Contact info.

National Astronomical Observatory of Japan
National Institutes of Natural Sciences, Japan
2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan
https://www.nao.ac.jp/en

Subaru Telescope
650 North A'ohōkū Place, Hilo
Hawai'i 96720, U.S.A.
https://www.subarutelescope.org

(2019.8)

This project is supported by "Project to Promote Large Scientific Frontiers" of MEXT.

Subaru Telescope

すばる望遠鏡

8.2 m Optical-Infrared Telescope

NAOJ/NINS

Subaru Telescope’s Endeavor

Stargazing compels us into no end of nostalgia at times. This Universe, where we humans live, has brought us into existence. This is an incontrovertible fact, and we may unconsciously reflect on this when looking at stars.

The Subaru Telescope saw its first light in 1999, and commenced its open use observations in 2000. Many innovative devices are utilized in the Subaru Telescope to achieve high-resolution observation of celestial bodies, including the primary mirror which was polished with supreme precision, the active control system with 261 robotic fingers to support the mirror, and the cylindrical enclosure that controls the airflow and removes heat shimmer. Its robust mounting structure provides a platform for instruments to be installed at prime focus that widens a field of view. A set of these technologies enable the Subaru Telescope to image a wide field of view, as well as to attain high resolution, without parallel to any other large telescopes.

Hyper Suprime-Cam (HSC), a key component currently in full operation, is the perfect instrument to leverage the Subaru Telescope’s advantages. With its exceptional imaging capability, HSC contributes to a wide array of research fields that includes cosmology, galaxy formation and evolution, and probes of celestial bodies in the Solar System. Prime Focus Spectrograph (PFS), being developed now, will allow spectral observation of 2,400 targets at a time with an aim to further advance results delivered by HSC. This new instrument to be in operation soon will significantly enhance effectiveness of the Subaru Telescope’s observation, greatly accelerating research progress.

Furthermore, adaptive optics instruments are currently utilized to the full extent to maximize the Subaru Telescope’ s capability of high-resolution imaging. They demonstrate the capabilities in observation of exoplanets, and deliver a series of breakthrough discoveries in research of stellar and planetary formation processes.

What is this attraction we feel when gazing stars? Pursuing this question, astronomers are constantly dedicated to unraveling the mysteries of the Universe from a scientific perspective. NAOJ’s Subaru Telescope provides opportunities and assistance for astronomers through maintenance of the telescope and development of new instruments. As a world-leading optical-infrared telescope, the Subaru Telescope firmly aims at further progress of astronomy.

The Subaru Telescope is located in the summit area of Maunakea, which rises well above most of Earth’s weather systems and much of the water in the atmosphere. Maunakea is one of the premier sites for astronomy; air flows smoothly over the summit since it is far removed from other land masses, and with no large cities nearby, there is almost no light pollution to hinder observations.

Maunakea is a spiritual and cultural landmark as well as a historical resource. The mountain is also home to rare plants, animals and geologic features. The Subaru Telescope and other telescope facilities located within the Astronomy Precinct are required to ensure sustainable use of the land with proper management.

Superb Light-Collecting and Resolving Power

The main function of a telescope is to collect light. The Subaru Telescope uses a large 8.2-meter diameter primary mirror for this purpose. As the telescope's mirror collects incoming light, it must bring it into sharp focus. Thanks to careful site selection, innovative enclosure design, and the use of pioneering technologies, the Subaru Telescope is able to observe never before seen areas of the Universe. Computerized actuators maintain the shape of the world's smoothest single-piece primary mirror with a surprisingly small margin of error (0.014 microns or 1/2,000,000 in.). The cylindrical enclosure minimizes air turbulence in and around the building. Linear motors drive the telescope mount smoothly and accurately. As a result of these innovative technologies, the Subaru Telescope can obtain its high resolution and has an international reputation for excellent image quality.

