Current Status of ALMA

Alison Peck
Joint ALMA Observatory/NRAO

ALMA

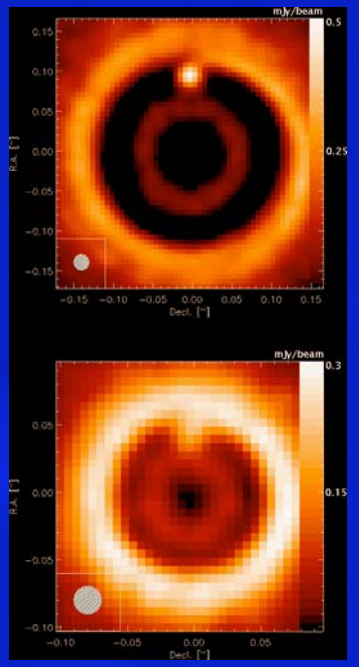
• International project to build & operate a large (>66-antenna) millimeter/submm (λ ~0.3-3mm) array at high altitude site (5000m) in northern Chile.

•Two orders-of-magnitude improvement in mm radio astronomy: improved antennas * site * BW * resolution…

•Merging of MMA, LSA, LMSA concepts… mid 90s.

•Prototyping began late 90's; construction project began in 2002; rebaselined 2005; site construction underway, hardware & software in production; phase closure end 2009; early science 2011, full science 2012.

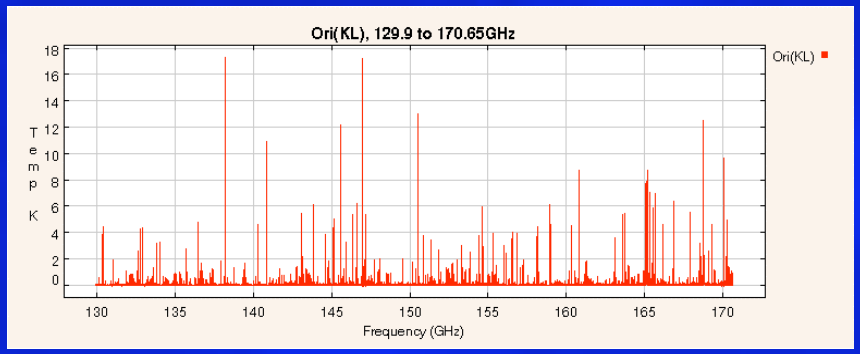
ALMA Key Science



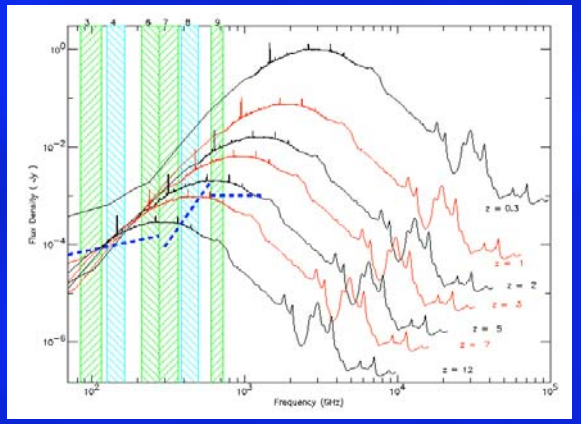
- Ability to image the gas kinematics in protostars and in protoplanetary disks around young Sun-like stars at a distance of 150 pc

- ability to detect spectral line emission from CO or CII in a normal galaxy like the Milky Way at large distances

- ability to provide precise images at an angular resolution of 0.1 arcsec



Spectrum courtesy B. Turner (NRAO)



Technical Specifications

- 54 12-m antennas, 12 7-m antennas, at 5000m site
- Surface accuracy <25 μm, 0.6" reference pointing in 9m/s wind, 2" absolute pointing all-sky.
- Array configurations between 150m and ~15-18km.
- Angular resolutions ~40 mas at 100 GHz (5mas at 900GHz)
- 10 bands in 31-950 GHz + 183 GHz WVR.
- 8 GHz BW, dual polarization.
- Interferometry, mosaicing & total-power observing.
- Correlator: 4096 channels/IF (multi-IF), full Stokes.
- Data rate: 6MB/s average; peak 64 MB/s.
- All data archived (raw + images), pipeline processing.

ALMA Predicted Sensitivity

(1-σ, 1 minute; AM=1.3; water values correspond roughly to the quartiles)

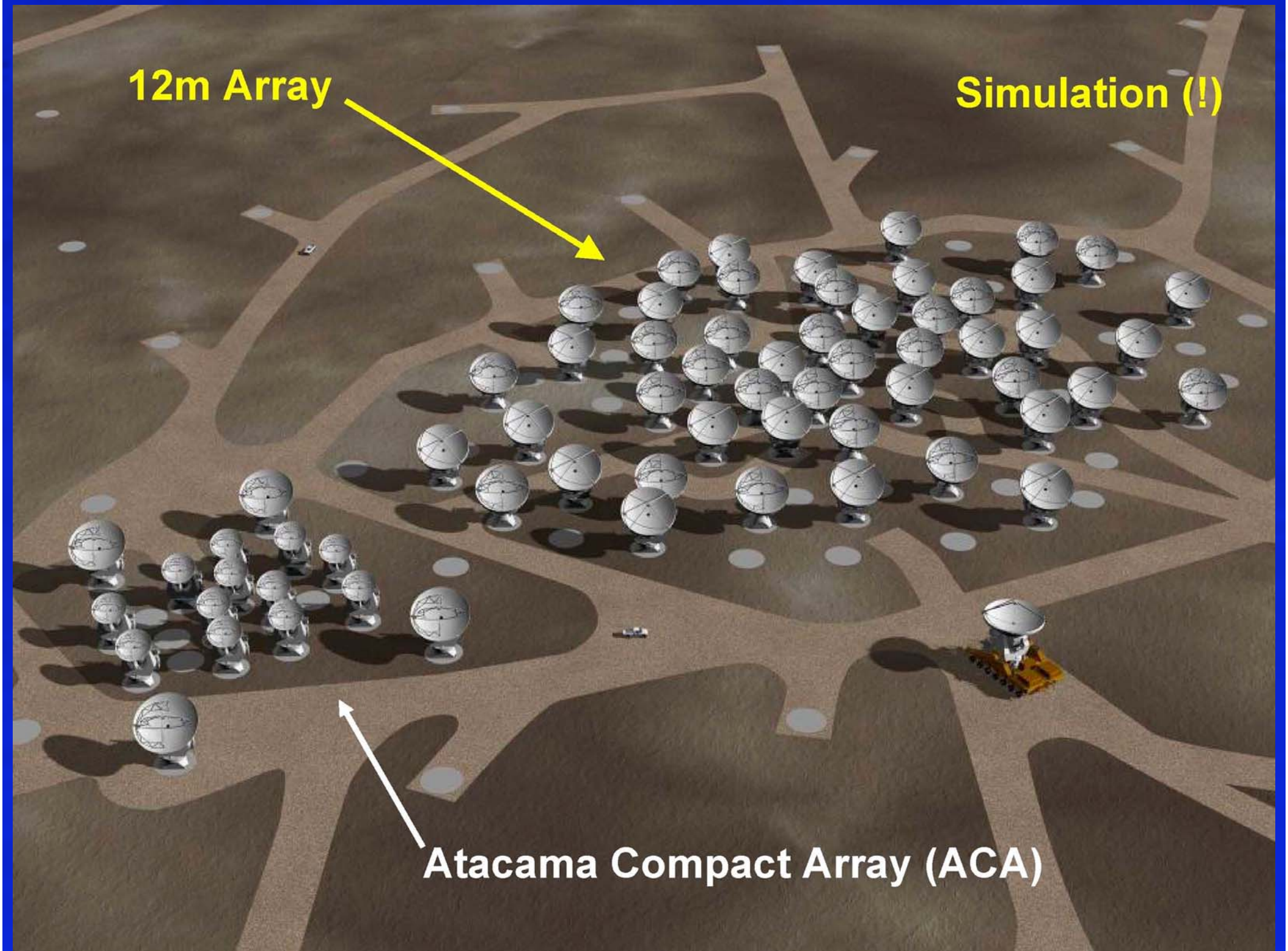
Frequency GHz	Zenith Water mm	Continuum mJy	Line 1km/s * mJy
110	2.3	0.05	7
140	2.3	0.06	8
230	2.3	0.1	11
345	1.2	0.2	18
410	1.2	0.4	31
675	0.5	0.7	41
850	0.5	1.4	72

*Spectral line sensitivity scales inversely with square root of velocity resolution. So for 25km/s, which might for example be used for a galaxy, divide by 5.

