ALMA Requirements

Robert Laing
ESO

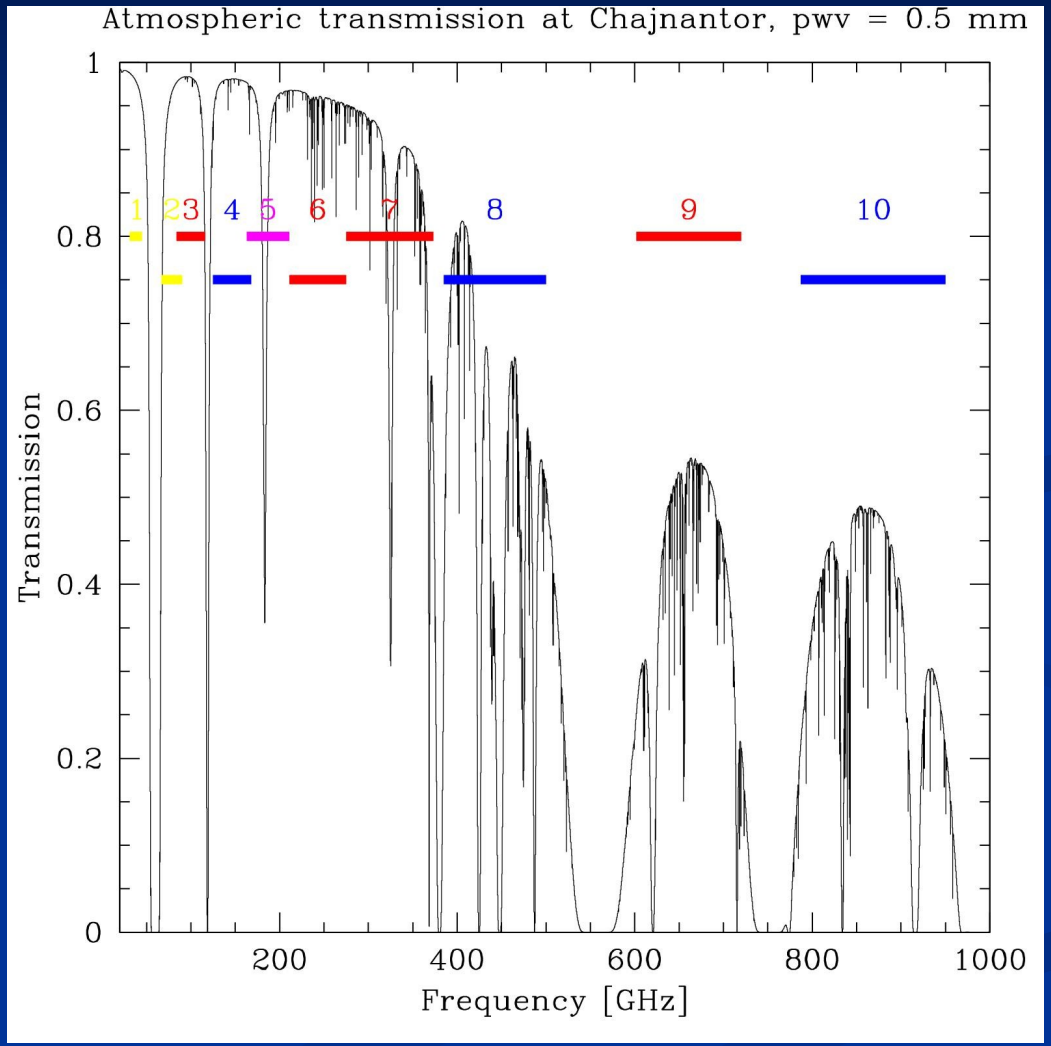
Imaging and Calibration Algorithms
for EVLA, e-MERLIN and ALMA
Oxford, Dec 1 - 3 2008

What is ALMA?

Atacama Large Millimetre/Submillimetre Array

- Aperture synthesis array optimised for millimetre and sub-millimetre wavelengths.
- High, dry site, Chajnantor Plateau, Chile
- Main array: 50 dishes with 12m diameter.
- ALMA Compact Array (ACA):
  - 12 7m dishes in compact configurations
  - 4 12m dishes primarily for total-power

