



Atacama Large Millimeter/submillimeter Array

# ALMA Construction Status and Science Perspective



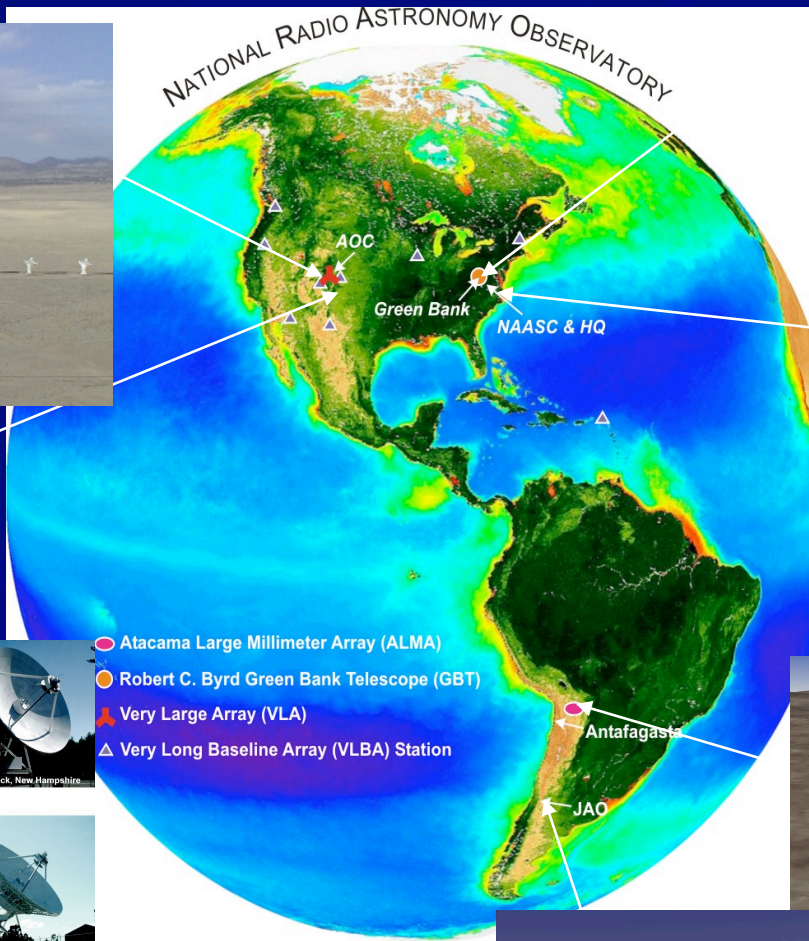
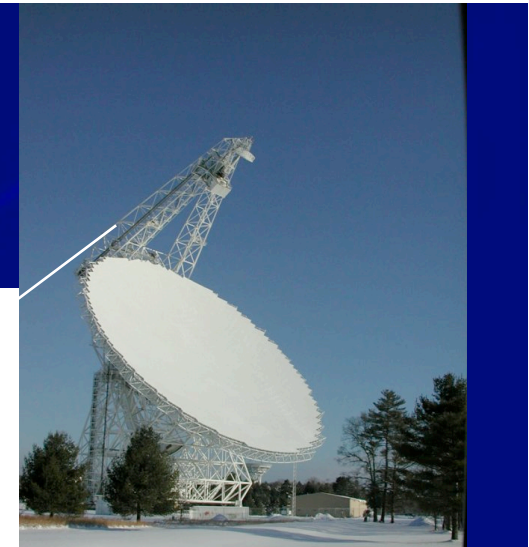
Al Wootten, ALMA/NA Project Scientist

2009 USNC/URSI Annual Meeting

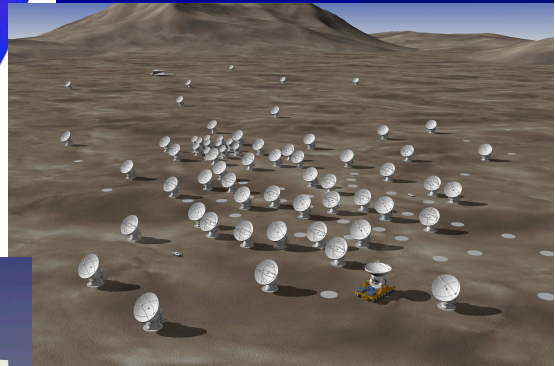
In search of our Cosmic Origins



# NRAO: A System of Complementary Telescopes Under an Open Skies Policy



ALMA in 2012



Joint ALMA Obs.



## Atacama Large Millimeter/submillimeter Array

Is an international astronomy facility, a partnership between Europe (32.5%), North America (32.5%) and East Asia (25%), in cooperation with Chile (10%) through agreements reached in 2003 and updated in 2006. ALMA is operated on behalf of North America by the National Radio Astronomy Observatory (NRAO), which is managed by Associated Universities, Inc. (AUI).

