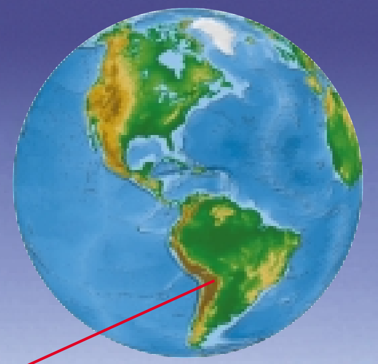
Building ALMA

ALMA is an international collaboration. Partners from North America include the United States (National Science Foundation, through its NRAO facility operated by Associated Universities, Inc.) and the Canadian National Research Council. European partners include the European Southern Observatory, the Centre National de la Recherche Scientifique (France), the Max-Planck Gesellschaft (Germany), the Netherlands Foundation for Research in Astronomy, the Netherlands Onderzoekschool Voor Astronomie, the United Kingdom Particle Physics and Astronomy Research Council, the Instituto Geográfico Nacional (IGN) and Ministerio de Ciencia y Technología (MCYT) (Spain) and the Swedish Natural Science Research Council. Japan is a partner in ALMA through the National Astronomical Observatory of Japan. Chile, as host nation for ALMA, participates in the project through its presence on the ALMA Coordinating Committee and by making available the superb astronomical site in the Atacama Altiplano.



(NRAO/AUI photo by Simon Radford)

Specifications

Array	Number of Antennas	64
	Total Collecting Area	7240 m^2
	Angular Resolution	0."02λ (mm)
Configuration	Compact	150 m
	High Resolution	14 km
Antennas	Diameter	12 m
	Surface Precision	<25 micrometers RSS
	Pointing	<0."6 RSS
Receivers	7 - 3 mm	20 - 50 K
	2 - 0.3 mm	6 - 10 hν/k SSB
Correlator	Baselines	2016
	Bandwidth	16 GHz per baseline
	Spectral Channels	4096 per IF

ALMA Sensitivity Goals

For an integration time of 60 seconds, the RMS flux density achieved will be:

Frequency (GHz)	Continuum ΔS (mJy)	Spectral Line ΔS (mJy) 1 km s^{-1}	Spectral Line ΔS (mJy) 25 km s^{-1}
35	0.020	5.1	1.03
90*	0.027	4.4	0.89
140	0.039	5.1	1.01
230*	0.071	7.2	1.44
345*	0.120	10.0	1.99
650*	0.849	51.0	10.20
850	1.260	66.0	13.30

*First light bands

Sensitivities for observations at 50° elevation. Quoted sensitivities for $\lambda > 1$ mm refer to the 75% quartile of atmospheric opacity: for $\lambda < 1$ mm it is the 25% quartile.

ALMA Timeline

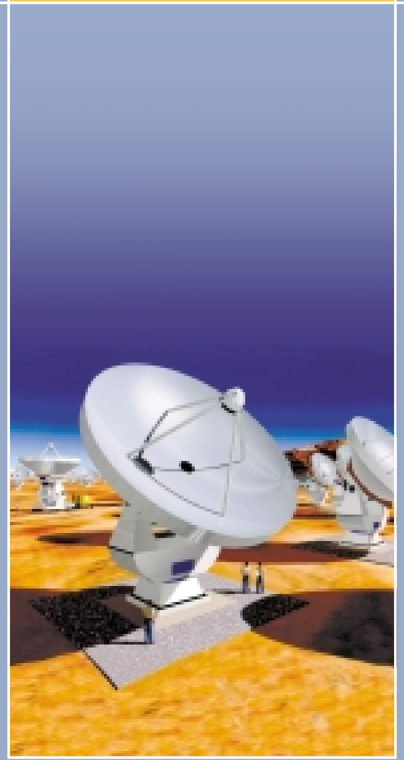
June 1998	Start of Phase I (Design & Development)
June 1999	U.S. / European Memorandum of Understanding for Design and Development
2002	Prototype antennas delivered to VLA site for testing
2002	Tripartite ALMA Agreement
2003	Prototype System testing
2005	First production antenna delivered to Chile
2006	Commissioning & early science operations with partial array
2007	Final antenna delivered

The National Radio Astronomy Observatory is a facility of the National Science Foundation, operated under cooperative agreement by Associated Universities, Inc.