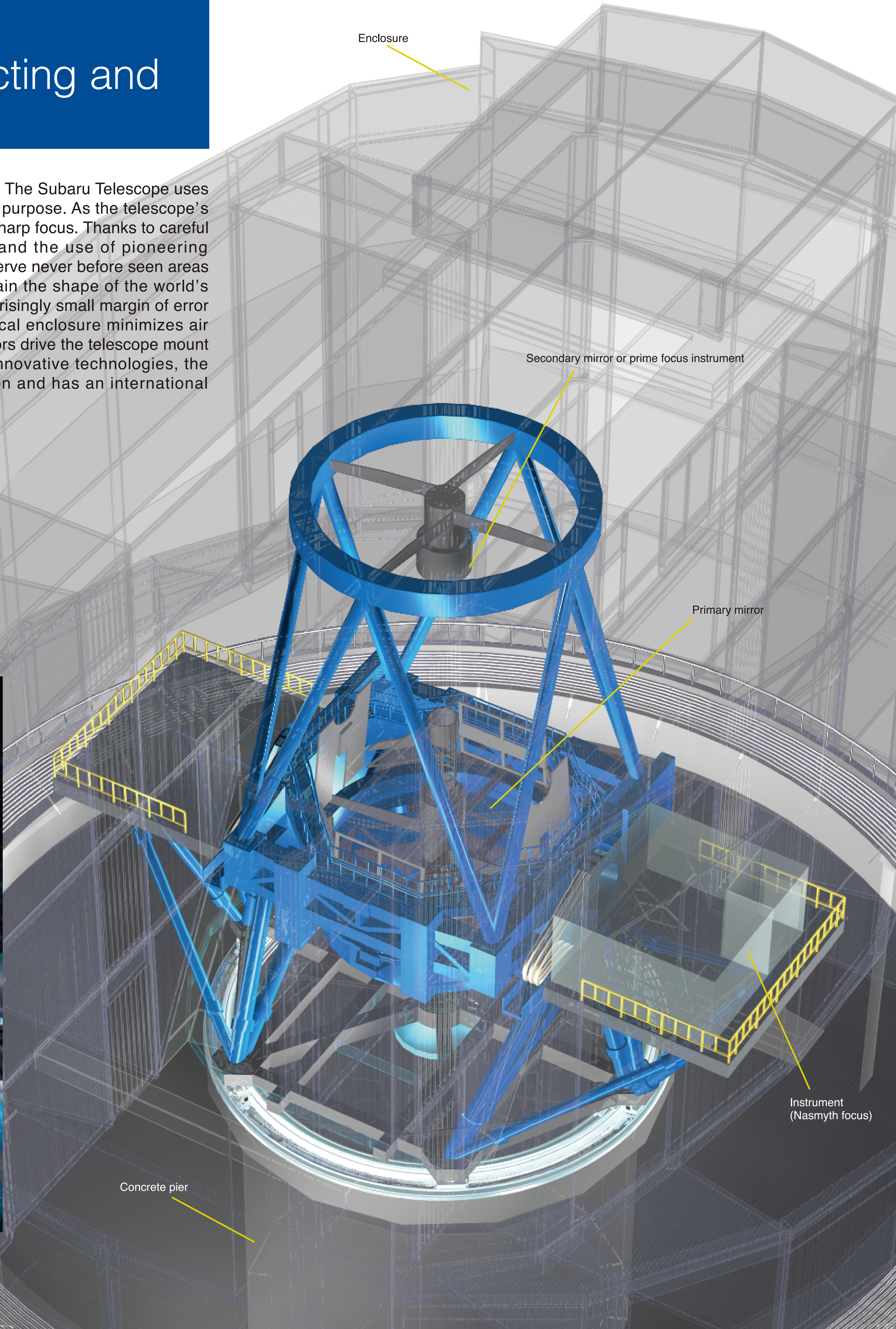
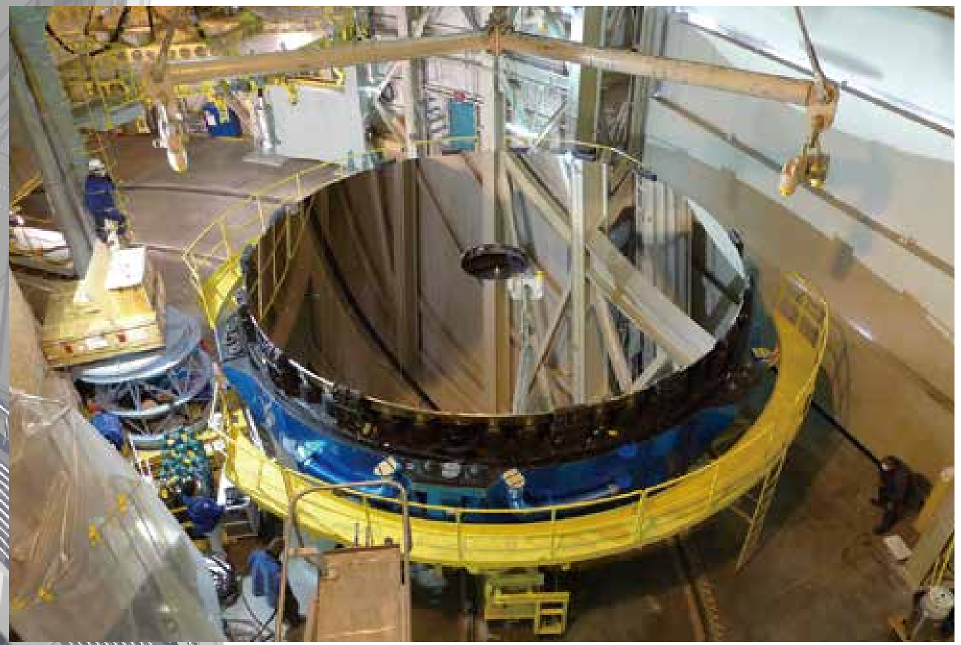


Image of the Subaru Telescope. An instrument is mounted at the Cassegrain focus (beneath the primary mirror).

The cylindrical enclosure of the Subaru Telescope is distinctive among the telescopes on Maunakea. Experiments with water flow, wind tunnel, and numerical simulations led to this design. The smooth airflow through the enclosure quickly equalizes the temperatures inside and outside of the building, thus ensuring the sharp imaging capability of the Subaru Telescope.



After getting a fresh coating of aluminum, the primary mirror is ready to go back to the telescope. When mounted, the shape of the mirror is supported by 261 robot actuators.

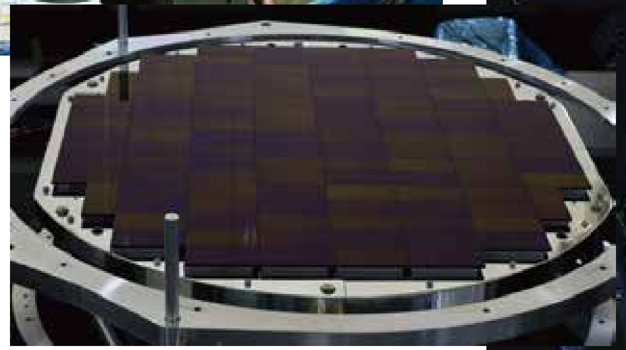
Specifications of the Subaru Telescope

Telescope optics	Ritchey-Chretien system
Effective aperture	8.2 m
Focal points	Prime focus (F2.0), Cassegrain focus (F12.2), Nasmyth foci (F12.6 for opt., 13.6 for IR)
Max. field of view	1.5 degrees (Prime focus)
Imaging performance	0.2 arcsec. (w/o adaptive optics, at 2.15 μm)
Tracking accuracy	better than 0.1 arcseconds
Wavelength coverage	0.3 – 25 μm

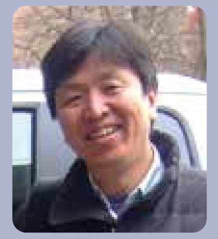
The New Eye of Telescope: Hyper Suprime-Cam (HSC)

Among 8-meter class telescopes, the Subaru Telescope has the unique capability of a very wide field of view at its prime focus. Performance combining the ability to observe a wide field of view and the ability to distinguish fine details is not easy to achieve. High performance observation capabilities were the focus through the design and construction phases. HSC is a second generation instrument, an 870 million pixel digital camera with an array of 116 large CCD detectors, each with 2048 x 4096 pixels. The field of view has a diameter of 1.5 degrees, equivalent to the area of 9 full moons. Its advanced technologies include a mechanism for precise adjustments to the position of the entire camera system, an optical corrector with huge lenses, the aforementioned CCD detectors, and a mechanical structure capable of handling the huge filters. The high efficiency for sky surveys provided by HSC observations will facilitate research such as the exploration of the outer Solar System, the exploration of distant galaxies, research into the secret of dark matter, and ground-breaking research related to the dark energy which determines the fate of the Universe.

