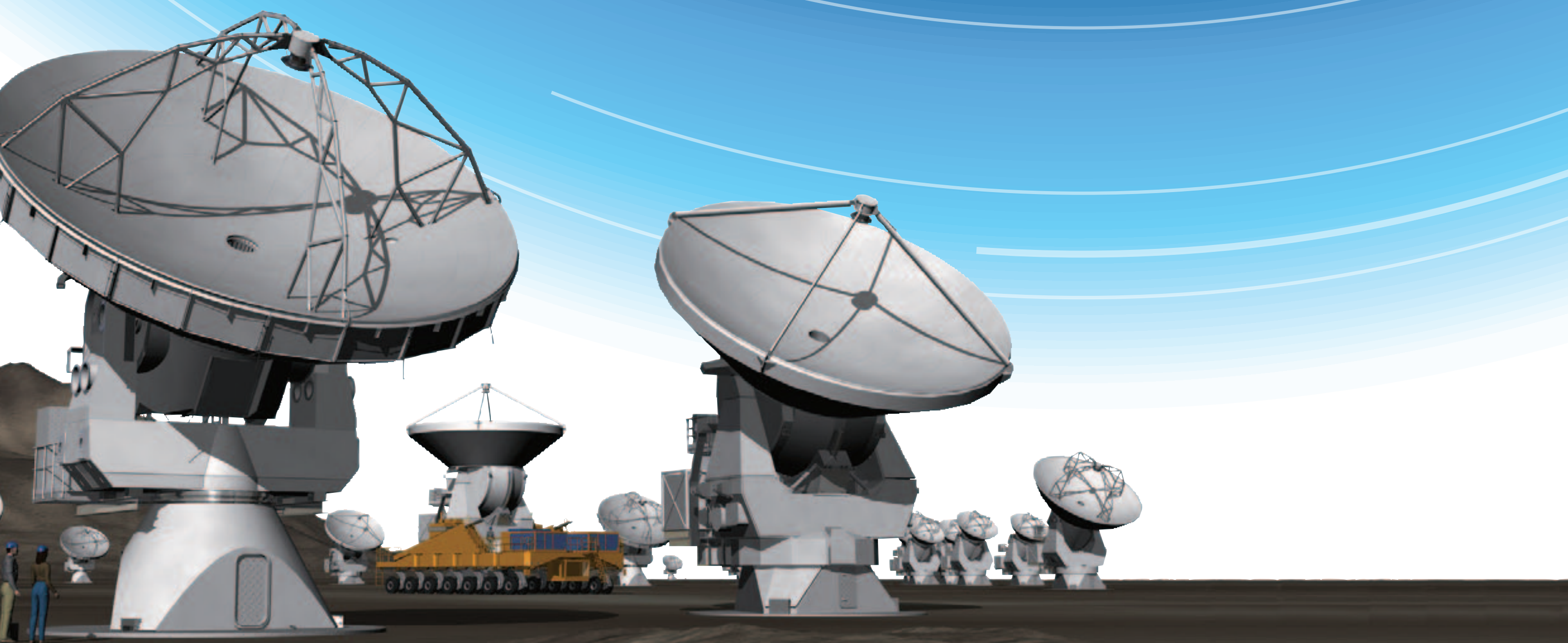
ALMA

Atacama Large Millimeter/submillimeter Array

In search of our Cosmic Origins



The Universe Explored by

**ALMA 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 evolution of materials in the universe.
Exploring mysteries of the universe,
ALMA will tell us how our solar system and the Galaxy were formed, and where the origin of life came from. When we solve these mysteries, we may be able to learn the roots of ourselves.**

I Birth of Galaxies

ALMA aims to observe protogalaxies formed in the dark ages of the universe just after the Big Bang that occurred 13.7 billion years ago.

ALMA (Atacama Large Millimeter/submillimeter Array)

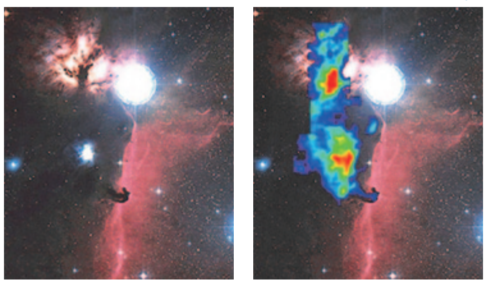
ALMA (Atacama Large Millimeter/submillimeter Array) is an astronomical facility constructed in the Atacama Desert at 5000 m above sea level in Northern Chile in cooperation among East Asia (Japan/Taiwan), Europe, North America, and the Republic of Chile. ALMA is a gigantic radio telescope consisting of 66 parabola antennas made up of fifty 12-m antennas manufactured by Europe and North America and four 12-m antennas and twelve 7-m antennas manufactured by Japan. The Japanese antennas are collectively called Atacama Compact Array (ACA) and nicknamed “IZAYOI”. By receiving millimeter/submillimeter waves at the shortest wavelength range in the radio waves, ALMA observes the dark region of the universe containing gas and dust which have never been observed at optical wavelengths. ALMA is expected to produce the world’s finest astronomical image with the resolution about 10 times better than that of Subaru and Hubble Space Telescope.

