year, featuring evening live performances & star lectures/viewing sessions, commemorative lectures, and a special opening of the VERA Ishigakijima Station.
2024/8/6 ~ 2024/8/15	The Office of International Relations, in collaboration with relevant departments within NAOJ, hosted an NAOJ booth primarily featuring “Subaru Telescope 2.0” at the General Assembly of the International Astronomical Union (IAU GA 2024) held in Cape Town, South Africa. Additionally, OAO Office hosted an OAO booth within IAU exhibition booth.
2024/8/7 ~ 2024/8/9	“Churahoshi Investigation Team Workshop” was held in Ishigaki Island.

2024/8/17	Subaru Telescope co-hosted the Tanabata Block Party 2024, a joint openhouse event of base facilities, with the Maunakea Observatories, and celebrated its 25th anniversary with the local community.
2024/8/21	Announcement that Iwate Galaxy Festival 2024 will be held in autumn (Saturday, October 12) to avoid the summer heat.
2024/8/24	Open House Day of Nobeyama Radio Observatory was held on-site.
2024/8/30	Undergraduate students of the SOKENDAI Summer Student program gave hybrid (in-person and online) presentations about their study results.
2024/8/30 ~ 2024/10/13	Information Space of Astronomy and Science "100 Years of Mitaka and the Observatory Walking Together" exhibit held.
2024/9/1	Commemoration ceremony and commemorative lecture held at Mitaka City Public Hall in celebration of the 100th anniversary since NAOJ (formerly Tokyo Astronomical Observatory) relocated to Mitaka.
2024/9/20	World-wide online APRSAF-30 stargazing party.
2024/9/21 ~ 2025/1/18	Subaru Telescope staff members contributed to a series of VEX robotics competitions as judges for elementary, intermediate, and high school teams.
2024/9/30	Kaho Morii, a third-year doctoral student in the University of Tokyo Department of Astronomy, received the L'Oréal-UNESCO For Women in Science Japan Fellowship Award for her research using ALMA.
2024/10/2	The 29th "Astronomy Lecture for Science Journalists" was held on the theme of "Technological Development in NAOJ and Collaboration with Industry 2."
2024/10/8 ~ 2024/10/9	ALMA Development workshop was held at Mitaka Campus and online.
2024/10/11 ~ 2024/10/21	Subaru Telescope live streamed Comet Tsuchinshan-ATLAS from Maunakea, Hawai'i, by temporarily installing a camera aimed at the western sky, with the cooperation of The Asahi Shimbun Company.
2024/10/12	The "Iwate Galaxy Festival 2024," announced on August 21, was held.
2024/10/15	In connection with the Iwate Galaxy Festival 2024, a special exhibition, "The Annals of Observatories," was held at the Kimura Hisashi Memorial Museum until mid-November.
2024/10/15	Held livestream of Comet Tsuchinshan-ATLAS.
2024/10/18	In collaboration with the Japan Planetarium Society (JPA), Subaru Telescope co-hosted the 100 Years of the Planetarium × 25 Years of the Subaru Telescope Online Event that connected Hilo Base Facility and 25 planetaria and science facilities in Japan (on October 19 in Japan).
2024/10/19	Mitaka Open House Day held. Some events such as main lectures were also provided online.
2024/10/24	OAO hosted International Webinar on Cultural Astronomy.
2024/10/30 ~ 2024/11/3	Commemorative display, "From Mitaka to Outer Space, 100 Years of Mitaka and the Observatory Walking Together," held at the Mitaka City Arts Center. Subaru Telescope provided images captured by the telescope for the exhibition.
2024/11/2	The 9th "Nagano Prefecture is Astro-Prefecture" meeting was held by "Nagano Prefecture is Astro-Prefecture" liaison council, which consists of Nobeyama Radio Observatory, Kiso Observatory of the University of Tokyo, and so on.
2024/11/2	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, Hawai'i, and provided fun science activities at their booths to the local community.
2024/11/2 ~ 2025/2/1	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 led of the contest.
2024/11/3	"Astronomy × Modern Art: 100 years of the Universe as observed by mankind. The ongoing story of the Universe woven by eyes and voices" event held in celebration of the 100th anniversary since the relocation.
2024/11/6	Announcement that the special exhibition "Christmas & New Year Cards from Around the World" would be held at the Kimura Hisashi Memorial Museum from mid to late January 2025.
2024/11/8 ~ 2025/11/13	Graduate students from the Graduate University for Advanced Studies (SOKENDAI) participated in an observational training class using the Subaru Telescope.
2024/11/11 ~ 2024/11/13	ALMA Workshop "AGN Feeding and Feedback in Massive Galaxies at the Centers of Galaxy Clusters," Kagoshima University, Japan.
2024/11/12 ~ 2024/11/15	OAO hosted Shaw-IAU Workshop on Astronomy for Education poster programs with IAU OAE (Office for Astronomy Education) office.
2024/11/16	The first Japanese session of Shadow the Scientist (StS) was held with the Subaru Telescope, enabaling participants to experience remote observations with scientists.
2024/11/18 ~ 2024/11/26	Director General Doi made courtesy visits to Ministry of Foreign Affairs and others in Chile.
2024/11/24 ~ 2025/3/2	In collaboration with the Japan Planetarium Society (JPA), Subaru Telescope co-hosted a lecture series by Subaru scientists at 10 planetaria and science museums across Japan.
2024/11/25	ALMA Workshop "Exploring Hierarchical Interstellar Matter with High-Spatial Dynamic Range and Multi-Line Observations" online.
2024/12/2	Held a press conference "Supercomputer 'ATERUI III' Opens New Era of Simulation Astronomy."
2024/12/8	Held livestream of the occultation of Saturn.
2024/12/18 ~ 2024/12/20	ALMA/45m/ASTE Users Meeting 2024 was held at Mitaka Campus and online.

