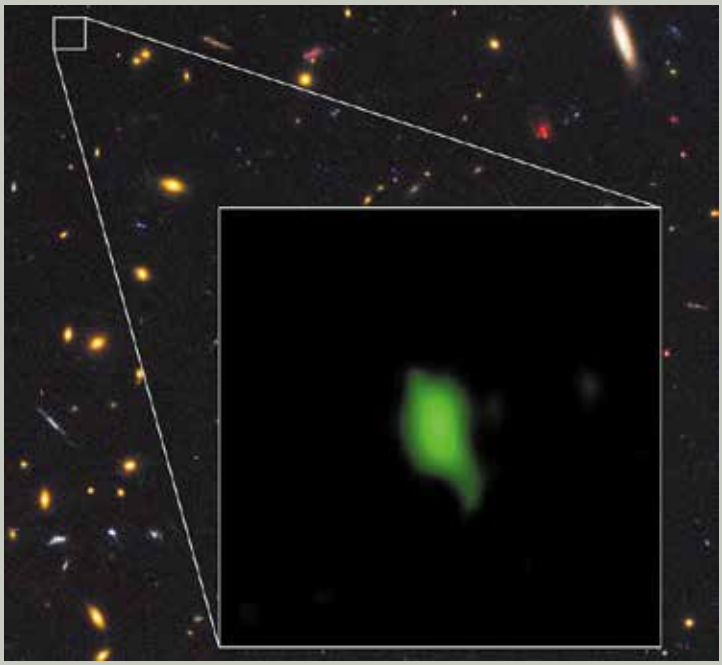
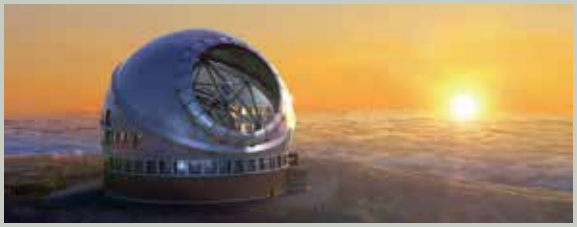
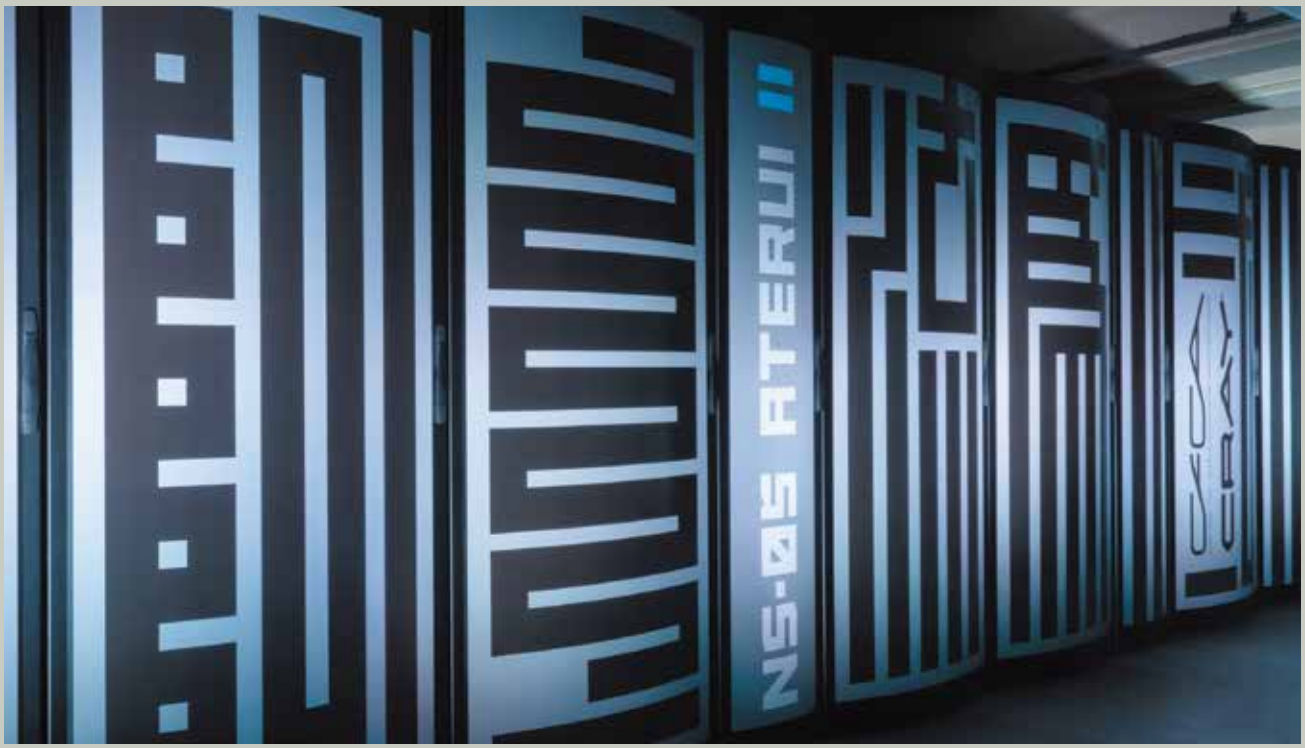
Inter-University Research Institute Corporation
National Institutes of Natural Sciences

National Astronomical Observatory of Japan







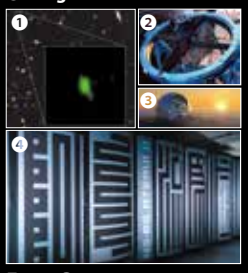
https://www.nao.ac.jp/en/

NAOJ

2018

contents

●Images from the NAOJ various observations and facilities.



Front Cover

1/ Oxygen distribution detected by ALMA in MACS1149-JD1, a galaxy 13.28 billion light-years away. (Green image, Background image from Hubble Space Telescope) [Image Credit: ALMA (ESO/NAOJ/NRAO), NASA/ESA Hubble Space Telescope, W. Zheng (JHU), M. Postman (STScI), the CLASH Team, Hashimoto et al.] ***2/*** Hyper Suprime-Cam (HSC) on the Subaru Telescope. ***3/*** Conceptual image of TMT when completed. ***4/*** Massively parallel supercomputer Cray XC50 "ATERUI II."

Back Cover

5 /Near infrared image of the star-forming region S 106 which is at a distance of approximately 2000 light-years from the Earth. A massive star called Infrared Source 4 (IRS 4) exists at the center of S 106. The hourglass appearance of S 106 is thought to be the result of the way material flows outwards from the central star. A huge disk of gas and dust surrounding IRS 4 produces the constriction at the center (Subaru Telescope).

Copyright 2018

Photo of NAOJ landscape : Yutaka Iishima

Illustration : Kouji Kanba • Four-Dimensional Digital Universe Viewer "Mitaka"

Design : Tamayo Arai

I wandered into the leafy, green grounds of the observatory ...

What is that star?

Director General　Dr. TSUNETA, Saku

Mitaka Campus, Astronomical Instrument Museum (former Photoelectric Meridian Circle) visible in background.

What is that Star?

Humans have been asking the same question since time immemorial. Now, we can see into the farthest reaches of the vast Universe.

The National Astronomical Observatory of Japan (NAOJ) has been searching for the answer to that question in the night sky. Over the past 20 years NAOJ has grown extensively, producing remarkable results in world astronomy. In particular, the very large role NAOJ has played in the ALMA Project, constructed and operated through international collaboration, is a milestone in the development of science in Japan.

To make the best use of this experience, it is important for us to apply our full strength to the development and operation of large projects, first and foremost the Thirty Meter Telescope (TMT) Project. One of the issues facing TMT is securing the large budget for the construction and operation. This is a nontrivial task. In an environment where large science projects tend to be severely restricted on the financial side, we need to be in a position to scrap-and-build on our own, and to use NAOJ's advanced capabilities in technology to help national endeavors or find solutions to expedite the growth of Japanese industry. From this point of view, we need to rethink from the beginning the justification for the continued existence of astronomy research in Japan.

Furthermore, we need to establish a plan for after the completion of TMT, based on NAOJ's achievements. It is vital to explain our vision to the tax-payers, government, and science community: what direction NAOJ will take over the course of the next 20 years and what new findings about the Universe we will bring about. Strategic suggestions about possible future directions to further enhance the appeal of astronomy, which now includes subjects like fundamental physics and life sciences, will help us secure excellent personnel, acquire the funding necessary to realize our plans, and be the leading partner in international collaborations. To do this, it is important to first establish a framework and scope for crafting such a plan for the future.

The "development of space missions" is one of the important topics we should include in the discussions of future plans. It is often forgotten that NAOJ, which has steadily carried out large projects and the development of leading edge technology in ground-based astronomy, is in a very favorable position to develop space instruments aboard satellites and probes, as demonstrated by the success of "Hinode." There's not that much of a difference between ground-based and space-based technologies; once a technology has been proven on the ground, it becomes possible to apply it to space missions. NAOJ must make better use of its potential in this regard. In addition to expanding the ground-based astronomy which is the core mission of NAOJ, we should consider proposing/creating unique instruments and missions for space.

In this way, by utilizing the heritage accumulated over many years, we will be able to promote our various projects, first and foremost TMT, and construct a shared vision for what lies ahead. With that, I believe NAOJ and world astronomy will be able to make great strides.

Activities and Objectives of NAOJ

The National Astronomical Observatory of Japan (NAOJ), the national center of astronomical research in Japan, promotes the open use of its facilities among researchers throughout Japan. NAOJ encourages collaborative research, observations and technological innovation, including inter-university research cooperation.
In addition, as one of the main international research bases in the world, NAOJ actively enhances flexible international research projects with personnel contributions and the most advanced observing facilities.
Modern astronomy has become highly advanced and large-scale. It is said that anymore constructing cutting-edge facilities and conducting observations to explore new horizons in astronomy is impossible without international cooperation.
NAOJ has taken part in many epoch-making international research projects throughout its 120 year history, gaining experience in research and technological innovation.
NAOJ aims to promote the development of astronomy, astro-physics, and the related fields of science.

Astronomy is one of the oldest and yet most active sciences. This means that human beings possess the fundamental desire to seek our origin and the reason for our existence through an understanding of the Universe. Since the establishment of the Big Bang theory of Universe creation in the 20th century, astronomers have been striving to describe the dynamics of the evolution of the Universe from its material production, the generation of stars and planets, the creation of life forms, up to the birth of human beings.

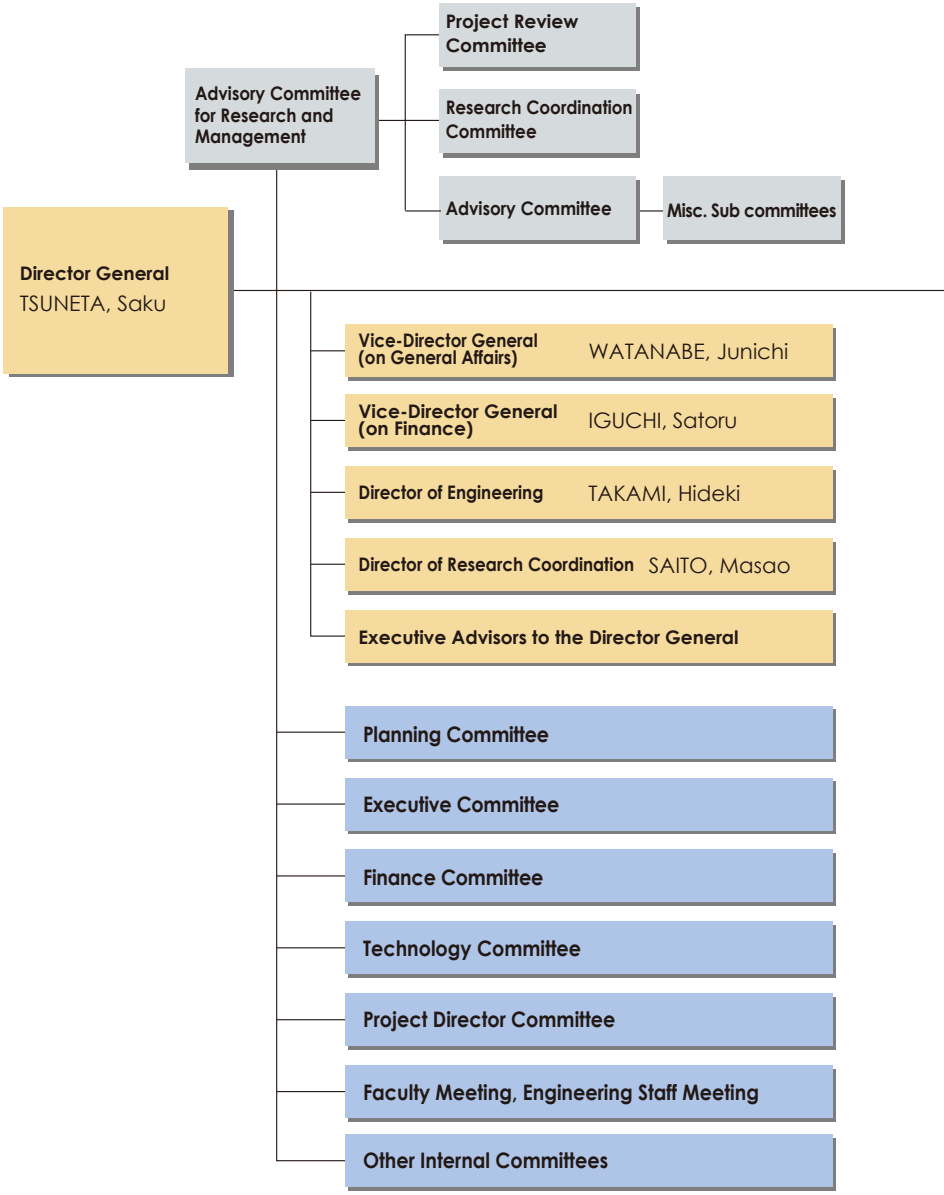
The 21st century will be the era in which we search for planets and life forms outside the Solar System.

The NAOJ is putting our best effort toward playing a key role in establishing a new paradigm for understanding the Universe, the Earth, and life as a whole.

For this purpose, we conduct observations of various objects, from the Earth to the Universe itself, and we consider the fundamental theoretically laws behind the observed phenomena. We also develop new technology to support these activities.

Organization

The Project System clarified the activities and plans of NAOJ in terms of projects, center and divisions, each with specific goals and deadlines. The goal is to raise awareness of our research activities and achieve further invigoration. The Project System advances the sharing of resources throughout the entire observatory; defines the responsibilities and capabilities of project leaders and staff; and improves the clarity and independence of research.

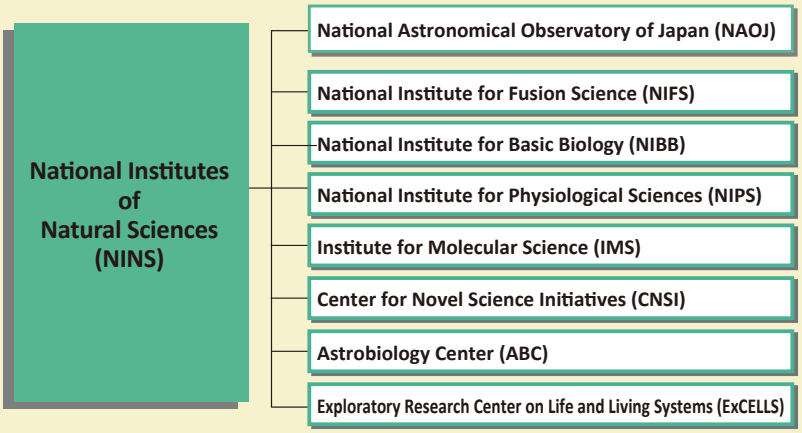


Research Objectives of NINS

The National Institutes of Natural Sciences (NINS), established on April 1, 2004, consisted of five inter-university research institutes specializing in natural science research: the National Astronomical Observatory of Japan, the National Institute for Fusion Science, the National Institute for Basic Biology, the National Institute for Physiological Sciences, and the Institute for Molecular Science.

