



The Atacama Large Millimeter Array

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NRAO

The Project

ALMA Commissioning Progress

• There are five 12m antennas at the 5100m Array Operations Site operating as a Commissioning Array. Sky-wide antenna surface errors measured by astronomical holography and pointing are well within specifications. Four additional antennas are undergoing outfitting integration and verification at the 2900m altitude Operations Support Facility. Surface errors on these measured using fixed source holography are around 10µm. At the contractor's camps at the OSF another three Mitsubishi antennas, six Alcatel antennas and eight Vertex antennas are in various stages of assembly.

• Sky-tested, the receivers all meet specifications, near quantum-limit noise and unprecedented bandwidth with no mechanical tuning. There are eight 'front end' assemblies at the ALMA site; all have receivers at 3mm, 1.3mm, .85mm and .45mm bands; the most recently-arrived package contains receivers at 2mm and .6mm as well.

• The first quadrant of the ALMA correlator is used in the commissioning array; two of the three remaining correlator quadrants are on-site. Blazingly fast in its single-minded functionality, the complete correlator will achieve greater than 10¹⁶ floating point operations per second. The 16 station correlator from NAOJ is also currently installed at the AOS TB.

• ALMA Regional Science Centers in North America, Europe and East Asia have been organized and are participating in user tests in preparation for the expected issuance of a call for proposals for Early Science early in about seven months.



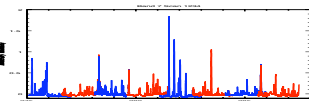
A fifth antenna joined the array on 31 May. Antennas are moved on one of two immense transporters.



Antennas at the OSF received from the vendors, undergo holography for panel setting and pointing (left) before incorporation into the new science configuration (right) for final integration and verification. After this program they are transported to join the commissioning array at 5100m (far right).



At the Control Room at the Operations Support Facility at 2900 feet elevation between Chajnantor and San Pedro de Atacama, teams test and commission the AOS Array (left), the OSF interferometer (off-view, right) and new antennas being outfitted for array operation (right).



Small section of spectrum of the Orion Hot Core obtained with the three dual-polarization antennas as part of a tunability test (30s per integration, total power mode). 2 GHz #s in color; 0-order baseline only subtracted.

Early Science: mid-2011

ALMA Early Science initiates a transformation of millimeter astronomy

The chart at right summarizes the instrument at Early Science (mid-2011) and at Inauguration (Sept 2012). With 10% of final sensitivity (charts below) and 120 of the eventual 1500 baselines at Early Science the instrument will excel at imaging to a precision never before attained. As new antennas arrive at the AOS at a rate of ~1 per month, sensitive multi-beam surveys are best executed with complete array. Spectral scans may be executed, though only a limited set of the more than five dozen correlator configurations are available, in part owing to the single quadrant available now. On longer baselines, active correction for phase corruption by what little atmospheric water lies above ALMA is under demonstration now for the <0.5km baselines which have been employed thus far.

The Atacama Large Millimeter Array (ALMA) Quick Reference

	Late 2010	Early 2011	Mid 2011	Mid 2012	2013			
Call for ALMA Early Science Proposals								
Early Science Proposal submission deadline								
Early Science begins								
ALMA Inauguration								
66 ALMA Antennas								
Bands:	3	4	5	6	7	8	9	10
Frequency (GHz)	84-116	125-163	163-211	211-275	275-373	385-500	602-720	787-950
Wavelength (mm)	3.57-2.59	2.40-1.84	1.84-1.42	1.42-1.09	1.09-0.80	0.78-0.60	0.50-0.42	0.38-0.32
Antennas	≥ 16 × 12m			≥ 50 (12m & 7m)				
Bands	≥ 3 bands (Bands 3,6,7,9 likely)			Bands 3,6,7,9 (+ 4,8 & 10 on some)				
Maximum Bandwidth	16 GHz (2 polarizations × 8 GHz)							
Correlator Configurations	≥ 5			0.01 - 40 km/sec, 71 configurations				
Maximum Angular Resolution	0.02" ($\frac{\lambda}{1 \text{ mm}}$)			10 km (max baseline)				
Maximum Baseline	At least 250m (may reach 1km)			15.3 km				
Continuum Sensitivity (60 sec, Bands 3-9)	~0.2 - 4.2 mJy			~0.05 - 1 mJy				
Spectral Line Sensitivity (60 sec, 1 km/sec, Bands 3-9)	~30 - 250 mJy			~7 - 62 mJy				

