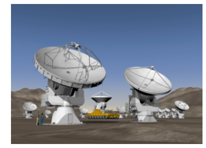
The Atacama Large Millimeter Array

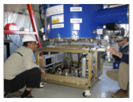
Al Wootten and the ALMA Science Team

NRAO



The Project

The first NA production antenna is assembled at the Operations Support Facility VertexRSI Site Erection building, undergoing final tests leading to acceptance.



The first ALMA production Front End has been delivered to Chile from the North American Front End Integration Center in Charlottesville. This package contains electronics for collecting the faint signals from the sky. Here it undergoes provisional acceptance in Chile at the OSF.

At the Operations Support Facility, at 9600 feet elevation between Chajnantor and San Pedro de Atacama, construction has been completed.

RECENT PROGRESS IN BUILDING ALMA

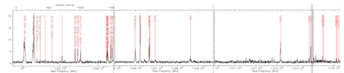
•The 12m antennas have been purchased, with both North America and Europe placing a contract for at least 25, and Japan having contracted for their 4. These antennas are the highest precision radio telescopes ever built. The first five North American and the first four Japanese production antennas are on the ALMA site. The transporters will shortly move the first antennas around the site. Two prototypes at the ALMA Test Facility (ATF) in Socorro, NM (upper right) have successfully demonstrated interferometry with a prototype system.

•Construction of the technical building (TB) on the 16,500-foot elevation Array Operations Site (AOS) has been completed (lower right). Construction at the mid-level Operations Support Facility (OSF) is also complete (Jan 2008; lower left)

•Prototype receivers all meet specifications, near quantum-limit noise, unprecedented bandwidth, and require no mechanical tuning. The first receiver package has undergone provisional acceptance at the Operations Support Facility.

•The first quadrant of the ALMA correlator is complete and under test. Blazingly fast in its single-minded functionality, the complete correlator will achieve greater than 10^{16} floating point operations per second. It will be installed in the AOS TB (right) later in 2008. The 16 station correlator from NAOJ is currently installed at the AOS TB.

•ALMA Regional Science Centers in North America, Europe and East Asia have been organized.



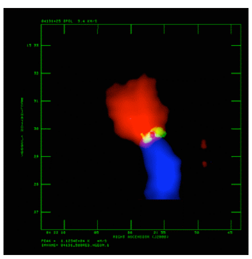
Spectrum of the Orion Hot Core obtained with the prototype system at the ALMA Test Facility and reduced with CASA

The Two ALMA transporters, one carrying a dummy antenna load, pass on the road to the AOS. Soon they will transport antennas about the site.

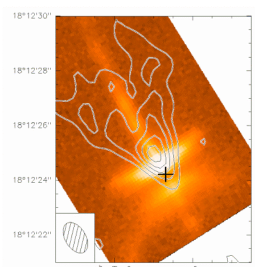
The Array Operations Site Technical Building, the world's highest altitude high-tech building at 16,500 feet

(Some of) The Science

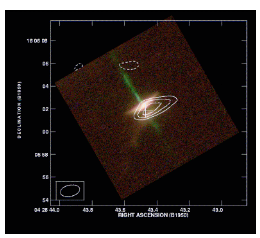
Protoplanetary Disks



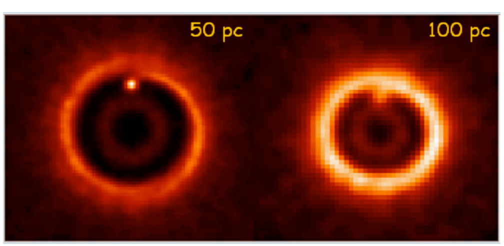
•Paradigm: material falls through a rotating circumstellar disk onto a forming star from more extensive envelope, fuelling a bipolar flow which allows loss of angular momentum (see HH30 disk, far right at best current resolution).
•After the formation of the star, planets form from the remnant disk. Planets forming from accretion will be directly imaged by ALMA in nearer star-forming regions.
•In later stages, planets mature, becoming cooler and smaller. Currently suspected exoplanets will emit only a few microJy of flux in the submillimeter, requiring weeks of ALMA observing time and are essentially not directly detectable.
•Reflex motions can be easily measured by ALMA. All accessible stellar hosts of exoplanetary systems can be imaged in seconds by ALMA which can measure positions to ~0.1 mas accuracy.
•Debris disks can easily be detected and imaged by ALMA. ALMA's resolution can relieve confusion from background galaxies. ALMA's accurate imaging will reveal debris disk patterns suggesting the presence of planets.



CO(2-1) contours superimposed on an HST image of HH 30. The HST observations in false colors (from Burrows et al. 1996) show the optical continuum emission tracing the reflected light in the flared circumstellar disk, together with the emission of bright atomic lines ([SII], Ha, [OI]), tracing a highly collimated jet, perpendicular to the disk. The contours represent the CO(2-1) emission, as observed with the IRAM Plateau de Bure interferometer with an angular resolution of 1.2"×0.7" by Gueth et al. in prep. Only the channel map at a velocity of 11 km/s is plotted (contours are 80 mJy/beam). It shows the conical molecular outflow emanating out of the disk and surrounding the jet. The cross indicates the position of the peak of the 1.3 mm continuum emission. ALMA's resolution will exceed that of this image by up to two orders of magnitude.