Millimeter/submillimeter Wave The vision for the Dark Universe

Celestial objects emit electromagnetic waves at various wavelengths according to the temperature. While optical telescopes observe visible light and infrared ray emitted from stars and galaxies of thousands of degrees Celsius, ALMA receives radio waves at millimeter/submillimeter wavelengths (0.3 to 10 mm) and observes cold gas and dust of minus 260 degrees Celsius in the dark universe that has never been explored at optical wavelengths.

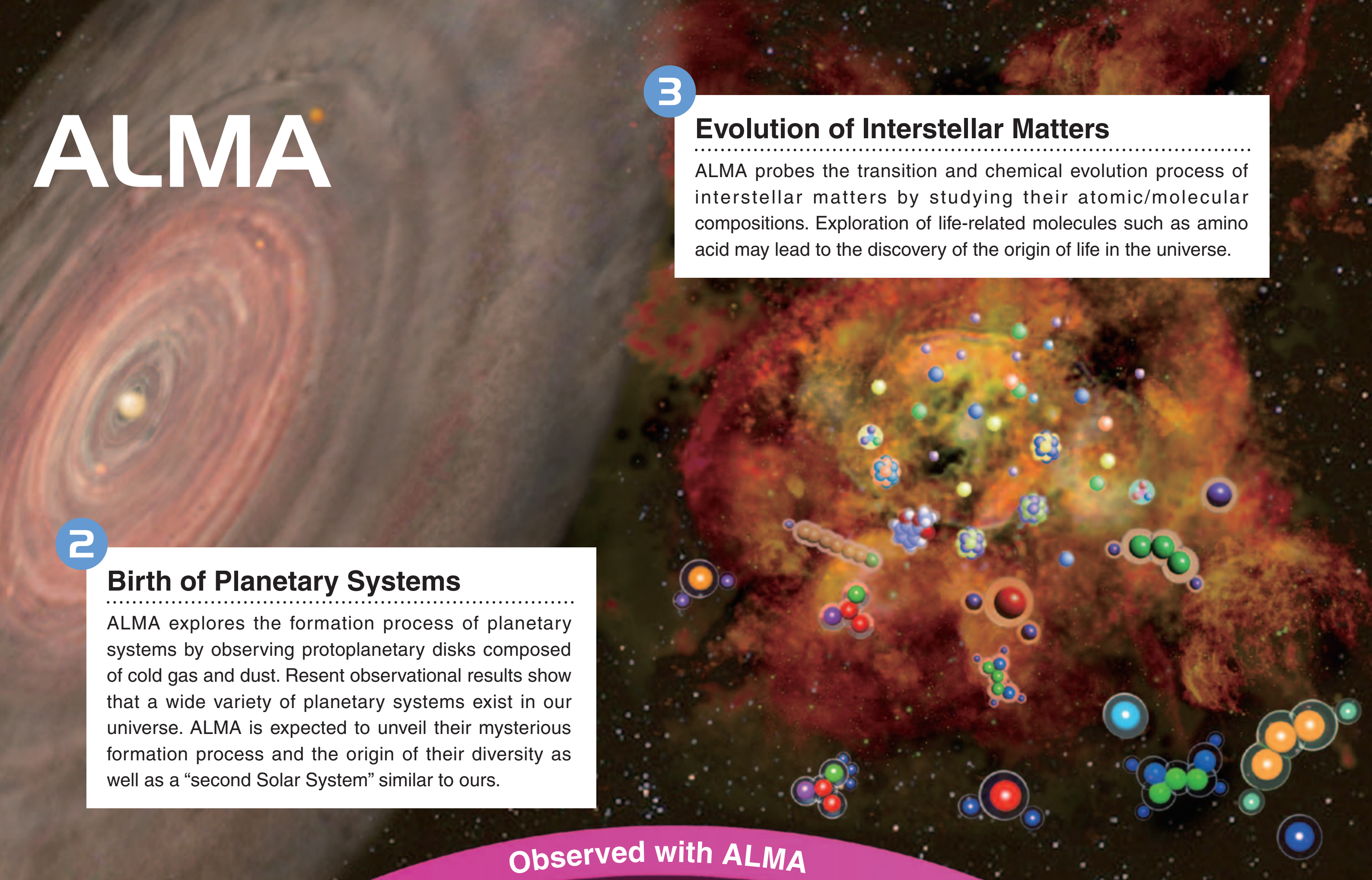
The Horsehead Nebula observed with an optical telescope (left) and the overlay of the radio image (right). In the radio wave image, strong radio emissions can be observed in the optically-invisible region. This suggests that optically-invisible dark regions contain cold interstellar matters evolving into stars and galaxies.