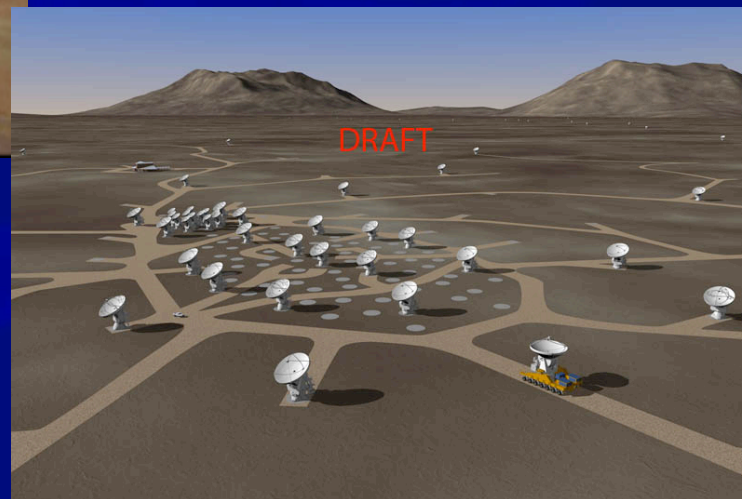


Llano Chajnantor  
Northern Chile  
at 5000m elevation

Inauguration 2012  
(Early Science in 2011)



$>50 \times 12\text{-m}$  telescopes  
+  
ACA:  $12 \times 7\text{-m} + 4 \times 12\text{-m}$





## ALMA Status: 2008 Highlights

- Handover of the first ALMA state-of-the-art production antenna.
  - Eleven more are on site, many in final stages of testing.
  - Tests show performance of production antennas exceeds that of the prototypes
- First ALMA Front Ends on site; one installed and tested in first antenna
- First ALMA Back Ends on site; one installed and tested in first antenna
- ALMA Test Facility demonstrated software, many system components; closed
- First quadrant of the 64 station correlator installed at Array Operations Site (AOS; 16,570' altitude), operating now.
- Concrete poured for dozens of foundations at AOS
- Antenna transporters both delivered, tested and performing well
- Operations Support Facility (OSF) Technical Buildings accepted, occupied.
- ALMA Operations has begun receiving and operating accepted equipment and facilities (roads, technical buildings at OSF and AOS, transporters, etc)
- ALMA Resource Centers functioning at all Executives
- Planning initiated for development beyond construction.



# ALMA Science Requirements

Three “level I” science goals:

- *Spectral line CO/C+ in  $z=3$  MWG < 24hrs*
- *resolve ProtoPlanetaryDisks at 150 pc – gas/dust/fields*
- *Precise 0.1” imaging above 0.1% peak*
- High Fidelity Imaging.
- Routine sub-mJy Continuum / mK Spectral Sensitivity.
- Wideband Frequency Coverage.
- Wide Field Imaging Mosaicing.
- Submillimeter Receiver System (..& site..).
- Full Polarization Capability.
- System Flexibility (hardware/software).