ALMA on the web: Find us on the web at
http://www.alma.nrao.edu
http://www.eso.org/projects/alma
http://www.nro.nao.ac.jp/~lmsa/index.html

ALMA

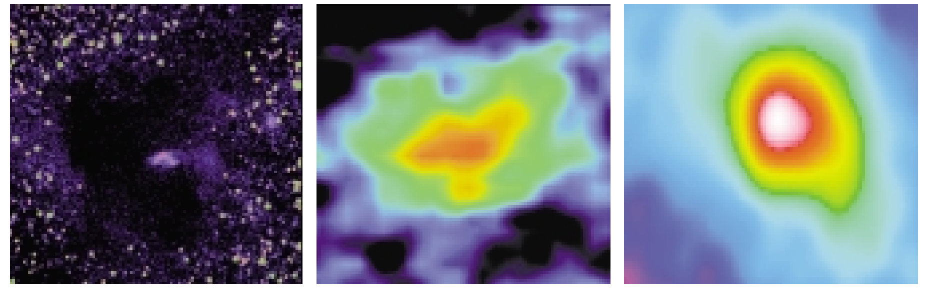
Atacama
Large
Millimeter
Array



The Atacama Large Millimeter Array (ALMA) project will bring to millimeter and submillimeter astronomy the aperture synthesis techniques of radio astronomy that enable precision imaging to be done on sub-arcsecond angular scales. The richness of the celestial sky at millimeter wavelengths is provided by thermal emission from cool gas, dust, and solid bodies, the same material that shines brightly at far infrared wavelengths. Presently, such natural cosmic emission can be studied from space only with the coarse angular resolution and limited sensitivity that small orbiting telescopes provide.

ALMA will image at 1 mm wavelength with the same 0.″01 resolution that will be achieved by the Next Generation Space Telescope. It will provide scientific insight at longer wavelengths that is complementary to that of the Very Large Telescope, and will do so with the same image detail and clarity. In addition, the reconfigurability of ALMA antennas gives ALMA a zoom-lens capability so that it also can make high-fidelity images of large regions of the sky. ALMA is astronomy's *complete imaging instrument.*

L483: Views of a star-forming cloud:
These views of the gas cloud L483 show that stars being formed shine brightly at millimeter wavelengths, but are invisible at optical wavelengths. With its high resolution (image detail) and high sensitivity, ALMA will be the first instrument to observe directly the condensation of material due to the gravitational collapse of molecular gas clouds from which stars form.



Optical (IRTF/NASA) | Molecular (NRAO/AUI) | Millimeter (JCMT)

An artist's conception of an ALMA antenna. (ESO)

Science

Millimeter and Submillimeter Astronomy

Cool radiation dominates our universe
In the Milky Way Galaxy, as in the diffuse extragalactic background elsewhere in the universe, the energy density of radiation peaks in the submillimeter; submillimeter wavelength photons are the most abundant photons in the universe.

Expansion redshifts emission
As the universe expands, radiation is shifted to millimeter wavelengths into a region that ALMA will image with ease and clarity.

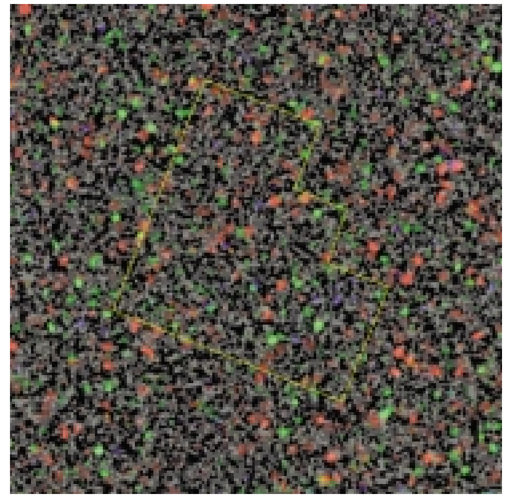
Heavy elements emit in the submillimeter regime
As cosmic processes produce heavy elements from the hydrogen and helium found in the first stars, large molecules and dust particles are formed. The dust obscures young stars and galaxies from view at optical wavelengths. Emission from cool dust and molecules shines brightly at short millimeter wavelengths.

