400 Years of the Astronomical Telescope

We look up at the night sky and wonder about the universe in which we live . How has our view of the universe been changing together with the evolution of the telescope ?

●Human Eye Diameter of the pupil : 7 mm (0.3 in.)
Before the telescope was invented, we observed the night sky with only the naked eye.

Stargazing at an Observatory

Astronomical telescopes are not only for astronomers. Anybody can buy a telescope or can watch stars at a public observatory which provides stargazing parties for citizens. In Japan there are more than 400 such public observatories.

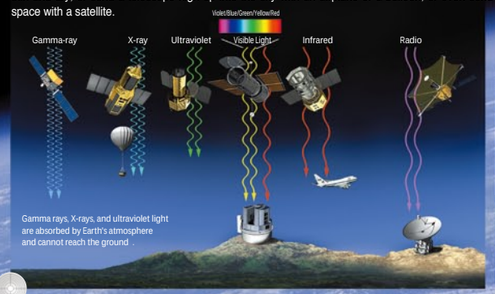
People enjoy looking into the nation's largest Nayuta Telescope at Nishi-Harima Astronomical Observatory, in Hyogo, Japan. The diameter of the main mirror is 2 m (6.6 ft) .

Studying the Universe in Various Ways

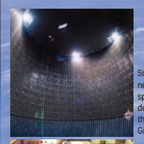
We receive many kinds of lights, that is to say, electromagnetic waves from outer space. The light we can see with the human eye is called visible light, and when we divide the sun light with a prism, we see a rainbow spectrum. Just beyond red, there is invisible light called infrared light and after that, radio waves. Just beyond violet, there is invisible light called ultraviolet light (UV), followed by X-rays, and gamma rays.
When we observe an object in different ways, we see different things. Using radio and infrared telescopes, we can observe gas and dust, the materials that stars are made of. By use of X-ray telescopes we can detect active stars and burned-out stars. Other than electromagnetic waves, we also receive cosmic rays and neutrinos which are both particles. Gravitational waves may reach Earth, too.

Orion Constellation with different types of light (False-color scheme is applied except visible light.)

All electromagnetic waves except for radio waves, visible light, and a part of the infrared light are absorbed by Earth's atmosphere and cannot reach the ground. Also astronomical images are sometimes blurred by the atmosphere's turbulence. Therefore, we have to build an observatory at high altitude where the air is thin and dry, or send a telescope high up into the sky with an airplane or a balloon, or even send one into space with a satellite.



Gamma rays, X-rays, and ultraviolet light are absorbed by Earth's atmosphere and cannot reach the ground .



Super-Kamiokande detects neutrinos particles from outer space. It was constructed deep beneath the ground at the former Kamioka Mine, in Gifu Prefecture.

With TAMA300 astronomers are trying to detect gravitational waves. It is located underground at the National Astronomical Observatory of Japan in Tokyo .

The Optical Telescope

The astronomical telescopes observing visible (optical) light are called "optical telescopes". In order to see fainter objects with higher spatial resolution, bigger telescopes with bigger lenses/mirrors were developed along the way using the cutting-edge technology of each era. Observational instruments such as the camera were also improved. New telescopes and new instruments enabled astronomers to resolve some of the mysteries of the universe. In the meantime, other new mysteries have been popping up. Today optical telescopes are also used for infrared observations.