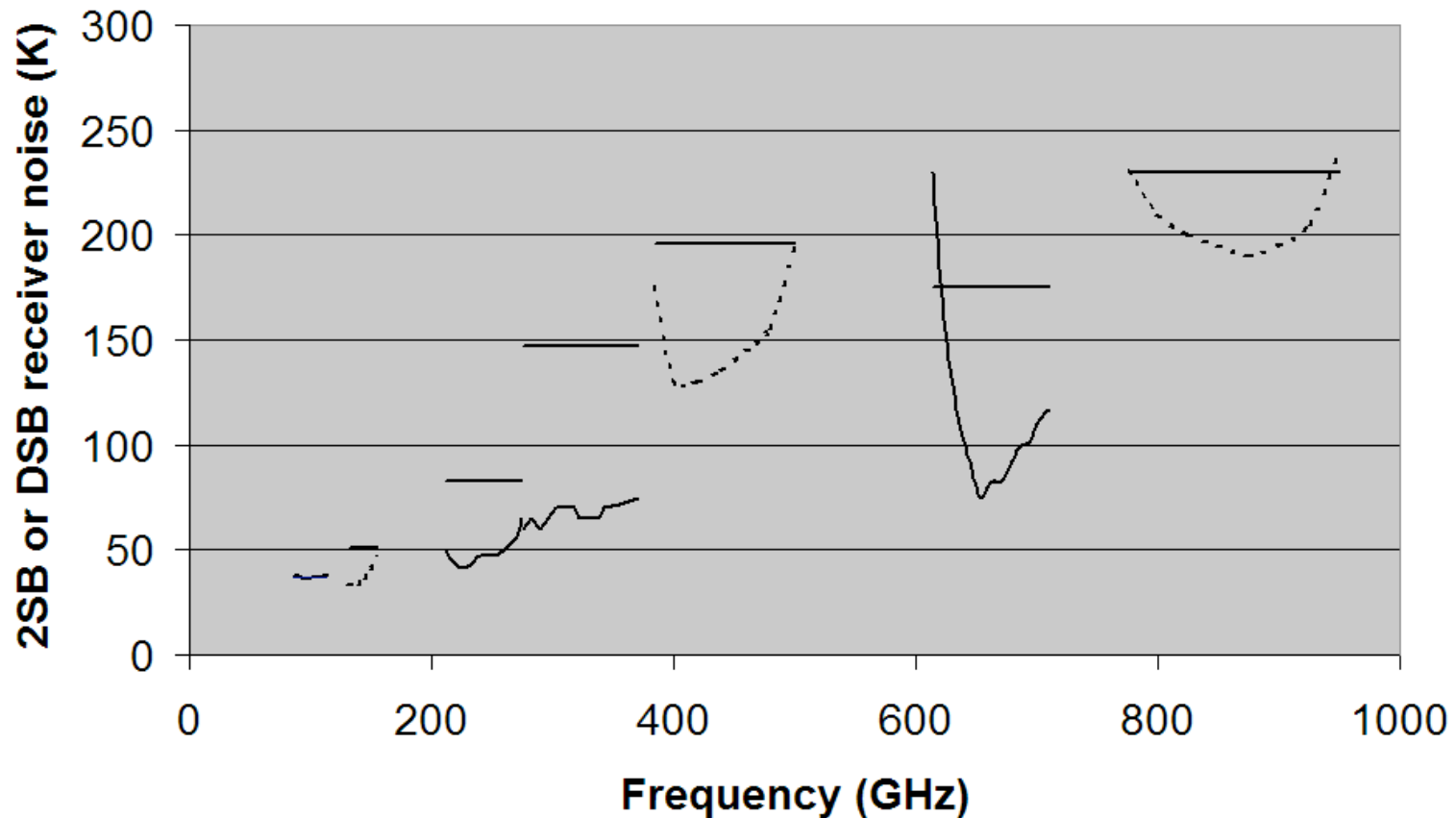


# Technical Specifications

- >54 12-m antennas, 12 7-m antennas, at 5000 m altitude site.
- Surface accuracy  $\pm 25 \mu\text{m}$ , 0.6" reference pointing in 9m/s wind, 2" absolute pointing all-sky.
- Array configurations between 150m to ~15 -18km.
- 10 bands in 31-950 GHz + 183 GHz WVR. Initially:
  - 84-116 GHz "3"
  - 125-169 GHz "4"
  - 163-211 GHz "5" 6 rx only, dual polzn
  - 211-275 GHz "6"
  - 275-373 GHz "7"
  - 385-500 GHz "8"
  - 602-720 GHz "9"
  - 787-950 GHz "10" initially partially populated
- 8 GHz BW, dual polarization.
- Flux sensitivity 0.2 mJy in 1 min at 345 GHz (median cond.).
- Interferometry, mosaicing & total-power observing.
- Correlator: 4096 channels/IF (multi-IF), full Stokes.
- Data rate: 6MB/s average; peak 60 MB/s.
- All data archived (raw + images), pipeline processing.



## ALMA Front End Noise Temperatures



Typical results for Bands 3, 6, 7, and 9. Bands 4, 8, and 10 are in development (dashed lines). The horizontal lines are the specification which applies over 80% of the band. Above 600 GHz, mixers are DSB.



# Specifications Breed Transformational Performance

- With these specifications, ALMA improves
  - Existing sensitivity, by about two orders of magnitude
    - Best accessible site on Earth
    - Highest performance receivers available
    - Enormous collecting area
  - Resolution, by nearly two orders of magnitude
    - Not only is the site high and dry but it is big! 18km baselines or longer may be accommodated.
  - Wavelength Coverage, by a factor of two or more
    - Take advantage of the site by covering all atmospheric windows with >50% transmission above 30 GHz
  - Bandwidth, by a factor of a few
    - Correlator processes 16 GHz or 8 GHz times two polarizations
- Scientific discovery parameter space is greatly expanded!





# ALMA – Major Elements

Twelve antennas now in Chile  
First Production Antenna Dec 18



Photo H. Heyer (ESO).

- Partners: US (NSF/NRAO)+Canada (NRC)+Taiwan (ASIAA) – ESO  
Chile – Japan (NINS)+ *Taiwan (ASIAA)*