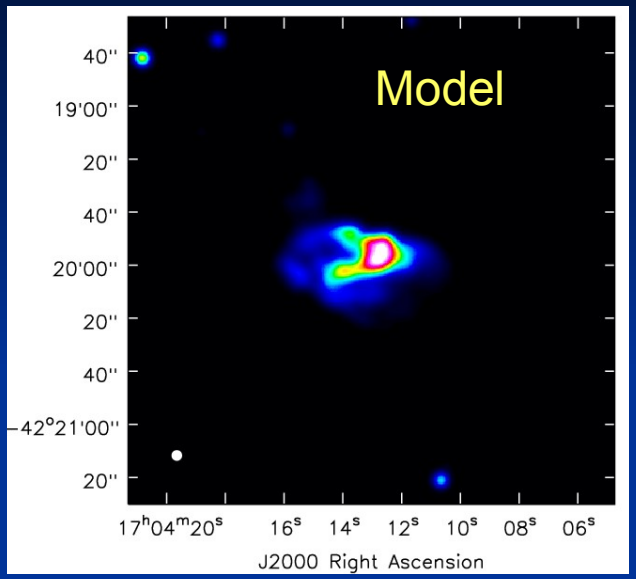
Transparent site allows full spectral coverage

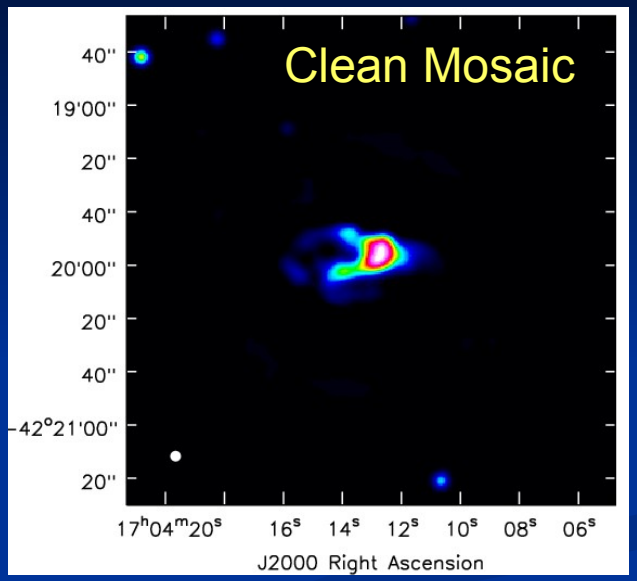


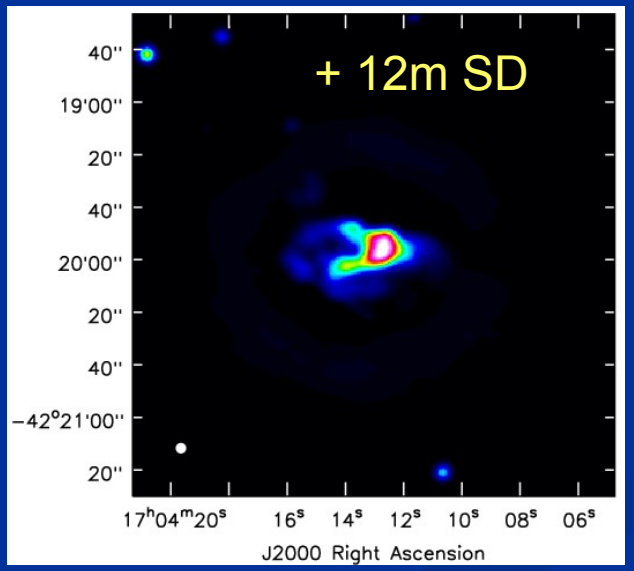
Key performance numbers

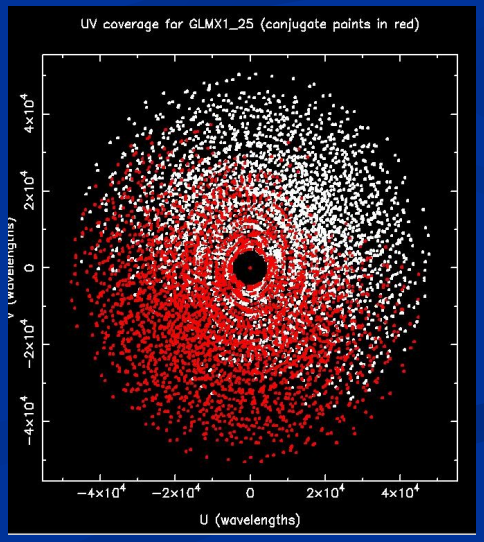
- Baseline range 15m – 14.5 km + ACA + single dish
- Good instantaneous uv coverage
- Primary beam / arcsec ≈ 17 (λ/mm) [12m dish]
- Resolution/ arcsec ≈ 0.2(λ/mm)/(max baseline/km)
  - 0.04 arcsec at 100 GHz, 14.5 km baseline
  - 0.005 arcsec at 900 GHz, 14.5 km baseline
- Wide bandwidth (8 GHz/polarization), low noise temperatures, good site and antennas, … → excellent continuum sensitivity and wide spectral coverage
- Full polarization