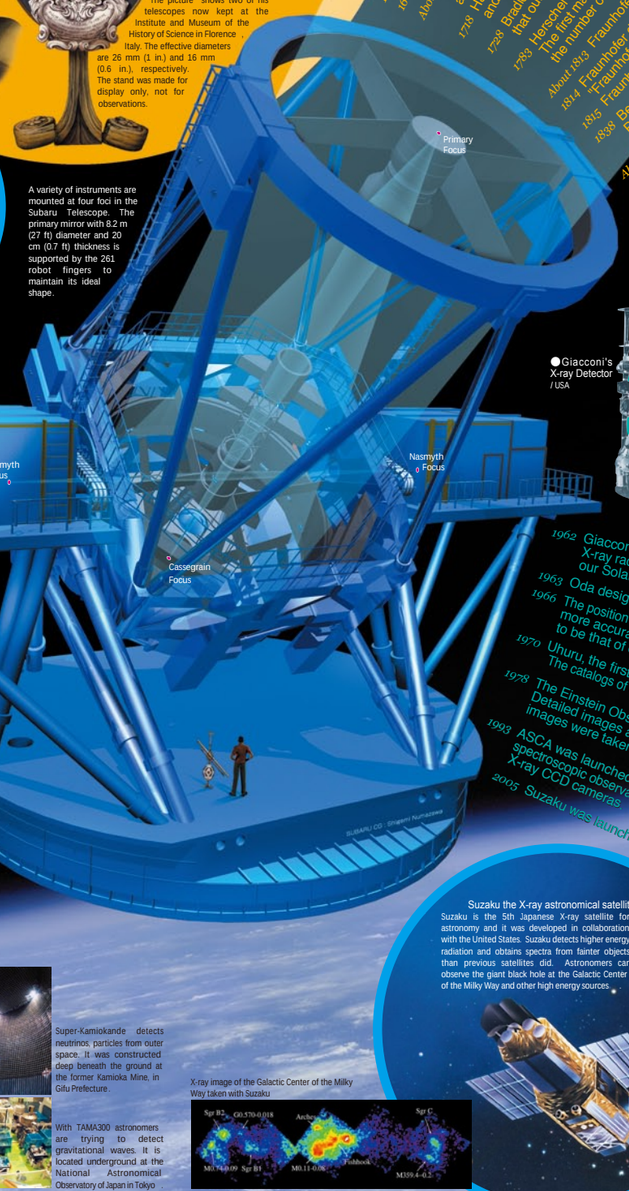
Galileo's Great Discoveries

In 1608 the telescope was invented by a Dutch optician who combined two lenses. In the following year, 1609, Galileo heard about the telescope and made one of his own. He pointed his telescope to the night sky and discovered craters on the Moon, four moons of Jupiter, the waxing and waning of Venus, and that the Milky Way is made up of many stars. This new technology began to play an important role in science. Galileo had also discovered the unlimited possibilities of the astronomical telescope.

●Galileo's Telescopes
Galileo Galilei, the Italian scientist, made a lot of telescopes.

The picture shows two of his telescopes now kept at the Institute and Museum of the History of Science in Florence , Italy. The effective diameters are 26 mm (1 in.) and 16 mm (0.6 in.), respectively. The stand was made for display only, not for observations.

1608 The telescope was invented.
1609 Galileo made the first astronomical observations through a telescope.
The 400th anniversary is celebrated as the International Year of Astronomy (IYA) 2009
1655 Huygens developed an aerial telescope without a tube.
1668 Newton developed a reflecting telescope.
About 1700 Positions of stars were measured accurately with a quadrant, a sextant, a transit instrument, and other such devices.
1718 Halley discovered the proper motion of stars and found the distances to stars not to be infinite.
1728 Bradley discovered annual aberration providing evidence that our Earth revolves around the Sun.
1783 Herschel developed the 20 foot reflecting telescope. The first map of the Milky Way was made by counting the number of stars.
About 1813 Fraunhofer developed the spectroscope.
1814 Fraunhofer discovered what are now called "Fraunhofer lines" in the spectrum of the Sun.
1835 Bessel discovered the annual parallax of a star. Parallax measurement is the method we use to measure the distance to a nearby star.
1838 Bessel discovered the annual parallax of a star. Parallax measurement is the method we use to measure the distance to a nearby star.
About 1850 A photographic plate was used for observations. A more accurate record of an astronomical image was made.
1897 The 40 inch (1 m) telescope, the world's biggest refracting telescope, was built at Yerkes Observatory. Since making bigger lenses is difficult, reflecting telescopes became the mainstream from this time on.
1917 The Hooker Telescope at Mount Wilson Observatory was built.
1923 By measuring the distance of a Cepheid variable, Hubble discovered that the Andromeda galaxy is outside of the Milky Way Galaxy.
1929 Hubble discovered that the more distant galaxies are moving away from us faster, hence the universe is expanding.
1934 Development of a glass with low thermal expansion made it possible to make large mirrors for reflecting telescopes.
1948 The Hale Telescope at Palomar Observatory was built.
About 1960 The world's first infrared telescope started observations.
About 1980 Charge Coupled Devices (CCDs) made it possible to take digital data and fainter objects could be observed.
1990 The Hubble Space Telescope was launched.
1999 The Subaru Telescope started observations.



A variety of instruments are mounted at four foci in the Subaru Telescope. The primary mirror with 8.2 m (27 ft) diameter and 20 cm (0.7 ft) thickness is supported by the 261 robot fingers to maintain its ideal shape.

The names of the countries are written with their present names.

●Huygens' Aerial Telescope
Diameter: 57 mm (2.2 in.) / Netherlands
The "Ears of Saturn" in Galileo's record were understood to be the rings of Saturn .