The integration of these research institutes, specialized in a wide range of scientific fields such as space, energy, materials, and life, is intended to promote the development of novel concepts and/or fields of natural science. Another aim of the NINS is to grow into a worldwide center of excellence in the natural sciences.

Astrobiology Center was established as of April 1, 2015 to promote the combined study of astronomy and life sciences. Also, Exploratory Research Center on Life and Living Systems (ExCELLS) was established as of April 1, 2018 to develop multidisciplinary approaches towards understanding the essence of living states.



NAOJ's "Philosophy"

"NAOJ's Philosophy" was codified in fiscal year 2014.

●Our Vision

・To be innovators striving to solve the mysteries of the Universe.

●Our Mission

・To develop and construct large-scale cutting-edge astronomical research facilities and promote their open access aiming to expand our intellectual horizons.
・To contribute to the development of astronomy as a world leading research institute by making the best use of a wide variety of large-scale facilities.
・To bring benefits to society through astronomy public outreach.

●Our Products / Deliverables

・To explore the unknown Universe and provide new insight into astronomy.
・To make our research outcomes widely known to society and pass on our dreams to future generations.
・To mentor next-generation researchers for their role on the world-stage.

NAOJ Facilities

Our research facilities have been set up around the world for better observational environments to explore the Universe.

Our research and observational facilities are scattered throughout various regions of Japan as well as in foreign countries. To better understand the Sun, stars, interstellar matter, galaxies and other celestial objects, the best quality data in a wide range of wavelengths, from visible to radio waves, are indispensable. For this purpose, our observational facilities are located in the optimum natural environments.

Open this fold out. This way, you can see an outline of the structure of the known Universe. Each of NAOJ's research and observational facilities is cooperating with the others to enhance efforts to unveil the mystery of the entire Universe.

NAOJ Nobeyama Nagano Prefecture

Nobeyama Radio Observatory (C Project) → p.15

Nobeyama Radio Observatory raised Japanese radio astronomy to the top tier, internationally. The 45-m Radio Telescope is one of the largest millimeter radio telescope in the world. It has achieved epoch-making results, such as discovery of new interstellar molecules and detection of signature of an intermediate blackhole in our galaxy. The Nobeyama Campus is open daily to the public.

GWPO Kamioka Branch Office (B Project) → p.18

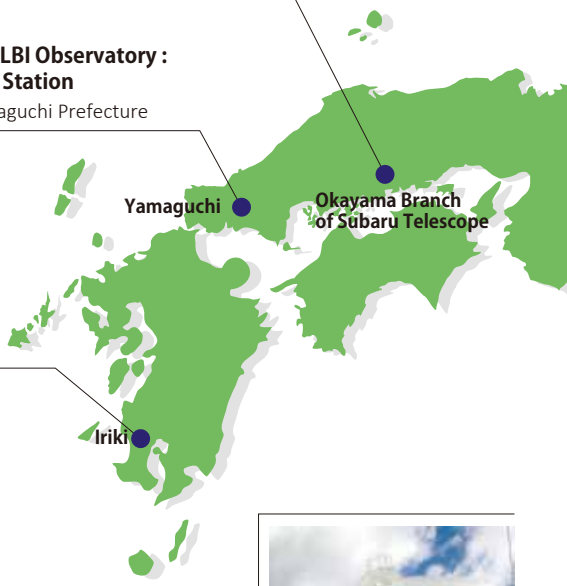
KAGRA, a gravitational wave telescope under construction in the Kamioka Mine, aims to expand the field of gravitational wave astronomy. The Kamioka Branch of the Gravitational Wave Project Office (GWPO) supports the installation and commissioning of KAGRA.

Subaru Telescope Okayama Branch Office

Open-use observations will be developed by NAOJ at the 3.8-m telescope of the Okayama Observatory, the Astronomical Observatory of the Graduate School of Science, Kyoto University. Open-use observing opportunities with the largest optical and near-infrared astronomy facility inside the main-land of Japan will be provided.

Mizusawa VLBI Observatory : Yamaguchi Station

Yamaguchi, Yamaguchi Prefecture



Six VLBI Stations (including Four VERA Stations)

Mizusawa VLBI Observatory : Iriki Station (VERA) (C Project) → p.14

Satsumasendai, Kagoshima Prefecture

Mizusawa VLBI Observatory : Ishigaki-jima Station (VERA) (C Project) → p.14

Ishigaki, Okinawa Prefecture

NAOJ Chile

NAOJ Chile Observatory (C Project) → p.17

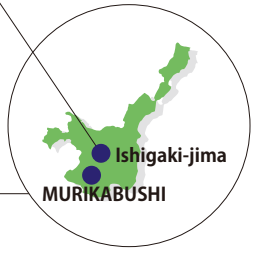
ALMA(Atacama Large Millimeter/submillimeter Array)

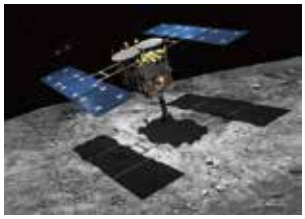
The Atacama Large Millimeter/submillimeter Array(ALMA) project is a partnership including Japan, Taiwan, South Korea, Member states of the European Southern Observatory and North America in cooperation with the Republic of Chile to operate an international radio astronomy facility on the 5000 m Atacama Desert in Chile.Now NAOJ is working full scale on this huge project, leading the operation of ALMA on behalf of the Japanese and East Asian science communities. ALMA was inaugurated as a completed observatory in March, 2013.

ASTE(Atacama Submillimeter Telescope Experiment)

The ASTE Telescope observes radio waves in the wavelengths range shorter than 1 mm. In the superb atmospheric conditions of the Atacama Desert, ASTE has made new scientific discoveries in the center of our own Galaxy, in nearby star-forming regions, and in distant galaxies.

MURIKABUSHI is a 105-cm telescope in Ishigakijima Astronomical Observatory.





Asteroid explorer "Hayabusa-2" (JAXA/Ikeshita).

NAOJ Mizusawa Iwate Prefecture

Mizusawa VLBI Observatory (VERA) (C Project) → p.14

Astrometry and geodesy are actively being researched, and the Time Keeping Office here contributes to the determination of Japan Central Standard Time. Our VERA telescope is creating a three-dimensional map of our Milky Way Galaxy.

Esashi Earth Tides Station

This facility has been monitoring the details of the tidal deformation of the Earth. Shown here are laser tiltmeters to measure the extension of the Earth's surface using laser beams.

RISE(Research of Interior Structure and Evolution of Solar System Bodies) Project (A Project) → p.22

The first accurate gravity and topography maps of the Moon were obtained using the KAGUYA mission's laser altimeter, relay satellite, and VLBI satellite. We intend to develop our research further by promoting exploration of not only the Moon but also asteroids and Jovian system.

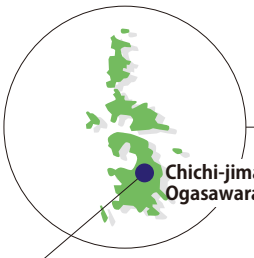
Mizusawa VLBI Observatory : Ibaraki Station

Takahagi, Hitachi, Ibaraki Prefecture

NAOJ Mitaka Tokyo Metropolis

As the headquarters of NAOJ, the Mitaka Campus houses offices of various projects and divisions, as well as administrative offices.

- Solar Science Observatory (C Project) → p.15
- Center for Computational Astrophysics (C Project) → p.16
- Gravitational Wave Project Office (B Project) → p.18
- TMT (Thirty Meter Telescope) Project Office (B Project) → p.18
- JASMINE (Japan Astrometry Satellite Mission for INfrared Exploration) Project Office (A Project) → p.21
- SOLAR-C Project Office (A Project) → p.22
- Astronomy Data Center → p.23
- Advanced Technology Center → p.24
- Public Relations Center → p.24
- Division of Optical and Infrared Astronomy → p.25
- Division of Radio Astronomy → p.25
- Division of Solar and Plasma Astrophysics → p.26
- Division of Theoretical Astronomy → p.26
- Office of International Relations → p.27



Mizusawa VLBI Observatory : Ogasawara Station (VERA) (C Project) → p.14

Chichi-jima, Ogasawara Islands Tokyo Metropolis

NAOJ Hawai'i

Subaru Telescope (in Hawai'i) (C Project) → p.16

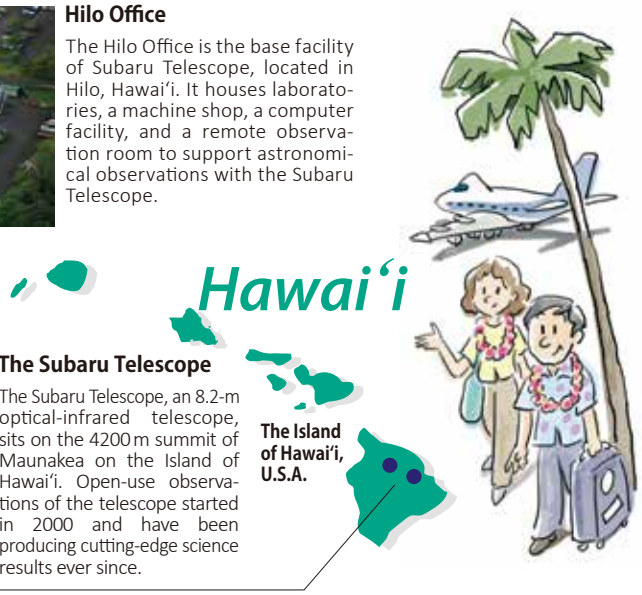
On the Island of Hawai'i, State of Hawai'i, U.S.A.

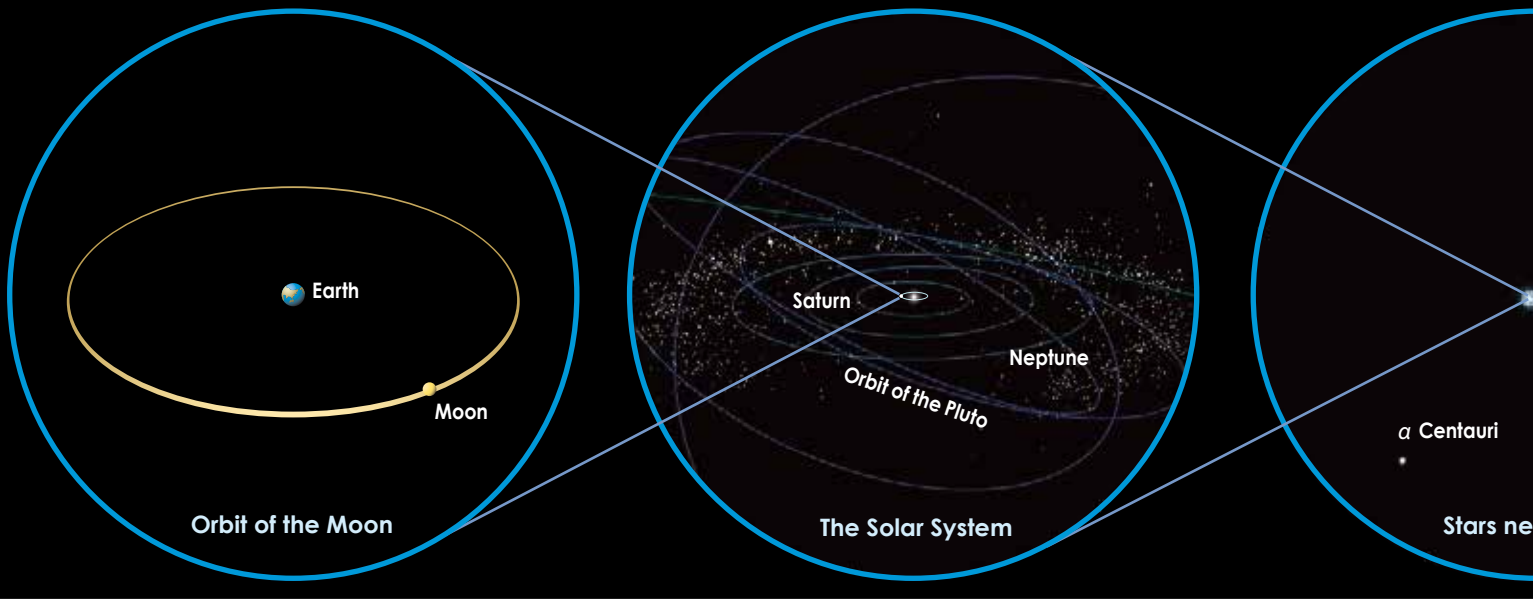
Hilo Office

The Hilo Office is the base facility of Subaru Telescope, located in Hilo, Hawai'i. It houses laboratories, a machine shop, a computer facility, and a remote observation room to support astronomical observations with the Subaru Telescope.

The Subaru Telescope

The Subaru Telescope, an 8.2-m optical-infrared telescope, sits on the 4200 m summit of Maunakea on the Island of Hawai'i. Open-use observations of the telescope started in 2000 and have been producing cutting-edge science results ever since.





➡Increasing distance from the Earth

10^6 (1 million) km

10^{10} (100 billion) km

10^{14} km (10

Hierarchy of the Solar System

◆Projects researching all the four categories, "the Expanding Universe", "Galaxies", "the Milky Way", and "the Solar System" ●Mizusawa

◆Projects researching "the Milky Way" and "the Solar System" categories ●Solar Science Observatory (p.15) ●Division of Solar and Plasm

◆Projects researching "the Solar System" category ●RISE Project (p.22)
●SOLAR-C Project Office (p.22)

Extent and History of the Universe

Let's have a look at the scale and the history of the Universe. The upper row displays the "extent of the Universe" in terms of distance, while the lower row illustrates the "history of the Universe and the Earth" as a scroll painting.

Since the speed of light is limited, we see the past Universe when we observe distant space. In other words, when we look at distant objects, we see back to study the beginning of the Universe. In this sense, telescopes are like time machines.