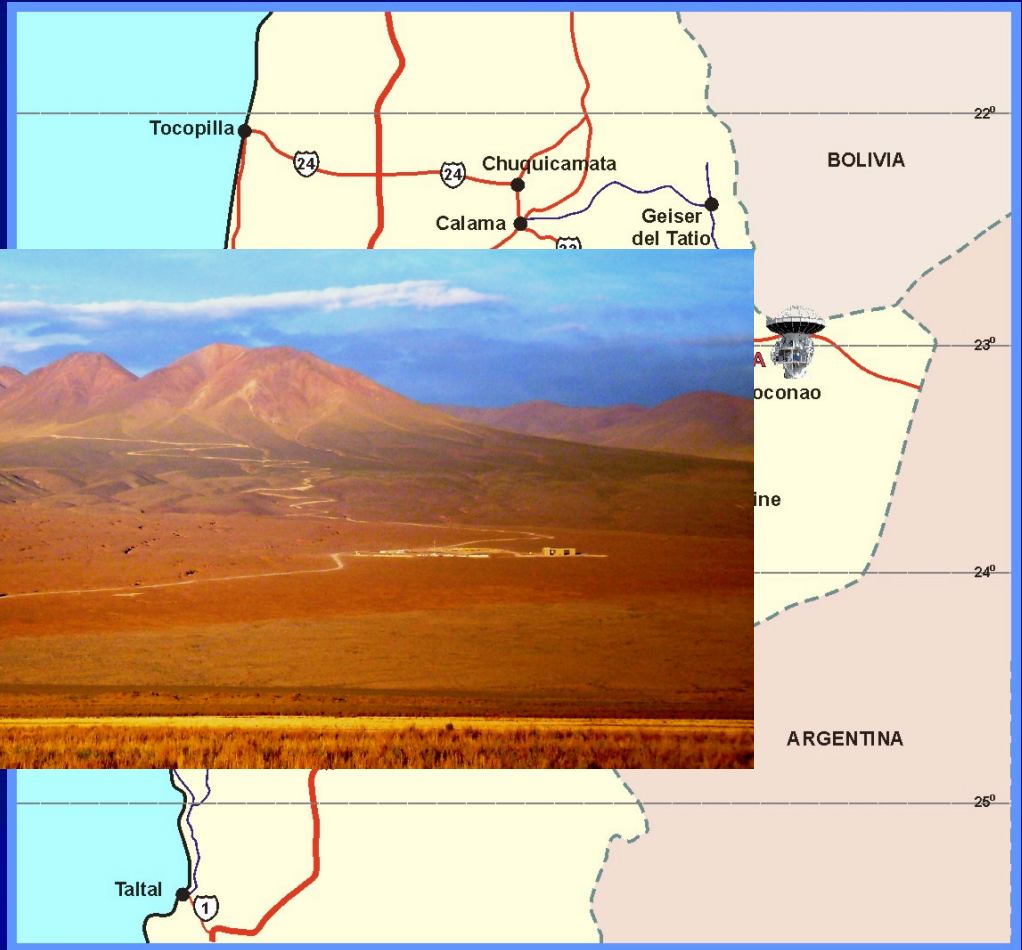
## Action Sites

- Array Operations Site – AOS 5000m
  - Operations Support Facility – OSF 2900m
  - Santiago Central Offices – SCO
  - ALMA Regional Centers – ARCs + ARC nodes
  - ALMA Test Facility--Near Very Large Array, NM
- 
- During full operation, the estimated flow into archive ~ 100 Tbytes per year
  - Dataset: proposal,  $u-v$  data, a reference image with pipeline processing history, calibration data... modern radioastronomy
  - Where are we in the construction phase?





# How can I find the ALMA Site?



Paranal

La Serena

Santiago



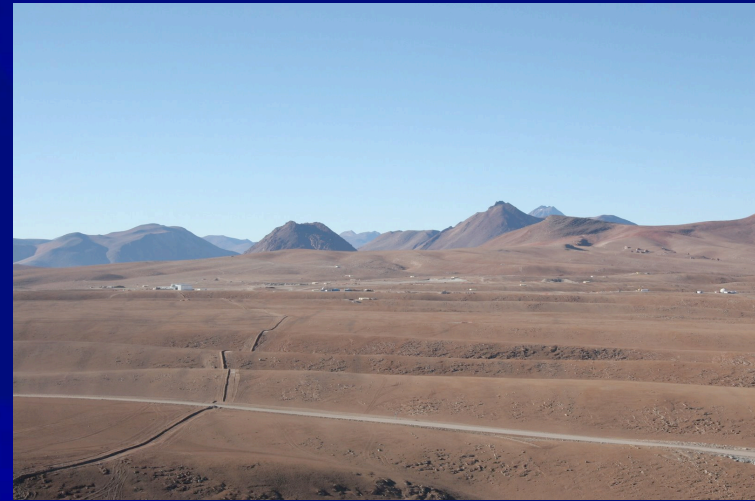


# Array Operations Site: 16400 feet

43 km from gate on CH23 on 51ft wide new road



Array Operations Site Technical Building



- Digitized signals from antenna to TB
- TB houses Correlator
- Local oscillator signals
- Antenna transporter shelter



# Array Operations Site: 16400 feet

43 km from gate on CH23 on 51ft wide new road



ACA Construction



A. Saez and first correlator quadrant



•Fiber Optic patch panel in AOS TB



# AOS general view, last week





# Compact Array Foundations





## Transporter at AOS





# Operations Support Facility: 9500 ft altitude

15 km from gate on CH23



- Antenna erection areas
  - VertexRSI (NA)
  - Mitsubishi (JP)
  - Alcatel (EU)