Angular resolution

(FWHM arcseconds. Source at ~70 degrees elevation)

	Maximum baseline length in meters			
Frequency GHz	160	750	3000	15000
110	4.2	0.90	0.23	0.045
140	3.3	0.71	0.18	0.035
230	2.0	0.43	0.11	0.022
345	1.3	0.29	0.07	0.014
410	1.1	0.24	0.06	0.012
675	0.7	0.15	0.04	0.007
850	0.5	0.12	0.03	0.006


12m Array
Simulation (!)
Atacama Compact Array (ACA)

ALMA Sites

- **Array Operations Site – AOS** – 5000m – Antennas, correlator, some (oxygenated) office space

- **Operations Support Facility – OSF** – 3000m – Array operation, equipment maintenance, living quarters

- **Santiago Central Offices – SCO** – Administration, scientific support. Will be located near ESO, currently Las Condes (also JAO - Joint ALMA Observatory)

- **ALMA Regional Centers – ARCs + ARC nodes** – interfaces to astronomy community

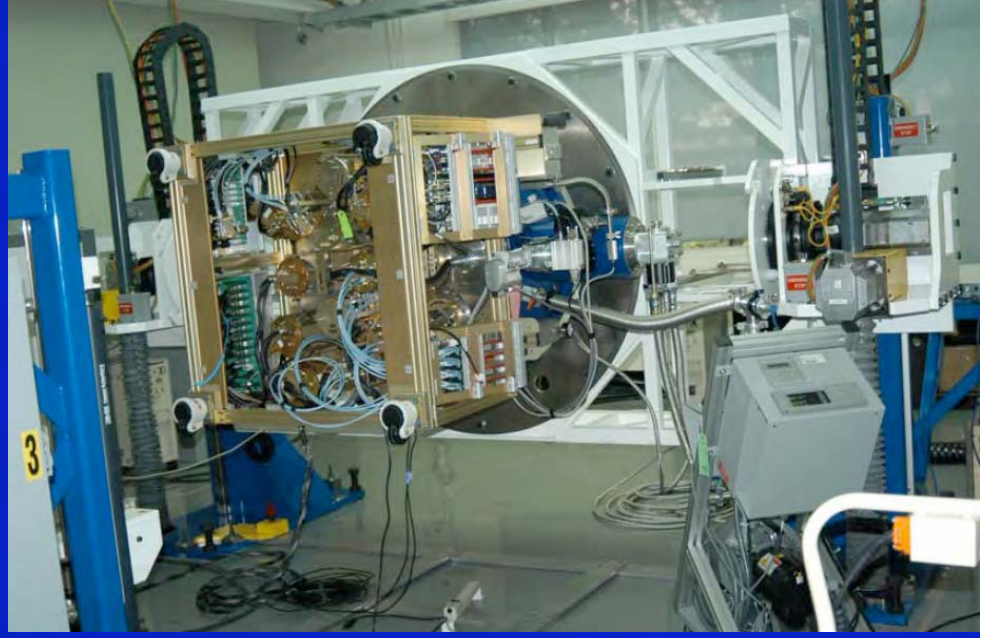
- **ALMA Test Facility – ATF** – Socorro, VLA site – prototype antennas, software development -- closed in 2008

Receivers / Front Ends

ALMA Band	Frequency Range	Receiver noise temperature		Mixing scheme	Receiver technology
		T_{Rx} over 80% of the RF band	T_{Rx} at any RF frequency		
1	31.3 – 45 GHz	17 K	28 K	USB	HEMT
2	67 – 90 GHz	30 K	50 K	LSB	HEMT
3	84 – 116 GHz	37 K	62 K	2SB	SIS
4	125 – 169 GHz	51 K	85 K	2SB	SIS
5	163 - 211 GHz	65 K	108 K	2SB	SIS
6	211 – 275 GHz	83 K	138 K	2SB	SIS
7	275 – 373 GHz	147 K	221 K	2SB	SIS
8	385 – 500 GHz	98 K	147 K	DSB	SIS
9	602 – 720 GHz	175 K	263 K	DSB	SIS
10	787 – 950 GHz	230 K	345 K	DSB	SIS

Initially for CSV, Bands 3 and 6 on all antennas, plus Band 7 or 9

First Front Ends: Testing at the Integration Center here and installation at OSF lab in Chile, April 2008



Back End racks being lifted into MELCO #2 receiver cabin

Early Science Capabilities (needed by start 2011)

- At least 16 antennas with 4 receiver bands

  Number of antennas available will build up quite fast through 2011 and 2012. (Sensitivity goes as N, imaging complexity as N^2 .)

- Baselines of at least 250m (1km goal) to start with, moving on to long baselines in 2012.

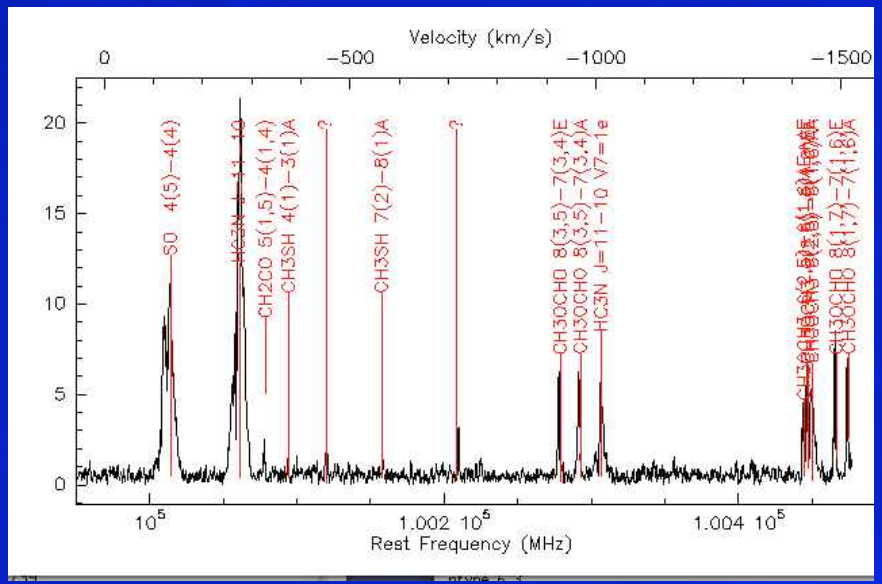
- Interferometry in single field or pointed mosaic mode, single-dish OTF mapping for zero spacing.

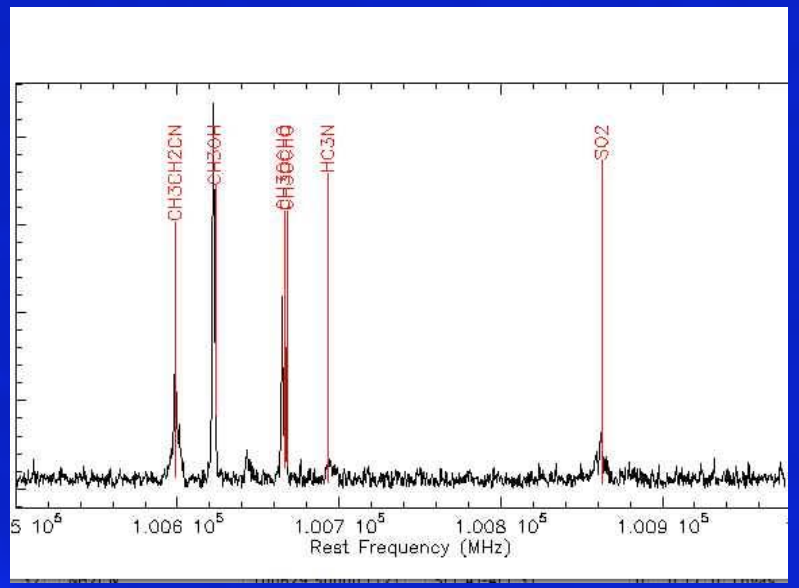
- Proper systems for user support in place:
  - proposal process
  - tools for preparing observations
  - data reduction package (CASA)
  - support from ALMA Regional Centers

Prototype Antennas at ATF (Socorro)

