# NRAO An NSF Facility



#### **National Radio Astronomy Observatory**



Atacama Large Millimeter/submillimeter Array Karl G. Jansky Very Large Array Robert C. Byrd Green Bank Telescope Very Long Baseline Array



#### **ALMA: First Results**

#### NealFest April 25-26, 2013



ALMA seen from the peak of Chajnantor in March 2013 (courtesy M. Lindqvist, Onsala Space Observatory)

#### Al Wootten NA ALMA Program Scientist



Associated Universities, Inc. Atacama Large Millimeter/submillimeter Array Karl G. Jansky Very Large Array Robert C. Byrd Green Bank Telescope Very Long Baseline Array



### Neal

- There was considerable excitement when Neal arrived at Texas—the infrared was exciting and new, as Steve mentioned, millimeter astronomy was exploding, and the submillimeter was on the horizon.
- Like Paul, he was approachable, full of ideas and encouraging of the development of one's own ideas and full of advice on how to put them into play.
- It was certainly among the best of times to be a grad student —one had a week a month at the MWO whether you wanted it or not, and everyone else in the world had to line up at the NRAO IIm.
- The Chili was fantastic (esp Black Hole Chile)





#### >90% Complete!

 Feb 2013 is the 30<sup>th</sup> year of NRAO involvement in a Millimeter Array, and the tenth anniversary of the Bilateral Agreement







#### Neal and ALMA

- 1981: NRAO 25m not included in Decadal review
- 1982: Barrett committee meets; 1983: 25m not in Budget
- 1983: Meeting at Bell Labs supports MMA
- I984: R.Wilson sends MMA Technical Advvisory Committee Report to Mort Roberts, asking NRAO to lead on an MMA
- 1985: Design Study Vol I. Neal Chaired Star Formation WG
- 1990: Proposal to NSF for MMA
- Neal was a member of the MAC (along with Ewine)
  - 1997: Recommended combining with ESO; 12m apertures
- 1999: ALMA Science Conference D. C., Evans among first members of ALMA Science Advisory Committee
- 2011: Chairman of the ALMA Proposal Review Committee (APRC)
- 2012: Chairman of the ALMA Board





#### **ALMA Construction**

- All 66 antennas on site; 57 antennas through 'AIV'; 55 antennas at AOS.
  - All North American and East Asian antennas delivered, Eu to finish by September.
- All Front Ends are in Chile
  - Test sets reassembled in Chile for integration of remaining cartridges for Bands 4,8,10 and further.
- ALMA Inauguration was held 13 March
- On budget, nearly on time!
  - Within the rebaselined 2005 budget, some delay from the 2005 schedule (Japan joined 2006).
- Commissioning of several modes (long baselines especially) remains.



#### **Collecting Area & Baselines**







**Circles Show Collecting Area (sensitivity)** Captions give # of antennas and # of baselines (fidelity)

NealFest 2013

#### **Frequency Coverage**



ΔΙ ΜΔ



## Commissioning

#### • Cycle I capabilities

- Array is now powered on the 'Permanent Power Supply' from propane, at 2900m.
- Three antennas on ~I km pads allows testing of long baselines
- ACA + 12m Array: Some details outstanding
  - Meshing of results from two correlators
  - Total Power independent SBs: SV datasets, casaguides on the way
- After commissioning of capabilities comes operation/data reduction
  - Works in progress
- Cycle 2 preparations
  - Polarization with restrictions may be offered
  - Bands 4 and 8 may be offered on a restricted set of antennas
    - First images at band 4 & 8 taken
    - Basic definitions needed for observing mode implementation (largely finished)
    - 80% of antennas outfitted by ~June/July 2014; delay executions until that date





### **ALMA Development Projects**

- Band 5 (163-211 GHz) and Band 1 (33-52 GHz), two of the bands dropped in March 2000, after subsequent ASAC ranking of band importance
- VLB phasing, to allow phasing of ALMA
  - Primary motivation is extremely high resolution imaging of AGN, especially Sgr A\* and M87
  - Science case for more general VLB phasing in draft
  - Not a part of construction since Feb 2004 System Review
- Landline internet connection to the Chilean backbone (increased reliability and throughput from site to SCO and beyond).
- Source on Honar for holography, polarization tests.





#### Future

- Current Development Studies complete this year
- Development Workshop 18 April for community
- Call for Development Studies I May, coordinated with other partners
- Call for Development Projects in NA I June



## The Formation of Planetary Systems: ASC



#### ALMA Images *P*-Oph 102: Grain Growthe and Molecular Gas in the Disk around a Young Brown Dwarf L. Ricci et al. 2012 ApJ 761 L20

06<sup>s</sup>.5

06<sup>s</sup> 4



NRA

- Dusty disk of size <40AU
- Surprisingly, dust grains are fairly large
- Molecular gas emission found at the location of the Brown Dwarf, indicating a gas-rich disk as typically found for disks surrounding young pre-Main Sequence stars
- Suggests that brown dwarf stars ۲ (failed stars) may produce planets in a similar fashion to normal stars.



#### Gas Flows through a Protoplanetary Disk Gap

- HD142527: IR data shows 10 AU inner disk, 140 AU gap, disrupted outer disk 140+ AU
  - Disruption attributed to unseen planetary mass body(s) at ~ 90 AU
- ALMA sensitivity and spatial resolution enabled images of dense gas in gap-crossing filaments, along with diffuse CO gas within gap.
  - Observation explains how the observed high accretion rate may be maintained
  - Dynamical models suggested outer disk gas could be channeled by putative protoplanets through gap-crossing bridges feeding the inner disk: these observations support these models









## ALMA Observation of the CO-Snowline Ring HD163296

- HD163296:12
- Luminous: sno
  - Qi et al (2
  - Mathews (
    - DCO-









### Massive Star Formation near SgrA\*

- ALMA detects SiO (5-4) clumps within 0.6pc (15") of Sgr A\*, interior to the 2-pc circumnuclear molecular ring.
- Three clumps closest to Sgr A\* show V~150 km s<sup>-1</sup>, broadest asymmetric linewidths (FWZI) ~ 110 147 km s<sup>-1</sup>.
  - Comparison with CARMA J=2-1 data shows the clumps are dense
  - Embedded protostellar flows near IR objects with YSO SEDs

Yusef-Zadeh et al 2013 arxiv:1303.3403

• In-situ star formation near SgrA\* suggested.













## **ALMA:** Nitrogen in the Early Universe

- Nitrogen is a secondary element, produced within low mass stars, hence its abundance rise in the Universe may be expected to lag that of O and C
- Spectrally, it is traced by the [N II] lines at 122 and 205 microns, which emit at about 5% of the [C II] intensity in the local Universe
- Nagao et al. (2012) report ALMA observations ٠ of [N II] in J03329.4, a starburst submillimeter galaxy at an age since the Big Bang of 1.27 Gyr (z=4.75). [N II]/[C II]~0.043 in this galaxy, suggesting a solar nitrogen abundance (the ratio is 0.05 in M82).





ALMA Image, Spectrum

03h32m29s.5 29s.4

29°.3 29<sup>5</sup>.2 J2000 Right Ascension



-600

-400 -200 Velocity (relative to Lya) [km/s]



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