Observed with the NRO 45-m Radio Telescope



Provided by NAOJ Nobeyama

ALMA

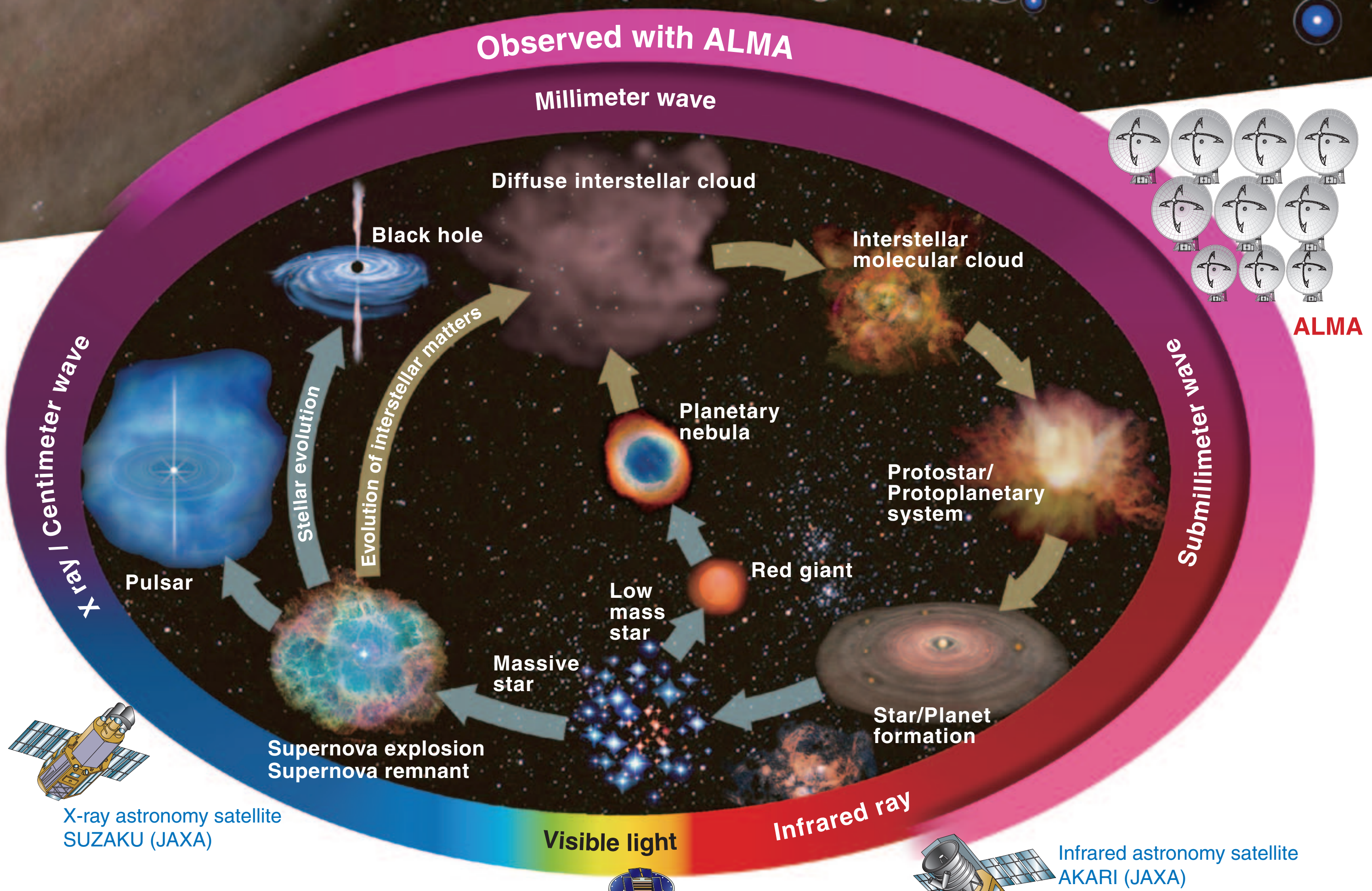


3 Evolution of Interstellar Matters

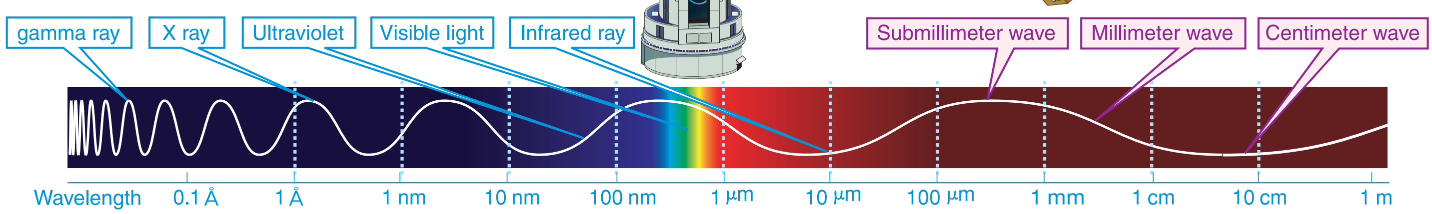
ALMA probes the transition and chemical evolution process of interstellar matters by studying their atomic/molecular compositions. Exploration of life-related molecules such as amino acid may lead to the discovery of the origin of life in the universe.

2 Birth of Planetary Systems

ALMA explores the formation process of planetary systems by observing protoplanetary disks composed of cold gas and dust. Resent observational results show that a wide variety of planetary systems exist in our universe. ALMA is expected to unveil their mysterious formation process and the origin of their diversity as well as a "second Solar System" similar to ours.



Electromagnetic spectrum



Observation Mechanism

Japanese State-of-the-Art Technology adopted by ALMA