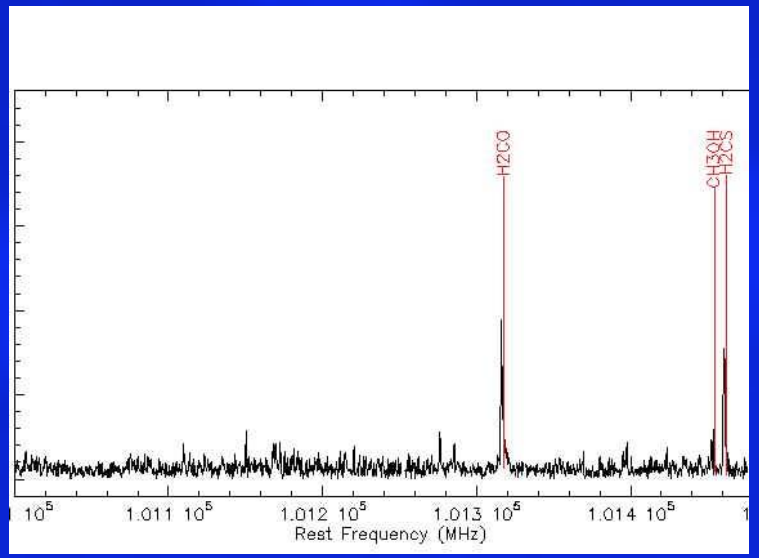
12-m, Carbon Fiber Support Structure

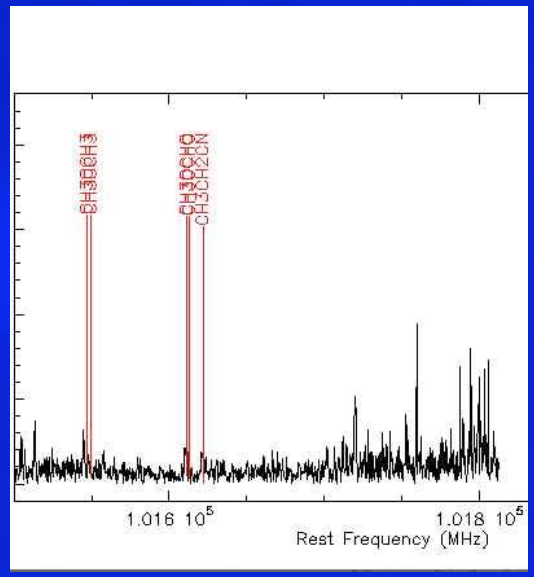
Interferometric spectrum: Orion - 101 GHz, April 2008





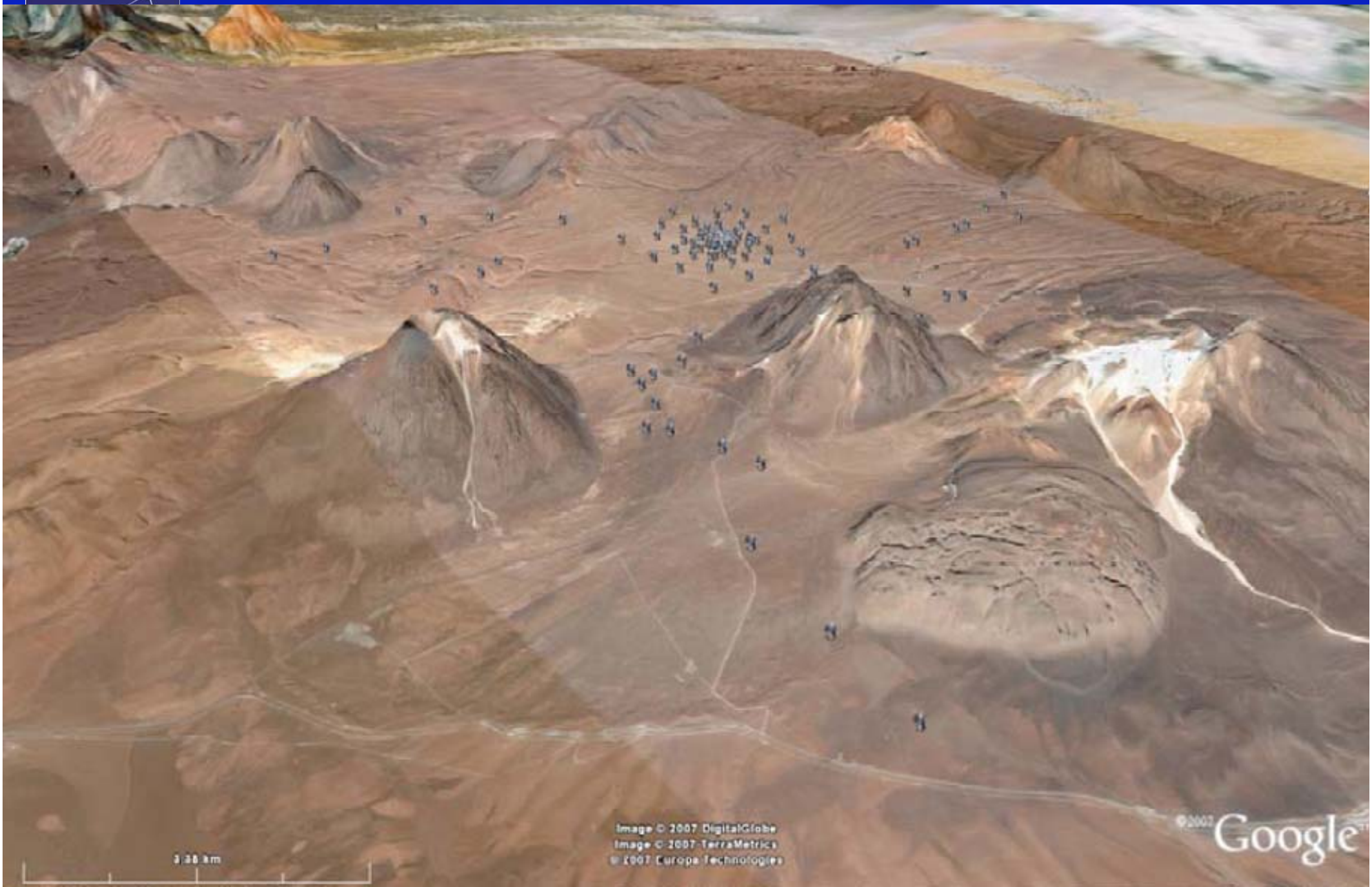
Taken at ATF, not using production receivers, but verifying software for control, tuning, correlator and data reduction

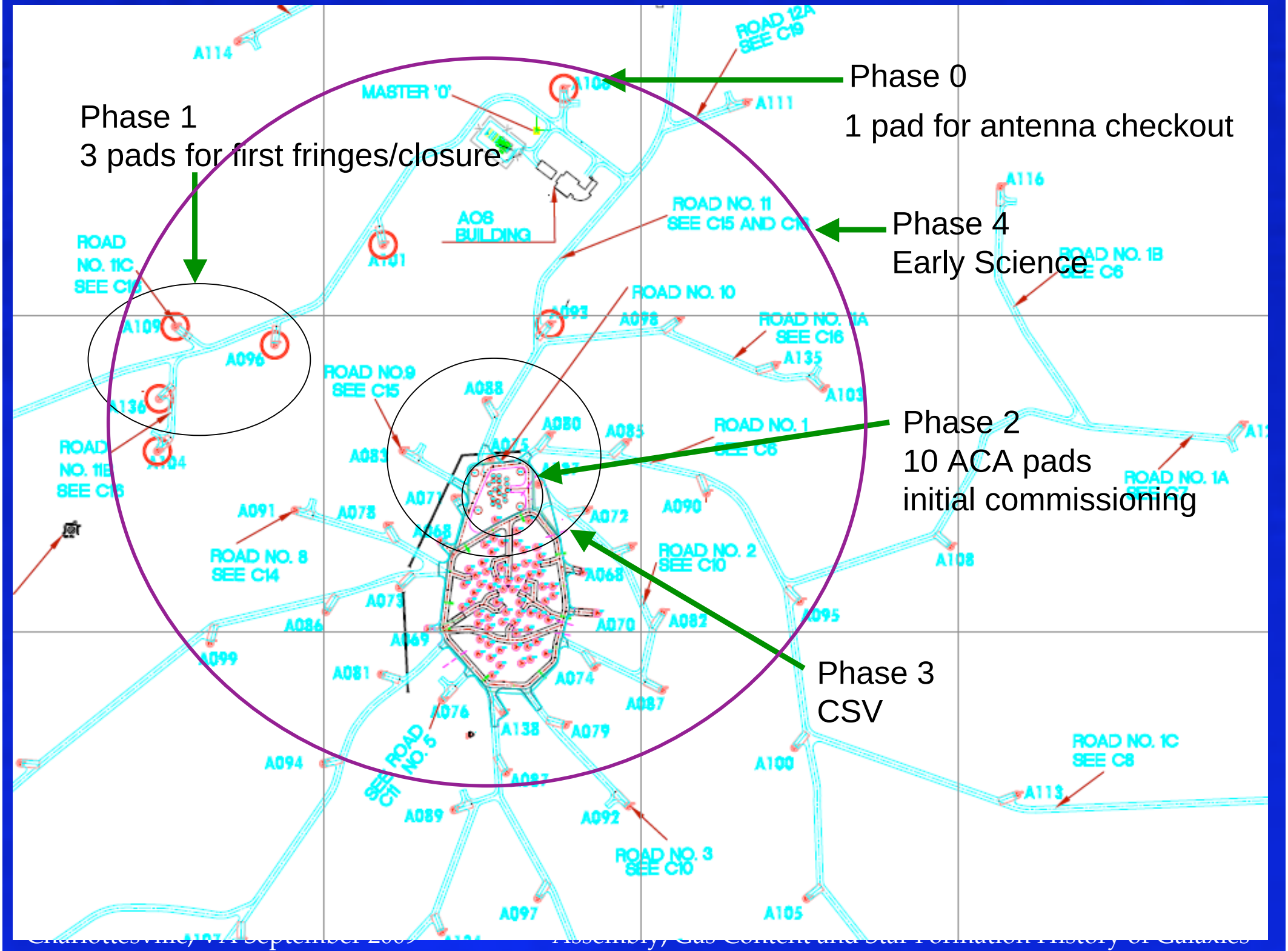




ALMA Location

Google Earth view of site with antennas in the most extended configuration – baselines to 16km