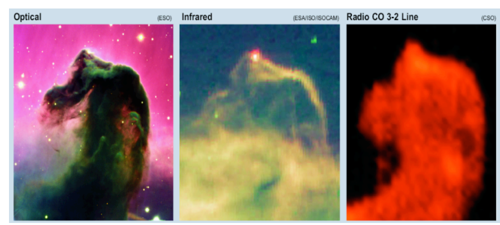


HH 30: Overlay of the integrated ^{13}CO 2-1 emission (contours) on the HST/WFPC2 image (color). A cross marks the position of the 1.3 mm continuum source. Stapelfeldt and Padgett (2001) in Wootten, A., ASP Conf. Ser. 235: *Science with the Atacama Large Millimeter Array*, 163. c



A simulation (Wolf & D'Angelo 2005) of ALMA observations at 950 GHz of a disk shows an embedded protoplanet of 1 Jupiter Mass around a 0.5 Solar Mass star (orbital radius: 5AU). The assumed distance is 50 pc or 100 pc as labeled. The disk mass is set to that of the Butterfly Star (IRAS 04302+2247) in Taurus. Note the reproduced shape of the spiral wave near the planet and the slightly shadowed region behind the planet in the left image. Image courtesy of S. Wolf

Formation of Stars and Planets

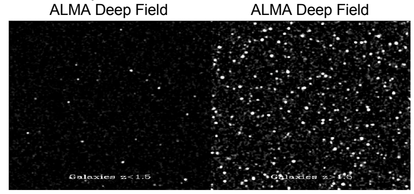


ALMA will be able to trace the chemical evolution of star-forming regions over an unprecedented scale from cloud cores to the inner circumstellar disk. At spatial resolution of 5 AU, it will determine the nature of dust-gas interactions the extent of the resulting molecular complexity, and the major reservoirs of the biogenic elements. Angular resolution will exceed that of the HST. In the optical, dust obscures star-forming activity in the Horsehead Nebula. In the infrared, hot dust glows but emission bears no kinematic signature. At radio wavelengths, both dust and trace molecules glow, providing a wealth of information on structure, density and kinematics of optically invisible regions. ALMA will map the glowing emission (rightmost panel) at the resolution of the optical image (leftmost panel).

ALMA Deep Field: Poor in Nearby Galaxies, Rich in Distant Galaxies

Nearby Galaxies in ALMA Deep Field

Distant Galaxies in ALMA Deep Field



Source: Wootten & Gallimore NRAO
Source: K. Lanzetta, SUNY-SB

Nearby (z<3) Galaxies in Hubble Deep Field

Distant (z>3) Galaxies in Hubble Deep Field

ALMA Deep Field: Most of the galaxies that will be detected in sensitive ALMA images will have large redshifts. This is illustrated in the top row that shows the number of low redshift (z<1.5) and high redshift (z>1.5) galaxies expected from a simulated deep ALMA observation. Although the high redshift galaxies are more distant, much more of the dominant emission from warm dust is redshifted into the ALMA frequency bands. The bottom row shows that with an optical image, such as the Hubble Deep Field, most of the detections are of galaxies with z<1.5. In stark contrast to the optical image, 80% of the ALMA detected galaxies will lie at high redshifts.

The Specifications and Requirements

Receiver Bands

Band Number	Frequency Range (GHz)	Wavelength (mm)	Instantaneous Bandwidth (GHz)
1	31.3 - 45.0	6.7 - 9.6	1 × 8
2	67 - 90	3.3 - 4.5	1 × 8
3	**84 - 116**	**2.6 - 3.6**	**2 × 4**
4	**125 - 163**	**1.8 - 2.4**	**2 × 4**
5	**163 - 211**	**1.4 - 1.8**	**2 × 4**
6	**211 - 275**	**1.1 - 1.4**	**1 × 8**
7	**275 - 373**	**0.8 - 1.1**	**2 × 4**
8	**385 - 500**	**0.6 - 0.8**	**2 × 8**
9	**602 - 720**	**0.4 - 0.5**	**2 × 8**
10	787 - 950	0.3 - 0.4	2 × 8

(Bands in bold font will be available at first light)

ALMA Sensitivity Goals for the 12 m Array

For an integration time of 60 seconds, a spectral resolution of 1 km s^{-1}, the RMS flux density, ΔS, and brightness temperature sensitivity, ΔT, with a 64 antenna array and maximum baseline, B_{max}, will be:

Frequency (GHz)	Continuum ΔS (mJy)	Spectral Line ΔS (mJy)	B_{max} = 0.2 km: Beam (arcsec)	B_{max} = 0.2 km: ΔT_{cont} (K)	B_{max} = 0.2 km: ΔT_{line} (K)	B_{max} = 14.7 km: Beam (arcsec)	B_{max} = 14.7 km: ΔT_{cont} (K)	B_{max} = 14.7 km: ΔT_{line} (K)
110	0.047	7.0	3.18	0.0005	0.070	0.038	3.3	482
140	0.055	7.1	2.50	0.0005	0.071	0.030	3.8	495
230	0.100	10.2	1.52	0.0010	0.104	0.018	6.9	709
345	0.195	16.3	1.01	0.0020	0.167	0.012	13.5	1128
409	0.296	22.6	0.86	0.0031	0.234	0.010	20.5	1569
675	1.042	62.1	0.52	0.0108	0.641	0.006	72.2	4305

Specifications

		Large Array	Compact Array
Array	Number of Antennas	up to 64	12 (7 m) + 4 (12 m)
	Total Collecting Area	up to 7240 m^2	460 + 450 m^2
	Angular Resolution	0.02" (λ /1 mm)(10 km/baseline)	5.7" (λ /1 mm)
	Continuous Zoom	150 - 18500 m	
Antennas	Diameter	12 m	7 m, 12 m
	Surface Precision	<25 μm	<20 μm, <25 μm
	Offset Pointing	<0.6"	<0.6"
Correlator	Baselines	2016	120
	Bandwidth	16 GHz per baseline	16 GHz per baseline
	Spectral Channels	4096	4096