Hyper Suprime-Cam mounted at the top of the Subaru Telescope.

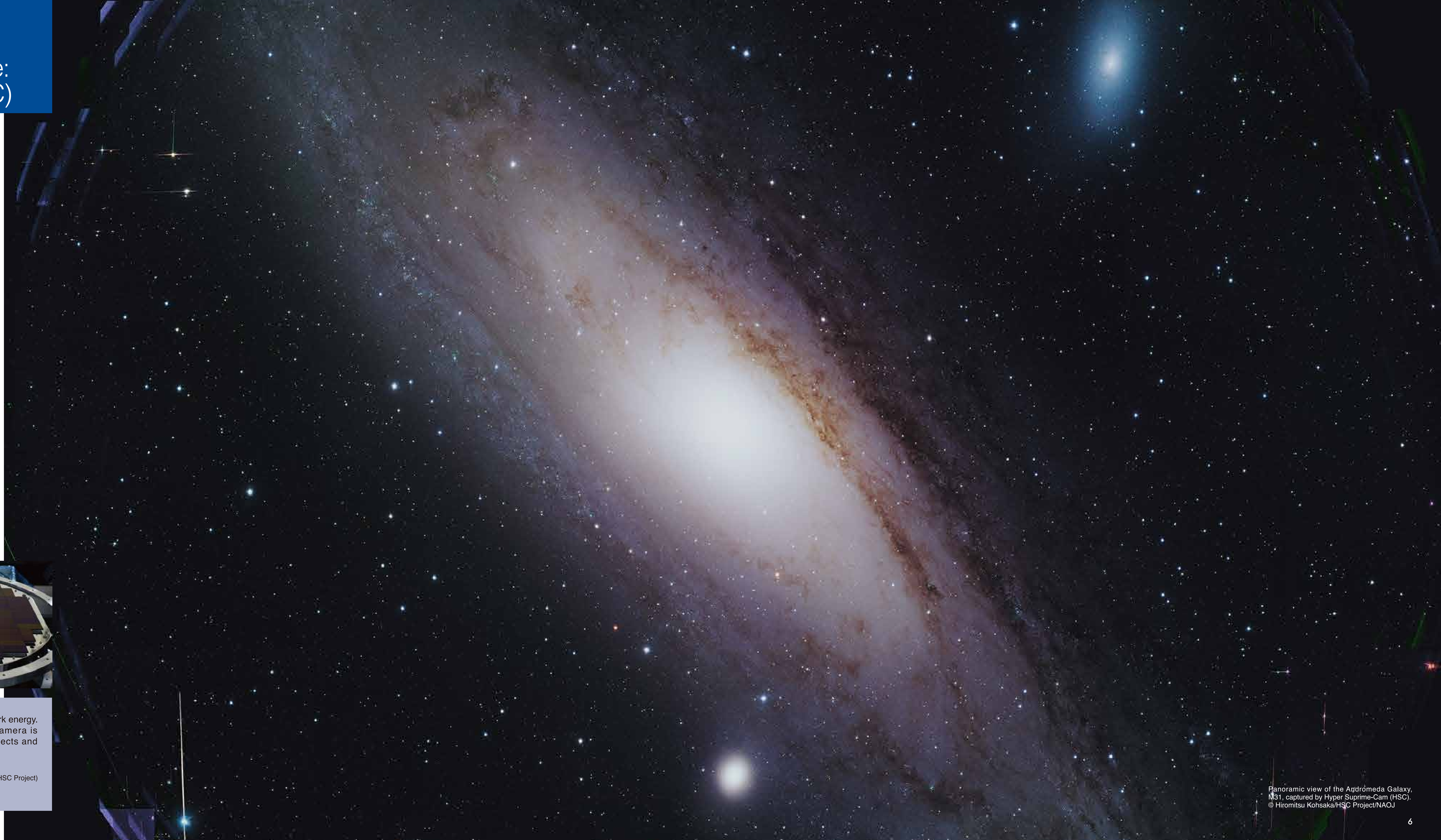


Sensors of HSC
116 CCDs, totaling 870 million pixels over the 50 cm diameter focal plane.



We developed HSC to investigate the mysterious dark energy. Of course this kind of ultra-wide field of view camera is powerful enough to capture other interesting objects and strange phenomena at various scales.

Satoshi Miyazaki (NAOJ / Leader of HSC Project)