Japanese state-of-the-art technology is highly expected for the realization of ALMA, completed with the world's most advanced technologies. ALMA is composed of 66 parabola antennas and related equipment. Main components manufactured by Japan are 16 high-precision antennas of 12 meters and 7 meters in diameter, high-sensitivity millimeter/submillimeter receivers for 3 frequency bands, and high-dispersion correlator. Technologies of radio telescopes developed before ALMA have been applied to a wide variety of areas such as amplifier for satellite broadcasting, supercomputer, Earth observation sensor, ultrahigh-speed network, and cryogenic cooler. Further major technical ramifications of these technologies are expected in various fields including medical applications of submillimeter imaging technology.

2 Receiving radio waves

High-frequency waves collected by the antenna are received by the receiver equipped with superconducting junction device. Received signals are converted to a lower frequency (4 to 12 GHz) for easier handling and amplified.

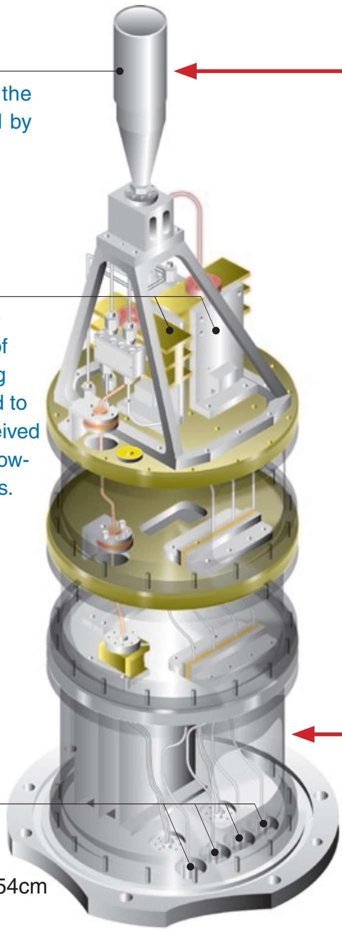
Horn

Inlet to take in the waves collected by the antenna.

Mixer

The heart of the receiver made of superconducting device and used to convert the received radio waves to low-frequency waves.