Forming objects are cool
As stars and planets form, they are too cold to emit visible light, but they emit strongly at short millimeter wavelengths. These are the wavelengths to be imaged by ALMA.

ALMA: Imaging Cosmic Dawn

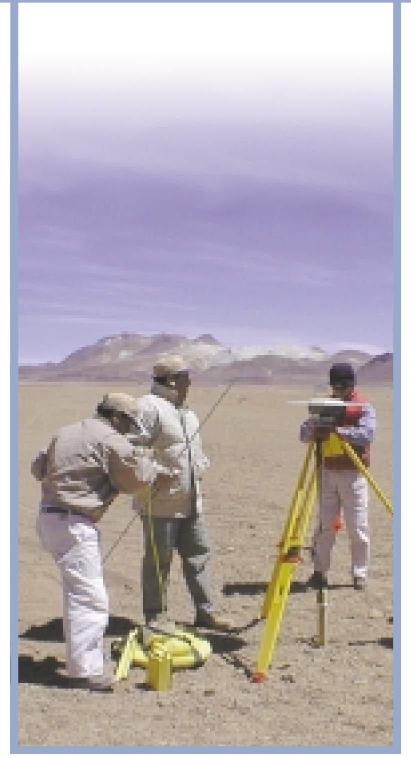
The Atacama Large Millimeter Array Will Image:

Young distant galaxies
As galaxies formed, stars created heavy elements giving rise to dust and molecules that hid the newly formed stars from view. In the submillimeter, that curtain of gas brightly shines; ALMA will image it with clarity at a sensitivity hundreds of times better than is possible today. For the early universe, the brightest portion of the spectrum of galaxies is shifted into the submillimeter, offering us a unique view of galaxies as they existed long, long ago. In the view shown below, a patch of sky the size of the Hubble Deep Field (HDF) is simulated for an ALMA integration of a few hours per field. In the HDF, galaxies seen at visual wavelengths are relatively nearby. These galaxies are blue in the simulation. In the ALMA field, very distant galaxies are colored red; these are the galaxies to be seen in the submillimeter sky. Furthermore, ALMA will obtain spectra of each object *allowing ALMA to image in the third dimension, distance.*



(NRAO/AUI)

This ALMA simulation reveals very distant galaxies (red) after a few hours' integration.

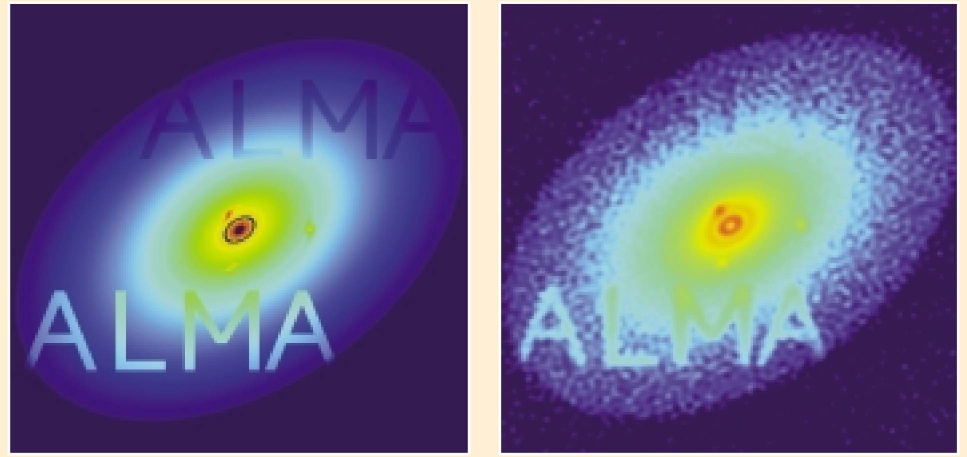


(NRAO/AUI photo by Bryan Butler)

Scientists using GPS to measure a location at the ALMA site.