Imaging: 50 antennas + SD









uv coverage
(3 mins)

Sampling of large spatial scales

ν	Primary beam λ/D		Minimum λ/D		Resolution
GHz	arcsec		arcsec		arcsec
	12m	7m	Compact	ACA	Compact
35	170	291	116	199	10
110	56	99	37	64	3.1
230	27	46	18	31	1.5
345	18	31	12	21	1.0
690	8.6	15	5.9	10	0.51
950	6.3	11	4.3	7.3	0.37

Also combine with 12m (single-dish) observations

Continuum sensitivity in 1 minute

ν	ΔS	ΔT_B
GHz	mJy	K
35	0.019	0.0003
110	0.033	0.0004
345	0.14	0.0018
409	0.31	0.0040
675	3.8	0.049
	0.46	0.0059
850	5.9	0.080
	1.1	0.014

RMS for 2 polarizations, each with 8GHz bandwidth; elevation of 50°. Brightness temperatures are for a maximum baseline of 200m; 50 antennas

Median PWV = 1.5mm

Best 5% PWV = 0.35mm

ALMA Memo 276

Some receivers will exceed specification

Sensitivity calculator available at

http://www.eso.org/projects/alma/science/bin/sensitivity.html

Line sensitivity

Frequency (GHz)	0.2km array Beam (arcsec)	0.2km array ΔT_B (K) 1 kms^{-1}	14.7km array Beam (arcsec)	14.7km array ΔT_B (K) 25 kms^{-1}
110	2.8	0.10	0.038	106
140	2.2	0.10	0.030	109
230	1.3	0.15	0.018	156
345	0.9	0.23	0.012	248
409	0.7	0.34	0.010	344
675	0.4	0.85	0.006	840

http://www.eso.org/projects/alma/science/bin/sensitivity.html

Spectral modes

- Channel bandwidth 31.25 MHz – 2 GHz (4 channels)
- Maximum 4096 x (4/N) x (2/P) spectral points/channel, where N = 1, 2 or 4 is the number of channels and P=2 for full polarization; 1 for parallel hands only.
- Maximum spectral resolution 3.8 kHz.
- Tunable FIR filter bank to subdivide bandwidth into 32 (possibly overlapping) sub-channels
- Flexible combinations of centre frequency and resolution
- Fastest integration times 16ms for interferometry; 1ms for autocorrelations
- All observations in spectral line mode (like EVLA, e-MERLIN)

Software

- Archive: VO compliant
- Data reduction in CASA
- Pipeline – data-cubes will be standard products, along with calibrated uv data
- Dynamic scheduling to make best use of variable atmospheric conditions

Calibration and imaging: issues

- Data volume
- Correction of tropospheric phase errors
- Dynamic range not usually a problem
- Structure on scales larger than either the primary beam or λ/D for the shortest baseline:
  - Image over the full primary beam
  - Calibrate and correct for primary beam in all Stokes parameters
  - Combine 12m and 7m arrays + single dish data
  - Mosaics
- Fractional bandwidth $\Delta\nu/\nu \sim 0.1$ for lowest frequency in initial set ~0.25 at lowest planned frequency.

Phase calibration
(Nikolic talk)

- **ALMA requirements**
  - Reduce atmospheric and electronic phase fluctuations to as low a level as possible
  - Required by imaging and flux scale (decorrelation)
  - Tropospheric water vapour (mostly)
  - Anisoplanatism (almost) not an issue
- **Techniques**
  - Fast switching (interleave with observations of a nearby calibrator, perhaps at a lower frequency). 20 – 300s cycle times. Requires calibrator within ~2^{o}
  - Water-vapour radiometry (measure emission from 183 GHz atmospheric line; deduce phase fluctuations on 1s timescales).
  - Self-calibration

More calibration problems

- Atmosphere (dual-load calibration device)
- Primary amplitude calibrators (often resolved; solar-system objects require time-dependent models)
- Bandpass (astronomical calibrators; high s/n needed; difficult for 7m array)
- Instrumental phase transfer between receiver bands (requires an accurate atmospheric model)
- Polarization (standard sources, differential gain stability, ...)
- Very accurate offset pointing (0.6 arcsec rms)