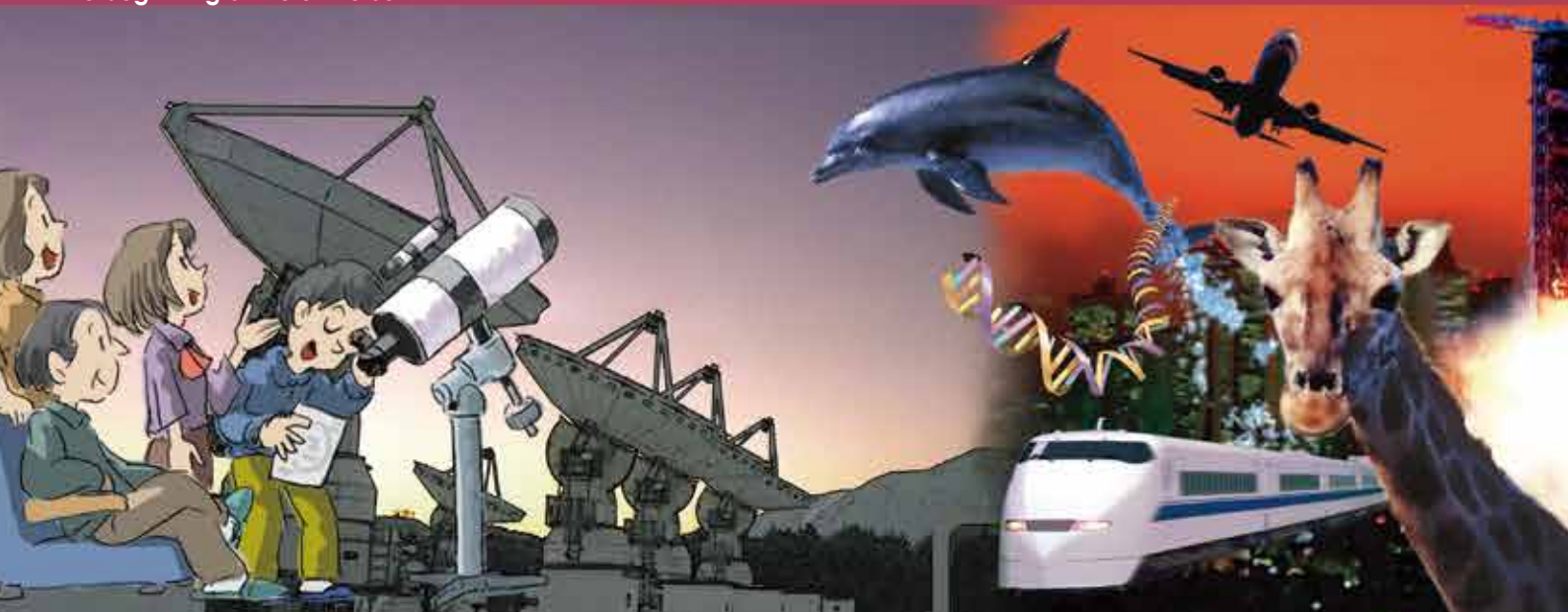
(©NASA)

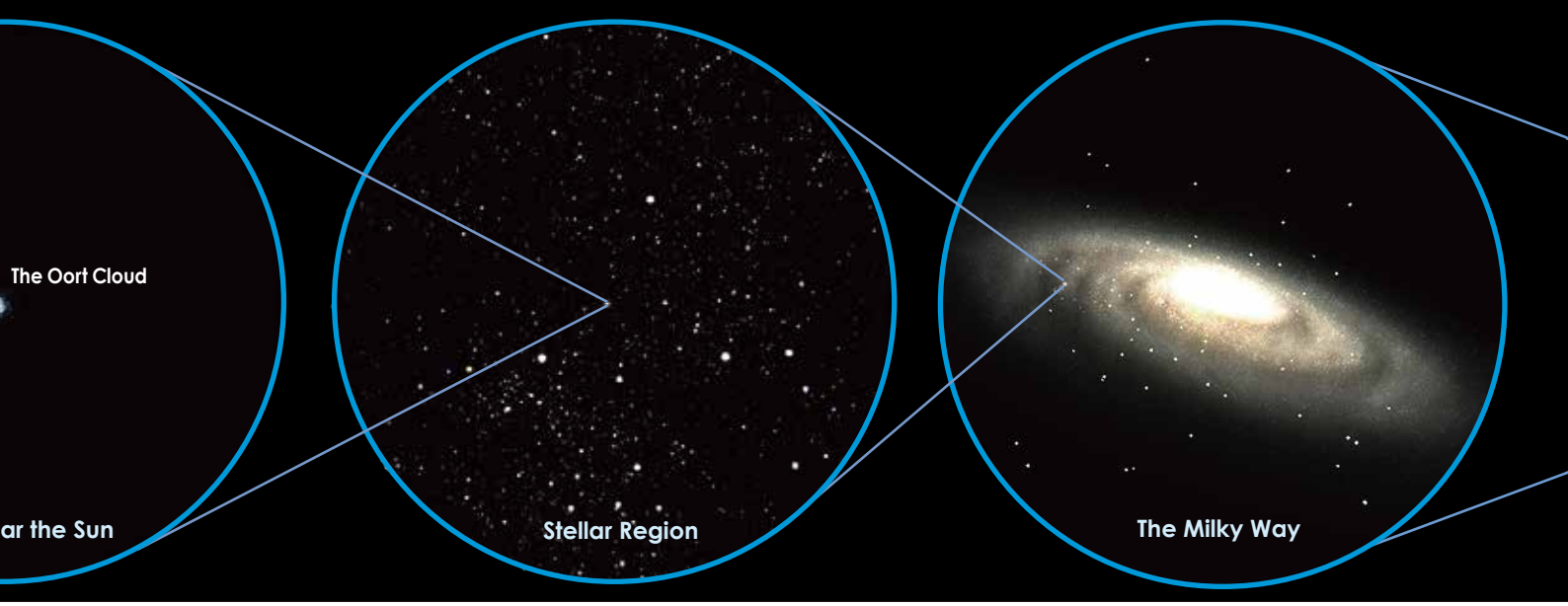
➡toward the beginning of the Universe

3 seconds ago

10 hours ago

10 ye





light-years) | 10^{16} km (1000 light-years) | 10^{18} km (0.1 million light-years)

Hierarchy of the Milky Way

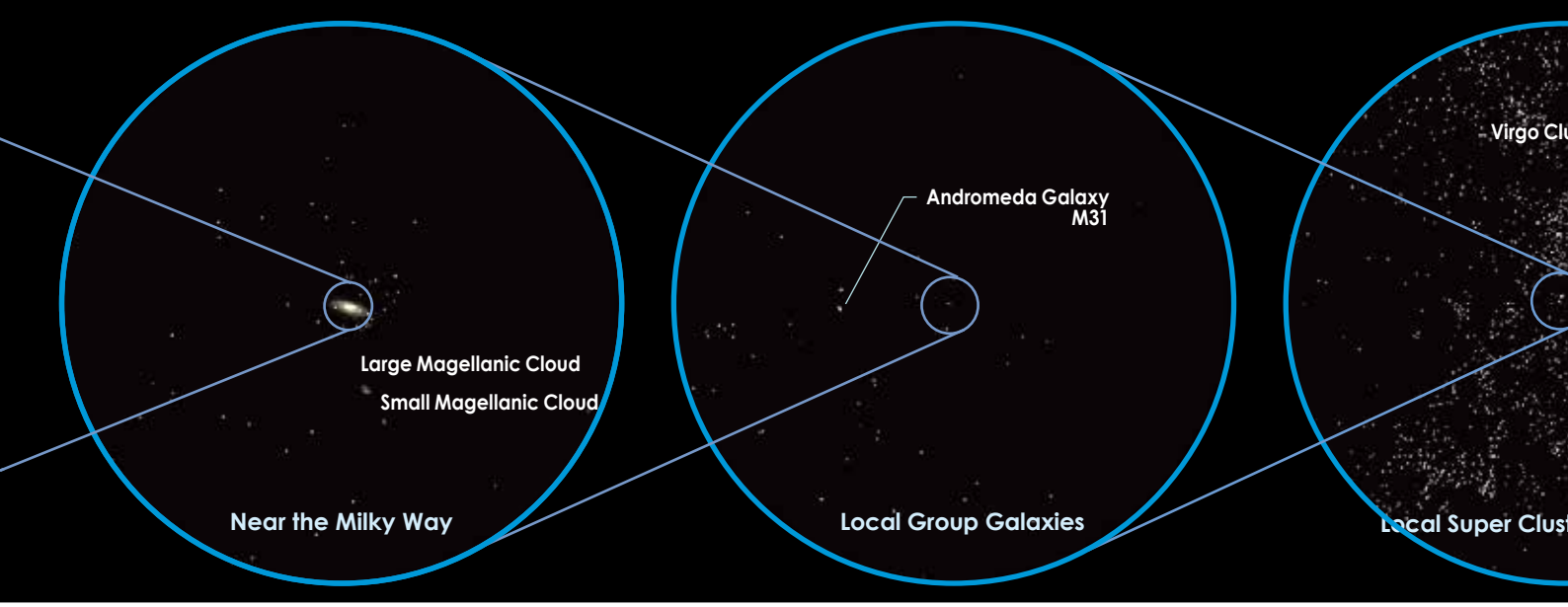
a VLBI Observatory (p.14) ●Nobeyama Radio Observatory (p.15) ●The Subaru Telescope (p.16)
ma Astrophysics (p.26)
◆Project researching the three categories,"the Expanding Universe","Galaxies","the Milky Way" ●Gravitational Wave Project Office(p.18)
◆Project researching "the Milky Way" category ●JASMINE Project Office (p.21)

Space-Time? Matter? Celestial Objects?
The Earth? Life? Human beings?

And what about my origin and future?

The star-forming region S106 IRS4 at a distance of about 2000 light-years from the Earth. (The Subaru Telescope)

ars ago | 1000 years ago | 100 thousand years ago



10^{19}km (1 million light-years) | 10^{20}km (10 million light-years) | 10^{21}km (100 milli

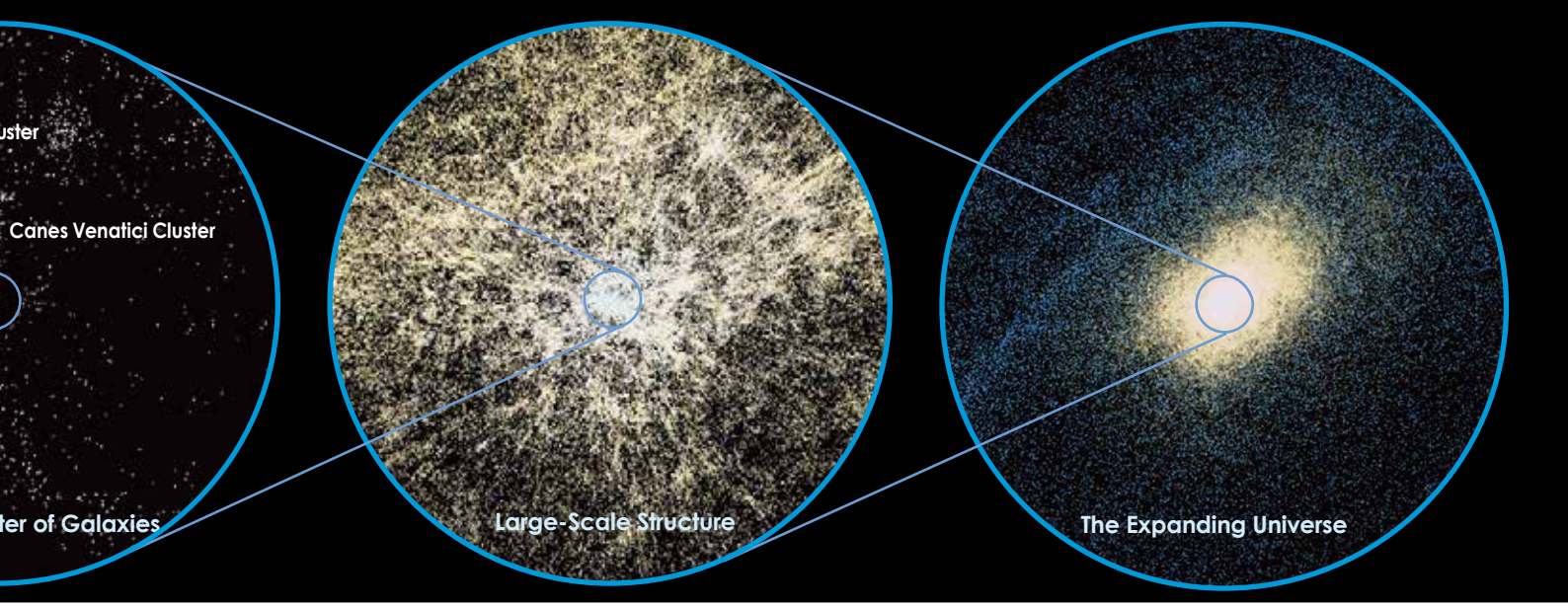
Hierarchy of Galaxies

● Center for Computational Astrophysics (CfCA) (p.16) ● NAOJ Chile Observatory (p.17) ● TMT Project Office (p.18) ● Division of Optical and Infra

Hickson Compact group of galaxies 40 (HCG40), which is 300 million light-years from us in the constellation Hydra (The Subaru Telescope).

All the answers can be found in the Universe.

1 million years ago | 10 million years ago | 100 million y



on light-years) | 10^{22}km (1 billion light-years) | 10^{23}km (10 billion light-years)

Hierarchy of the Expanding Universe

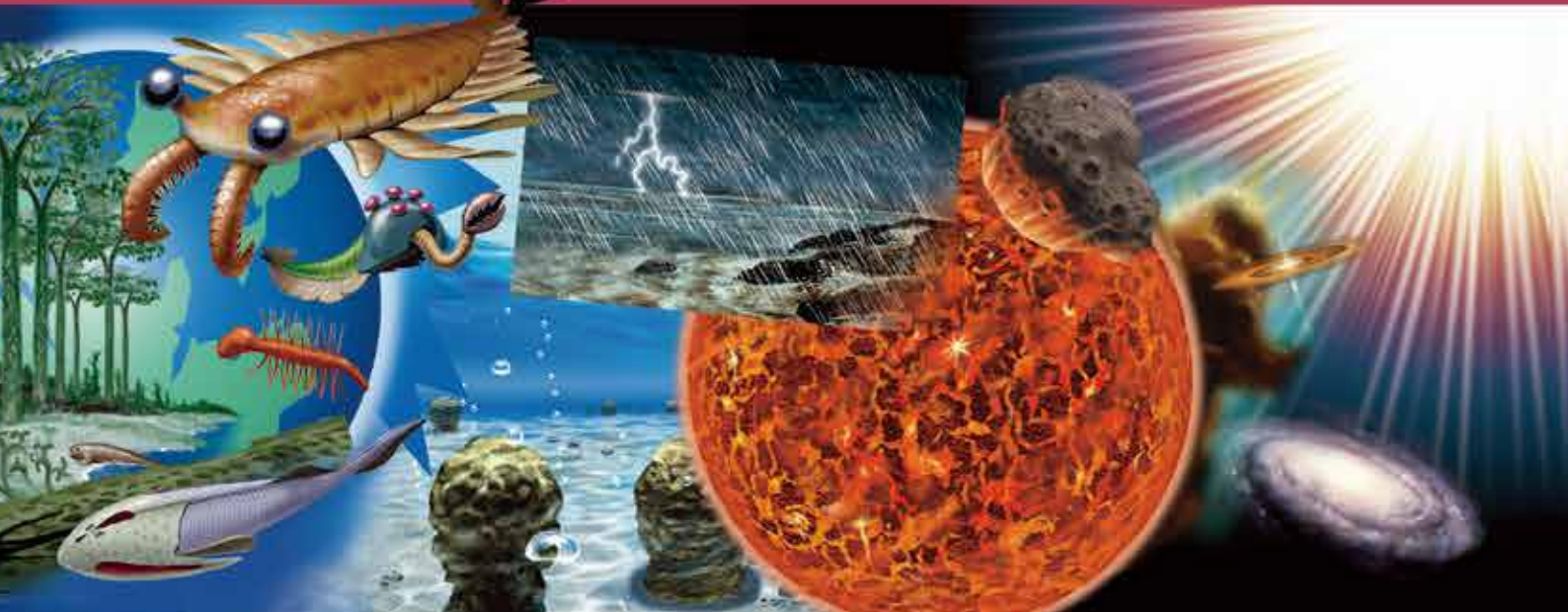
red Astronomy (p.25) ● Division of Radio Astronomy (p.25) ● Division of Theoretical Astronomy (p.26)

A quasar located some 9.8 billion light-years away. The gravitational lens created by a huge cluster of galaxies (SDSS J1004+4112) makes 4 images of the distant quasar.
(The Subaru Telescope)

●What can we learn from this map?