Phase 0
1 pad for antenna checkout
Phase 1
3 pads for first fringes/closure
Phase 4
Early Science
Phase 2
10 ACA pads
initial commissioning
Phase 3
CSV
MASTER '0'
AOS BUILDING
ROAD NO. 11 SEE C15 AND C16
ROAD NO. 10
ROAD NO. 1A SEE C16
ROAD NO. 1B SEE C6
ROAD NO. 1C SEE C8
ROAD NO. 1 SEE C6
ROAD NO. 2 SEE C10
ROAD NO. 3 SEE C10
ROAD NO. 5 SEE C11
ROAD NO. 8 SEE C14
ROAD NO.9 SEE C15
ROAD NO. 11B SEE C16
ROAD NO. 11C SEE C16
ROAD NO. 12A SEE C19
A114
A111
A116
A101
A109
A096
A136
A104
A093
A098
A135
A103
A088
A080
A085
A083
A075
A077
A091
A078
A068
A072
A090
A108
A073
A086
A069
A070
A082
A095
A099
A081
A074
A087
A076
A138
A079
A094
A100
A113
A089
A092
A097
A105

Foundations for the Compact Array

July 2009 - Pads nearly done. Power and fibres next.

Foundation being kept warm while it cures

5000m: occupied, correlator and LO installed, office furniture on order

3000m: TF offices in use, safety and medical facilities in place, labs & control room being finished

Correlator First Quadrant at AOS

3 ACA 12-m antennas en route to OSF

(2007 - 15 km/hr for 3 days)

Four MElCo Antennas being tested (2008)

ACA 7m Antenna under Construction

Assembly of Vertex antennas in Chile

Vertex testing in camp at OSF

AEM #1

- CFRP cabin
- Stiff yoke
- Direct drives

Drive tests complete
Stiffer Az bearing support being added

Current Status of AEM Assembly in Europe

AEM in Chile

ALMA Camp - OSF

Recent Views of the OSF

ALMA
ATACAMA LARGE MILLIMETER ARRAY

Transporter being unloaded in Chile - February 2008

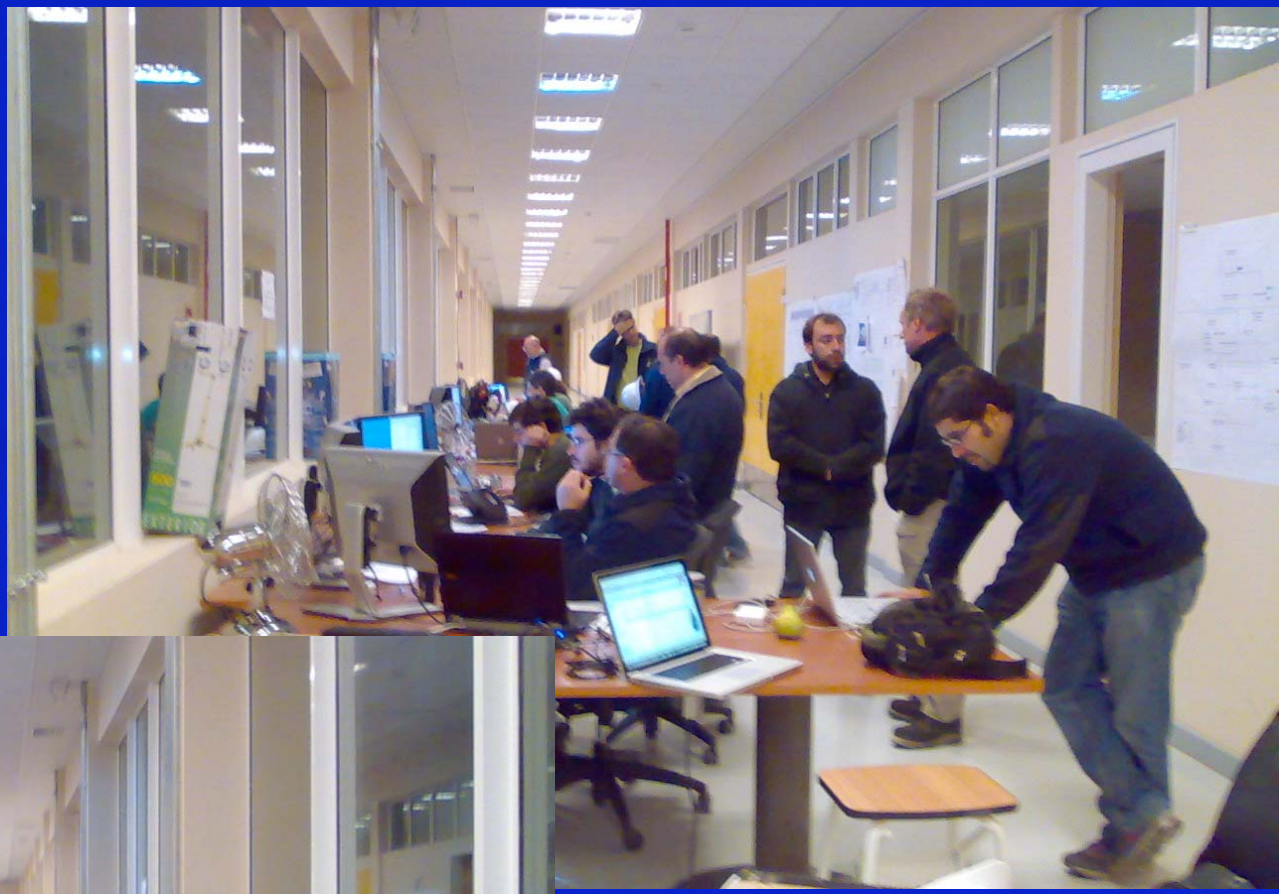
On the road to the OSF

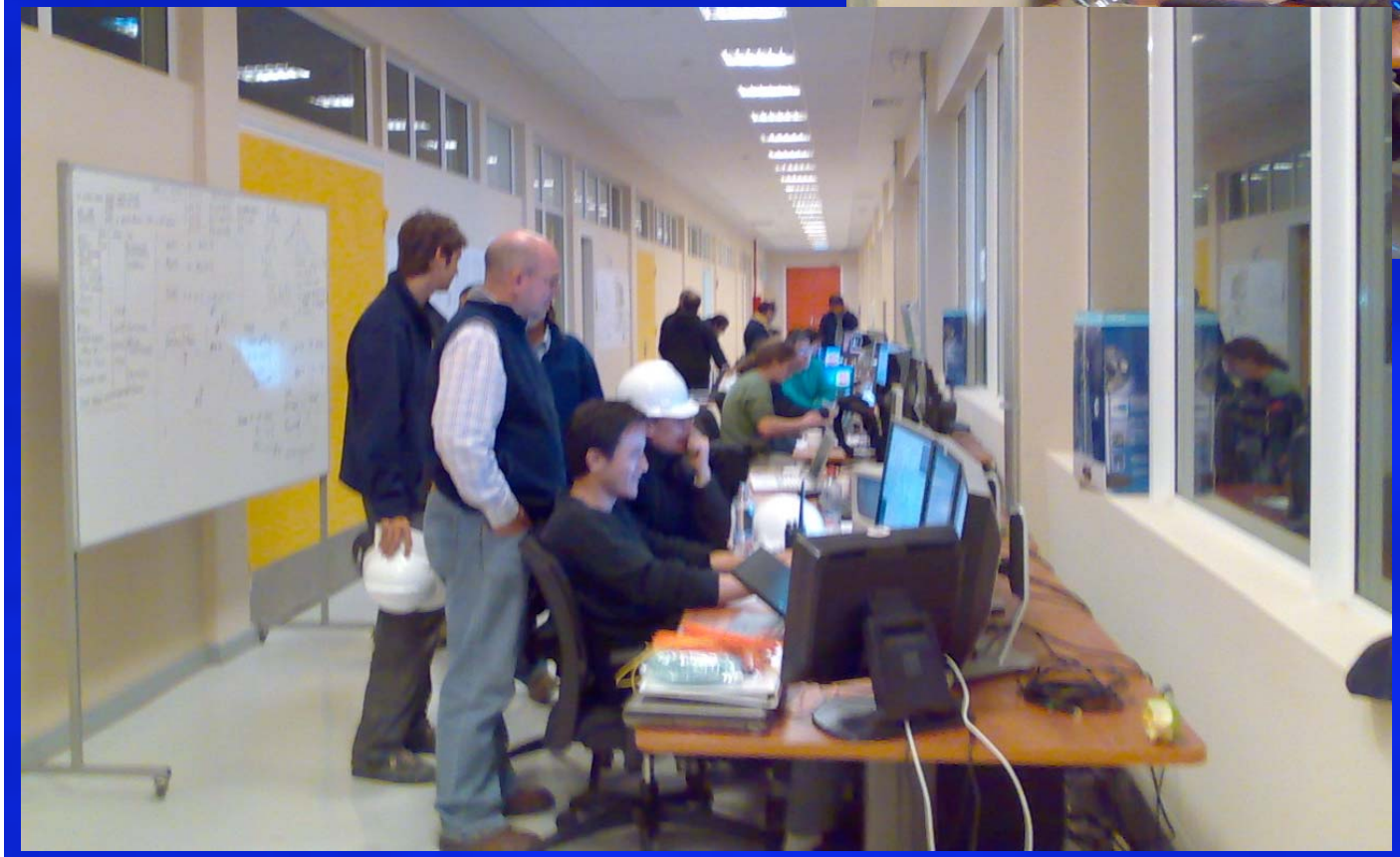
Antennas moved from vendor camps to OSF testing area