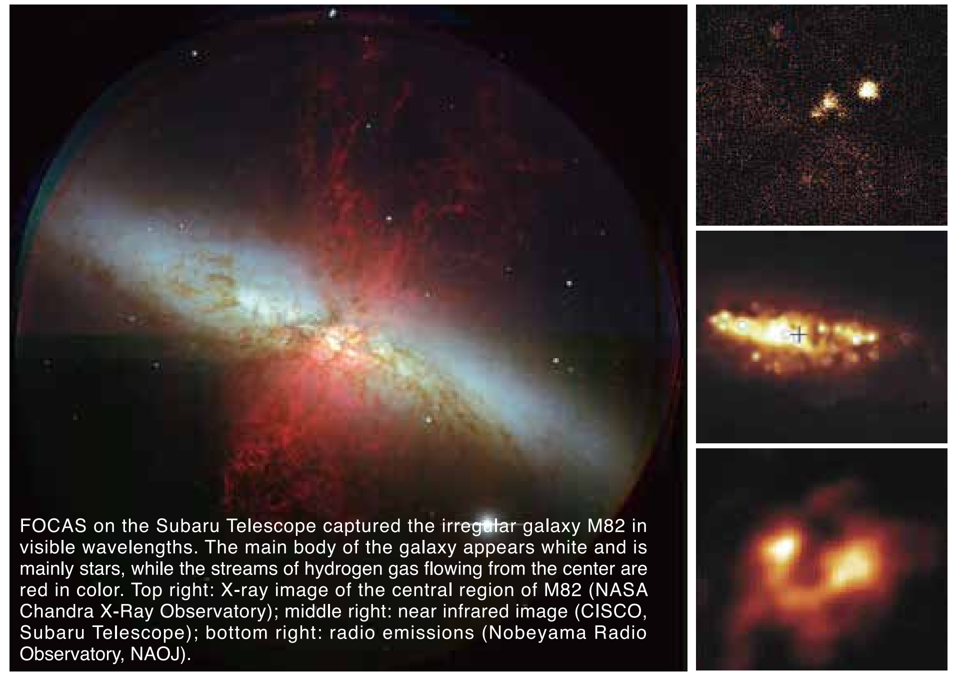


Panoramic view of the Andromeda Galaxy, M31, captured by Hyper Suprime-Cam (HSC).
© Hiromitsu Kohsaka/HSC Project/NAOJ

The Mysteries of the Universe to be Tackled with the Subaru Telescope

The Universe Seen in Visible and Infrared Light from the Earth

Information about the Universe can be obtained by analyzing the light that reaches us from celestial bodies. The Subaru Telescope bears the responsibility of observing the visible and infrared portions of the spectrum. Stars, like our Sun, and the galaxies they form are observed in visible light. Low-temperature star forming regions and objects hidden in interstellar dust are seen in the infrared. In the case of distant galaxies, light originally emitted as ultraviolet and visible light is observed as infrared due to the effect of red-shift. The Subaru Telescope, applying adaptive optics to correcting the deterioration of images due to Earth's atmosphere, achieves resolving power higher than that obtained with space telescopes in the near infrared observations.

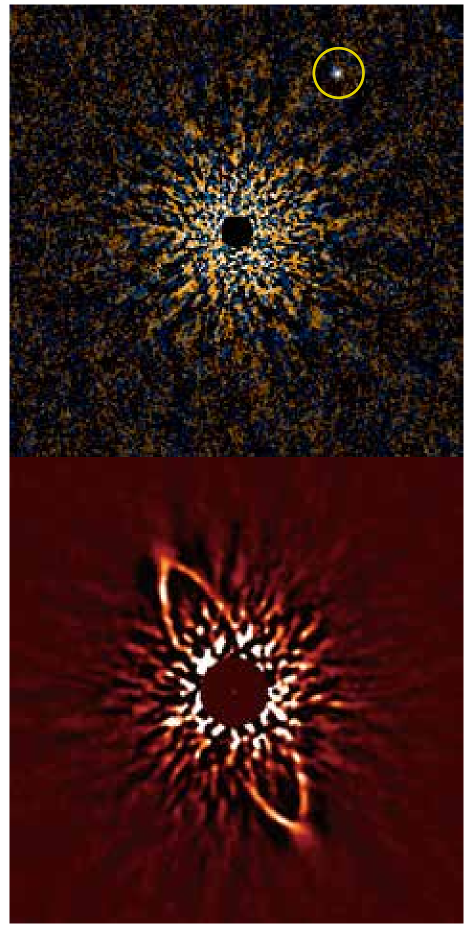


FOCAS on the Subaru Telescope captured the irregular galaxy M82 in visible wavelengths. The main body of the galaxy appears white and is mainly stars, while the streams of hydrogen gas flowing from the center are red in color. Top right: X-ray image of the central region of M82 (NASA Chandra X-Ray Observatory); middle right: near infrared image (CISCO, Subaru Telescope); bottom right: radio emissions (Nobeyama Radio Observatory, NAOJ).

Exoplanets - Peeking at Alien Worlds

Does a "second Earth" harboring life exist in the Universe? Since the first confirmed exoplanet discovery in 1995, thousands of exoplanets have been found. But taking a direct image of a planet is extremely difficult compared to indirect methods such as using spectroscopy to detect a wobble in a star caused by a planet. That is because compared to the central star, a planet orbiting it is extremely faint.