2024/12/23 ~ 2024/12/24	Subaru Telescope participated in the annual Garden Enchantment at Lili'uokalani Gardens as a member of Maunakea Observatories.
2024/12/27	ASTE Science and Development Workshop 2024 was held at Mitaka Campus and online.

2025

2025/1/9	The second 24/7 live camera, CFHT-Asahi StarCam on Maunakea, operated by the Canada-France-Hawaii Telescope and The Asahi Shimbun in collaboration with Subaru Telescope, started live streaming.
2025/1/10	Subaru Telescope and the Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU) jointly held a press conference at Hitotsubashi Hall in Tokyo, regarding the Prime Focus Spectrograph (PFS) mounted on the Subaru Telescope.
2025/1/12 ~ 2025/1/16	AAS 245: IAU, OAO initiated Astronomy for Mental Health discussion.
2025/1/20	Parliamentary Vice-Minister of Education, Culture, Sports, Science and Technology Ken Akamatsu visited Mitaka Campus.
2025/1/23	Minister of Education, Culture, Sports, Science and Technology Toshiko Abe visited Mitaka Campus.
2025/1/24	The 30th "Astronomy Lecture for Science Journalists" was held on the theme of "The Universe Depicted by Supercomputers? from ATEURI II to ATERUI III."
2025/1/28 ~ 2025/1/30	The annual Subaru Users Meeting FY 2024 was held in a hybrid style of on-site and online.
2025/2/3 ~ 2025/2/7	Subaru Telescope and TMT Project staff members participated in the annual educational program Journey Through the Universe and delivered interactive presentations at classrooms of public elementary, intermediate, and high schools in Hilo, Hawai'i.
2025/2/5	Takafumi Tsukui at the Australian National University received Inoue Research Award for Young Scientists for his research using ALMA.
2025/2/13	Announcement that a lecture will be held on Sunday, March 2 on Chichijima Island in Ogasawara Village, where the VERA Ogasawara Station is located.
2025/2/13 ~ 2025/2/15	In collaboration with other institutes, exhibited a booth at the American Association for the Advancement of Science Annual Meeting (AAAS2025).
2025/2/20	The Subaru Telescope successfully captured images of asteroid 2024 YR_4, which will pass close to the Earth in 2032.
2025/2/22	The Subaru Telescope was showcased at the 39th NINS Symposium at the NAOJ booth.
2025/2/27 ~ 2025/2/28	As part of the FY 2024 NAOJ project evaluation, an international external evaluation of the CfCA Project was conducted at Mitaka Campus.
2025/3/2	The lecture announced on February 13 was given.
2025/3/3	Takako Ito, Ambassador of Japan to Chile, visited NAOJ Mitaka Campus.
2025/3/3 ~ 2025/3/4	ALMA Workshop "Exploring Hierarchical Interstellar Matter with High-Spatial Dynamic Range and Multi-Line Observations" was held in Nagoya University and online.
2025/3/11 ~ 2025/3/13	ISC (International Science Council) Women in Science Forum 2025 panel discussion, Women and Girls in Astronomy panel discussion: IAU OAO.
2025/3/13	Subaru Telescope live streamed the total lunar eclipse from Maunakea.
2025/3/17	The main building of the Temporary Latitude Observatory (Kimura Hisashi Memorial Museum) and 200 MHz Solar Radio Telescope were recognized as Japanese Astronomical Heritage in 2024 (the 7th listing).
2025/3/21	Cycle 12 proposal preparation meeting was held at Mitaka Campus and online.
2025/3/21	Origami Workshop was held at Joint ALMA Observatory Santiago Central Office for Open Day.
2025/3/22	Open use of the Subaru Telescope's Prime Focus Spectrograph (PFS) started.
2025/3/23 ~ 2025/3/28	African Astronomical Society Meeting: IAU OAO.
2025/3/26 ~ 2025/3/27	ALMA Workshop "Multi-scale Perspectives in Galaxy Evolution, 2025/3/26–27" was held in Osaka Electro-Communication University and online.
2025/3/28	The "25 Years of Cosmic Discovery with the Subaru Telescope" image collection, commemorating the Subaru Telescope's 25th anniversary, was published in collaboration with Crevis.

Throughout the year

Subaru Telescope provides 24/7 live streaming from Maunakea, Hawai'i with the Subaru-Asahi StarCam in collaboration with The Asahi Shimbun Company.
OAO streamed "Women in Solar Physics talks": once per month, public.
OAO streamed "STEAM Machines talks": once per month, NOCs with online access following.
OAO streamed "Pathways to the Cosmos": about once per month, public.

XIII Publications, Presentations

1. Refereed Publications

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