This illustration is a macroscopic view of space and time.
Our expanding Universe was born about 13.8 billion years ago during the Big Bang. Today, the observationally reachable edge of the Universe is 13.8 billion light-years from us. In this figure, "today" is located in the left corner. The upper axis shows the distance scale of the Universe and increases by factors of ten from left to right. The time shown in the lower axis goes deeper into the past with increasing distance, where the scale indicates the diameter of a corresponding sphere of subspace. The middle panel classifies the Universe into four categories (the Expanding Universe, galaxies, the Milky Way, and the Solar System) according to the distance scale and shows the research fields of each of NAOJ's project teams.

ears ago | 1 billion years ago | 10 billion years ago



▲Mitaka Campus in spring. A row of cherry blossoms tints the entire campus pink.

Six Projects as Main Driving Force of NAOJ

The C projects group consists of the six projects, such as Subaru Telescope, ALMA (NAOJ Chile Observatory), HINODE Solar Observatory and Nobeyama Radio Observatory, which have been completed as NAOJ facilities and are operating. This project group is the main driving force of NAOJ actively supporting leading edge observations and research.

Each observatory or research division explores a variety of mysteries of the Universe by analyzing electromagnetic waves of various wavelengths. These icons express the main wavelength coverage of the observational techniques of each project and division.

- cm Centimeter wave (radio)
- mm Millimeter wave (radio)
- smm Submillimeter wave (radio)
- IR Infrared radiation
- V Visible light
- UV Ultraviolet radiation
- EUV Extreme ultraviolet radiation
- X X-ray
- GW Gravitational Wave (Different from electromagnetic wave)

cm mm

Mizusawa VLBI Observatory

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Phone +81-197-22-7111
http://www.miz.nao.ac.jp/en

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- Ogasawara Station : Asahiyama, Chichi-jima, Ogasawara, Tokyo 100-2101 / Phone +81-4998-2-7333
- Ishigaki-jima Station : 2389-1, Tonoshirotakeda, Ishigaki, Okinawa 907-0004 / Phone +81-980-88-0011
- Ishigakijima Astronomical Observatory : 1024-1, Arakawa, Ishigaki, Okinawa 907-0024 / Phone +81-980-88-0013
- Ibaraki Station : 608-1, ishitaki, Takahagi, Ibaraki 318-0022
- Yamaguchi Station : 123, Nihonakagou, Yamaguchi, Yamaguchi 753-0302

Creating a Map of the Milky Way Galaxy Using the Triangulation Technique with a Baseline the Size of Earth's Orbit

We formed a giant VLBI (Very Long Baseline Interferometry) observational network across Japan by combining observational data from 20 m radio telescopes erected in 4 locations around the country (Oshu City, Iwate Prefecture; Satsumasendai City, Kagoshima Prefecture; Ogasawara, Tokyo; and Ishigaki City, Okinawa Prefecture). Through this network, we conduct observations to measure the positions of celestial objects in the Milky Way Galaxy with high precision. The positions of stars appear to shift due to the orbital motion of the Earth around the Sun (annual parallax). Using this parallax we can accurately determine the distance to a star, while at the same time researching the motion of the Milky Way Galaxy. Remote observations using the 4 radio telescopes are controlled from Mizusawa Campus, and the observational data is combined and correlated in the Mizusawa Campus correlation center. Additionally, we are advancing the study of active galactic nuclei located in the centers of other galaxies through high precision measurements. Utilizing various radio telescopes, we conduct collaborative research with universities: Yamaguchi University (32 m), and Ibaraki University (Takahagi 32 m and Hitachi 32 m).

We are also advancing VLBI observations throughout Japan via cooperation with various observation faculties: NICT (Kashima 34 m), JAXA (Usuda 64 m), and radio telescopes belonging to local universities (for example: Gifu University's 11 m).

We are promoting international collaboration with countries in East Asia. Observations combining VERA and three KVN (Korean VLBI Network) radio telescopes located in South Korea are ongoing. Additionally, we are working to complete the East Asia VLBI Network through cooperation with organizations in multiple Chinese telescopes in Shanghai, Urumqi and Kunming. To this end, we are investing in the Japan-Korea Joint VLBI Correlator at the Korea Astronomy and Space Science Institute. It is playing an important role as the main correlation center for VLBI observations in the East Asia region.

▲Mizusawa Campus correlation center.

▲The position of 144 sources in the Galaxy measured by VERA, VLBA and EVN.

Director :
Prof. HONMA, Mareki

memo

cm Centimeter wave | Electromagnetic waves with wavelengths between 1 cm and 10cm (broadly 1 cm to dozens of cm). Using this wavelength range, we observe basic atoms such as atomic hydrogen, which is the most abundant element in the Universe. Synchrotron radiation from explosions can also be observed.

cm mm

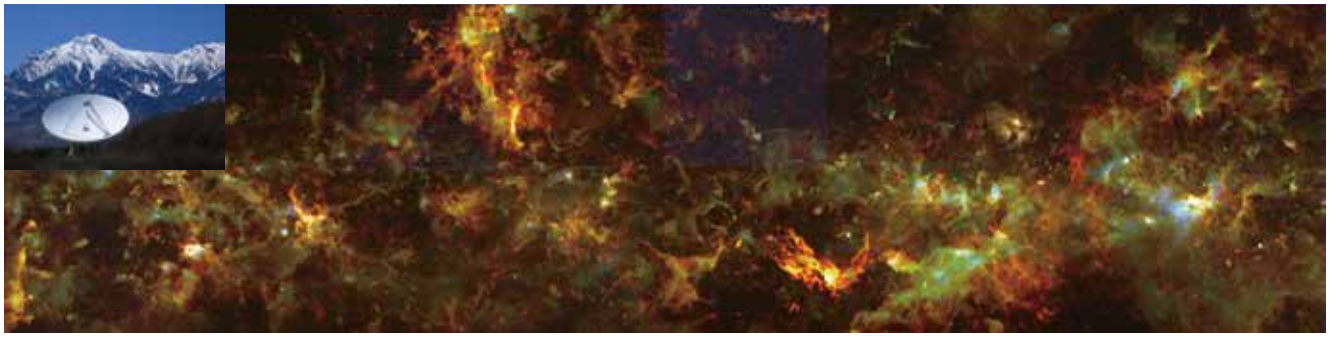
Nobeyama Radio Observatory

462-2, Nobeyama, Minamimaki, Minamisaku, Nagano 384-1305
Phone +81-267-98-4300
http://www.nro.nao.ac.jp/en/index.html

The Nobeyama 45-m Telescope is the Largest Radio Telescope at Millimeter Wave, Exploring Millimeter Wave Astronomy

The Nobeyama Radio Observatory (NRO) operates the 45-m Radio Telescope that is one of the largest telescopes for millimeter wave observations in the world. Radio telescopes can reveal the structures of the Universe that we cannot see with our own eyes. For example, a radio map of the interstellar medium in our galaxy enables us to investigate how various stars are formed. Until today, the 45-m telescope has obtained significant results such as detecting signature of an intermediate mass black hole near the center of our galaxy and exploring the formation process of bio-molecules. The 45-m telescope continues to to unveil the invisible Universe.

Director :
Prof. TATEMATSU Ken'ichi



▲Radio image of the Milky Way obtained with the new receiver mounted on the 45-m radio telescope (the upper left). High angular resolution enables us to image fine structures of molecular clouds. Red, green, and blue represent the radio intensities of the carbon monoxide isotope.

IR V

Solar Science Observatory

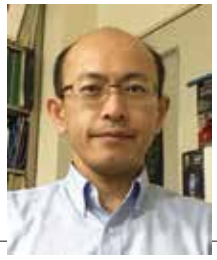
2-21-1, Osawa, Mitaka, Tokyo 181-8588
Phone +81-422-34-3600
http://solarwww.mtk.nao.ac.jp/en/ssobs_e.html

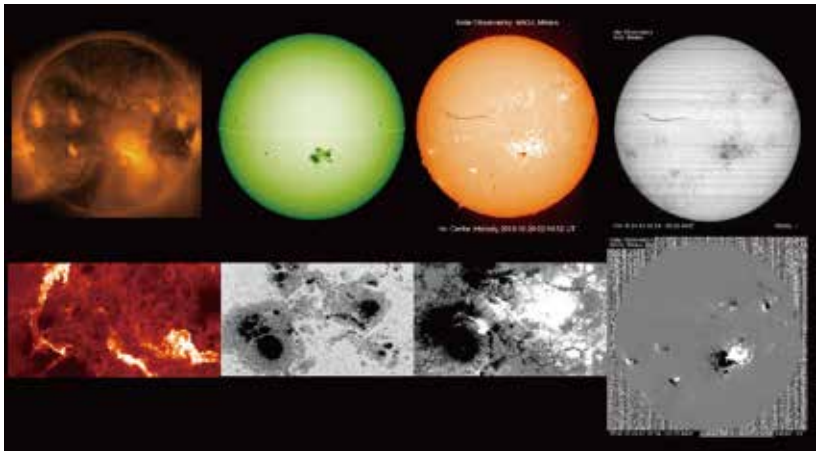
Elucidating the solar magnetic activity from space and ground-based observations

The Sun is a typical star, but as the nearest star, it dominates the Solar System and influences all of our activities. The magnetic activity in the Sun is representative of phenomena ubiquitous throughout the Universe. One of our major goals is to understand the solar magnetic field and magnetic activity through various scientific observations and analyses.
In the Solar Science Observatory, we push forward the leading edge of solar physics, by making maximum use of data taken with spacecraft and large ground-based facilities, and by developing advanced observational instruments. We also promote the scientific operation of the Hinode satellite in cooperation with the Institute of Space and Astronautical Science, and support studies using the data obtained by Hinode. We carry out long-term continuous observation via our facilities in NAOJ and provide data for joint studies. Theoretical considerations and computer simulations are necessary tools for the analyses of these data, and we help develop them as important research methods as well.

▼Largest sunspots of the current activity cycle (Top row from left to right: Whole Sun images in X-rays, white light, Hα, and HeI10830Å lines. Bottom row from left to right: Hinode/SOT CaIIH line image, white light image, circular polarization image, and whole Sun circular polarization map.)

Director :
Assoc. Prof.
HARA, Hirohisa





memo

mm Millimeter wave

Electromagnetic waves with wavelengths between 1 mm and 1 cm. Many molecules radiate emission lines in this wavelength range. With this range, we can study interstellar molecular clouds and learn about the process of star formation in these clouds.

IR V

Subaru Telescope (in Hawai'i)

650 North A'ohoku Place, Hilo, Hawai'i, 96720, U.S.A.
Phone +1-808-934-7788
https://subarutelescope.org/index.html

Subaru Telescope's Suite of Optical and Infrared Instruments Continually Enriches Our Knowledge of the Universe

Subaru Telescope (Observatory) operates an 8.2-m optical-infrared telescope, the Subaru Telescope. The telescope is installed at the summit of Maunakea, Hawai`i Island with excellent observing conditions, and is promoting open-use observations opened to the world astronomical community. Utilizing the wide field of view and high resolution observation capability of the Subaru Telescope, astronomers investigate the mysteries of modern astronomy, such as the formation and evolution of stars and planets; the history of galaxies; or the nature of dark matter and dark energy. In parallel, various observation instruments which will open up new research fields are being developed under international collaboration. The observatory staff are doing their best day and night so that even better science research can be done. From FY 2018, Okayama Astrophysical Observatory was reorganized as the Subaru Telescope Okayama Branch Office and promotes the open-use of Kyoto University's 3.8-m telescope. Subaru Telescope will continue to challenge the mysteries of the Universe and to produce the world's most advanced research results.

◀A pseudo-color image of a starburst galaxy NGC 6240 Its star formation rate is estimated to be 25-80 times that of our galaxy. Blue, green, and red colors are attributed to the B-band, R-band, and H-alpha (emission line from ionized hydrogen gas) images, respectively. The giant ionized gas blown out from the galaxy is seen in red. (Credit : Hiroshima University/NAOJ)

Director :
Prof. YOSHIDA, Michitoshi

▶Astronomers can use the Subaru Telescope to observe in a wide range of wavelengths, from the short-visible to the mid-infrared(0.3 ~ 25 micrometers). A suite of imagers and spectrographs is available for their research.

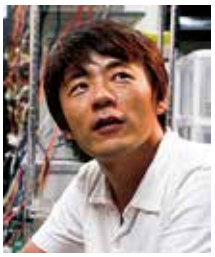
Center for Computational Astrophysics (CfCA)

2-21-1, Osawa, Mitaka, Tokyo 181-8588
Phone +81-422-34-3600
http://www.cfca.nao.ac.jp/~cfca/index.html.en

Universe in a Computer

Numerical simulation in astronomy is regarded as the third methodology of astronomy alongside observational and theoretical astronomy. We need computer simulation because it is practically impossible for us to perform laboratory experiments of astronomical phenomena due to their huge time and spatial scales. We create universes in computers (often very large ones, referred to as supercomputers) reproduce astronomical phenomena there, and observe their behavior. In other words, computers are experimental tools to create virtual universes, and at the same time telescopes to observe them. In these virtual universes, we can watch the very early stage of the cosmos and its evolution, we can reproduce the formation of galaxies, and we can witness the origin, evolution, and final fate of planetary systems including our own. Our project, CfCA, possesses various types of high-performance computers such as a massive parallel computer Cray XC50 "ATERUI II," a bunch of special-purpose computers for gravitational many-body problems "GRAPE" and other facilities, all of which operate twenty-four hours a day, throughout the year. Astronomers all over the world use these resources. In addition, CfCA works on research and development for new software algorithms for the next-generation of simulation astronomy that will enable us to perform the largest numerical experiments ever attempted. By numerical simulations with supercomputers, we will, probably in the very near future, solve the longstanding questions such as the formation of galaxies, the origin of the Solar System, and the real picture of black holes.

▲Supercomputer, Cray XC50 "ATERUI II."



Director :
Prof. KOKUBO, Eiichiro

▲Various structures of the Milky Way Galaxy, simulated based on fundamental physical processes such as the gravitational interactions between stars and gas; the dynamics and evolution of the gas; star formation in the gas clouds; and energetic feedback from the stars.

▶Special-purpose computers for gravitational many-body problems, GRAPE.

memo

smm Submillimeter wave | Electromagnetic waves with wavelengths between 0.1 mm and 1 mm. This wavelength is between the millimeter wave and the far-infrared light. We can explore objects surrounded by dense interstellar dust such as protoplanetary disks and protogalaxies.

