ALMA

Atacama Large Millimeter/submillimeter Array

Astronomical Observatory Closest to the Universe

ALMA (Atacama Large Millimeter/submillimeter Array) is under construction in the Atacama Desert at an altitude of approximately 5000 meters in northern Chile. The annual rainfall of the area is less than 100 mm, and the sky is always clear almost throughout the year. In the Atacama Desert at high altitudes, incoming radio waves are less susceptible to absorption by terrestrial water vapor and thus we can observe radio waves at relatively shorter wavelengths (at higher frequencies). Combination of these favorable conditions opens the way for the submillimeter observations with ALMA. A flat and wide space of the Chajnantor Plateau is also perfect for the construction of a large-scale array.

ALMA Telescope –Gigantic Eyes Looking Far Out into the Universe-

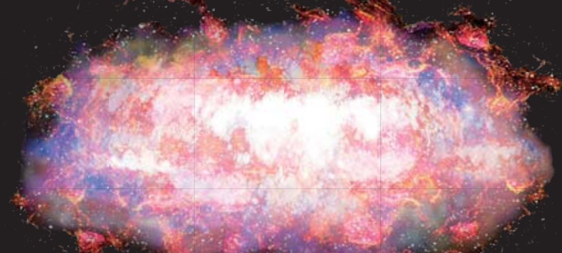
ALMA is a gigantic radio interferometer array with 66 parabola antennas. ALMA consists of fifty 12-m antennas and "Atacama Compact Array (ACA)" which is composed of four 12-m antennas and twelve 7-m antennas.

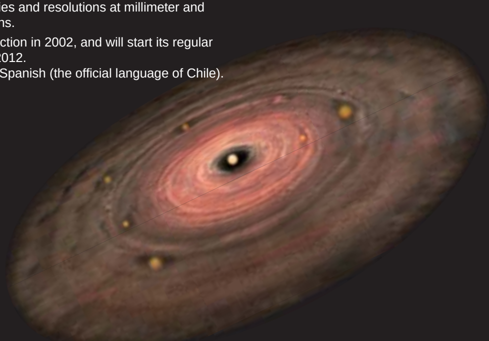
By spreading these transportable antennas over the distance of up to 18.5 km, ALMA achieves the resolution equivalent to a telescope of 18.5 km in diameter, as a telescope with the world's highest sensitivities and resolutions at millimeter and submillimeter wavelengths.

ALMA started its construction in 2002, and will start its regular science operation from 2012.
"ALMA" means "soul" in Spanish (the official language of Chile).

Millimeter and Submillimeter Waves

Electromagnetic waves are divided into several classes according to their wavelengths. Light visible to our eyes is a kind of electromagnetic waves called "visible light." Radio wave closest to infrared rays (at the shortest wavelengths) is called "submillimeter wave" (wavelength: 1 mm to 0.1 mm, frequency: 300 GHz to 3 THz) and the second shortest radio wave after submillimeter is called "millimeter wave" (wavelength: 10 mm to 1mm, frequency: 30 GHz to 300 GHz). Subaru Telescope observes the universe at infrared and optical wavelengths.
We cannot observe dust and gas in the universe with optical telescopes because they are very cold (down to -260?C) and do not emit visible or infrared emission. However, with a radio telescope, we can observe such dark regions of the universe through millimeter/submillimeter waves emitted by cold dust and gas.
Until recent years, observation at submillimeter wavelengths was not so common due to technical difficulty and geographical restriction (effected by water vapor absorption); ALMA overcomes these difficulties and opens the way to the submillimeter observations.





What We Can See

When ALMA starts its regular science operation, we can see what has never been observed at optical wavelengths, such as protogalaxies formed in the very early years of the universe, birth of stars and planets like our solar system, and matters related to the origin of life such as organic molecules.

Global Collaboration

ALMA is a global collaboration among the National Astronomical Observatory of Japan on behalf of East Asia, National Radio Astronomy Observatory on behalf of North America, and European Southern Observatory on behalf of Europe. The Republic of Chile (host country) also participates in the ALMA project by providing land and cooperation for the construction and operations of ALMA.

The ALMA Project was launched in April 2001 by uniting three different projects of three institutes.

Developing three projects into one global partnership led the way to the joint construction and operation of a high-precision gigantic telescope that is difficult to complete for a single institute in terms of resources and costs. Also, cooperation among East Asia, Europe, and North America, sharing tasks in their respective field of expertise, brought about enhanced performance of the telescope.

Japanese Contributions

In global partnership among three parties, Japan is responsible for the development of 16 ultrahigh-precision antennas, collectively called "ACA (Atacama Compact Array)" which is located near the center of the 66 antennas, as well as that of three receiver bands (frequency bands) including submillimeter band (terahertz band) whose development is supposed to be especially difficult.

ALMA is capable of observing millimeter/submillimeter waves at wavelengths from 0.3 mm to 10 mm, and we will manufacture receivers covering this frequency range, which is divided into 10 frequency bands.

Band 4, 8, and 10 Superconducting Receivers

Radio waves collected by an antenna are transmitted to seven superconducting receivers (to be increased to 10 in the future) corresponding to a certain frequency band. The development of seven receiver cartridges is shared by Japan, Europe, and North America.

To achieve unprecedented high performance of ALMA, receivers need to meet very high level of requirements. These requirements will be only satisfied with high development capabilities: unified standards jointly agreed among three parties; extremely low-noise design realized by installing the receivers in a cryogenically-cooled tank at the absolute temperature of 4 K (-269 degrees C); and robust structure with low failure rate for 30-year operation. In spite of such strict requirements, Japan is engaged in the development of multiple receiver bands, and successfully developed three superconducting receivers for Band 4, 8, and 10.