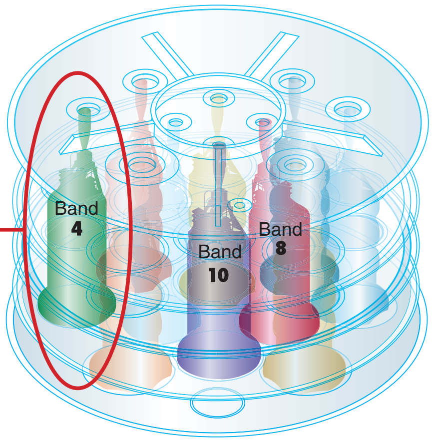
Output signal



Height: 54cm

Receiver cartridges in the cryogenically-cooled dewar

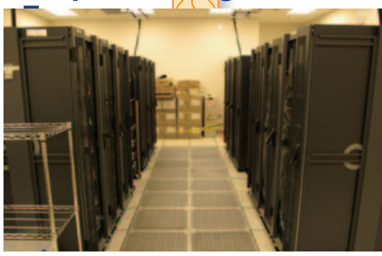
The cryogenically-cooled dewar is installed in the receiver cabin of the antenna. The dewer containing 10 receiver cartridges is maintained as a vacuum by vacuum pump and cryogenic cooler. The upper part of the receiver cartridge holding super-low-noise, high-sensitivity mixer is cooled to a temperature of minus 269 degrees Celsius. One cryogenically-cooled dewar is installed in each of 66 antennas.



3 Transmitting signals through optical fiber

Amplified radio signals are converted to digital signals and transmitted through optical fiber (6 terabits per second).

4 Correlation processing



Ten Receiver Bands

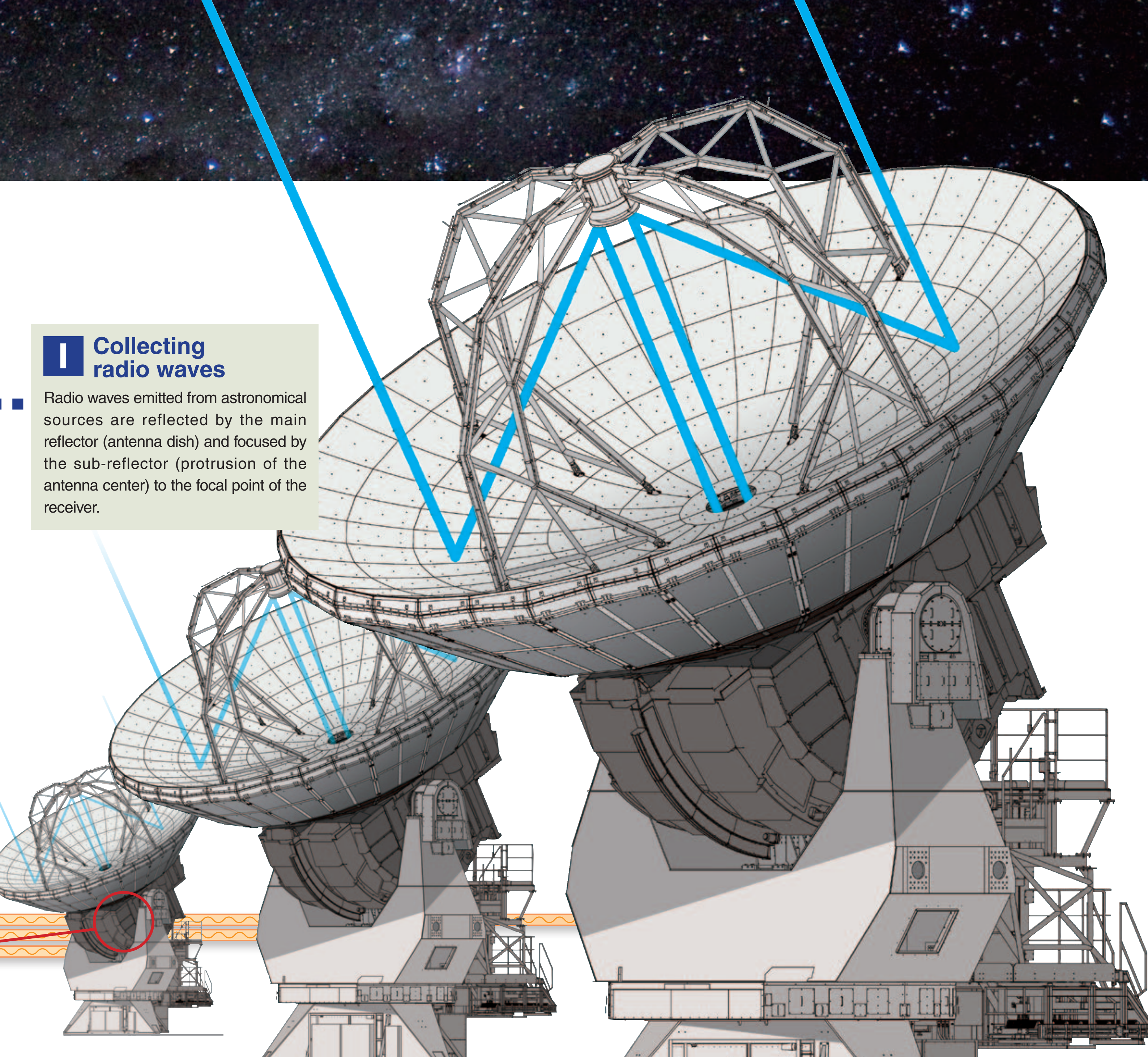
The ALMA antenna has 10 receiver cartridges from Band 1 to 10 that cover a wide frequency range from 31 GHz to 950 GHz. The figure above shows the receiver cartridge of Band 4, the frequency band containing an abundance of interstellar organic molecular lines with frequencies at millimeter wavelengths. ALMA-Japan develops and manufactures receiver cartridges of Band 4, as well as Band 8 (385 to 500 GHz) to probe spectral lines emitted by carbon atoms, which are important constituents of interstellar matters, and Band 10 (787 to 950 GHz) to open new frontiers in submillimeter astronomy. These receiver cartridges boast the world's highest performance.