OSF TB

- Camps: House, feed and amuse >500 people
  - ALMA
  - Contractors
  - Temporary Offices

- Technical Building
  - Warehouse
  - Shops, offices, antenna area





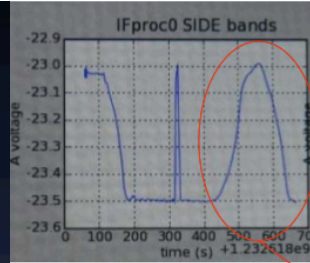
Melco No2=PM02=AIV1  
VX No 1 = AIV2



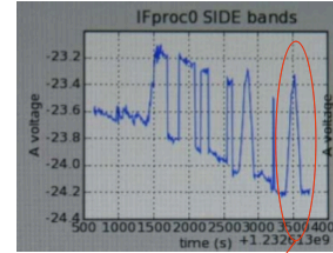


# First Light!

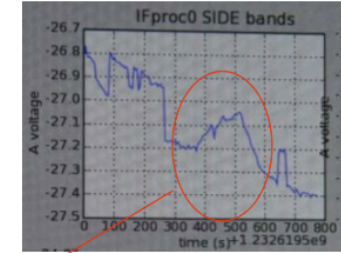
The ALMA first light succeeded !  
January 22, 2009



Band 3

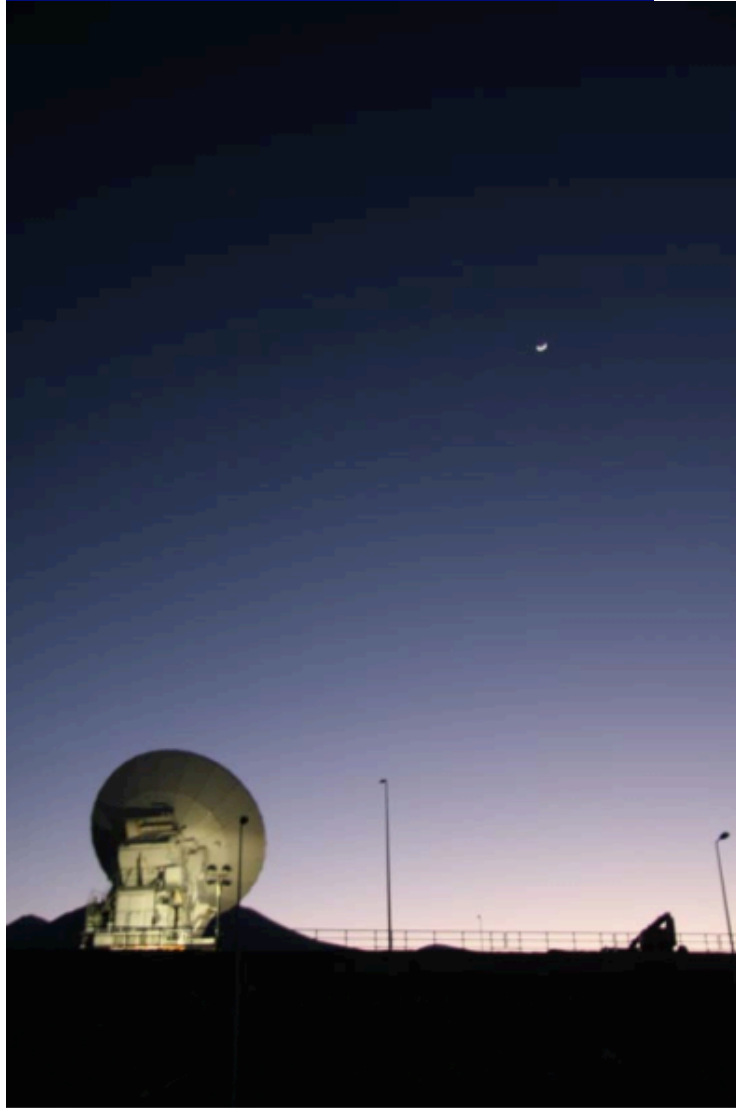


Band 6



Band 7

Drift scans of the Moon was obtained using a continuum receiving system.