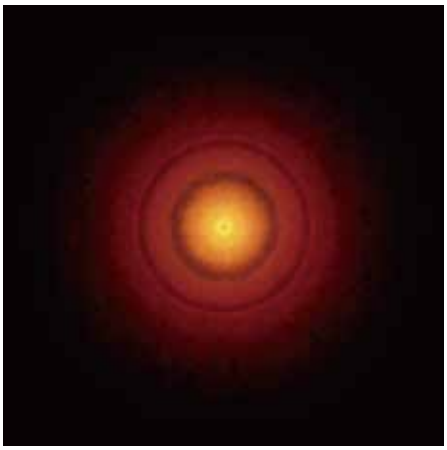
mm smm

NAOJ Chile Observatory

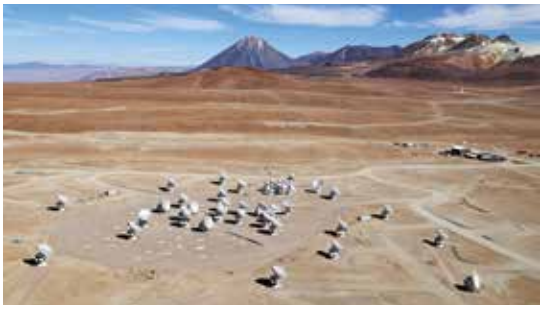
Alonso de Córdova 3788, Oficina 61B, Vitacura, Santiago, Chile / Phone +56-2-2656-9253
2-21-1, Osawa, Mitaka, Tokyo 181-8588 / Phone +81-422-34-3600
https://alma-telescope.jp/en/

ALMA: the new eye on the cool universe

ALMA was built and is operated in Chile, on the Andean plateau 5000 m above the sea level, by a global partnership among Japan/Taiwan /Korea, North America, Europe, and Chile. ALMA "sees" astronomical objects in millimeter and submillimeter waves using 66 antennas with diameters of 7 or 12 meters. ALMA is delivering breakthroughs in solving the great mysteries of the Universe, such as the formation of galaxies right after the Big Bang, the ongoing births of planetary systems, and the evolution of matter in the Universe leading to the origin of life. The NAOJ Chile Observatory, established in April 2012, is committed to the completion, operations and maintenance of ALMA, as well as the operations of the 10-m ASTE Submillimeter Telescope in Chile. The East-Asian ALMA Support Center (EA ASC) in Mitaka, Tokyo, promotes research activities using ALMA in East Asia.



▼ALMA image of the dust disk around a young star TW Hydrae. The image reveals a series of concentric bright rings and dark gaps, suggesting infant version of our Solar System could be emerging from dust and gas.
Credit: S. Andrews (Harvard-Smithsonian CfA), ALMA (ESO/NAOJ/NRAO)



▲ALMA antennas at the Array Operations Site (AOS)
Credit：Clem & Adri Bacri-Normier (wingsforscience.com) /ESO

Director :
Prof. SAKAMOTO, Seiichi

Departments of NAOJ　B Projects

▲TAMA300, the world's first science grade Gravitational Wave Telescope, based on a laser interferometer now serves as a test-bed, developing new technologies for KAGRA. (Upper Left) Areal photo, blue shows locations of arm tunnels. (Upper Right) Inside an arm tunnel. (Bottom) Input/output optics lab.

Two Developing Projects for NAOJ's Future

The B projects group includes two project offices that are under construction or being developed. These are expected to undertake NAOJ observations and research in the near future. The Gravitational Wave Project Office is undertaking gravitational wave observations using KAGRA, the large-scale laser interferometer located in Kamioka, Gifu Prefecture, aiming to develop the field of gravitational wave astronomy. The TMT (Thirty Meter Telescope) Project is planning to construct the next-generation large telescope succeeding the Subaru Telescope. With its 30-m primary mirror consisting of 492 segments and its Adaptive Optics (AO) system, it will achieve a resolution ten times higher than that of the Hubble Space Telescope.

Each observatory or research division explores a variety of mysteries of the Universe by analyzing electromagnetic waves of various wavelengths. These icons express the main wavelength coverage of the observational techniques of each project and division.

- cm Centimeter wave (radio)
- mm Millimeter wave (radio)
- smm Submillimeter wave (radio)
- IR Infrared radiation
- V Visible light
- UV Ultraviolet radiation
- EUV Extreme ultraviolet radiation
- X X-ray
- GW Gravitational Wave (Different from electromagnetic wave)

memo

IR **Infrared radiation** | Electromagnetic waves with wavelengths between 0.77 μm (0.00077 mm) and 0.1 mm. These wavelengths are suitable for studies of thermal radiation from protostars and interstellar dust. We must avoid wavelengths absorbed by the Earth's atmosphere.

GW

Gravitational Wave Project Office

2-21-1, Osawa, Mitaka, Tokyo 181-8588
Phone +81-422-34-3600
http://gwpo.mtk.nao.ac.jp/en/

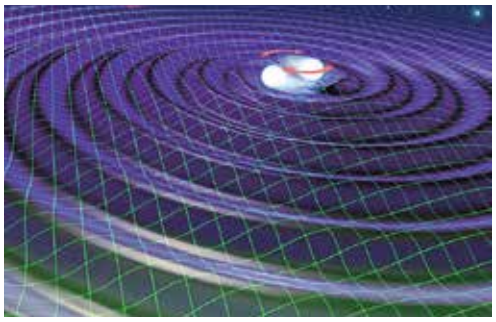
Gravitational Wave Telescopes are revealing new aspects of the Universe

The first observations of gravitational waves from the merger of two black holes made by the LIGO detectors, have shown the potential of gravitational wave astronomy in revealing new aspects of the Universe that cannot be observed by other means. In order to open this new window over the Universe, we are promoting the KAGRA project in collaboration with ICRR, KEK and other universities. KAGRA is a large cryogenic gravitational wave telescope using a 3 km laser interferometer placed in the Kamioka underground site. TAMA300, the 300-m laser interferometer situated on Mitaka campus, is a prototype of KAGRA and acts as a test facility to evaluate key elements and techniques before its installation on KAGRA. The project office is also promoting DECi-hertz Interferometer Gravitational wave Observatory (DECIGO) in space in anticipation of its future development.

▶Illustration of the gravitational waves emitted by a coalescing neutron star binary (illustrated by KAGAYA). KAGRA will detect the waves if such an event were to occur within 700 million light years of Earth.

Director :
Prof. WATANABE, Junichi

◀The KAGRA beam splitter suspension system about to be installed into a vacuum chamber.



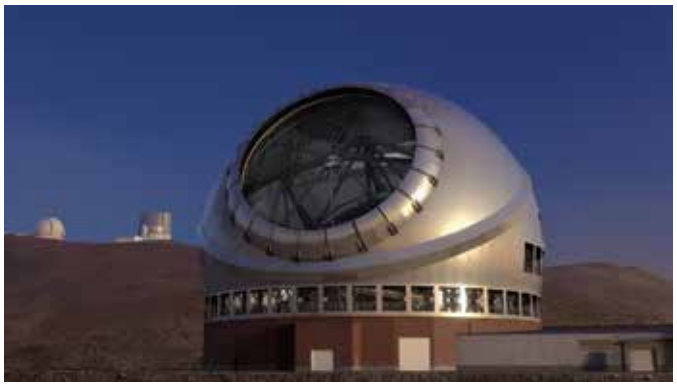
IR V

TMT-J Project Office

2-21-1, Osawa, Mitaka, Tokyo 181-8588
Phone +81-422-34-3600
http://tmt.nao.ac.jp/

Constructing a 30-m Optical-Infrared Telescope for the 2020's

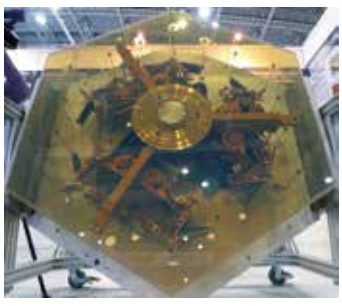
Based on the scientific and engineering success of the 8.2-meter Subaru Telescope, astronomers are preparing to begin construction of the Thirty Meter Telescope (TMT) as an international science project.
With an aperture of 30 m, TMT will have more than 10 times as much light-gathering power as the Subaru Telescope, and will boast more than 10 times the resolution of the Hubble Space telescope together with adaptive optics systems. NAOJ promotes the TMT Project, and will play a leading role in astronomy in the 2020's to deepen the human perception of the structure and evolution of the Universe, and the origins of stars, planets and life.



▲Artsts' rendering of TMT, a next-generation extremely large optical/infrared telescope. The expected construction site is close to the Subaru Telescope site on Maunakea.

Director :
Prof. USUDA, Tomonori

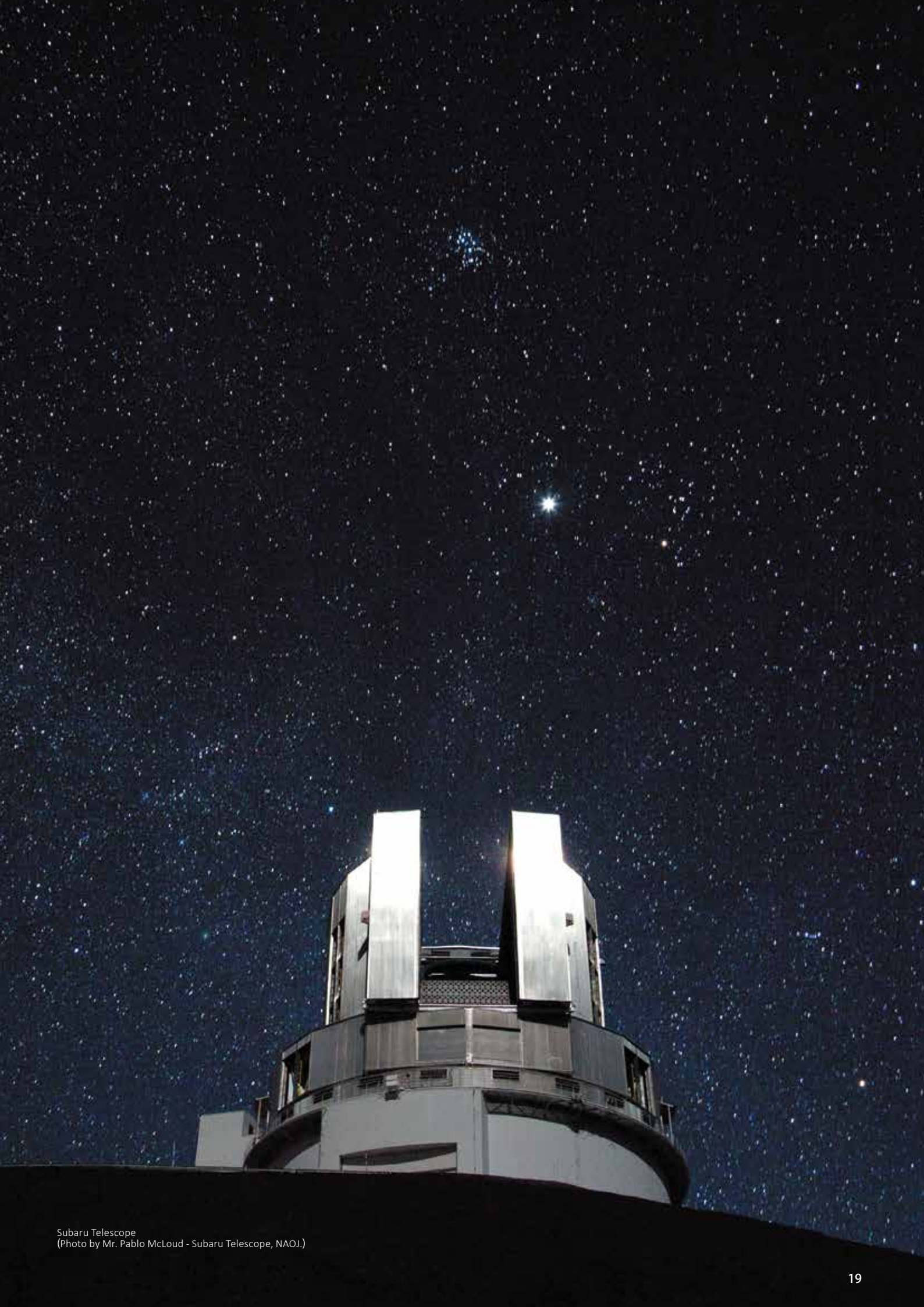
▶Artists' rendering of the telescope structure and a prototype of a segment mirror manufactured and polished in Japan. The TMT Project is driven by international collaboration consisting of five partner countries: Japan, USA, Canada, China, and India. Japan is in charge of constructing key components of the telescope such as the telescope structure and segment mirrors for the primary mirror.



memo

V Visible light

Visible light is the portion of the electromagnetic spectrum covering the wavelengths of 380 nm (0.38 μm) to 770 nm (0.77 μm). These wavelengths have been used for observation since the most ancient times because of their visibility to the unaided human eye. Visible light is observed for a wide variety of objects including stars, star clusters, and galaxies.

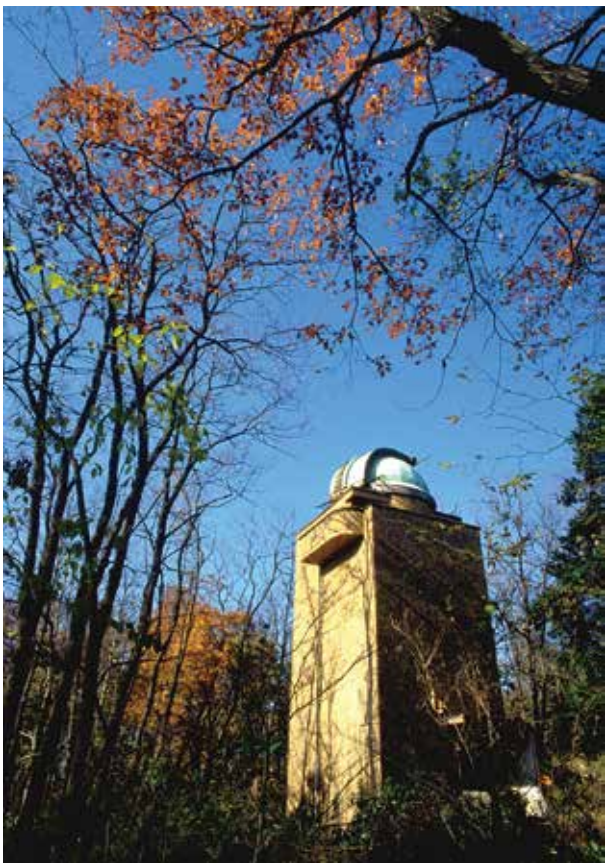


Subaru Telescope
(Photo by Mr. Pablo McLoud - Subaru Telescope, NAOJ.)

ALMA
(Photo by KAWAMURA, Akira)

Departments of NAOJ

A Projects



▲Solar Tower Telescope (Einstein Tower) at Mitaka Campus. It became a registered cultural property in 1998.

Three Projects for NAOJ's Future

The A projects group is designed and established to foster pioneering research and development (R&D) activities. This aims to encourage the creativity of researchers and create a diverse and advanced R&D environment. Three project offices, that are JASMINE Project Office, the RISE Project, and the SOLAR-C Project Office; are classified into the A project group. Each project has selected an ambitious theme, and is performing the R&D that will open the way to a new era of Astronomy.