Band	Frequency (GHz)	Developed by
1	31-45	—*
2	67-90	—*
3	84-116	North America
4	125-163	Japan
5	162-211	—*
6	211-275	North America
7	275-373	Europe
8	385-500	Japan
9	602-720	Europe
10	787-950	Japan

*These receiver bands are not available at the start of the full operation in JFY 2012.

Semiconductor clean room at NAOJ

ALMA-Japan manufactures receivers in a clean room of the Advanced Technology Center at the NAOJ Mitaka Campus. The clean room has high-precision equipment for manufacturing superconducting devices installed in the mixer.

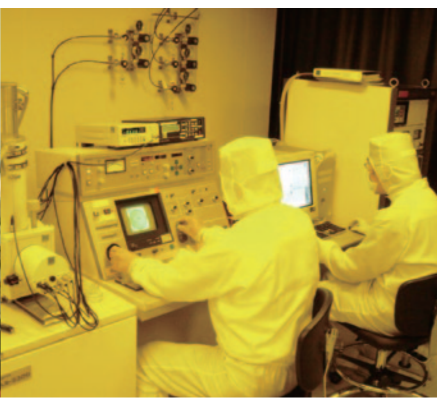


1 Collecting radio waves

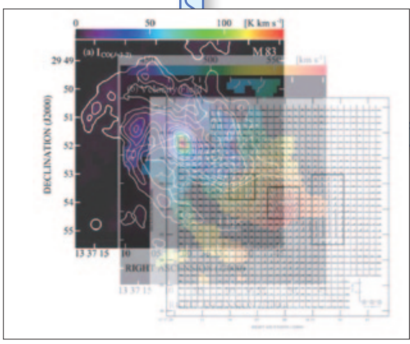
Radio waves emitted from astronomical sources are reflected by the main reflector (antenna dish) and focused by the sub-reflector (protrusion of the antenna center) to the focal point of the receiver.

High-speed correlation processing are is performed to obtain the information of the target object such as brightness, position, and velocity, etc from the digital signals transmitted from the antenna through optical fiber.

High-dispersion correlator installed in the Technical Building at the Array Operations Site (AOS)



5 Analyzing the data



Raw data is accumulated and processed by high-speed computer to produce radio images of the target objects. The processed data is compiled in a database.

6 Using the observation data and images

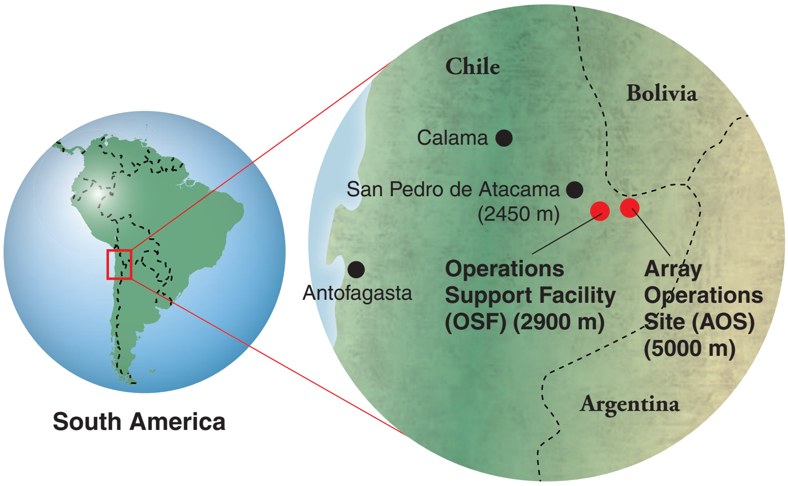
East Asian ALMA Regional Center

East Asian ALMA Regional Center (EA-ARC) archives vast amounts of processed data and supports research activities of the researchers in East Asia.