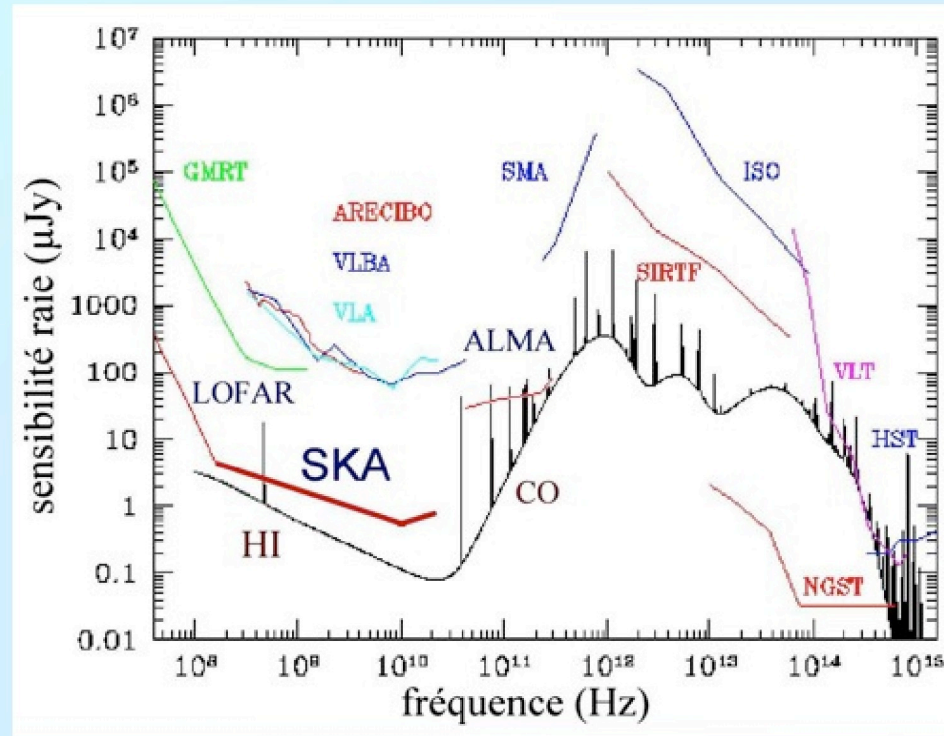
# First NA antenna place on OSF pad





# Science Goal I: Detect CO or C+ in MWG

At  $z=2$  this can be done  
At  $z=3$  this becomes  
difficult.