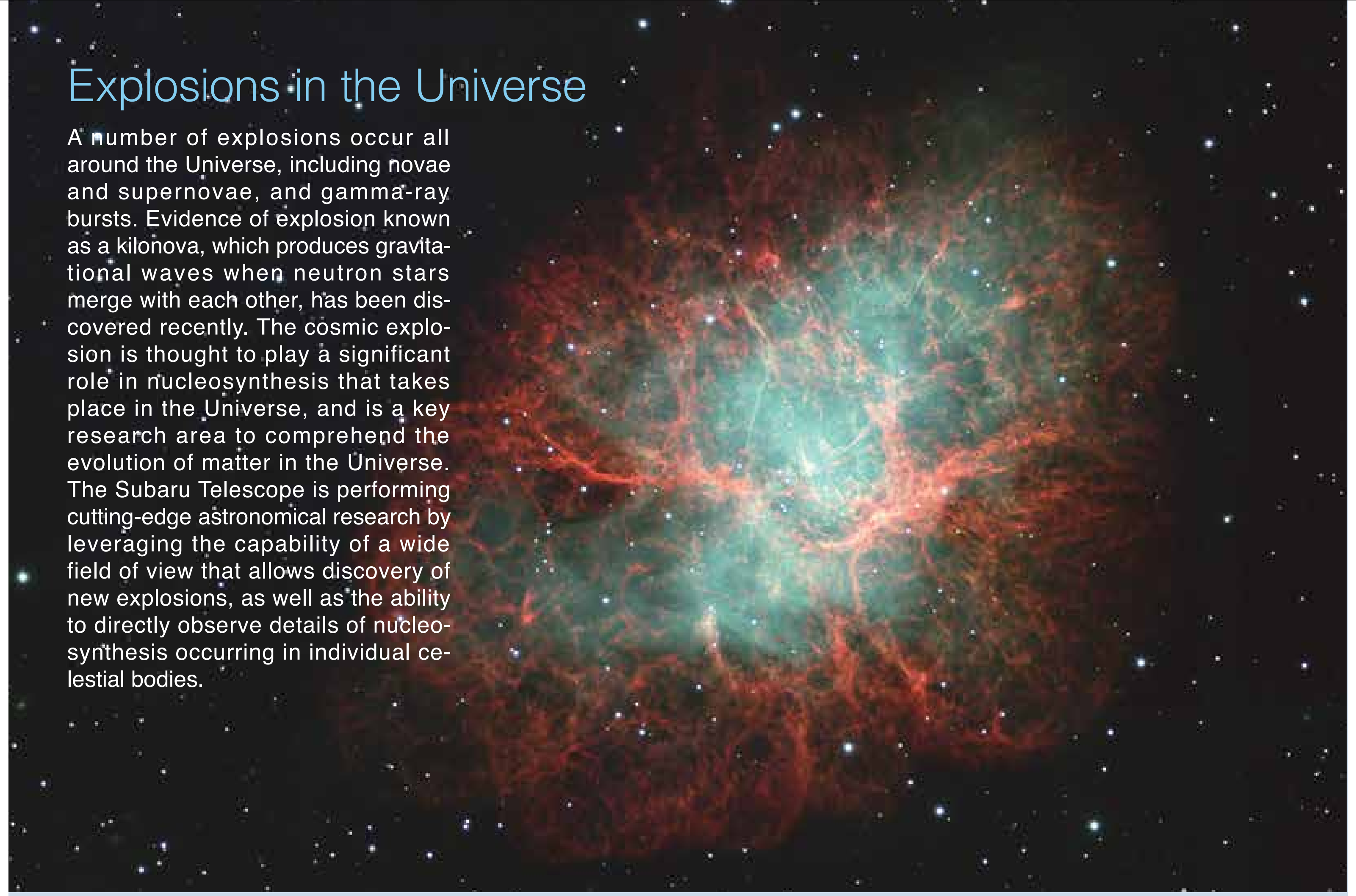
The Subaru Telescope is exploring faint extrasolar planets and protoplanetary disks around nearby stars by direct imaging using high contrast near infrared imagers with the adaptive optics system AO188. Another approach to find extrasolar planets is to measure wabbles in cool stars with small mass with the infrared spectrometer IRD aiming at detection of earth-like planets. The ultimate goal of these observations is to answer the question whether the second earth is really exists, or the Earth is a special object.



Top: Direct image of an exoplanet GJ 504 b, a "second Jupiter."
Bottom: A dust ring around the star HR 4796 A. Planetesimals, which are the materials leftover after planet formation, might have formed this ring by colliding with each other and scattering dust.

21st century technology opened the door for the search for life outside of the Solar System. The Subaru Telescope looks for Earth-like exoplanets to be observed in more detail in the future by the Thirty Meter Telescope (TMT). At last, this kind of ambitious search has become feasible.

Motohide Tamura (University of Tokyo / ABC / NAOJ)



Explosions in the Universe

A number of explosions occur all around the Universe, including novae and supernovae, and gamma-ray bursts. Evidence of explosion known as a kilonova, which produces gravitational waves when neutron stars merge with each other, has been discovered recently. The cosmic explosion is thought to play a significant role in nucleosynthesis that takes place in the Universe, and is a key research area to comprehend the evolution of matter in the Universe. The Subaru Telescope is performing cutting-edge astronomical research by leveraging the capability of a wide field of view that allows discovery of new explosions, as well as the ability to directly observe details of nucleosynthesis occurring in individual celestial bodies.

Crab Nebula (M1) imaged by Suprime-Cam is the remnant of a supernova that occurred in the year 1054. A supernova is the explosion of a heavy star at the end of its life.

Follow-up Observation of Gravitational Wave Events

A signal of gravitational waves called GW170817 was detected on August 17, 2017. The Subaru Telescope followed up the signal in the visible and infrared regions, and identified the site where GW170817 was emanated. This was the first observation of the gravitational-wave source across the electromagnetic spectrum, with success in tracking the time evolution of its brightness.

GW170817 is suggested to have come from the merger of neutron stars. Portions of neutron stars are rapidly ejected into space during a merger, which triggers a set of nuclear reactions, and then produces heavy elements such as platinum. Energy from the radioactive decay of these elements are emitted as electromagnetic radiation. The observational results of GW170817 by the Subaru Telescope and other detectors are well consistent with this theoretical prediction of the kilonova.

Light emitted from the gravitational-wave signal GW170817, observed by Hyper Suprime-Cam. The brightness significantly changed over a week (the left image captured on August 18, 2017, and the right on August 25, 2017).