Developing receivers at shorter wavelengths requires higher manufacturing techniques. Though the development of the Band 10 receiver at the shortest wavelengths was thought to be the most difficult among ALMA frequency bands, the Band 10 receiver developed by NAOJ has successfully achieved the world' s best noise performance.

How the First Galaxy was Formed after the Big Bang

Subaru Telescope is capable of observing the universe dating back about 8 billion years after the birth of the universe, but optical telescopes are unable to observe the universe prior to this point due to the effect of the redshift. On the other hand, in the spectrum of millimeter/submillimeter waves, redshifted galaxies appear brighter and dust in galaxies emitting millimeter/submillimeter waves is also observable. With ALMA, we may be able to observe the birth of the galaxies that occurred just after the cosmic "Dark Ages."

It is expected that ALMA will be a key to solving mysteries of the formation of galaxies just after the Dark Ages.

Clue to the Origin of Life

Is the beginning of life a mere result of chemical reactions that occurred only on the Earth? Did our planetary system have the seed of life when it was formed? Did the space hold any materials that could be an origin of life? There are various theories about the beginning of life. Obtaining a clue to the origin of life is one of the main goals of ALMA.

How the Solar System and Planets were Formed

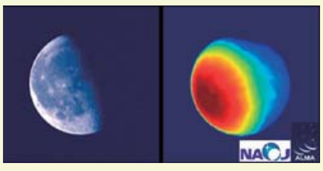
How were the planetary systems like our solar system formed? Since the discovery of the first planet outside the solar system in 1995, about 4000 planets were found directly or indirectly outside the solar system so far. Study results on these planets showed that planetary systems have a wide variety of forms. To explore their formation process, it is necessary to observe the birth of the planetary system, but ingredients of planets (e.g. gas and dust) are too cold to be observed by optical telescopes.

However, with millimeter/submillimeter telescopes, we can observe gas and dust before evolving into stars and planetary systems. Though existing radio telescopes are only capable of seeing object structures vaguely due to lack of angular resolution, ALMA that has a resolution far better than previous radio telescopes is capable of observing with unimaginable clarity the formation process of fixed stars as well as that of planetary systems. The aim of ALMA is to probe unexplored regions of the universe that have not been reached by previous telescopes.

== Latest Progress in ALMA Construction ==

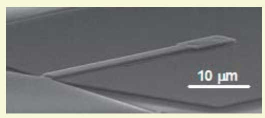
Mar 18, 2008 Result of the Initial Testing of the Japanese ACA 12-m Antenna for ALMA

Japan constructs sixteen parabolic antennas for the Atacama Compact Array (ACA) as part of the ALMA, and three of them were assembled in Chile in the latter half of last year.
One of these three antennas (12 m in diameter) was equipped with a Japanese receiver and was used to obtain the first radio image of the moon at a wavelength of 2 mm (140 GHz). The obtained image shows clearly the temperature distribution of the moon and weak radio emission from the right half of the moon, which is dark in the optical image. This is the first radio image of the celestial object taken with Japanese ACA 12-m Antenna in Chile.

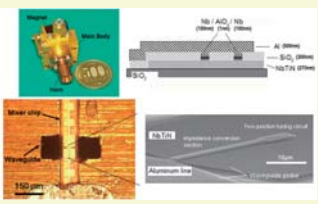


Jun 16, 2009 NAOJ successfully developed the Band 10 receiver

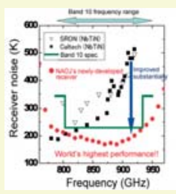
NAOJ successfully developed the Band 10 receiver covering the frequency band from 787 GHz to 950 GHz, whose development was thought to be the most difficult among ten receiver bands to be installed in ALMA. This low-noise receiver is based on a superconductive integrated circuit designed and fabricated using a high-quality film made of compound superconductive material NbTiN (niobium-titanium nitrides). The performance test was conducted with this circuit installed in the newly-developed receiver. As a result of the test, it was proved that the world's highest performance low-noise receiver was successfully developed.
The picture shows the superconductive integrated circuit micrographed by an electron microscope.



Jun 16, 2009 World's Highest Performance Submillimeter (terahertz) Receiver - Band 10, the highest frequency receiver in ALMA, was successfully developed -



Submillimeter (terahertz) receiver system using NbTiN (upper left).Superconductive integrated circuit using NbTiN, micrographed by an electron microscope (lower right) and its cross section structure (upper right).



Previously, the world's highest performance of the 750 to 950 GHz receiver (operation temperature at 4K) was achieved by the California Institute of Technology, and SRON (Netherlands Institute for Space Research: one of the major research institutes in Europe). NAOJ research team has succeeded in improving the performance substantially with its newly-developed receiver.

Jan 05, 2010 Successful Three-Antenna Interferometry at ALMA 5000-meter Site

ALMA has passed a key milestone crucial to producing the high-quality images that will be the trademark of this revolutionary new tool for astronomy. A team of astronomers and engineers successfully linked three of the observatory's antennas at the 5000-meter elevation observing site in northern Chile. The three antennas observing in unison for the first time allowed the ALMA team to correct errors that can arise when only two antennas are used, thus paving the way for precise images of the cool Universe at unprecedented resolution.
On 20 November 2009 the third antenna for the ALMA observatory was successfully installed at the Array Operations Site, the observatory's "high site" on the Chajnantor plateau, at an altitude of 5000 meters in the Chilean Andes. After complex technical tests over the subsequent weeks, astronomers and engineers were able to observe the first signals from an astronomical source making use of all three 12-meter diameter antennas linked together.

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