Each observatory or research division explores a variety of mysteries of the Universe by analyzing electromagnetic waves of various wavelengths. These icons express the main wavelength coverage of the observational techniques of each project and division.

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- mm Millimeter wave (radio)
- smm Submillimeter wave (radio)
- IR Infrared radiation
- V Visible light
- UV Ultraviolet radiation
- EUV Extreme ultraviolet radiation
- X X-ray
- GW Gravitational Wave (Different from electromagnetic wave)

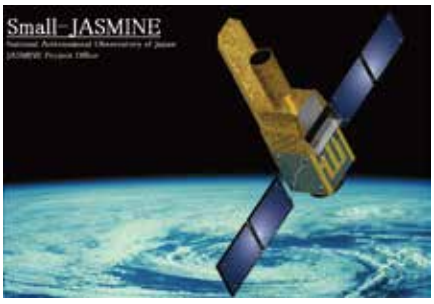
IR

JASMINE Project Office

2-21-1, Osawa, Mitaka, Tokyo 181-8588
Phone +81-422-34-3600
http://www.jasmine-galaxy.org/index.html

Drawing a Detailed Map of the Milky Way at Infrared Wavelengths Using an Astrometry Satellite

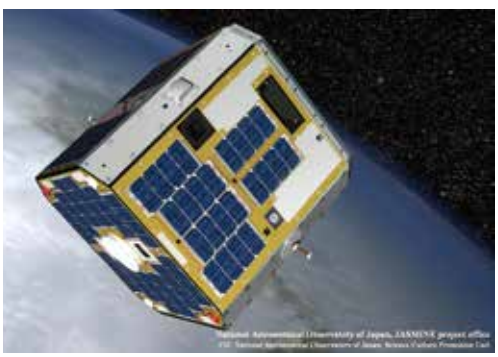
JASMINE is a satellite for measuring the distances and apparent motions of stars around the central bulge of the Milky Way with yet unprecedented precision. First we are planning the launch of a small science satellite in around FY2024. This Small-JASMINE with a 30 cm diameter primary mirror will focus on the survey of a restricted region limited to only a few square degrees of the nuclear bulge. Secondly we plan to launch a middle-sized satellite with an 80 cm diameter primary mirror in the 2030s that will survey the entire region of the bulge. By observing infrared light that can penetrate the Milky Way, these JASMINE missions will be able to obtain reliable measurements of extremely small stellar motions with the accuracy of 0.01 milliarcseconds (1 / 360,000,000 of a degree) on the sky. These will provide the precise distances and velocities of many stars up to 30,000 light years away. With such a completely new map of the Milky Way, including the information about stellar movements, we expect that many new exciting scientific results will be obtained in various fields of astronomy.



▲Artist's impression of JASMINE (the Small- JASMINE satellite : the small science-satellite with 30 cm primary mirror diameter) observing the Milky Way.

Director :
Prof. GOUDA, Naoteru

▶Before the launch of Small-JASMINE, we are developing a very small astrometry mission satellite, Nano-JASMINE (5-cm diameter primary mirror, 35 kg satellite). It is determined that the Nano-JASMINE satellite will be launched in the near future. Nano-JASMINE will provide a star catalogue covering the whole sky with a positional accuracy of 3 milliarcseconds. Moreover high-accuracy proper motions (~0.1 milliarcseconds /year) can be obtained by combining the Nano-JASMINE catalogue with the Hipparcos catalogue.



memo

UV Ultraviolet radiation | Electromagnetic waves with wavelengths between 10 nm and 100 nm. We can investigate high-energy and super high temperature phenomena in the Universe. Since the Earth's atmosphere absorbs most of the ultraviolet radiations, observations in this wavelength are made from outside the atmosphere.

cm IR V

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

2-12, Hoshigaoka,Mizusawa,Oshu, Iwate 023-0861
Phone +81-197-22-7111
http://www.miz.nao.ac.jp/rise/en

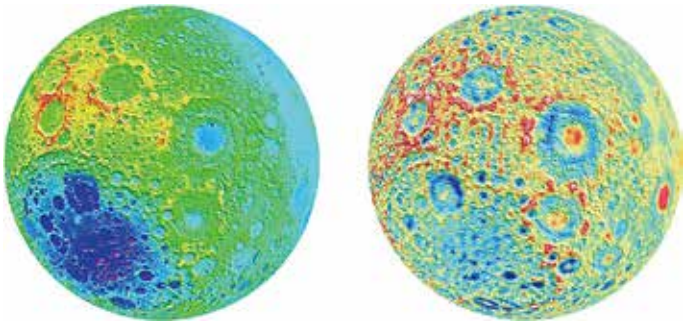
We Investigate the Evolution of Solar System Bodies by Spacecraft Exploration

We restarted a project with a new status, phase-A (future missions), in April, 2012. The term of "RISE" now stands for "Research of Interior Structure and Evolution of solar system bodies". We have obtained important results in SELENE (Kaguya) such as clarifying the lunar gravity field in the far side and creating the global topographic map including the polar region through development and operation of radio sources for VLBI and laser altimeter.

Our goal is to elucidate the origin and the evolution of the solar system bodies by studying their interior. We therefore intend to develop our research further by promoting exploration of not only the Moon but also the other solar system bodies such as Mercury, Mars, Jovian system, and asteroids. Now we are preparing for the study of an asteroid currently called Ryugu with collaborators in JAXA, universities and institutes by using a laser altimeter aboard Hayabusa2 asteroid explorer. We also participate in the development of a laser altimeter called “GALA” (Ganymede Laser Altimeter) with Germany, Switzerland, and Spain for the JUICE mission, which will explore the Jovian system.

▲Imaginary figure of touch-down of Hayabusa2 spacecraft on the asteroid Ryugu (JAXA)

Director :
Prof. NAMIKI, Noriyuki



▲The first accurate lunar topography map (left) and gravity anomaly map (right). (NAOJ/Chiba Inst. tech./JAXA)

IR V UV EUV X

SOLAR-C Project Office

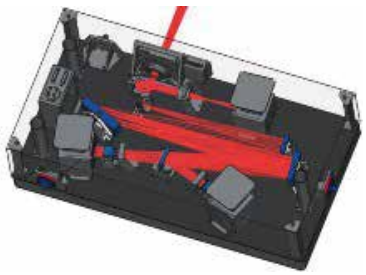
2-21-1, Osawa, Mitaka, Tokyo 181-8588
Phone +81-422-34-3705
http://hinode.nao.ac.jp/SOLAR-C/index_e.html

Planning of the SOLAR-C Mission for Visualizing the Origin of Solar Activity

We aim to carry out the SOLAR-C satellite mission which follows HINODE to elucidate the fundamental physical processes that govern the solar activity. HINODE observations have shown that there are unexpected ubiquitous activity consisting of tiny jets and waves in the 10^4 K temperature chromosphere, and new small-scale heating events with dynamical motions at the base of the corona. These are understood as phenomena that are strongly associated with the solar magnetic fields. Based on unprecedented high-resolution spectroscopic observations in UV/EUV, SOLAR-C will resolve the fundamental structures formed by magnetic fields in the upper solar atmosphere. It will reveal the origins of solar activity through the measurement of energy and mass transport in the chromosphere and corona. We are also perusing sounding-rocket and balloon programs to acquire the necessary technology for high precision spectroscopy in space.

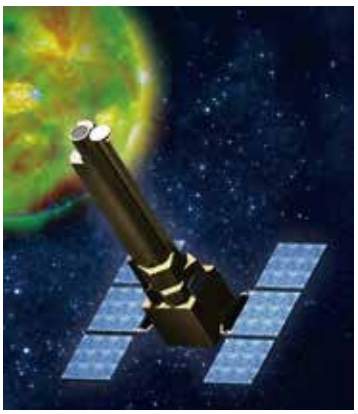
▲FOXSI-3; a sounding rocket experiment to conduct X-ray photon counting observation. (NAOJ, JAXA, UMN, UCB、NASA/GSFC).

▲CLASP-2; a sounding rocket experiment to conduct UV spectropolarimetry. (NAOJ、JAXA、NASA/MSFC).



▲Sunrise-3/SCIP; a balloon experiment to conduct IR spectropolarimetry. (NAOJ/JAXA).

Director :
Prof. ICHIMOTO, Kiyoshi



▶Solar-C satellite in orbit (artist’ s illustration) with solar image in EUV. credit: NAOJ/JAXA/NASA.

memo

EUV Extreme ultraviolet radiation

Extreme ultraviolet radiation is electromagnetic waves with wavelengths between 10 nm and 124 nm. This wavelength is well suited for the observation of high-temperature astronomical phenomena, from 10,000 degrees C to 20,000,000 degrees C. These observations must be conducted outside the atmosphere.

Departments of NAOJ　Centers & Divisions

Three Centers Developing NAOJ's Strengths, and Four Research Divisions Supporting NAOJ

The three Centers exceed the framework of individual projects and play key roles in equipment development/technological research, the numerical simulations, data analysis, data archiving, and public outreach activities. The Centers simultaneously have characteristics of both projects and basic infrastructures of NAOJ. The four Research Divisions have been newly set up to secure spontaneous ideas and individual research by each astronomer as well as to enhance the flexibility of our staff. Each researcher working for their project belongs to one of these infrastructures.

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- GW Gravitational Wave (Different from electromagnetic wave)

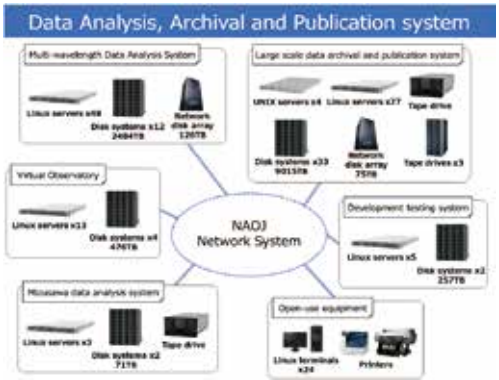
▲Snowy morning (Mitaka Campus) . The winter sunlight shines on the snow-clad Musashino forest.

Astronomy Data Center

2-21-1, Osawa, Mitaka, Tokyo 181-8588
Phone +81-422-34-3600
https://www.adc.nao.ac.jp/E/index-e.htm

Center of Data Intensive Astronomy

As one of the largest data centers in the world, the Astronomy Data Center (ADC) is a "hub" of astronomical data and will launch a new era, where Data-Intensive Astronomy is the fourth paradigm in astronomy. ADC delivers observational data from NAOJ's Subaru Telescope, ALMA, Nobeyama Radio Telescopes, VERA, ASTE, HINODE, RISE, and so on. Data from other observatories in the world are also delivered through the "Japanese Virtual Observatory (JVO)". Since observational research is often conducted by data analyses, ADC also supports various data reduction software, covering a wide range of wavelengths. ADC operates an extremely high-speed and secure computer network with a maximum speed of 100 Gbps. In addition to supporting astronomical research activities, ADC research staff have their own research goals such as reducing the large amounts of data produced at astronomical observatories accurately and effectively, and enhancing network security under distributed and complicated network configurations.



▲The NAOJ Data Analysis, Archival, and Publication system that has been in operation since March, 2018.

▲SMOKA . Raw observational data publication system for the Subaru Telescope and other observatories.

◀The JVO system enables the exchange and publication of observed data between astronomical observatories worldwide.

Director :
Assoc. Prof. Dr.
TAKATA, Tadafumi

memo　X X-ray　Electromagnetic waves with wavelengths between 0.01 nm and 10 nm. We can investigate high-energy and super high-temperature phenomenon in the Universe. Because the Earth's atmosphere completely absorbs X-rays, observations of this wavelength are made from outside the atmosphere.

Advanced Technology Center

2-21-1, Osawa, Mitaka, Tokyo 181-8588
Phone +81-422-34-3600
http://atc.mtk.nao.ac.jp/E/index_e.html

Center for Advanced Instrumentation and Technology Development for Astronomy

Advances in astronomy are realized through state-of-the-art instrumentation. Many advanced NAOJ projects require the development of the latest technologies that are not readily available elsewhere. Basic development of key technologies is also critically important for our future. The Advanced Technology Center (ATC) provides a platform to meet the current and future technology needs in astronomy. ATC owns world-class equipment such as high-quality clean rooms for the SIS mixer for ALMA and space-astronomy instruments, space chambers, optical methodology instruments, ion-beam sputtering machines for thin-film coating, and precision machinery. These facilities are widely used by scientists and engineers both inside and outside of NAOJ. Our products include Hyper Suprime-Cam (HSC) on the Subaru Telescope, the solar observation satellite Hinode, and the ALMA band 4, 8 and 10 receivers. We are developing the gravitational waves detector KAGRA, and the focal plane instruments for the Thirty Meter Telescope (TMT) as well as various basic development programs vital for future ground-based and space astronomy.

▲Large clean room for the development of space-astronomy instruments.

Director :
Prof. TAKAMI, Hideki

▶The machine shop for fabrication of astronomical instruments and for consultation on manufacturing solutions.

Public Relations Center

2-21-1, Osawa, Mitaka, Tokyo 181-8588
Phone +81-422-34-3600
https://prc.nao.ac.jp/prc/en.php

We Present the Latest Scientific Knowledge of the Universe in Understandable Ways.

The Public Relations Center (PRC) was created in 1998 to share the latest astronomy research results with the public. We communicate and promote research breakthroughs in a manner that is understandable, relevant, and exciting. For this purpose, we offer a range of services and deliver amazing scientific information through a variety of media including the Web and scientific publications. We have also built an effective partnership with dissemination experts working for public observatories, science museums, and planetariums. The PRC is organized into seven branches: the Public Relations Office, the Outreach and Education Office, the IAU Office for Astronomy Outreach, the Ephemeris Computation Office, the Publications Office, the Library and the General Affairs Office. We also collect information about newly discovered objects and provide astronomical reading materials for the public.

▲On Mitaka campus, a 50-cm (diameter) telescope is used for social education programs including stargazing and observation practice. We offer stargazing parties for the public twice per month, on the Friday before the second Saturday and on the fourth Saturday. PRC supports students who come for practice observation or extracurricular classes.

Director :
Prof. FUKUSHIMA, Toshio

▼We answer more than 10 thousand questions a year from the general public.

memo

GW Gravitational wave

Unlike electromagnetic waves, gravitational waves are ripples in the fabric of space-time itself. Because their effects are very small, scientists were unable to directly observe them until 2015. They carry information about gravitational phenomena which are fundamentally invisible to electromagnetic waves.

IR V

Division of Optical and Infrared Astronomy

2-21-1, Osawa, Mitaka, Tokyo 181-8588
Phone +81-422-34-3600
http://optik2.mtk.nao.ac.jp/index-e.html

Ever Powerful Tool of Exploration - Visible Universe with Enhanced Sight.

It is possible to see entirely different universes when we look at our Universe in different wavelengths. The Universe observed in optical and infrared wavelength looks just as it does when you see it with your own eyes. Instead of eyes, we use large ground-based telescopes such as the 8-m Subaru Telescope, which have thousands to millions of times greater visual power than eyes, in order to investigate the Universe to answer many unsolved questions. What structure does our Universe have ? When was it born? How were planets and stars born? When and how did life appear in the Universe? We would like to answer these fundamental questions thorough our various scientific research. We are also working as liaison for different projects, the promotion of exploratory projects, public outreach, and education of graduate students.

Division Chair:
Assoc. Prof.
HAYASHI, Saeko S.