Nova Explosions: Lithium Factories in the Universe

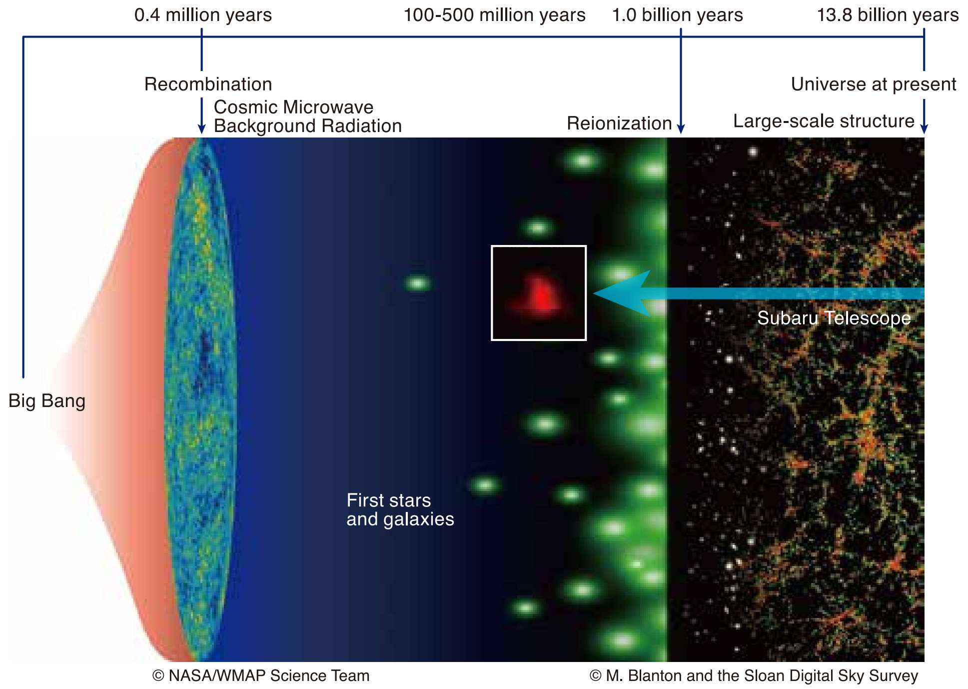
The Subaru Telescope revealed with its detailed spectroscopic observation that an abundance of lithium is synthesized in the nova explosion V339 Del that appeared in 2013. Lithium, the third lightest element, is thought to be synthesized at several places in the Universe, including stellar interiors, novae, as well as through Big Bang nucleosynthesis. It is a key element for studying the origin of the elements and the evolution of matter. The Subaru Telescope's observation of V339 Del was marked as the first observation to directly identify the celestial body that produced and expelled lithium, and will greatly advance the understanding of the evolution of matter in the Universe.

With its widest field of view among 8-meter class telescopes, the Subaru Telescope immensely contributes to search for explosions in the Universe. A large number of observations of supernovae that take place in distant parts of the Universe will help to unlock history of the expansion of the Universe and star formation. The Subaru Telescope may detect undiscovered explosions. We are excited about what the Subaru Telescope will show to us.

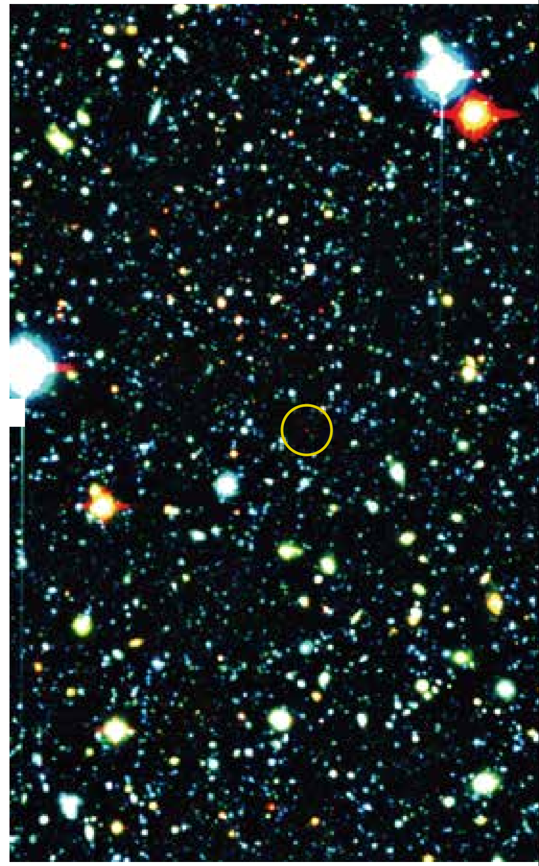
Masaomi Tanaka (Tohoku University)

Chronicling the Evolution of the Universe

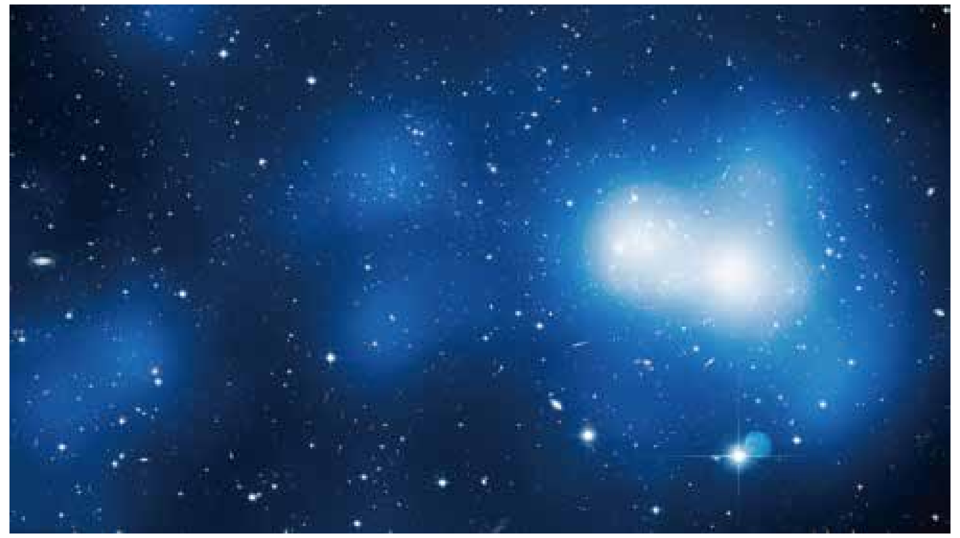
Groups of galaxies are themselves clustered into a larger pattern known as the "large-scale structure of the Universe." The current understanding is that the matter distribution just after the Universe's birth shaped the large-scale structure and the galaxies which comprise it. Astronomers are now conducting observations to piece together the complete picture of the Universe's early history. The key is to determine when and how the first stars and galaxies were born. The Subaru Telescope has succeeded in discovering a galaxy 13.1 billion light-years away. This means that the light we observe was emitted 13.1 billion years ago, when the Universe was only 700 million years old.