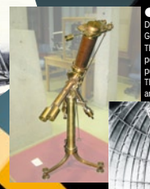
●Newton's Reflecting Telescope
Diameter: 51 mm (2.0 in.) / UK

A metallic mirror was used for this telescope. Now, in modern ages, a glass with metal coating is used for a mirror .

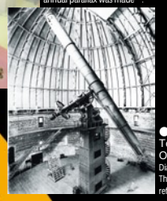
●Sextans at Greenwich Observatory / UK
In the 17th and 18th centuries, an accurate star catalog was needed for navigation on the sea. Thanks to the accurate star catalogs, proper motion and aberration were discovered .

The first map of the Milky Way was made by Herschel measuring the distribution of stars.

●Herschel's 20-foot Reflecting Telescope
Diameter: 48 cm (19 in.) / UK
The name of this telescope comes from its focal length (20 feet, 6 m)



●Fraunhofer's Heliometer
Diameter: 16 cm (6.3 in.) / Germany
The Heliometer made it possible to measure a star's position with higher accuracy . The first detection of an annual parallax was made .



●The 40-inch Refracting Telescope at Yerkes Observatory
Diameter: 1.0 m (40 in.) / USA
This is the world's largest refracting telescope .

How an Astronomical Telescope Works

There are two kinds of optical telescopes: one is a refracting telescope (refractor) with a convex lens, and the other is a reflecting telescope (reflector) with a concave mirror. Both types of telescopes have a focus where light from space is gathered and produces an image. An eyepiece enlarges the image like a magnifying glass. A human eye has the same structure as a refracting telescope, and the parabolic antenna of a radio telescope gathers radio waves like a reflecting telescope. Now humans have got a large "eye" to see smaller and fainter things in space by using a telescope.

Refracting telescope with a convex lens

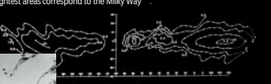
Reflecting telescope with a concave mirror
The Subaru Telescope is similar to an amateur telescope in principle .

●Jansky's Antenna / USA

The Radio Telescope

Radio waves, which are used for telecommunications, also come to us from outer space.
With a radio telescope we can observe new types of stars and interstellar matter which cannot be observed in visible light. The interferometer is one of the novel innovations of radio astronomy. Combined with many antennas to improve angular resolution, it works as a huge radio telescope.

Reber's radio map of outer space shows that the brightest areas correspond to the Milky Way .



●Reber's Radio Telescope
Diameter: 9 m (30 ft) / USA

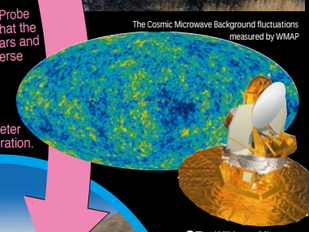
●The Horn Antenna at Bell Laboratories
Aperture: 6 m x 6 m (20 ft x 20 ft) / USA
The cosmic microwave background, the evidence that the universe began from the Big Bang, was detected .

1931 Jansky first detected cosmic radio waves.
1940 Reber developed the world's first radio telescope.
1946 Ryle and others invented the radio interferometer.
About 1950 The atomic hydrogen line was first detected. A start of radio spectroscopy in astronomy.
1965 Penzias and Wilson discovered cosmic microwave background radiation.
1981 The 45 m (148 ft) telescope at Nobeyama Radio Observatory started observations.
2001 The Wilkinson Microwave Anisotropy Probe (WMAP) was launched. It revealed that the age of the universe is 13.7 billion years and that only 4% of the mass of the universe is composed of the normal matter and the other 96% is made up of dark matter and dark energy.
2012 Atacama Large Millimeter/submillimeter Array (ALMA) will begin regular operation.

The interstellar molecules discovered at Nobeyama Radio Observatory

●The 45-m Telescope at Nobeyama Radio Observatory
Diameter: 45 m (148 ft) / Japan
How a star is formed was revealed, and many kinds of interstellar molecules which do not exist on Earth were discovered .

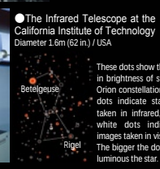
The Cosmic Microwave Background fluctuations measured by WMAP



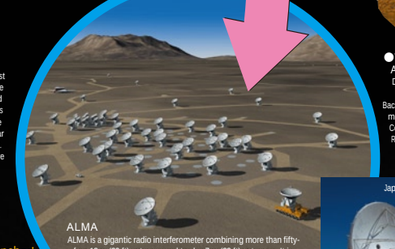
●The Wilkinson Microwave Anisotropy Probe (WMAP)
Diameter: 1.4 m (4.6 ft) / USA
It succeeded the Cosmic Background Explorer (COBE) and measured the temperature of the Cosmic Microwave Background Radiation of the whole universe with high accuracy .