▼Member of Division.

cm mm smm

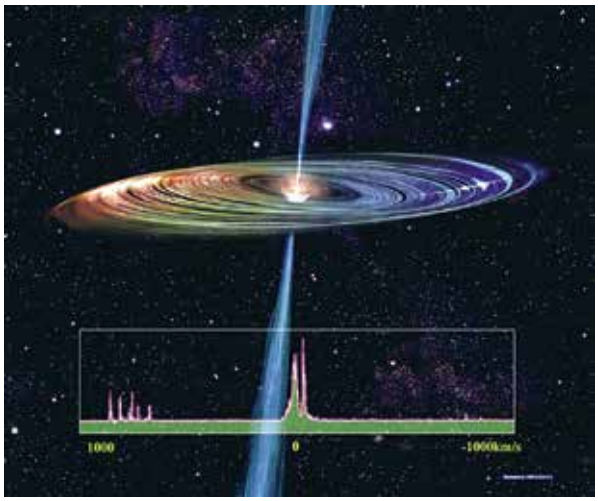
Division of Radio Astronomy

2-21-1, Osawa, Mitaka, Tokyo 181-8588
Phone +81-422-34-3600

Radio Astronomy to Explore the Universe Not Seen at Optical Wavelengths

Radio astronomy unravels mysteries and phenomena of the Universe by studying pictures taken at radio wavelengths invisible to human eyes. There are many questions about the Universe that have yet to be answered, including “How were galaxies formed after the Big Bang?” “How have galaxies evolved for 13.8 billion years and developed into the Milky Way Galaxy where we live?” “What is the detailed structure of the Milky Way Galaxy like?” “What is the formation process of the Solar System and other planetary systems?” “What did it take to give birth to the Earth abundant in fauna and flora, and also to the Moon close to the Earth?” and, “How and when did life arise during the evolution process of cosmic materials?” These questions and other mysteries of the Universe are studied in close cooperation by the members of the Division of Radio Astronomy of the National Astronomical Observatory of Japan : the Nobeyama Radio Observatory, the Mizusawa VLBI Observatory, the RISE Project, and the NAOJ Chile Observatory that has constructed the ultimate radio telescope in Chile.

▼Artist's impression of the rotating disk around the supermassive black hole in NGC 4258. From measurements of the disk's rotation speed of 1000 km/s, the mass of the black hole is estimated to be 36 million times the mass of the Sun. (Credit: J. Kagaya)



Division Chair :
Prof. IGUCHI, Satoru

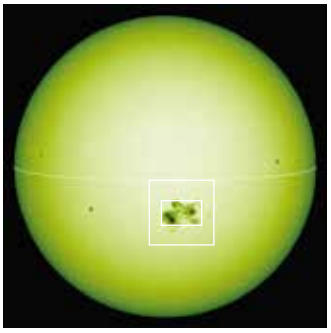
cm IR V UV EUV X

Division of Solar and Plasma Astrophysics

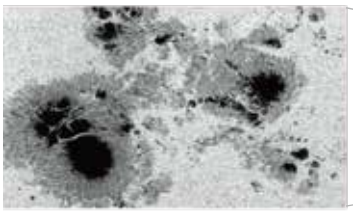
2-21-1, Osawa, Mitaka, Tokyo 181-8588
Phone +81-422-34-3600
http://solarwww.mtk.nao.ac.jp/en/index.html

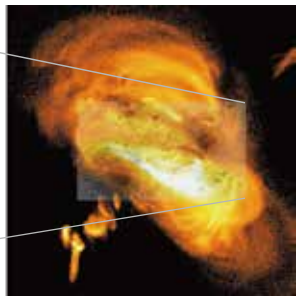
The Sun is Our Star Just Right There

The Sun is a star only 150 million kilometer away from the earth. The earth is full of life, not freezing cold, owing to the energy supplied from the Sun. Occasionally the Sun shows "flare explosion", and the blast wave reaches the earth in about one day and shakes the magnetosphere and produces aurorae. In the Division of Solar and Plasma Astrophysics, we are studying the Sun from its interior to the surface and to the outer atmosphere (the corona), using both of the ground-based and spaceborne solar telescopes. Our challenge is to understand the mechanism of the Sun's magnetic activity and its influence on the earth and human activity.



Division Chair :
Dr. HANAOKA, Yoichiro





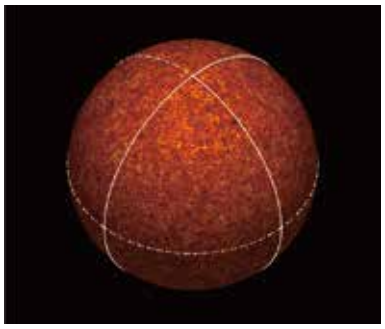
The Sun from the ground and from the space
These pictures show a big sunspot group appearing on 2014 Oct 24. Many flares occurred around these spots. The above two pictures, which are taken by ground-based telescopes, show the photoshere (left) and the chromosphere (right). The below two, taken with spaceborne telescopes, show the details of the sunspot group (left, showing the area of the inner box of the above left picture) and surrounding corona (right, the outer box of the above left picture).

Division of Theoretical Astronomy

2-21-1, Osawa, Mitaka, Tokyo 181-8588
Phone +81-422-34-3600
http://th.nao.ac.jp/index_en.html

Theoretical Astronomy : Intellectual Bases of Astronomy.

We are working on theoretical astronomy and astrophysics. It may often be imagined that an astronomer watches the dark sky every night through a telescope. Instead, we use papers, pencils and computers to carry out our research. Being motivated by the latest observational data, we are trying to extract the essence of various complicated astronomical phenomena. Occasionally we request telescope time to prove a theory. The development of astronomy is brought about by both theoretical and observational work. The objects we are investigating are diverse: moons, planets, stars, space plasma, galaxies, clusters of galaxies, active galactic nuclei, large scale structures of the Universe, and the Universe itself. One of our major efforts is dedicated to numerical simulations. Unlike experiments in the laboratory, astronomical phenomena are usually impossible to examine from many viewpoints. Numerical simulations make it possible to investigate these phenomena in detail. We are using the CfCA supercomputer, which is among the best in the world, as a “Telescope for Theory” and producing the newest research results.



▲Dark matter distribution causing gravitational lensing effect of distant galaxies.

Division Chair:
Prof. TOMISAKA, Kohji

▼Member of Division.

Office of International Relations

2-21-1, Osawa, Mitaka, Tokyo *181-8588*
Phone +81-422-34-3600
http://naoj-global.mtk.nao.ac.jp/index.html

We Facilitate the Internationalization of NAOJ

The Office of International Relations strives to promote further internationalization at NAOJ by maintaining an environment where multi-cultural researchers and students can engage cooperatively in research and educational activities. We are engaged in the promotion of astronomical research and education in the East Asian region by serving as the Secretariat of the East Asia Observatory (EAO) and the East Asian Core Observatories Association (EACOA). We also conduct preliminary legal review of agreements, provide translations for official documents written in Japanese, and handle Security Export Control. Through the Support Desk, we offer assistance to our international staff and students throughout their entire stay in Japan, including arrangements to ensure a smooth arrival and departure. We also encourage international understanding by providing Japanese language classes and organizing events to experience Japanese culture such as Tanabata, Otsukimi, and Setsubun.

▲Our first booth exhibition at the AAS (American Astronomical Society) Meeting in Washington D.C. where we received many positive responses. We plan to exhibit at various international conferences in the near future.

◀A "Setsubun Party" was held to facilitate better communication between the international & Japanese staff and students. This lively international party provided opportunities for the participants to meet and interact with researchers and students from other projects.

Director:
HASUO, Ryuichi

Ishigakijima Astronomical Observatory

Observatory on a Tropical Island Where the Southern Cross and 21 Stars of the First Magnitude Twinkle

The observatory is located on Ishigakijima at 24 degrees north latitude, on the southwest edge of Japan. The "Southern Island Star Festival" that started with the foundation of the VERA Ishigakijima Station has developed into an event in which 10,000 people participate. Meanwhile, the observatory was constructed for astronomy outreach and observational study of Solar System bodies in 2006. Observations are powerfully performed for transient objects such as gamma-ray burst afterglows, supernovae, and comets. In 2013, the astronomy lecture room where we can enjoy the 4D2U (Four-Dimensional Digital Universe) theater was established as an annex to the observatory. Including the participants for the star parties held on weekends and holidays, Over 10,000 people visit there annually.

▲The Ishigaki-jima Astronomical Observatory and the Milky Way. The 105-cm reflecting telescope is the largest in the Kyushu and Okinawa areas and is known by the name "MURIKABUSHI（star cluster, Pleiades）".

4D2U Dome Theater

The Theater Takes Us to the Four-Dimensional Universe

▲Screening at the 4D2U Dome Theater.

How big is our Universe? What kind of celestial bodies are in it? Mapping of the Universe reveals the Universe we live: Earth in the Solar System, stars nearby the Sun, Milky Way Galaxy with hundreds of billions of stars, nearby galaxies, and large-scale structure of the Universe. The 4D2U (Four-Dimensional Digital Universe) Dome Theater has the atlas of our observable Universe based on astronomical observations. Movie contents visualize numerical simulations of astronomical research and show us how the Universe evolved in its 13.8 billion-years history. At the theater, you will find a clue to answer fundamental questions such as: What are we? Where did we come from?

●When is the theater open?

The 4D2U Dome Theater is open every month on the Friday before the second Saturday and, on the first, second, third Saturdays (reservations required). Currently operated in Japanese only.
Visit https://prc.nao.ac.jp/4d2u/ , for details in Japanese.

Time Keeping, Ephemeris Computation, and Open Houses of NAOJ

Japanese Central Standard Time and Atomic Clocks

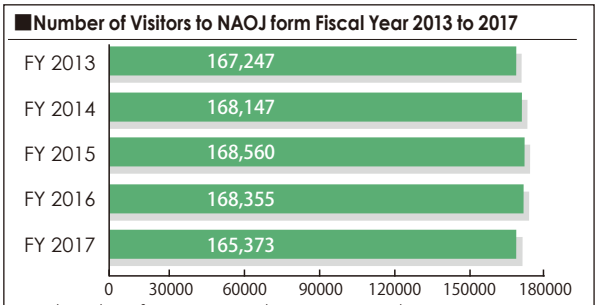
The Astronomical Time Keeping Office determines and sets Japanese Central Standard Time. It has been annexed to the Mizusawa VLBI Observatory and runs a group of atomic clocks for keeping time. The clocks are compared with those of other time keeping centers around the world via the GPS satellite link and contribute to the determination of the International Atomic Time, the world's standard time. The Mizusawa VLBI Observatory contributes to the determination of the Universal Time based on the Earth's rotation by observing quasars with VLBI. Japanese Central Standard Time is determined through these observations and disseminated through the NTP service.

Atomic clocks at the Time Keeping Office. The office encourages the development and studies of high-precision time measurement and for the dissemination of time signals for astronomical observations, such as the observations of pulsars. It also provides official approval for clocks.

Open Houses of NAOJ

NAOJ Welcomes Visitors to Our Research and Observation Facilities.

We release the latest findings and research results to the public. Many outreach activities are also provided such as the Visitors' Area, open house days, and regular stargazing parties at the headquarters and other observation facilities. Our activities are getting popular and the annual number of visitors to NAOJ campuses has exceeded 150,000 in recent years. Our outreach programs cover various themes and purposes to meet a broad range of public interest in astronomy and outer space.



Total number of visitors to Mitaka, Mizusawa, Nobeyama, Okayama (FY 2017 activities ceased on October 4), Hawai'i and Chile campuses.

Mitaka, Mizusawa and Nobeyama Campuses are open daily to the public and annual open house days are held at each campus. It is also possible to tour the Subaru Telescope Enclosure in Hawai'i and the ALMA Operations Support Facility in Chile. Our staff members at other campuses also offer public outreach programs such as open house days, special stargazing parties, and guided tours of the facilities. Each campus has set up its own website to communicate a variety of information. Everybody can enjoy virtual-tours of our research and observation facilities, and learn about cutting-edge astronomy.

●Mizusawa VLBI Observatory

http://www.miz.nao.ac.jp/en
2-12 Hoshigaoka, Mizusawa, Oshu, Iwate, 023-0861
Phone +81-197-22-7111

- **Visitors' Area** (Open hours; 9:00 ~ 17:00 except Year-end and New Year Holidays)
- **Annual Open House Day**

Kimura Hisashi Memorial House is one of the main pageantries of Mizusawa sightseeing. Visitors can learn about the history of the first Director of the Latitude Observatory, Dr.Hisashi Kimura, who discovered the z-term of the latitude variation.

●VERA Iriki Station
●VERA Ogasawara Station
●VERA Ishigaki-jima Station

- **Visitors' Area** (Open hours; 9:00 ~ 17:00 except Year-end and New Year Holidays)
- **Annual Open House Day**

●Ishigakijima Astronomical Observatory

- **Visitors' Area** (Open hours; 10:00 ~ 17:00 except Mon. and Tue., Year-end and New Year Holidays)
- **Regular Stargazing Parties** (19:00 ~ 22:00 on Sat. Sun. and holidays)

Oshu Uchu Yugakukan.

●NAOJ Mitaka (the headquarters)

https://www.nao.ac.jp/en/
2-21-1 Osawa, Mitaka, Tokyo, 181-8588 Japan
Phone +81-422-34-3600

- **Visitors' Area** (Open hours; 10:00~17:00 except Year-end and New Year Holidays)
- **Annual Open House Day**
- **Regular Stargazing Parties** (Reservations required, see page 24)
- **4D2U Dome Theater Screenings** (Reservations required)

Guidebook of the Visitors' Area on Mitaka Campus. Japanese, English, Chinese, Korean and Spanish versions are available.

●Nobeyama Radio Observatory

http://www.nro.nao.ac.jp/en/
462-2 Nobeyama, Minamimaki, Minamisaku, Nagano, 384-1305
Phone +81-267-98-4300

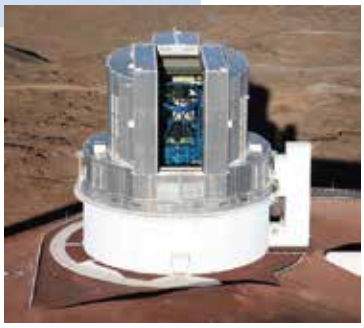
- **Visitors' Area** (Open hours; 8:30~17:00 except Year-end and New Year Holidays)
- **Annual Open House Day**

Photo of the annual open house day on Nobeyama Campus. The Visitors' Area has become a pillar of Nobeyama sightseeing.

●Subaru Telescope (in Hawai'i)

http://subarutelescope.org/index.html
650 North A'ohoku Place, Hilo, Hawai'i, 96720, U.S.A.
TEL +1 (808) 934-7788

- **Public Tour inside the enclosure**
  (Reservation is required through the Subaru Telescope's website for pre-scheduled time slots.)



The Subaru Telescope enclosure. Visitors can tour this facility and see the giant telescope up close.

●ALMA (in Chile)

https://alma-telescope.jp/en/visit
Kilometro 121, Carretera CH 23, San Pedro de Atacama Chile

- **Public Visits to the ALMA Operations Support Facility**
  (Every Saturday and Sunday. Reservations are required through the ALMA observatory's website.)

Guests see an antenna under maintenance. Detailed explanations (Spanish and English) are provided by professional guides.