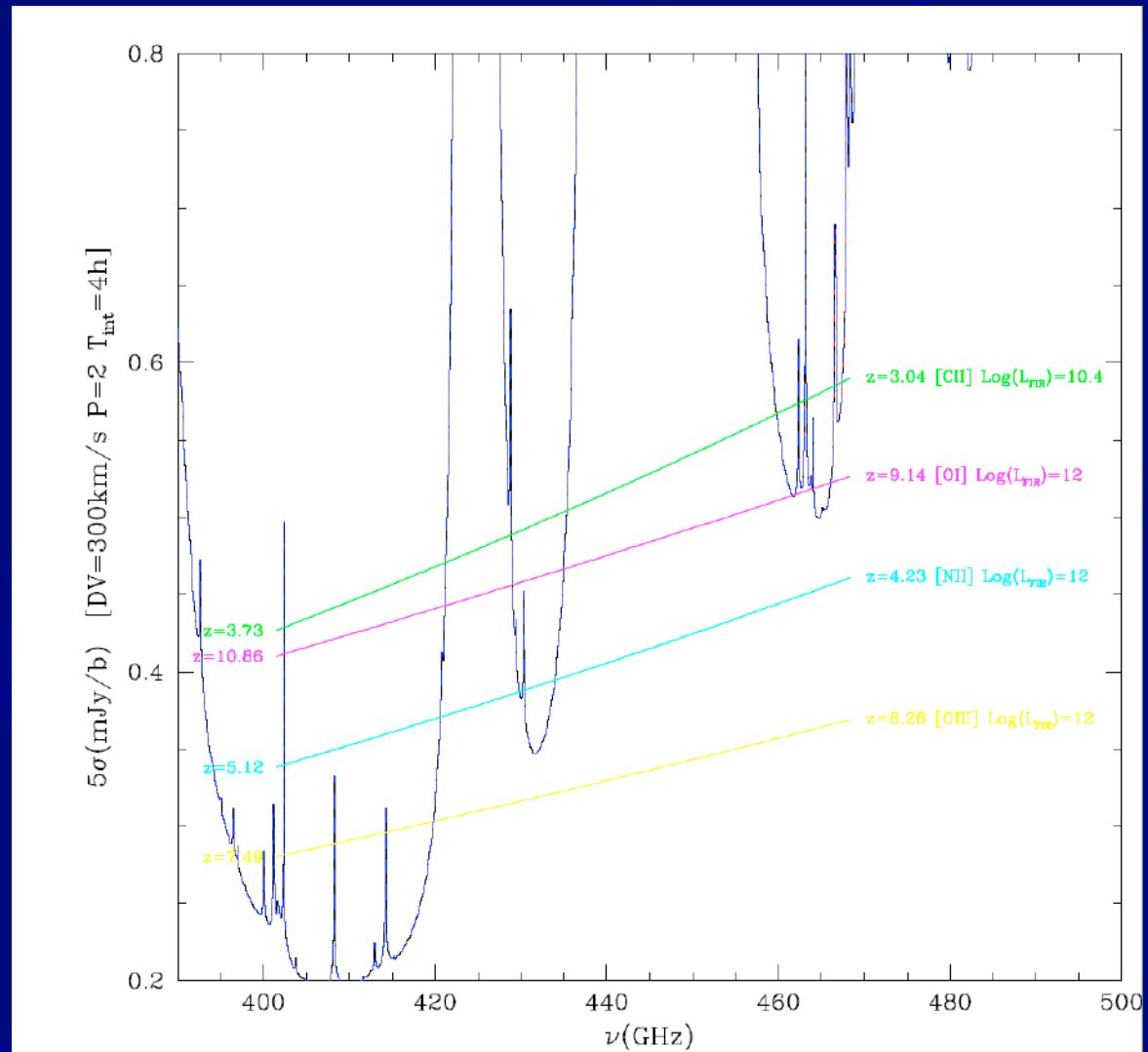


Detection of spectral lines of a 'standard' spiral galaxy at  $z = 2$   
 $5\sigma$  in 1 hour



# Science Goal I: Detect CO or C+ in MWG

Viable; depends on  
Exact redshift and  
transparency window  
lineup.





# Submm Sources at High and Low $z$



Wang 2008

Simulation based on:

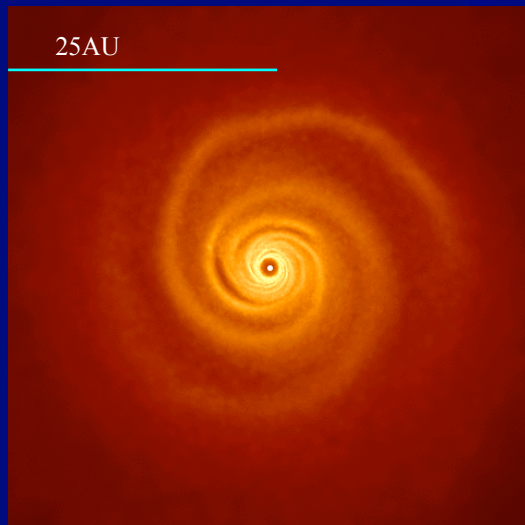
- (1) blank-field bright-end number counts (Wang, Cowie, Barger 2004)
- (2) lensing cluster faint-end number counts (Cowie, Barger, Kneib 2002)
- (3) redshift distribution of the submm EBL (Wang, Cowie, Barger 2004)



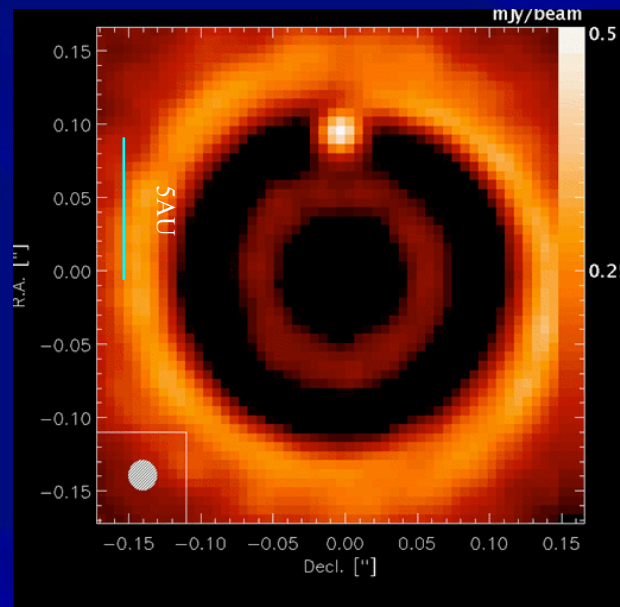
# Birth of Stars and Planets

Evolutionary Sequence—  
Molecular Cloud Core to Protostar ( $10^4$  yrs) to  
Protoplanetary Disk (to  $\sim 10^6$  yrs) to  
Debris Disk (to  $10^9$  yrs)