Antennas at the OSF Technical Facility

"Handover Shift" during testing with 3 antennas

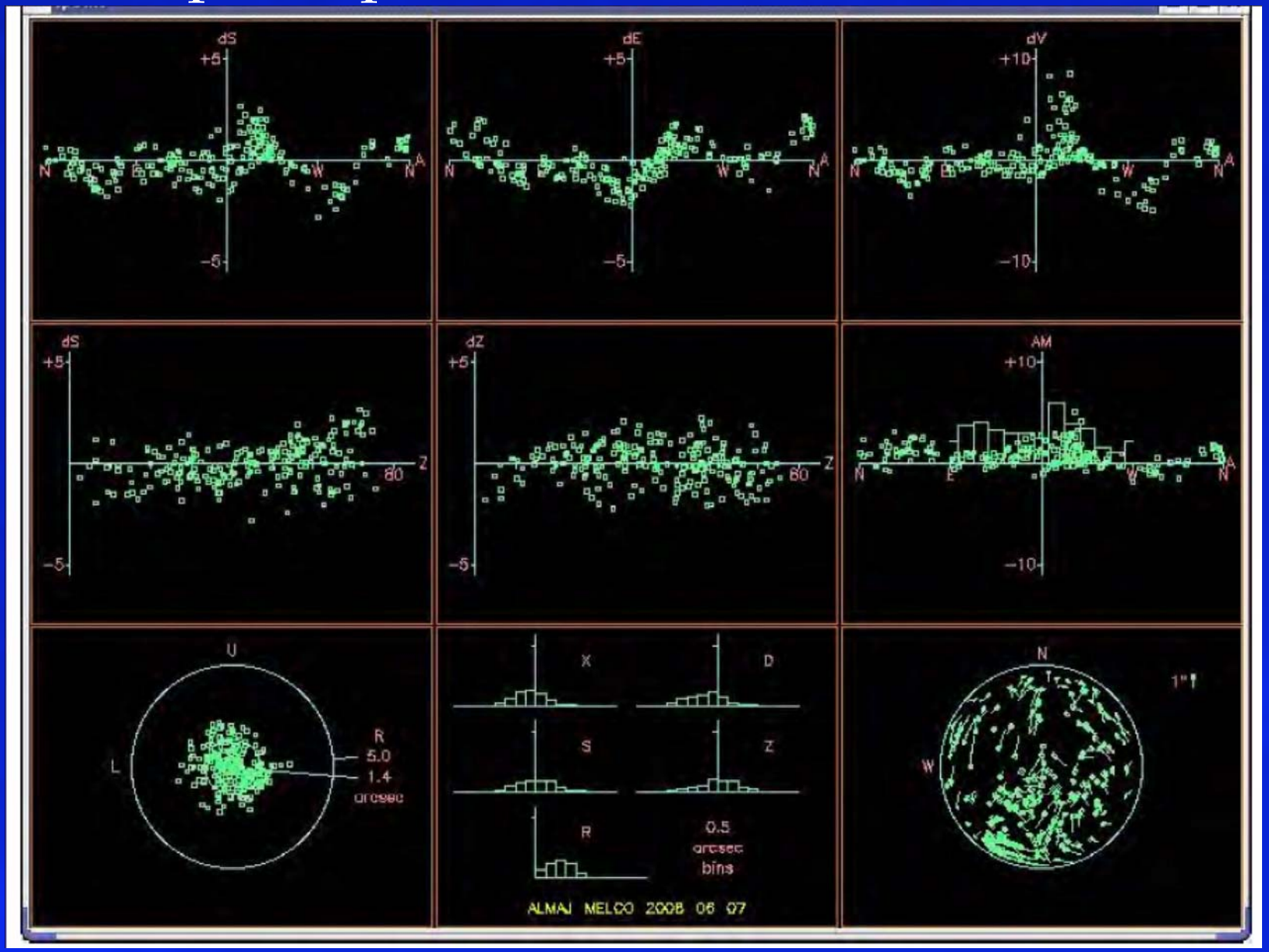
(2 for interferometry, one for SD)