© NASA/WMAP Science Team © M. Blanton and the Sloan Digital Sky Survey

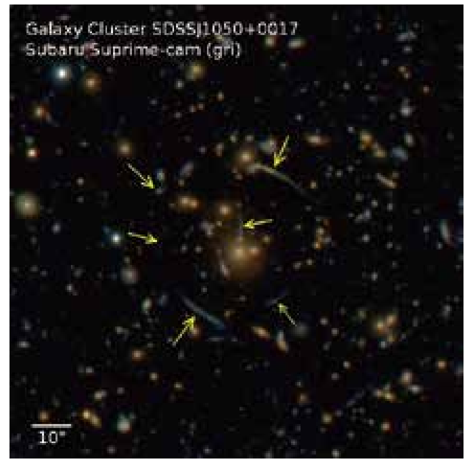


400 thousand years after the Big Bang, the Universe became transparent to electromagnetic waves. After that epoch, the first stars and galaxies were born. The Subaru Telescope explores these early times.

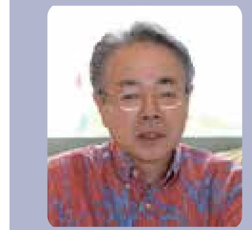


The cluster of galaxies MACS J0717 overlaid with a false-color blue graphic indicating the dark matter distribution revealed by observations from the Subaru Telescope.

© NASA, European Space Agency (ESA), Harald Ebeling (Institute of Astronomy, University of Hawai'i at Mānoa), and Jean-Paul Kneib (Laboratoire d'Astrophysique de Marseille)



Galaxy Cluster SDSS J 1050+0017
Arrows point to lensed images of distant galaxies behind this cluster of galaxies. The images are stretched due to the gravitational lens effect.



Studying a galaxy as a congregation of stars requires an understanding of the growth of the galaxy as well as the evolution of the individual stars. The Subaru Telescope has enabled observations of galaxies in various developmental stages. I would like to promote collaboration and increase the output from the Subaru Telescope.

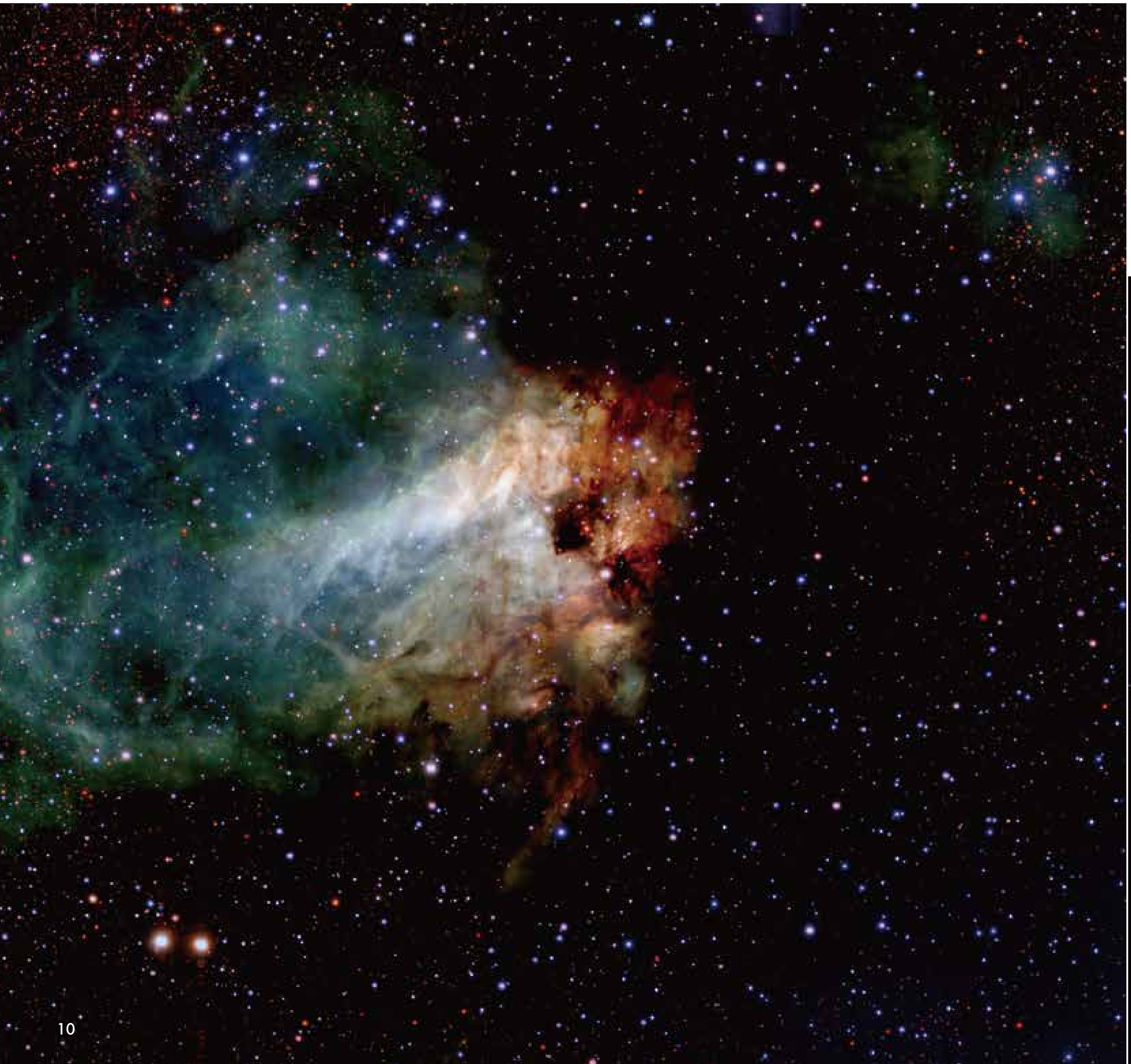
Nobuo Arimoto (NAOJ)

Cosmic Scenes Captured by the Subaru Telescope

Aspects of the Solar System and the Milky Way

Observations by the Subaru Telescope portray the various stages of the lives of stars like our Sun: from the formation of stars inside clouds of cold gas and dust drifting inside galaxies; through their lifetimes of shining through stable nuclear fusion reactions; on toward old ages when they release their materials through various, sometimes explosive, methods. Chemical analysis of the Universe reveals that the materials which stars return to interstellar space near the ends of their lives become the foundational materials from which the next generation of stars forms.