The formation of stars
Stars are born in dusty, optically opaque cocoons of gas and dust. We know that mass infall, disks, jets and interstellar material all complicate our understanding of how stars form; these structures can only be resolved through application of high resolution spatial and kinematic imaging, such as that afforded by ALMA. ALMA will be able to image and chart the progress of interstellar shocks accompanying infall and outflow on timescales of a single revolution of the protostellar disk, or shorter. ALMA will image the gaps created in the disks by the motions of forming planets; it will also image the protoplanets themselves as they form from the debris disk.

The formation of planets
Planets are thought to form from accretion of material from the debris disk accompanying star formation. The chemical structure of the disk, as well as the spatial and kinematic structure of the disk, will be imaged in unprecedented detail by ALMA.



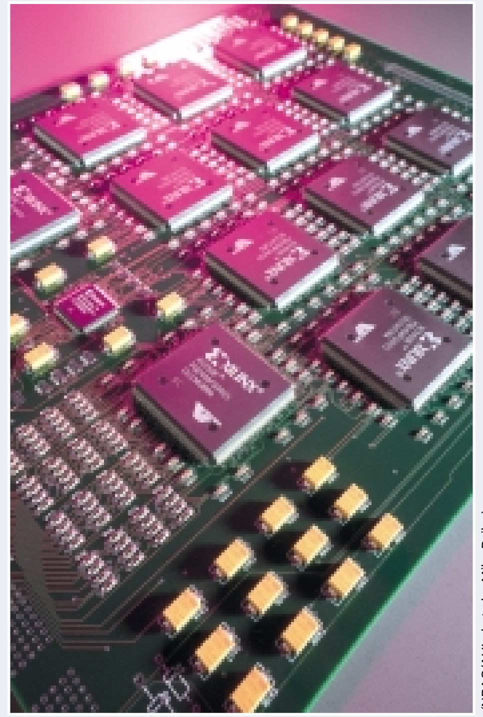
(Lee Mundy, University of Maryland)

This simulation of a proto-planetary disk, using the 10-km-diameter array configuration yielding a resolution of 20 milli-arcseconds at 230 GHz, shows what ALMA can do for studies of planet-forming environments. The model is on the left. ALMA's view is on the right.

Technology

A precision imaging telescope
The antenna, the heart of ALMA, must maintain its precise figure under the strains of remote high altitude operation on the Llano de Chajnantor site at 5,000 m (16,500 feet) elevation in the Atacama Region of northern Chile. Here temperatures may vary from below freezing at night to blazing hot in the day, and a constant breeze scours the earth. The site, the highest ever located for a telescope on Earth, offers the exceptionally dry and clear sky required for ALMA. The ALMA design, being done by the experienced ALMA partners, will fully exploit this superb site.

Detector technology
Receiving systems on ALMA will cover the entirety of the electromagnetic spectrum observable from the Earth's surface from 7 mm to 0.3 mm in wavelength. At the heart of the receiving system are sensitive superconducting tunnel junction mixers, operating at just 4 degrees above absolute zero. Together, the mixer systems on the 64 ALMA antennas will provide the most extensive superconducting electronic receiving system in the world.



(NRAO/AUI photo by Mike Bailey)

A circuit board for the ALMA correlator, made at the NRAO Central Development Laboratory.

Signal processing capacity
ALMA forms images by continuously combining signals from each antenna with those from every other antenna. There are 2,016 such antenna pairs. From each antenna a bandwidth of 16 GHz will be received from the astronomical object being observed. The electronics will digitize and numerically process these data at a rate of over 16,000 million-million operations per second (1.6x10^{16}). Astronomical images are constructed from the processed data.

A site to meet the demands
Since 1995, the U.S. National Radio Astronomy Observatory, the European Southern Observatory, and the National Astronomical Observatory of Japan have collected atmospheric and meteorological data at the Llano de Chajnantor site in northern Chile, which is at an elevation of 5,000 m (16,500 feet). These studies show the sky above the site has the unsurpassed clarity and stability essential for ALMA. The site is large and open, allowing easy re-positioning of the antennas over an area 14 km (10 miles) in extent. An international highway provides access to the site, a natural gas pipeline crossing the site will be tapped as a source for electric power, and logistical support is available from the nearby village of San Pedro de Atacama.