ALMA Observation Site in Chile

Location

ALMA is constructed in the Atacama Desert in northern Chile. ALMA antennas are assembled and adjusted at the Operations Support Facility (OSF) at 2900 m, and the assembled antennas are transported to the Array Operations Site (AOS) at 5000 m asl for observation. The annual rainfall in the Atacama Desert is less than 100 mm, and incoming radio waves are less susceptible to absorption by terrestrial water vapor. These favorable conditions of location enable the observation of radio waves at higher frequencies (shorter wavelengths) including submillimeter waves in the highest frequency band in ALMA. Also, a flat and wide space of the Chajnantor Plateau is perfect for the construction of ALMA which can be extended up to 18.5 km.



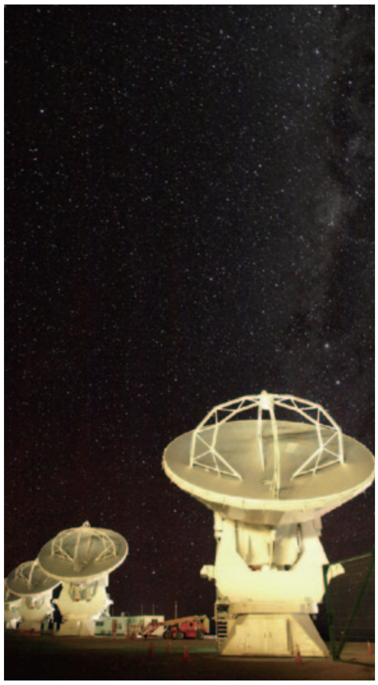
Operations Support Facility (OSF)

The Operations Support Facility (OSF) has antenna assembly areas of East Asia, Europe, and North America, work area of the Joint ALMA Office (JAO), accommodation facilities, and staff cafeteria where people from various nations are working. ALMA antennas are assembled, adjusted, and tested at the OSF, and then transported to the Array Operations Site (AOS).

Installation of the receiver in the antenna

Antenna transporter carrying an ALMA antenna

Antenna surface adjustment on a manlift



Adjustment test under the Milky Way (at the OSF)

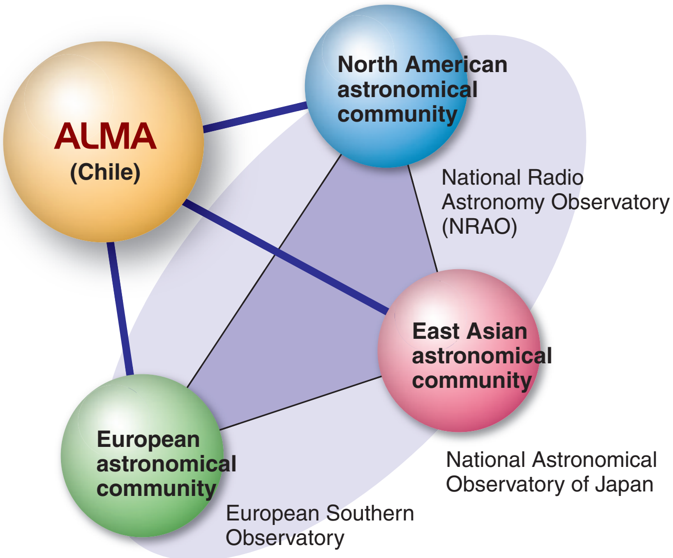
Array Operations Site (AOS)

At the AOS at 5000 m asl, 66 high-precision antennas will be situated in a vast area of 18.5 kilometers in diameter. Correlators to synthesize the signals received by the antennas are installed in the AOS Technical Building. It is not allowed to stay the night at the AOS because the amount of oxygen is only about a half of that at sea level. The antennas are remotely controlled during observation. ALMA started early science operation from September 2011. Toward the start of the regular operation from JFY 2012, construction of ALMA is well underway.

ALMA antennas at the AOS [Credit:ALMA(ESO/NAOJ/NRAO),J.Guarda(ALMA)]

Network for Observation and Operation

ALMA is a global project among East Asia, Europe, and North America. Being constructed in a site with the best possible observing conditions on earth, and assembling state-of-the-art technologies from all over the world, ALMA will be the ultimate telescope with unprecedented sensitivity and resolution.



Observing proposals are accepted by the Joint ALMA Observatory (JAO) and reviewed by the experts from all over the world. Adopted proposals are executed by JAO staff from various nations and local staff, according to the observation procedures prepared by the proposer. Acquired observational data is sent to the proposer after the observation and made accessible to other researchers after a set period of time.