Diffuse nebula M17, imaged by Suprime-Cam, forms a number of stars. The left part of the image appearing like blue filaments consists of gas ionized by strong ultraviolet radiation from those newborn stars.



Three-color (J,H,K) image of Jupiter and its satellite Ganymede, captured by IRCS with an adaptive optics system. Ganymede moved with respect to Jupiter during the three filter observations.

The long tails of Comet ISON (C/2012 S1) spanning a distance of more than twice the diameter of the full moon, were clearly imaged by Hyper Suprime-Cam (HSC) during the early morning of November 5, 2013 in the i band (760 nm wavelength).

Spiral Galaxy NGC 6946 captured by Suprime-Cam. This face-on galaxy enables detailed study of the galaxy's star forming regions which appear pink-ish colors.

Spiral galaxy M81 captured by Suprime-Cam. This large galaxy, M81, has a strong influence on its neighbor M82.

Memories of the Universe Interwoven with Galaxies

Our Milky Way Galaxy is said to contain 200 billion stars. It is thought that there are over 100 billion galaxies like ours in the Universe. Their shapes and sizes vary dramatically. These differences reflect differences in the history of each galaxy. Neighboring galaxies have a mutual effect on one another. In fact, it's not unusual for galaxies to crash into each other. An important theme of modern astronomy is how galaxies are born and evolve.

Dwarf galaxy NGC 4449 (lower left) grows by swallowing a smaller galaxy (upper right). This visible light image was also captured by Suprime-Cam. Blue glare in NGC 4449 indicates active star formation, while the redder color in the outskirts and in the small galaxy shows the old red giant stars.

(Composite image produced by R. Jay GaBany.)

Umbrella Galaxy NGC 4651. A composite of a Suprime-Cam image and one from Blackbird Observatory's 0.5 m telescope. The interesting structure came from a tiny galaxy (the dot in the center of the insert) which was torn apart by NGC 4651.

(Composite image produced by R. Jay GaBany.)

The Subaru Telescope's History and Future

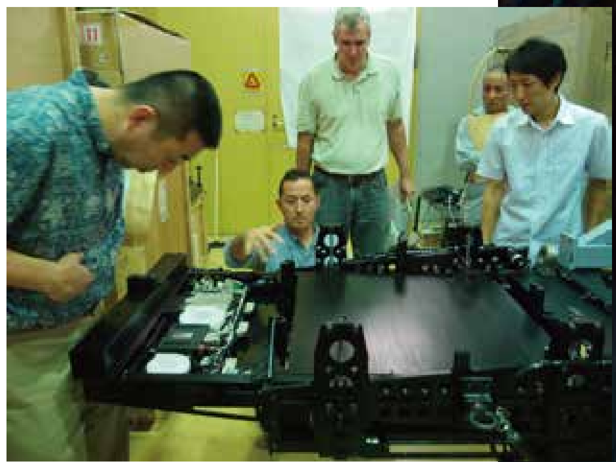
Open Use of Telescope Time and Graduate-level Education

The Subaru Telescope started open use observations in 2000. Every year research teams throughout Japan and around the world submit proposals and the best proposals are granted observing time. Graduate students play an active role in these observations and in the development of new instruments for the Subaru Telescope.

Graduate students conduct observations at the Subaru Telescope as part of their course work

International Collaboration

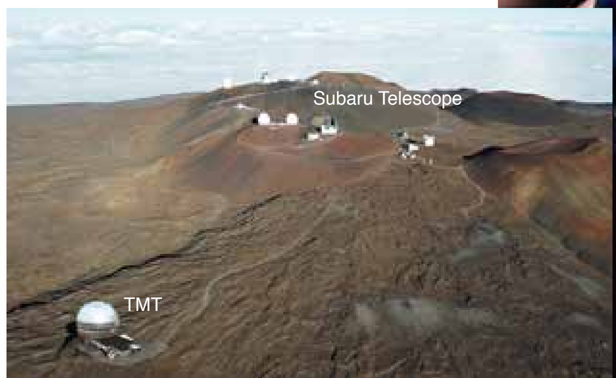
In addition to observation time exchange plans with other nations' 8-10 meter class telescopes, international teams collaborate to develop new instruments and software for the Subaru Telescope. Major partners include the University of Hawai'i and Princeton University in the United States, the Academia Sinica's Institute of Astronomy and Astrophysics in Taiwan, and Tohoku University, the University of Tokyo, and Kavli IPMU (WPI) in Japan.



Inspection of HSC's filter exchange system upon its arrival in Hawai'i

Synergy with TMT

The National Astronomical Observatory of Japan (NAOJ) and international partners are now engaged in the construction of the Thirty Meter Telescope (TMT). TMT will be able to choose targets for detailed study based on the surveys made possible by the wide field-of-view observations of the Subaru Telescope. Together with TMT, the Subaru Telescope will continue to be a world leader in optical-infrared astronomy.



The Subaru Telescope and artist's rendition of TMT on Maunakea

1980s
Preparations for the construction of the Japan National Large Telescope (JNLT)

1988
NAOJ founded, JNLT Project Office founded

1991
Budget request approved, manufacturing of the telescope began

1992
Telescope named "The Subaru Telescope," groundbreaking ceremony on Maunakea

1997
Enclosure completed, NAOJ's Hawai'i branch established, Hilo Base Facility completed

1998
Telescope mount completed, primary mirror polishing finished

1999
First light

2000
Open use observations began

2004
Public tour program started

2006
Discovery of the most distant galaxy ever detected up to this point

2009
Successful direct imaging of an exoplanet around a Sun-like star

2013
HSC started observations