Almanacs and "*Rika Nenpyo* (Chronological Scientific Tables)"

Almanacs The Ephemeris Computation Office computes the 24 Sekki, the traditional Japanese seasons markers, such as vernal and autumnal equinoxes. It also calculate the rising and setting of the Sun and the Moon, solar and lunar eclipses, planetary phenomena, etc., and produces a "Calendar and Ephemeris" each year. On February 1st, we announce its summary as "Reki Yoko" in the official gazette. Since the information on the koyomi (citizen's calendar) is closely related to human life, we also publish "Rika Nenpyo" and provide useful tools on our website to make them available for many people to use.

Rika Nenpyo

In cooperation with many research organizations, we have been publishing "Rika Nenpyo" , which has a history of over 90 years as the most reliable data source for natural sciences in Japan.

"Rika Nenpyo" has been quoted in many examinations and textbooks.

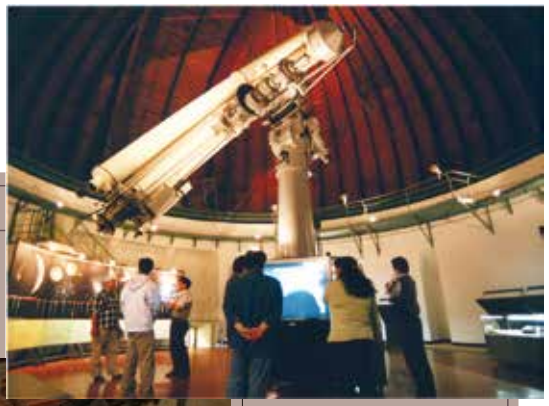
Visitors' Area at Mitaka Campus

Visitors' Area is open daily to the public except Year-end and New Year Holidays.

Open Hours : From 10:00 AM to 5:00 PM

Observatory History Museum

The dome built in 1926 was renovated as a museum. The 65-cm telescope is the largest refractor in Japan. Panels, old instruments, and documents illustrating the history of NAOJ are displayed inside of the dome.



65-cm Refractor Telescope

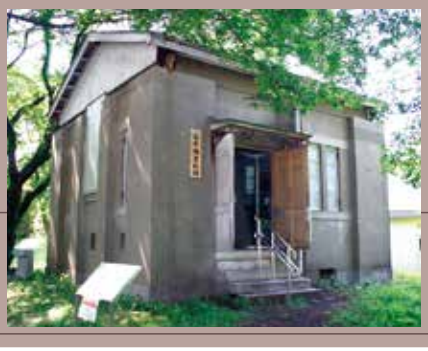
We preserved the big 65-cm Refractor Telescope at the center on the deck of the second floor. The telescope was used for astronomical research observations until 1998.

65-cm Telescope Dome

This is a big structure with a height of 19.5 meters and a dome diameter of 15 meters. In the late 1920' s, Japanese builders had no techniques to build a semi-spherical dome. So the construction of the dome was conducted by shipbuilders, who had techniques for building ship hulls. It became a Registerd Tangible Cultural Property of Japan.

Exhibits

Exhibits on the first and second floors display various photos, documents, instruments, and so on to explain the past and present of NAOJ.



Repsold Transit Instrument Building

This building was erected in 1925. In 2011 the Repsold Transit Instrument was registered as an Important Cultural Property of Japan, because of its value in the historical development of Japanese astronomy.

Exhibition Room

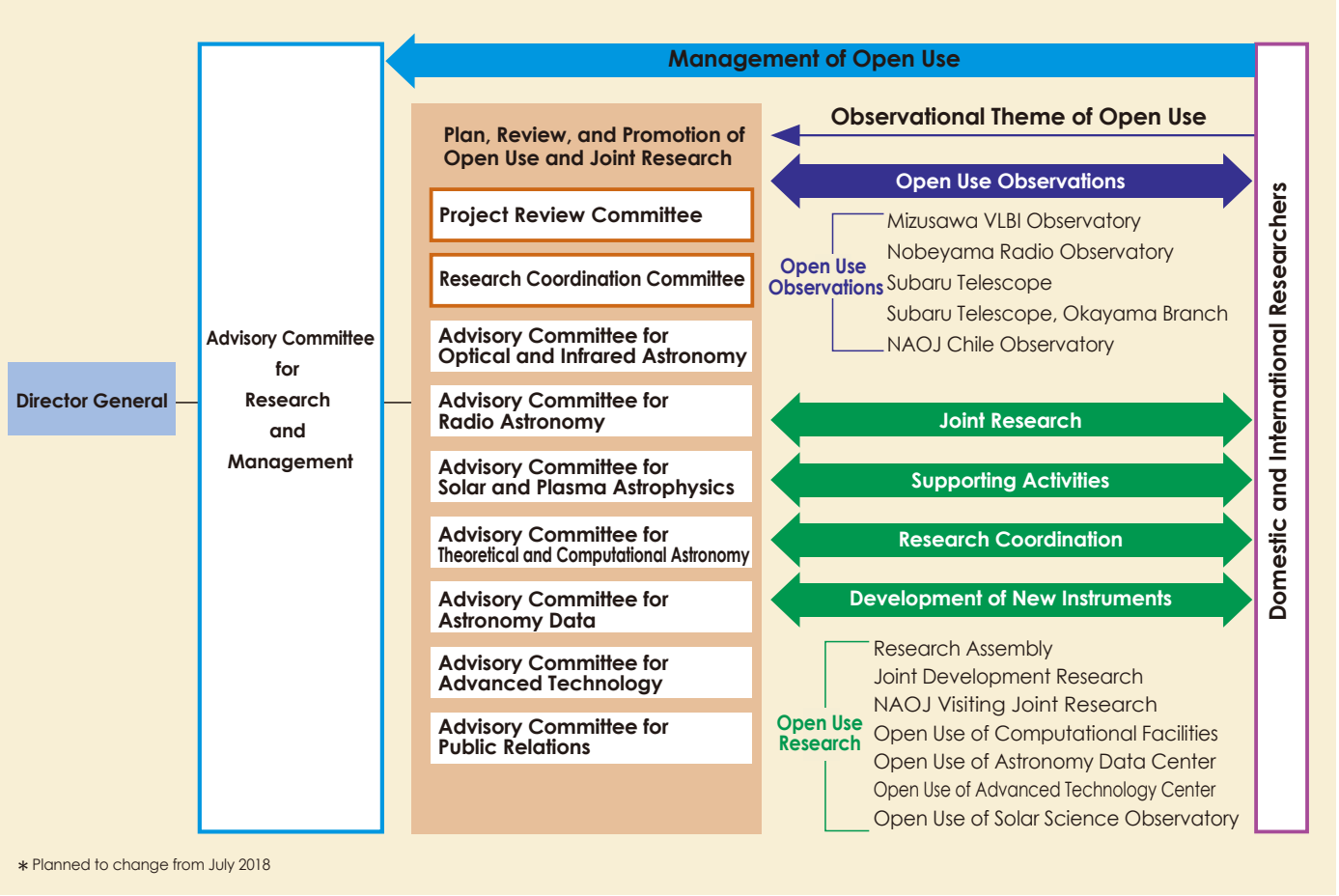
The Exhibition Room in the Visitors' Area of the Mitaka Campus contains models of the state-of-the-art, major telescopes of NAOJ such as the Subaru Telescope, the Nobeyama 45-m Radio Telescope, ALMA, and TMT. There are also many displays explaining the recent results of our research.

Solar Tower Telescope

The Solar Tower Telescope (Einstein Tower) is located in the Visitors' Area of the Mitaka Campus. It was completed in 1930 and its classic architecture represents the so-called Taisho-Era style. It is preserved as a Registerd Tangible Cultural Property of Japan. The inside of the tower is closed to the Public.

NAOJ as an Inter-University Research Institute

As an open-use institute for universities, the National Astronomical Observatory of Japan (NAOJ) actively promotes joint observation and joint research programs, as well as international cooperative projects. The success of these activities is based on the foundation of research and education provided by universities and other institutes throughout the country. To promote the open use of our facilities based on active relationships with researchers nationwide, NAOJ provides the following arrangement:



∗ Planned to change from July 2018

Administration for Open Use

As an open-use institute for universities, the National Astronomical Observatory of Japan (NAOJ) is administrated by astronomical researchers from universities and related institutes as well as by NAOJ staff. The Advisory Committee for Research and Management, an interface between the astronomical community and NAOJ, is the highest committee to determine key issues for management, such as overseeing personnel administration, restructuring, and so on.

NAOJ Advisory Committee for Research and Management (the eighth term)

(period; April 1, 2018—March 31, 2020)

From universities and related institutes

ICHIMOTO, Kiyoshi : Professor, Graduate School of Science, Kyoto University

OHASHI, Masatake : Professor, Institute for Cosmic Ray Research, The University of Tokyo

KAWAKITA, Hideyo : Professor, Faculty of Science, Kyoto Sangyo University

KUSANO, Kanya : Professor, Institute for Space-Earth Environmental Research, Nagoya University

CHIBA, Masashi : Professor, Graduate School of Science, Tohoku University

○ **DOI, Mamoru** : Professor, Graduate School of Science, The University of Tokyo

FUJISAWA, Kenta : Professor, The Research Institute for Time Studies, Yamaguchi University

MATSUSHITA, Kyoko : Professor, Faculty of Science Division I, Tokyo University of Science

MITSUDA, Kazuhisa : Professor, Institute of Space and Astronautical Science

MURAKAMI, Izumi : Professor, National Institute for Fusion Science

From NAOJ

IGUCHI, Satoru : Vice-Director General (on Finance)

USUDA, Tomonori : Professor, TMT-J Project Office

GOUDA, Naoteru : Professor, JASMINE Project Office

KOKUBO, Eiichiro : Professor, Center for Computational Astrophysics

SAITO, Masao : Director of Research Coordination

SAKAMOTO, Seiichi : Professor, NAOJ Chile Observatory

TAKAMI, Hideki : Director of Engineering

TOMISAKA, Kohji : Professor, Division of Theoretical Astronomy

HONMA, Mareki : Professor, Mizusawa VLBI Observatory

YOSHIDA, Michitoshi : Professor, Subaru Telescope

◎ **WATANABE, Junichi** : Vice-Director General (on General Affairs)

◎Chair ○Vice-Chair (listed in the order of Japanese phonetics)

Graduate Course Education

NAOJ constitutes the Department of Astronomical Science of the Graduate University for Advanced Studies (SOKENDAI). NAOJ also cooperates with the Graduate School of Science of the University of Tokyo to educate graduate students. In addition, graduate students from other universities study at NAOJ. Through the educational activities above, NAOJ contributes to fostering the education of graduate students in a variety of leading research fields.

Number of Graduate Students (as of April 1, 2018)

SOKENDAI (five-year doctoral course) ····· 24
Other Universities (master and doctoral course) ····· 28

■Department of Astronomical Science, School of Physical Sciences, the Graduate University for Advanced Studies (SOKENDAI)

●We accept both 3- and 5-year doctoral candidates, the latter is a unified 2-year masters and 3-year doctoral course. The entrance examinations for 3-year doctoral course usually are held August and January.
(except in FY 2018 it will be in September and January)

●Five-year doctoral course. The entrance examination usually is held in every August.
(except in FY 2018 it will be in September)

●Course Organization

- Optical and Near Infrared Astronomy Course
- Radio Astronomy Course
- General Astronomy and Astrophysics Course

■Visiting Graduate Students Program

Graduate students from the University of Tokyo, Tohoku University, and so on (FY 2018)

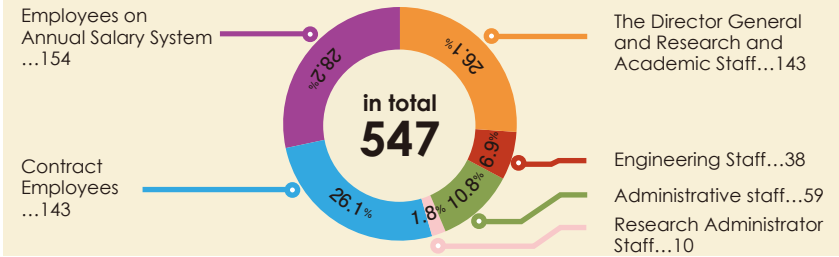
Cooperation in Graduate Course Education

Graduate School of Science, the University of Tokyo
Graduate School of Science, Kyoto University
Graduate School of Science and Engineering, Kagoshima University
Graduate School of Science, Toho University
Graduate School of Science, Tohoku University
Graduate School of Science, Hiroshima University
Graduate School of Science, Kobe University
Graduate School of Humanities and Science, Ochanomizu University
Graduate School of Science and Engineering, Hosei University
Graduate School of Engineering, Iwate University

▲ An observation training course at the Subaru Telescope

Profile of NAOJ (as of April 1, 2018)

■Number of Employee



■Campus Area

1,020,662m²
(tenancy 559,127m²)

■Budget (including personal salaries)

12,810,888,000 yen

History of NAOJ (1888-2018)

Tradition and the Leading Edge. NAOJ Continues to play a Key Role in Japanese Natural Sciences.

NAOJ was established in 1988 as an Inter-University Research Institute by reorganizing the Tokyo Astronomical Observatory of the University of Tokyo, the Latitude Observatory, and a part of the Nagoya University Atmospheric Research Center. The antecedent institutes had long histories and made many research contributions.

1888	The Tokyo Astronomical Observatory was established by the Faculty of Science, the University of Tokyo.
1899	The Latitude Observatory was established in Mizusawa.
1908	Astronomical Society of Japan was established.
1925	Publications of "Rika Nenpyo" began.
1946	Publication of Almanacs and "Calendar and Ephemeris" began.
1949	The Nagoya University Atmospheric Research Center was established.
	Norikura Solar Observatory began observations.
1960	Okayama Astrophysical Observatory began observations.
1969	Nobeyama Solar Observatory began observations.
1970	Nobeyema 6-m Radio Telescope began observations.
1972	A Leap second began to be included calendar calculations.
1981	Astronomical Satellite "HINOTORI" began solar observations.
1982	Nobeyama Radio Observatory began observations.
1988	The National Astronomical Observatory of Japan was established.
1991	Astronomical Satellite "YOHKOH" began solar observations.
1992	Nobeyama Radioheliograph began observations.
1996	Introduction and open use of supercomputers.
1997	Space VLBI satellite "HALCA" began observations.
1999	Subaru Telescope began observations.
	Laser Interferometer Gravitational Wave Antenna "TAMA300" began observations.
2000	Visitors' Area opened at Mitaka Campus.
2001	Agreement of ALMA project among Europe, the United States, and Japan.
	VERA Stations began observations.
2004	NAOJ was incorporated as the National Astronomical Observatory of Japan, National Institutes of Natural Sciences.
	Construction of ALMA began.
2006	Ishigakijima Astronomical Observatory began observations.
	HINODE began solar observations.
2007	As a part of the Four-Dimensional Digital Universe (4D2U) project, the tridimensional dome theater was completed.
	The Lunar Explore "KAGUYA" was launched and began observations.
2008	One of 12-m antennas of NAOJ was certified as the first ALMA antenna.
2010	Norikura Solar Observatory was closed after 60 years of service.
2013	Regular ALMA observations started.
2014	TMT International Observatory was established.
	NAOJ participated as an initial member.
2015	Nobeyama Solar Observatory was closed.
2018	Okayama Astrophysical Observatory was closed.

Now, we understand that star ……

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