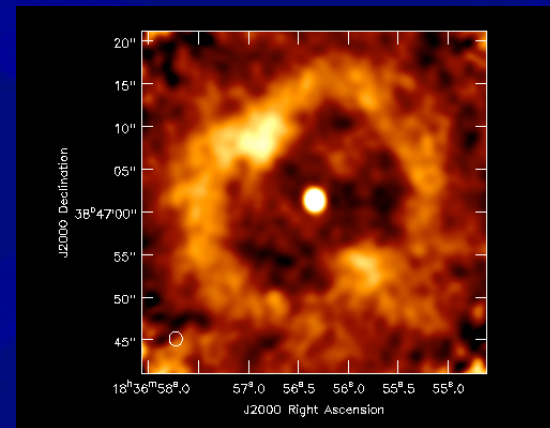
Lodato and Rice 2005



Wolf and D'Angelo 2005



M. Wyatt; R. Reid



Vega Dust Disk



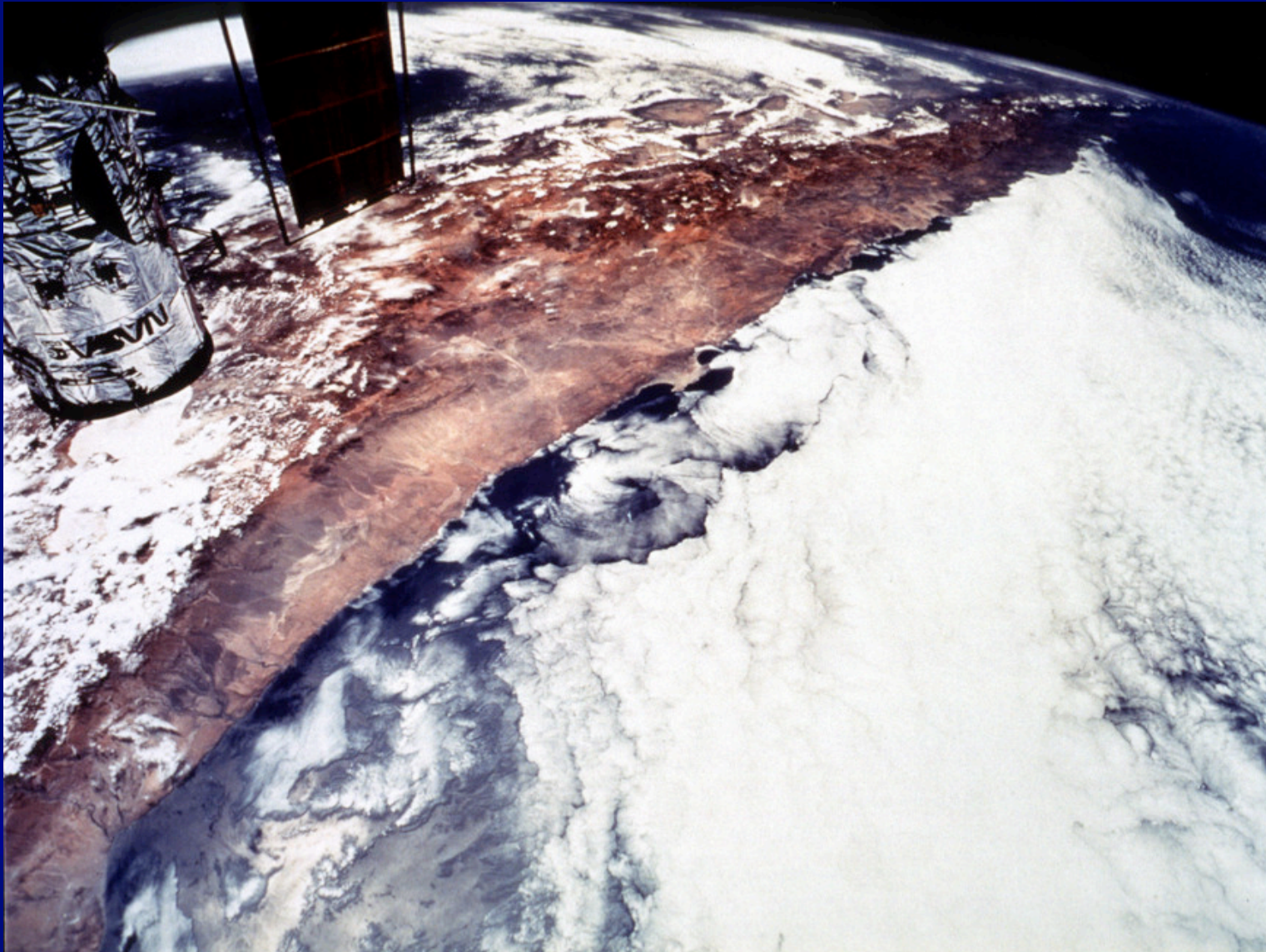
[www.alma.info](http://www.alma.info)

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





# Where is ALMA?





# ALMA and Contractor Camps



- ALMA Camp
  - Housing
  - Offices
  - Dining Hall
  - Recreation Hall
  - Tennis court
  - Temporary technical building
- Future: Residence

**View to the ALMA Camp**



# ALMA and Contractor Camps



- Contractors Camp
  - Housing
  - Offices
  - Dining Hall
  - Recreation Hall

**View to the Contractor Camp**



# Antenna Vendor Areas

Four Melcos;

Melco 12m Antennas



**View of AEM, MEICo, VxRSI areas (l-r)**

Holographic surface measurements on  
MEICo No 1 confirm night stable @14  $\mu\text{m}$ !

VxRSI No 2,3,4,5

VxRSI No 1



# Antenna Locomotion: Transporters



- 10 meters wide, 20 meters long and 6 meters high,
- Now rolling around at the OSF site--moving VxRSI antenna from building this week.