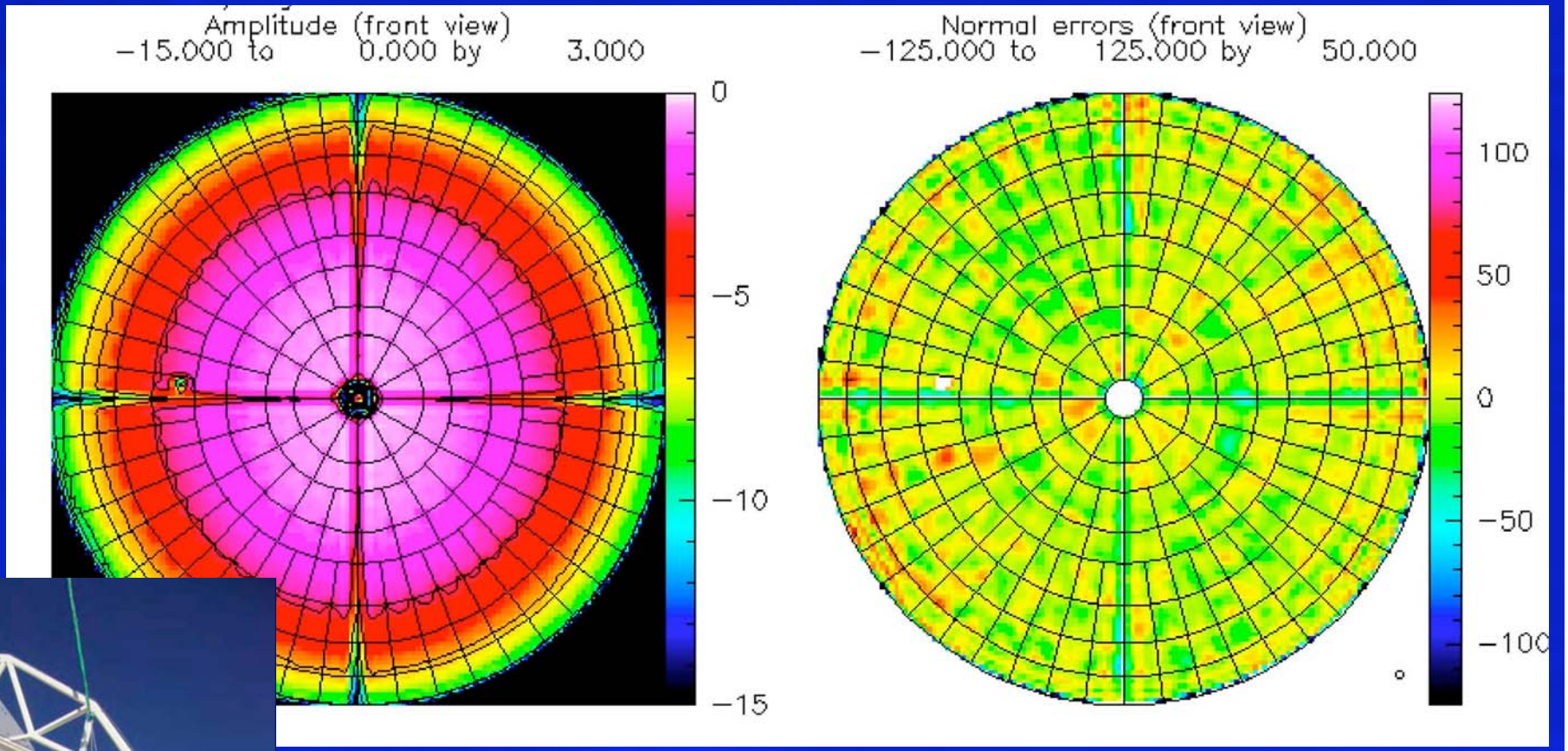


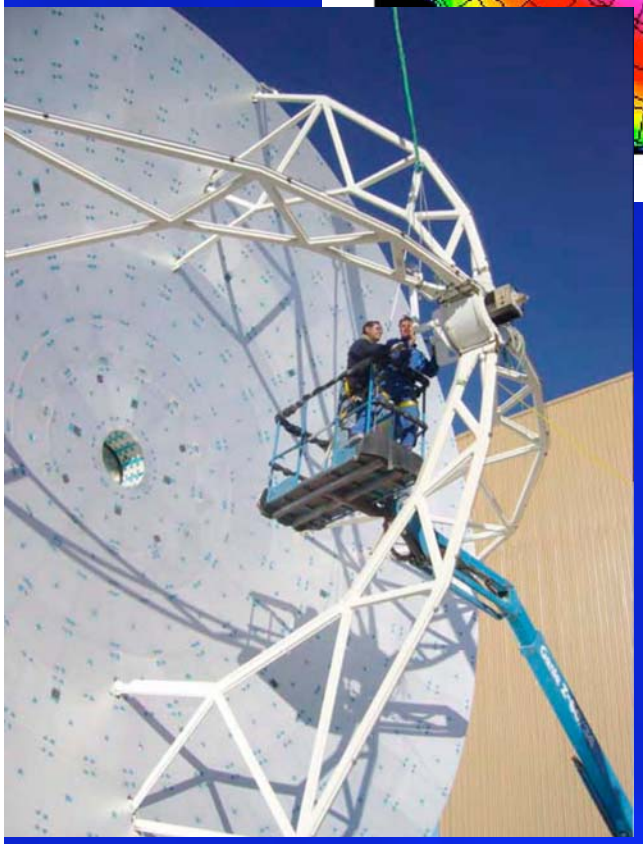


Moving out of the corridor!!

Data taken using prototype optical pointing telescope on production antenna-- rms~1.4 asec





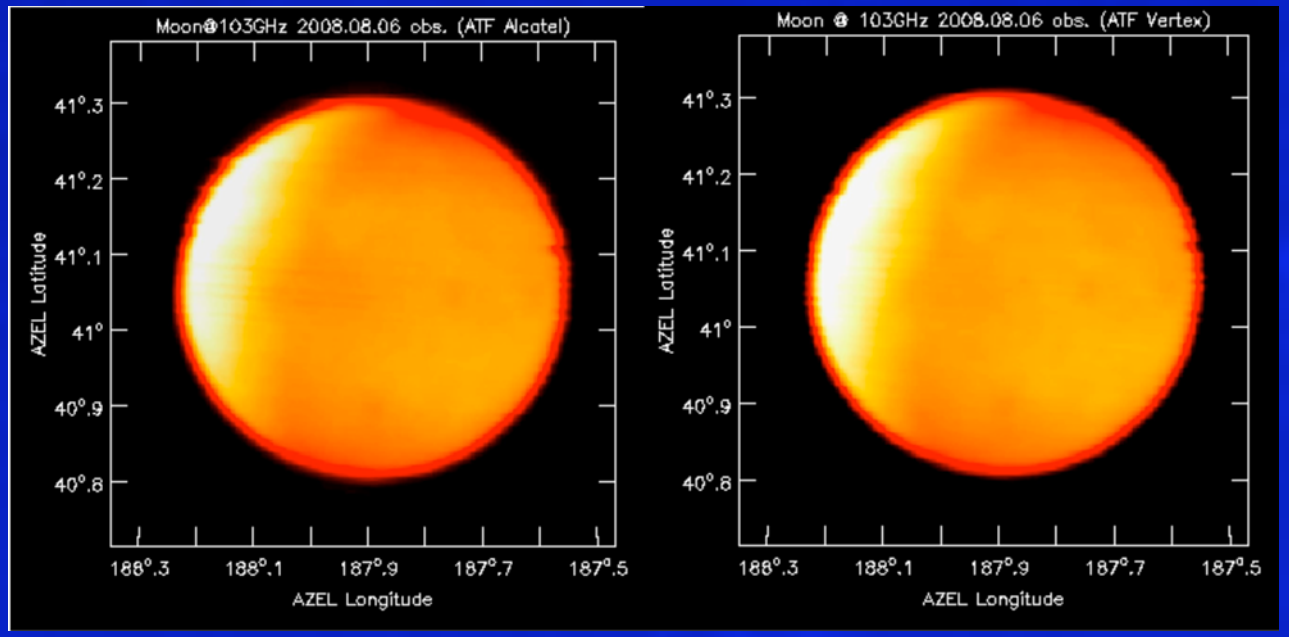


Holography Results:

Done on both MElCo and Vertex antennas -
Surfaces better than 12 microns

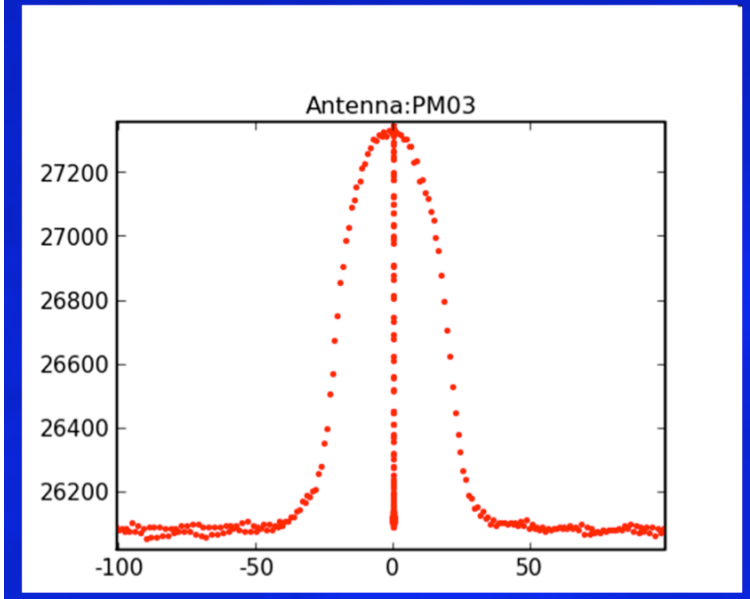
Teams Trained for Panel Setting

Raster maps and beam patterns

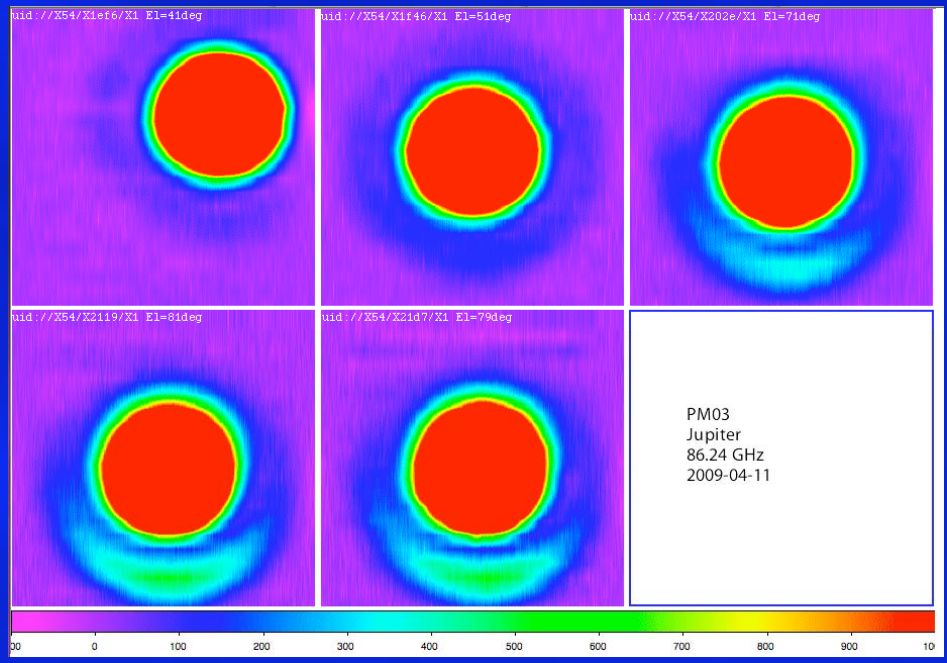


Moon maps with Vertex and Alcatel prototypes at ATF

Checking optics and subreflector control

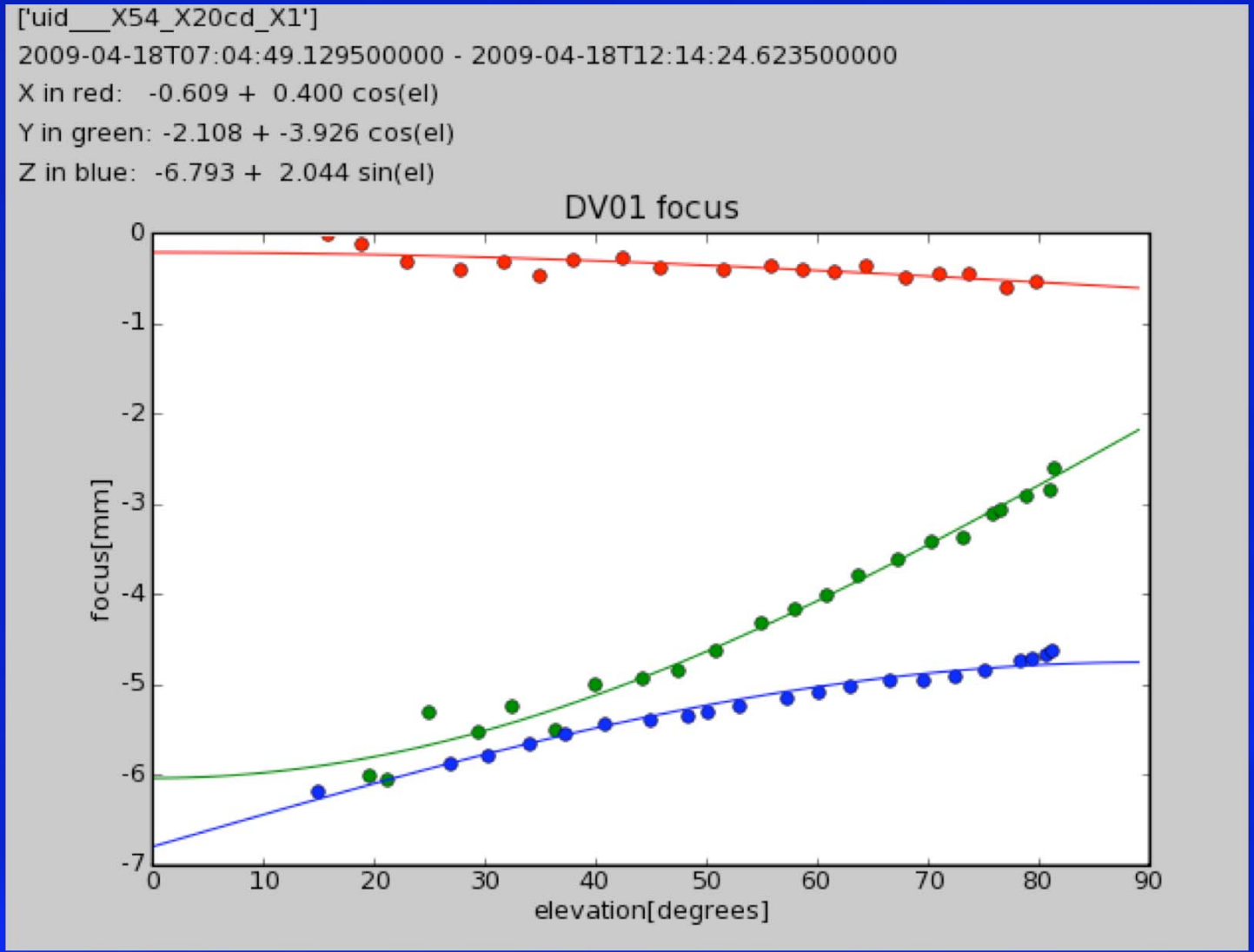


Band 9 Jupiter scan (650 GHz)
Charlottesville, VA September 2009



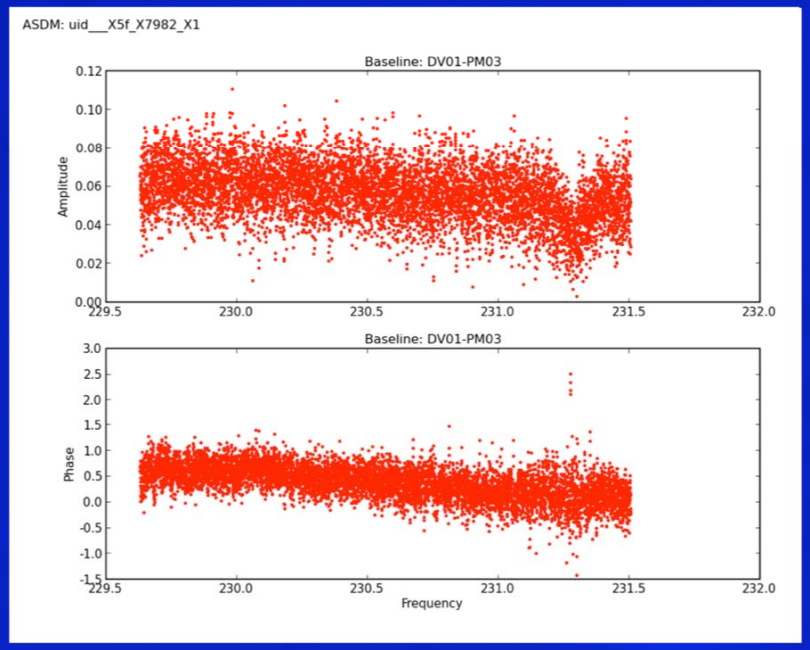
Assembly, Gas Content and Star Formation History of Galaxies

Focus Curves Measured at 3mm and 850 μm

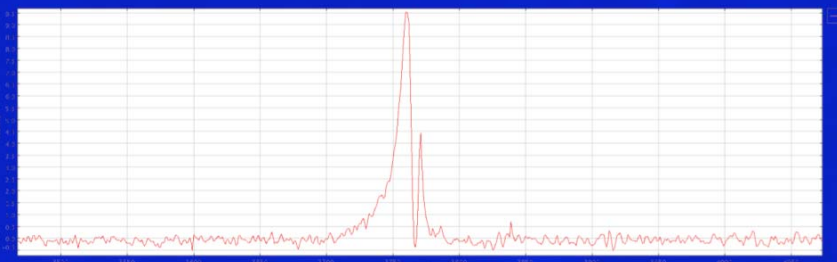


Recent Fringes and Spectra

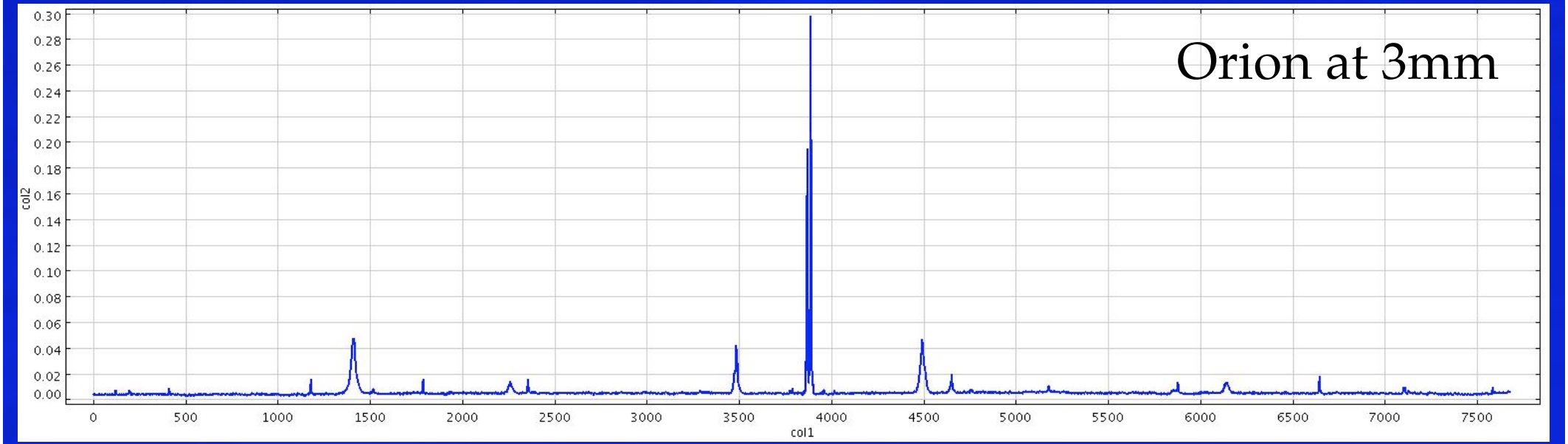
Band 6 Amp and phase vs frequency on 3c273



