ALMA

The Atacama Large Millimeter Array

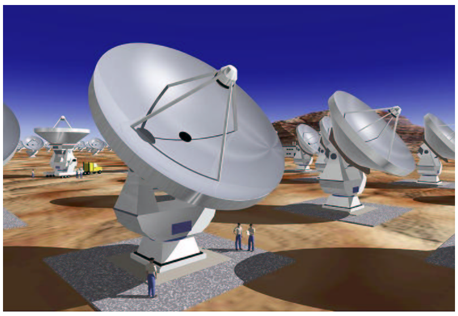
ALMA at Chajnantor
(Courtesy NAOJ)

ESO PR Photo 14/01 (6 April 2001)

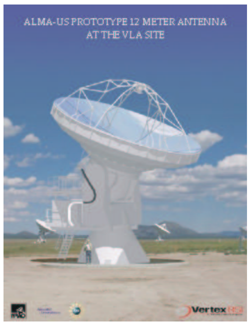
ALMA site

5 km altitude at the foot of the high Andes

ALMA telescopes (EU)



ALMA telescopes (US)



ALMA specifications

- 64 antennas, at 5km height
- 12m diameter, ±20 μm, 0.6” in 9m/s wind
- arrays of 150m to 12km
- 10 bands in 31-950 GHz + 183 GHz WVR. Initially:
  - 86-119 GHz
  - 211-275 GHz
  - 275-370 GHz
  - 602-720 GHz
- 8 GHz Δν, dual polarisation, 4096 channels/IF

  (Note: varying numbers mentioned throughout project)
- 600 M$US

ALMA specifications

- all bands online
- any 1 + 0.5 bands accessible
- filled (150m) to ring (12km) and log-spiral or ring
- data rate: 1M visibilities/s average

  (= 6Mb/s average; 60Mb/s must be sustainable)
- all data archived (raw + images)
- AC (Compact or Complementary)A
  - 6-10 antennas of 6-8m diameter in ring or hexagon for short spacings

Sensitivity goals

GHz	$\Delta S(\mu Jy)$	$\Delta S(mJy)@1km/s$
35	20	5.1
90*	27	4.4
140	39	5.1
230*	71	7.2
345*	120	10.0
650*	849	51.0
850	1260	66.0

At 50 deg elevation and best 25% weather for λ<1mm;
best 75% for λ>1mm

Other arrays

Comparison with other mm arrays

Array	Total Area (m^2)	Mosaic Speed (nD)	SSB Tsys @ 90 GHz	η_a	Freq. range (GHz)	Pol	BW (GHz)	Max. Bsln (km)	Line sens. (mJy)	Cont. sens. (mJy)
BIMA (10*6.1m)	290	61	150	0.7	70-115, 210-270	1	0.8	1.5	23	1.4
OVRO (6*10.4m)	510	62	250	0.7	86-116, 210-270	1	1.0	0.2-0.4	23	1.3
NMA (6*10m)	470	60	400	0.65	85-116, 126-152, 213-237	1	1.0	0.4	43	2.4
IRAM PdB (5[6]*15m)	880 [1060]	75 [90]	150	0.7	80-115, 210-250	1	0.5	0.4	8.2 [6.7]	0.63 [0.5]
ATCA (5*22m)	1900	110	250	0.4	85-110	2	0.2	3.0	7.9	1.0

Sensitivity estimates are for 1 hr integration at 90 GHz, all pols. combined.
Line sensitivity is for a 10 km/s channel.
Actual sensitivity will depend on atmospheric phase.

(Courtesy Tony Wong)

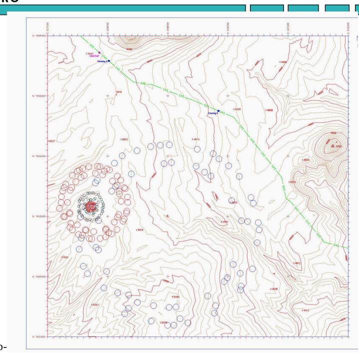
ALMA map

Geographical Map with VLT and ALMA Locations

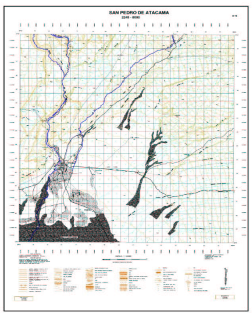
ESO PR Photo 24d/99 (8 June 1999)