Successful antenna control test (October 2007)

History of Japanese Millimeter/ submillimeter Astronomy

Since the establishment in 1982, the NAOJ Nobeyama Radio Observatory (NRO) has contributed to the advancement of the Japanese radio astronomy. Discoveries of protoplanetary disks and black holes using the large radio telescopes pushed the level of Japanese radio astronomy to the highest in the world. Meanwhile, Japanese universities have built small and medium-sized unique radio telescopes, prior to ALMA, for pioneering astronomical research of the southern sky.

45-m Radio Telescope

Nobeyama Millimeter Array

VST2

ASTE Telescope

1982
NRO completed the 45-m Radio Telescope

1985
NRO completed the Millimeter Array

1994
The University of Tokyo built the 60-cm radio telescope VST2 in Chile

1996
Nagoya University built the 4-m radio telescope NANTEN in Chile

1998
A research team led by the University of Tokyo built the Mount Fuji Submillimeter-wave Telescope

2002
NAOJ built ASTE Telescope in Chile

2004
Nagoya University built NANTEN2 in Chile

ALMA Construction and Operation Schedule

About 25 years ago, while Japanese astronomical community was making a plan of the Large Millimeter/Submillimeter Array (LMSA; the forerunner of ALMA), U.S. and Europe were discussing other plans: the Millimeter Array (MMA) and the Large Southern Array (LSA) respectively. In 2001, these three projects were united as ALMA project.

Japanese antenna accepted by JAO as the first ALMA antenna (Dec 19, 2008)

Radio waves from a target source were successfully received by the two antennas linked as an interferometer (First fringe) (Apr 30, 2009).

2001
ALMA project launched

2002
North America started construction

2003
Europe started construction

2004
Japan started construction

2008
Japanese antenna was accepted as the first ALMA antenna

2011
Start of Early Science Operation

JFY2012
Start of Regular Operation

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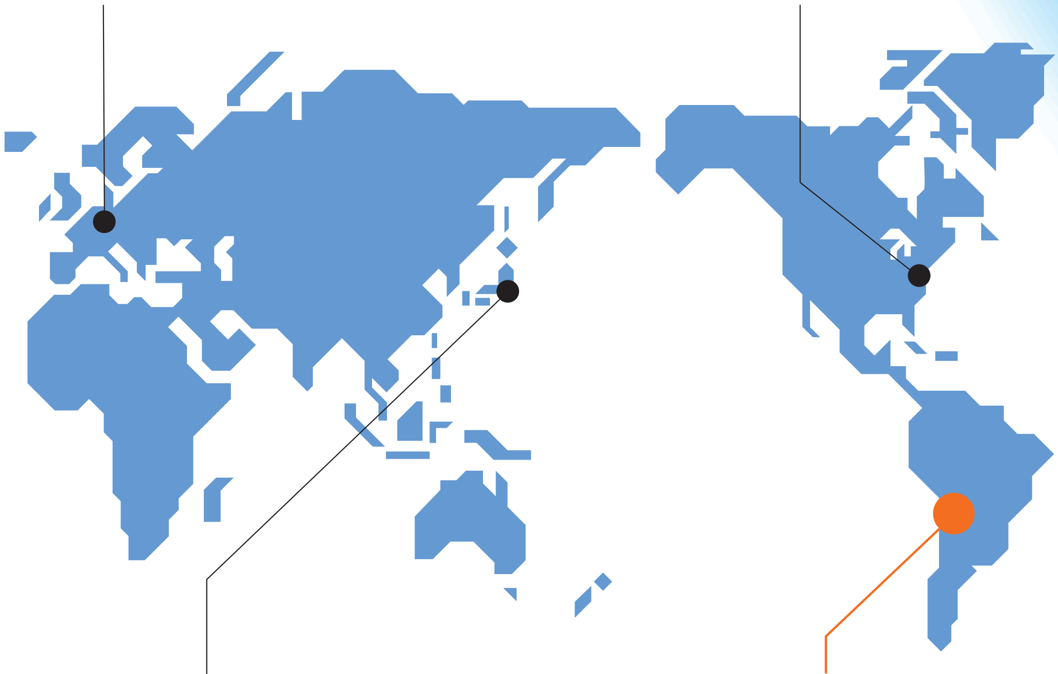
European Southern Observatory

http://www.eso.org/

National Radio Astronomy Observatory

http://www.nrao.edu/



National Astronomical Observatory of Japan

http://www.nao.ac.jp/E/

Joint ALMA Office (JAO)
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http://www.almaobservatory.org/

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