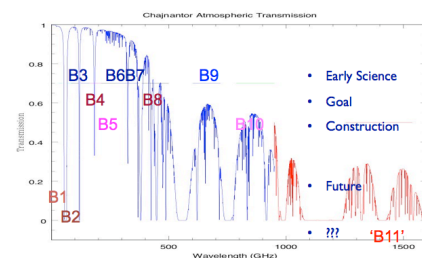
Sensitivity Calculator: <http://science.nrao.edu/alma/tools.shtml>

Table 1. Summary of ALMA Early Science Parameters

Band ^a	Frequency (GHz)	T _{SSB} ^b (K)	Configuration of Receiver	Continuum ^c ΔS (mJy)	Spectral Line ^d ΔS (mJy)	Beam ^e (arcsec)
3	84 - 116	41	2SB	0.18 (0.05)	29	2.5
6	211 - 275	83	2SB	0.46 (0.15)	47	1.1
7	275 - 373	147	2SB	0.71 (0.22)	63	0.8
9	602 - 720	175	DSB	3.2 (1.0)	164	0.4
4	125 - 163	51	2SB	0.25 (.08)	33	1.8
8	385 - 500	196	2SB	1.5 (0.49)	111	0.6

^a All bands provide two polarizations. ^b Requirement for 80% of the radio frequency band. ^c Bandwidth = 8 GHz, two polarizations. 16 antennas assumed with 50-antenna sensitivity in parentheses; 1σ for 60s integration given for nominal atmospheric conditions. One Jansky (Jy) = 10⁻²⁶ W m⁻² Hz⁻¹. ^d Bandwidth = 1 km s⁻¹ (equivalent Doppler spread at line frequency), two polarizations, 16 antennas. ^e 250m baseline resolution.

ALMA Bands and Transparency



The Specifications and Requirements

Band	Frequency	B _{max} = 0.2 km			B _{max} = 15 km		
		Beam(°)	ΔT _{cont} (K)	ΔT _{line} (K)	Beam(°)	ΔT _{cont} (K)	ΔT _{line} (K)
Band 1	31.3 - 45 GHz						
Band 2	67 - 90 GHz						
Band 3	84 - 116 GHz	3.18	0.0005	0.07	0.038	3.3	482
Band 4	125 - 163 GHz	2.5	0.0005	0.071	0.03	3.8	495
Band 5	163 - 211 GHz						
Band 6	211 - 275 GHz	1.52	0.001	0.104	0.018	6.9	709
Band 7	275 - 373 GHz	1.01	0.002	0.167	0.012	13.5	1128
Band 8	385 - 500 GHz	0.86	0.0031	0.234	0.01	20.5	1569
Band 9	602 - 720 GHz	0.52	0.0108	0.641	0.006	72.2	4305
Band 10	787 - 950 GHz	0.38			0.005		

To be developed in the future. Available for early science.

ALMA Specifications

Hardware	Specification
Antennas	
Number of Antennas	at least 50 (12m) [ALMA] + 12 (7m) & 4 (12m) [ACA]
Maximum Baseline Lengths	0.15 - 15 km
Angular Resolution (")	0.2" × (300 / √[GHz]) / baseline (km)
14m Primary beam (")	21" × (300 / √[GHz])
Correlator	
Number of Baselines	up to 2016
Bandwidth	8 GHz per baseline or equiv. 8000 × (300 / √[GHz]) km/s
Velocity Resolution	0.5 × (300 / √[GHz]) km/s with 8 GHz bandwidth 0.008 × (300 / √[GHz]) km/s with 125 MHz bandwidth