© European Southern Observatory

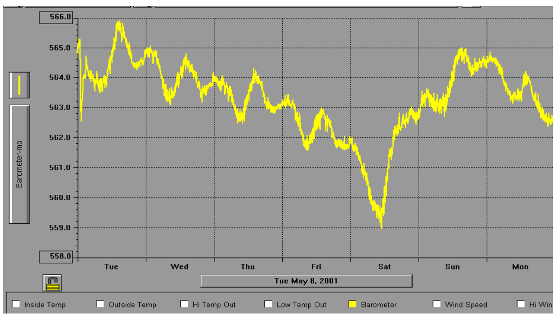
ALMA local area



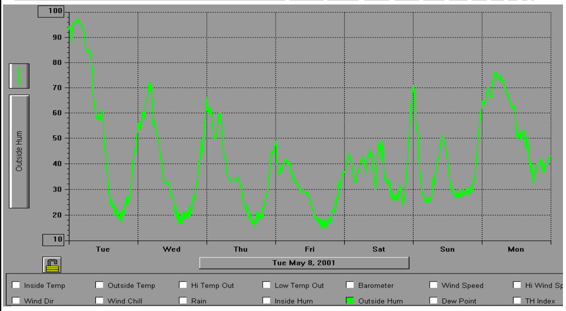
ALMA topo



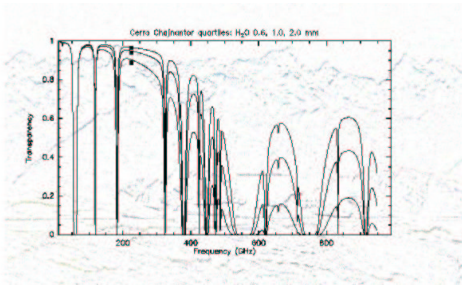
ALMA barometer



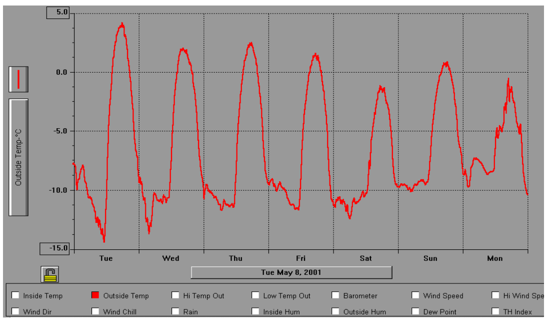
ALMA humidity



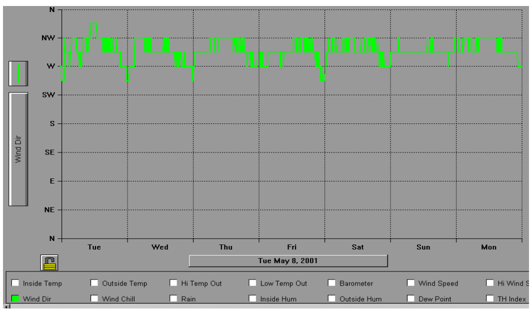
Atmospheric transparency



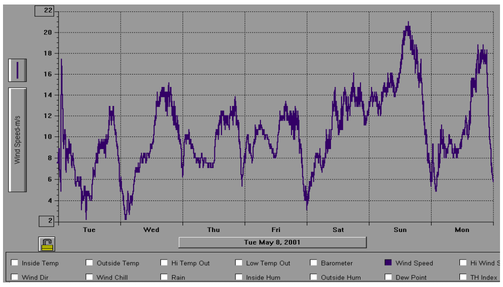
ALMA temperature



ALMA wind direction

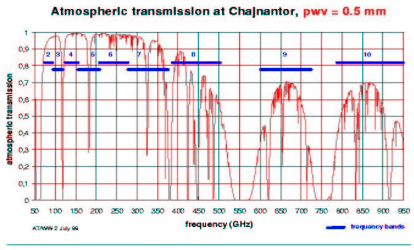


ALMA wind speed



wnb-010928 Synthesis Imaging Workshop 17

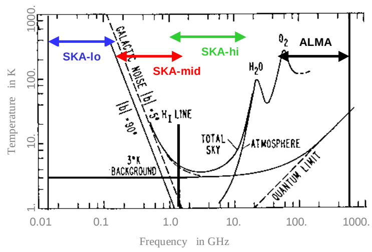
ALMA bands



(courtesy Wolfgang Wild)

wnb-010928 Synthesis Imaging Workshop 18

Noise regimes

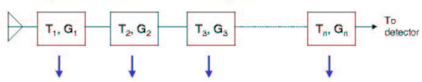


wnb-010928 Synthesis Imaging Workshop 19

System noise source

Noise Contributions from Receiver Components

Receiver as a series of linear two-ports:



$T_{rx} = T_1 + T_2/G_1 + T_3/(G_1 G_2) + \dots + T_n/(G_1 G_2 \dots G_n)$

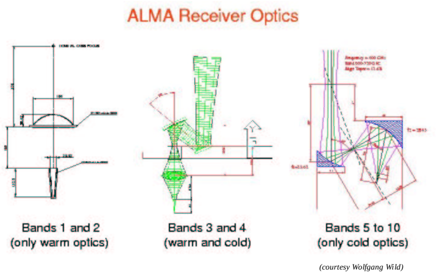
⇒ Receiver noise temperature determined by first few elements

⇒ Cooled optics for high frequencies

(courtesy Wolfgang Wild)

wnb-010928 Synthesis Imaging Workshop 20

Receiver optics



ALMA schedule

Proposed schedule:

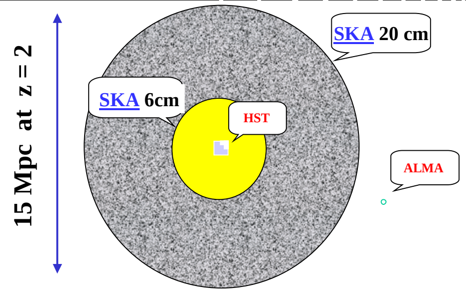
- 2 prototype (US and EU) antennas in August 2002
  - 6-9 months delayed
- January 2002: Construction (Phase 2) start
  - delayed due to US president budget stop for new projects
  - possible move of astronomy from NSF to NASA
  - future projects uncertain at the moment
- April 2003 decision on antennas (+ 0.5 year?)
- 2006 interim operations
- 2011 full science operations

ALMA status

Decisions:

- ESO (+E) December 2001 (when and if US decision)
- USA (+CA) Hopefully next budget
- JP Contract signed in April 2001
- First talks about work division for 3 partners held in Paris
- For computing 3rd partner adds 12% to cost
- US proposes to cut project by 20%
- ESO wants no cuts, at most 10% - accepted by all parties
- JP still hopes to add extra bands; next correlator
- JP also talking ACA
- Fight for money started (e.g. software/computing is 32M$) by partners

Field-of-view



Primary beam from 180” (30GHz) – 6” (900GHz)

ALMA mosaicing

Many objects to be observed by ALMA, such as nearby galaxies and molecular clouds in our own galaxy, will be diffuse and much larger than ALMA's primary beam. Mosaicing will have to be done. However, mosaicing places stronger constraints on the antennas than single pointing interferometry.
Why not build a 70~m single dish to observe these big sources? Mosaicing is faster than single dish observations, mainly because of the multiple synthesized beams which can be formed within each primary beam.

Mosaicing limits

Pointing: Because the emission spans beyond a single primary beam in mosaicing, small antenna pointing errors can have a large effect on the observed flux of a feature which lies near the half power point of the beam. Pointing accuracy of about 1/25th of the beamwidth will permit mosaics of about 1000:1 dynamic range (linear with ν).
Surface Accuracy: Surface errors will scatter radiation into the primary beam sidelobes, and unmodeled primary beam sidelobe structure will limit the quality of mosaic images. While surface accuracy of 1/16th of a wavelength only degrades the dish efficiency by a factor of 2 from Ruze losses, 1000:1 dynamic range mosaics will require surface accuracies of about 1/40th of a wavelength (quadratic with ν).

Mosaicing limits

Getting Very Short Spacings: The homogeneous array concept requires that the antennas be fairly close together (ie, 1.3 times the dish diameter for zenith observations) to be able to measure spatial frequencies in the range of the dish diameter. However, the antennas can actually smack into each other if the separation is less than about 1.5 dish diameters (depending upon the design). To improve the short spacing capabilities (i.e. the large scale structure) the ACA has been proposed with about 10 antennas of about 6m diameter.

Phase stability

Inhomogeneously distributed water vapour results in different electrical path lengths above the different antennas, or phase error. The phase errors scatter flux, limiting the dynamic range, and also cause decorrelation, which artificially decreases the source amplitude.
The initial calibration is planned with a 183GHz spectral line WVR (*cf* the ATCA 22GHz WVR).

Calibration possibilities

The complete ALMA array, with 64 telescopes has about 2000 baselines, many more than any other existing telescope. This enables the use of algorithms different from used in today's mm instruments. E.g.:

- use of redundant and quasi-redundant baselines
- use of parameterized models for the phase errors across telescope aperture
- use of pointing correction model parameters

ALMA

With NGST, ALMA and SKA in the second decade of this century the electro-magnetic spectrum from 1µm till 10m will be available to the next generation of astronomers with a resolution of about 0.02", and high sensitivities.