●The Hale Telescope at Palomar Observatory
Diameter: 5.1 m (200 in.) / USA
With its large reflecting mirror, this telescope made it possible to see fainter objects. The Local Group, the group of galaxies which includes our Milky Way Galaxy and Andromeda Galaxy, was discovered .

●The Infrared Telescope at the California Institute of Technology
Diameter 1.6m (62 in.) / USA



These dots show the contrast in brightness of stars in the Orion constellation. The red dots indicate star images taken in infrared, and the white dots indicate star images taken in visible light. The bigger the dot the more luminous the star.



ALMA
ALMA is a gigantic radio interferometer combining more than fifty-four 12 m (39 ft) antennas and twelve 7 m (23 ft) antennas. It is being built on an Andean plateau in Chile, South America located 5,000 m (16,400 ft) above sea level
The international project is in collaboration with Japan, North America, Europe, and others .

Japanese 12 m (39 ft) antennas delivered to Chile .

●Giacconi's X-ray Detector / USA

The X-ray Telescope

X-ray radiation is used in the medical field. Since cosmic X-ray radiation cannot reach the Earth's surface, its first detection was made in outer space from a rocket. Since X-ray radiation cannot be gathered like visible light, unique approaches had to be established to find the position of an X-ray source and to take an X-ray image of it. X-ray radiation is emitted from hot gas several million to hundreds of millions of degrees Celsius. This hot gas is found around black holes and clusters of galaxies.

●Uhuru, the First X-ray Satellite / USA

This map shows X-ray sources observed by Uhuru

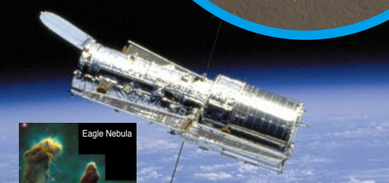
1962 Giacconi detected cosmic X-ray radiation coming from outside of our Solar System by use of a rocket.
1963 Oda designed the modulation collimator.
1966 The position of an X-ray source was determined more accurately, and that source was found to be that of one seen in visible light.
1970 Uhuru, the first X-ray satellite was launched. The catalogs of 339 X-ray sources were made.
1978 The Einstein Observatory was launched. Detailed images as sharp as visible images were taken.
1993 ASCA was launched. Detailed spectroscopic observations started with X-ray CCD cameras.
2005 Suzaku was launched.

Suzaku the X-ray astronomical satellite
Suzaku is the 5th Japanese X-ray satellite for astronomy and it was developed in collaboration with the United States. Suzaku detects higher energy radiation and obtains spectra from fainter objects than previous satellites did. Astronomers can observe the giant black hole at the Galactic Center of the Milky Way and other high energy sources .

X-ray image of the Galactic Center of the Milky Way taken with Suzaku

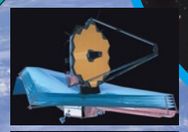
The Subaru Telescope
Diameter: 8.2 m (27 ft) / Japan
The telescope was built at the summit of Mauna Kea, Hawaii located 4,200 m (13,800 ft) above sea level. By using new technology to correct the effect of air turbulence in real time, the spatial resolution of the Subaru Telescope is improved to the point where it is as good as a space telescope's. With the 8.2 m (27 ft) main mirror, Subaru can see objects about 100,000 times fainter than the naked eye can. Distant galaxies in the early universe have been discovered by Subaru .

Infrared image of the star-forming region S106 taken with the Subaru Telescope



Eagle Nebula

●Hubble Space Telescope
Diameter: 2.4 m (7.9 ft) / USA, Europe
This telescope can obtain sharp images in space because there is no air turbulence .



●The Optical and Infrared Telescopes for the Next Generation
The James Webb Space Telescope (JWST) with a 6.5 m (21 ft) primary mirror is seen at the left top. To avoid light from the Sun and Earth, it will orbit Earth about 4 times father away than the Moon .
The Thirty Meter Telescope (TMT) with a 30 m (98 ft) primary mirror is seen at the left bottom . The giant mirror for the grand-based telescope will consist of 492 hexagonal segments .

Are there any planetary systems outside of the Solar System ?
How were the first stars and galaxies formed ?
What is the future of the expanding universe ?
Astronomers are looking for the clues and answers to these unsolved mysteries by using telescopes all over the world .

THE UNIVERSE YOURS TO DISCOVER
INTERNATIONAL YEAR OF ASTRONOMY 2009

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2009 is the year of Basic Science Abilities Enhancement