CO 2-1 in IRAS 16293-2422

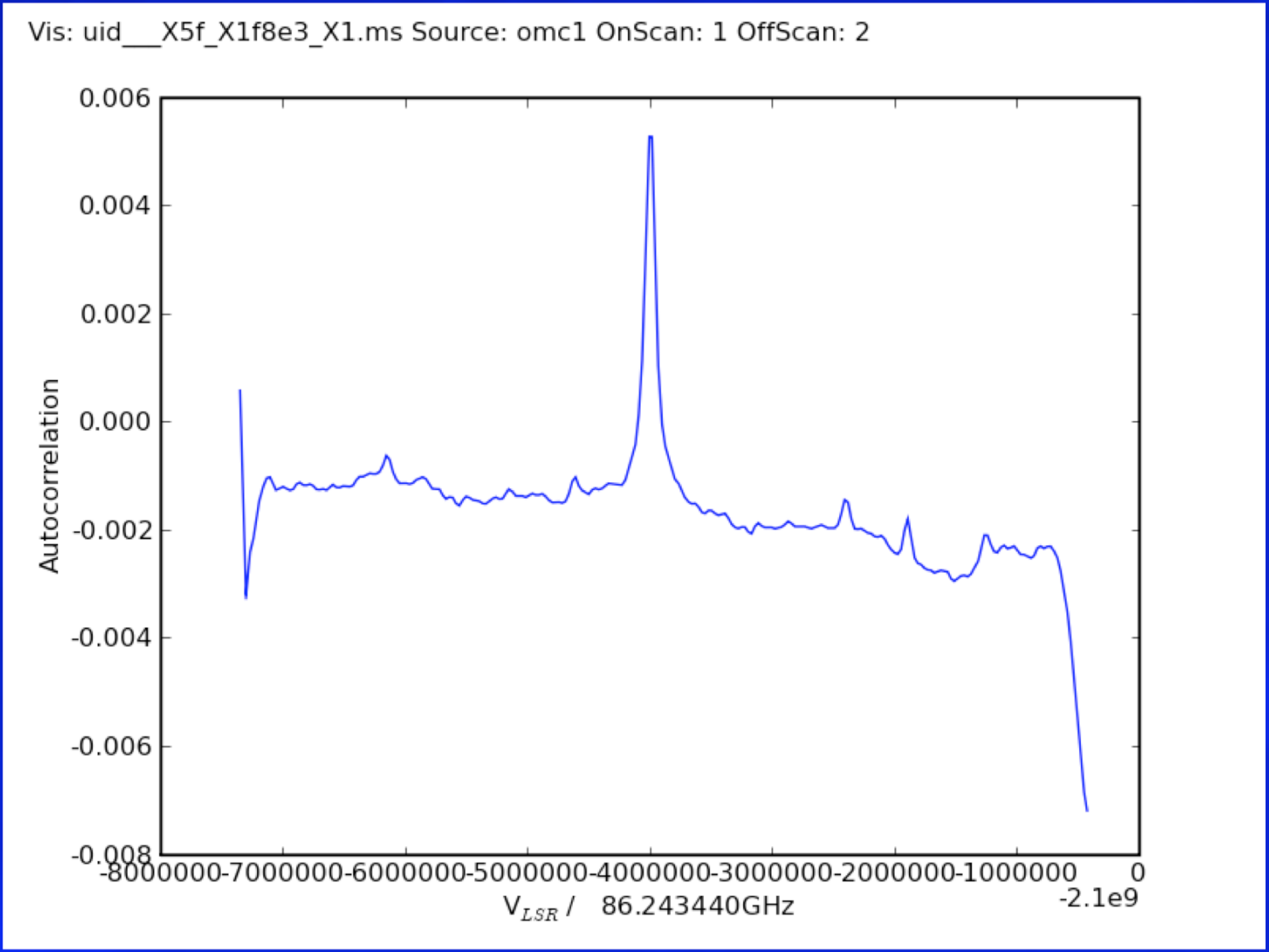


July / August at OSF



Low resolution autocorrelation spectrum toward Orion centered on CO(6-5) at 691 GHz

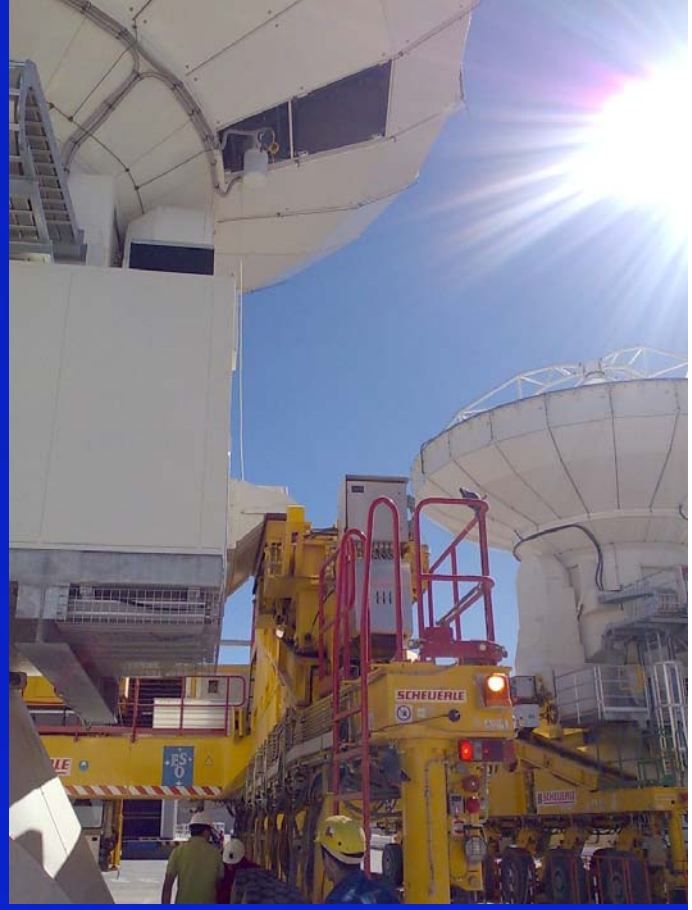
Sept 20, 2009 - OSF



D'oh! Plotting program not expecting Band 9 yet…

Multi-antenna move at the OSF TF

Multi-antenna move at the OSF TF



Charlottesville, VA September 2009

Assembly, Gas Co

First Move to AOS

Photo credits: L. Knee, J. McMullin

First Move to AOS

Photos courtesy ALMA EPO group

PM03 at the High Site

Status Summary

Santiago:

- Antenna Integration, Commissioning and Operations teams ~70% in place (now 18 scientists at JAO)
- Remote monitoring station available at JAO
- OSF / AOS:
- Buildings essentially done (except permanent residence)
- Roads, power, foundations well under way
- Antennas, electronics arriving and being integrated
- End to end testing underway
- ARCs:
- Many scientists in post
- Preparations for Early Science and Operations!

What's next?

- Now: Completing interferometric testing at the OSF with 2 Vertex
- Sept/Oct: First tests of antennas and other systems at AOS
  - (Production LO, correlator, WVRs, etc)
- Goal to have fringes with 3 antennas around the end of 2009
- Commissioning and Science Verification in full swing throughout 2010
- Call for proposals for Early Science end of 2010.
- Early Science start in second half of 2011.

How to become involved:

Current job advertisements:

https://careers.nrao.edu
https://jobs.eso.org
http://www.nao.ac.jp/E/index.html

Visitor's program:

- Some support (typically at least travel and lodging) for people who can take leave or sabbatical from their home institutions to participate in CSV.
- Beginning mid 2009.
- Stays of 3 months to 1 year recommended
- No proprietary data during this period
- Contact me for more information at apeck@alma.cl

For more info on current status and (soon) for proposing and job ads:

http://www.almaobservatory.org

The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership of Europe, North America and East Asia in cooperation with the Republic of Chile. ALMA is funded in Europe by the European Organization for Astronomical Research in the Southern Hemisphere (ESO), in North America by the U.S. National Science Foundation (NSF) in cooperation with the National Research Council of Canada (NRC) and the National Science Council of Taiwan (NSC) and in East Asia by the National Institutes of Natural Sciences (NINS) of Japan in cooperation with the Academia Sinica (AS) in Taiwan. ALMA construction and operations are led on behalf of Europe by ESO, on behalf of North America by the National Radio Astronomy Observatory (NRAO), which is managed by Associated Universities, Inc. (AUI) and on behalf of East Asia by the National Astronomical Observatory of Japan (NAOJ). The Joint ALMA Observatory (JAO) provides the unified leadership and management of the construction, commissioning and operation of ALMA.