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National Radio Astronomy Observatory

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

Preparing for ALMA

http://science.nrao.edu/alma

National Radio Astronomy Observatory

North America ALMA Science Center

Charlottesville, Virginia U.S.

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ALMA: The March to Early Science and Beyond

Al Wootten

North America ALMA Project

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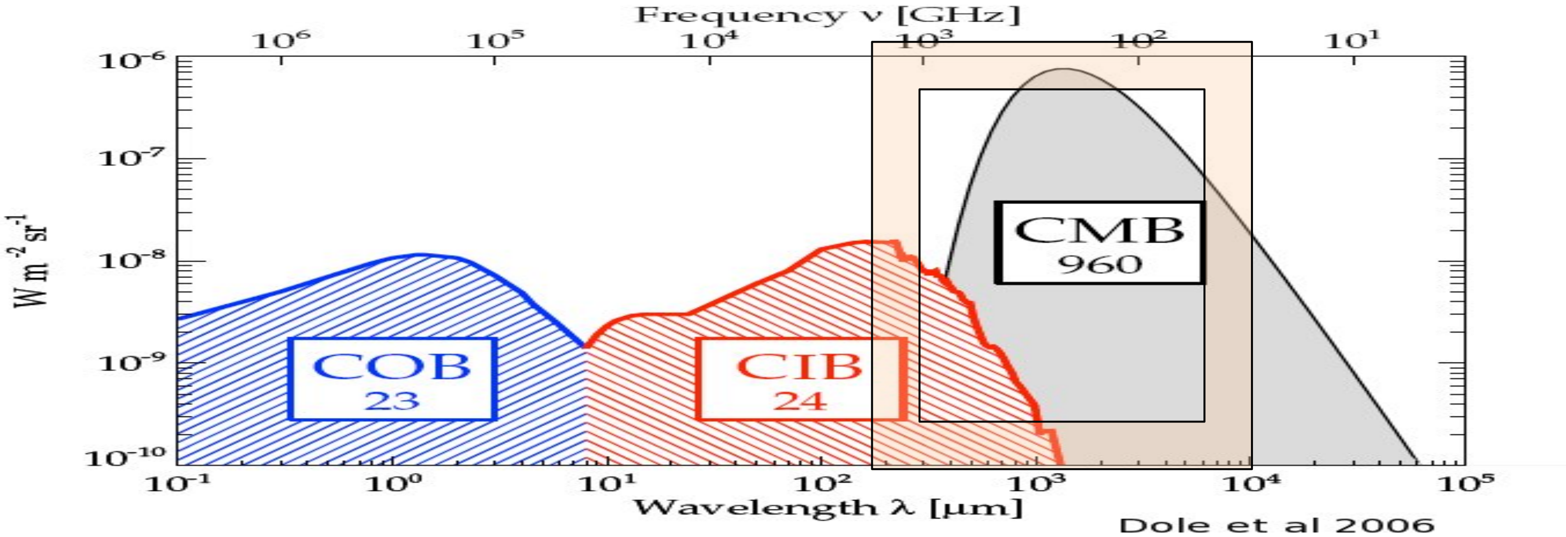
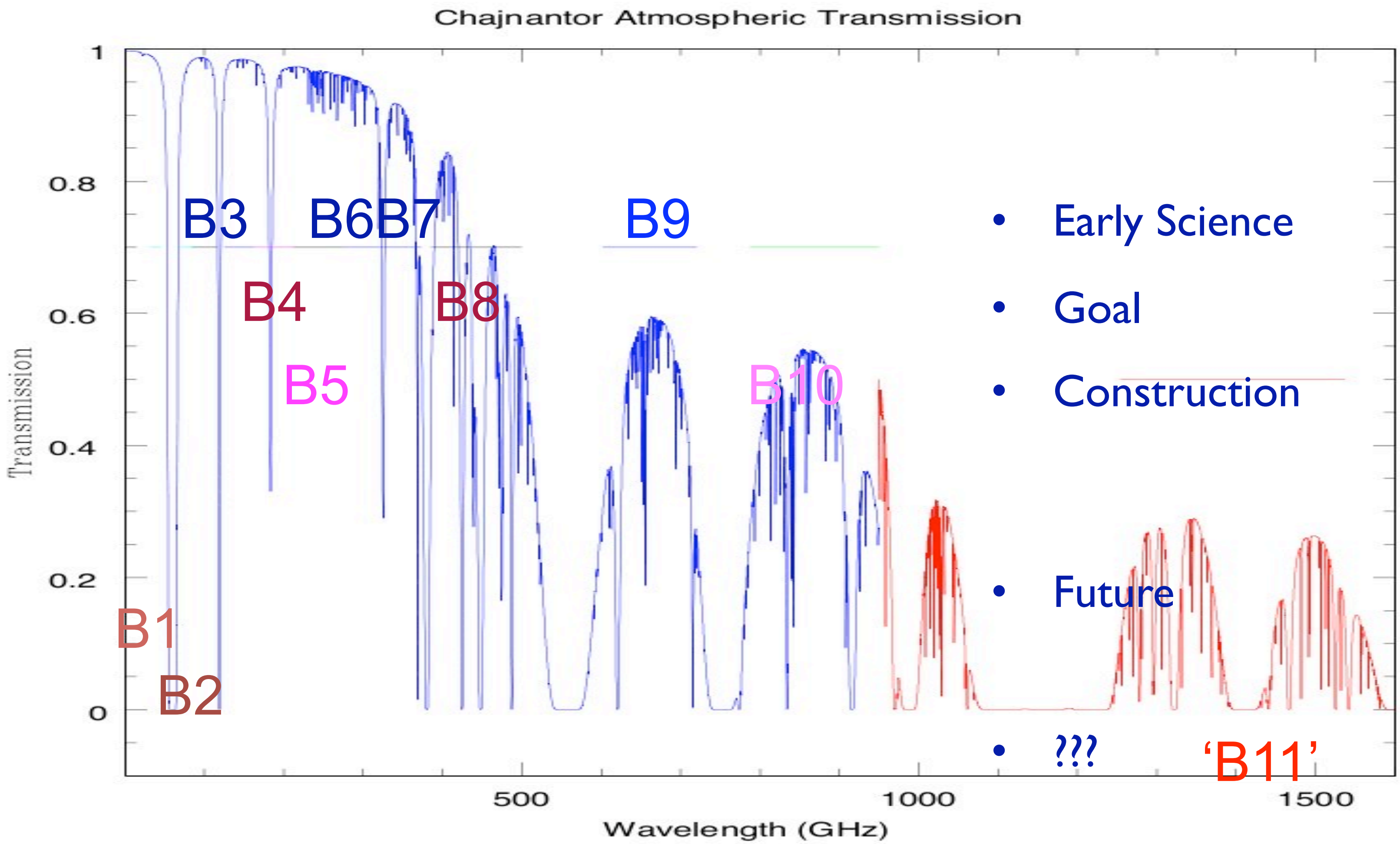
The mm/submm Spectrum: Focus of ALMA

ALMA



- Millimeter/submillimeter photons are the most abundant photons in the cosmic background, and in the spectrum of the Milky Way and most spiral galaxies.
- ALMA range--wavelengths from 1cm to ~0.3 mm, covers both components to the extent the atmosphere of the Earth allows.

ALMA Bands and Transparency

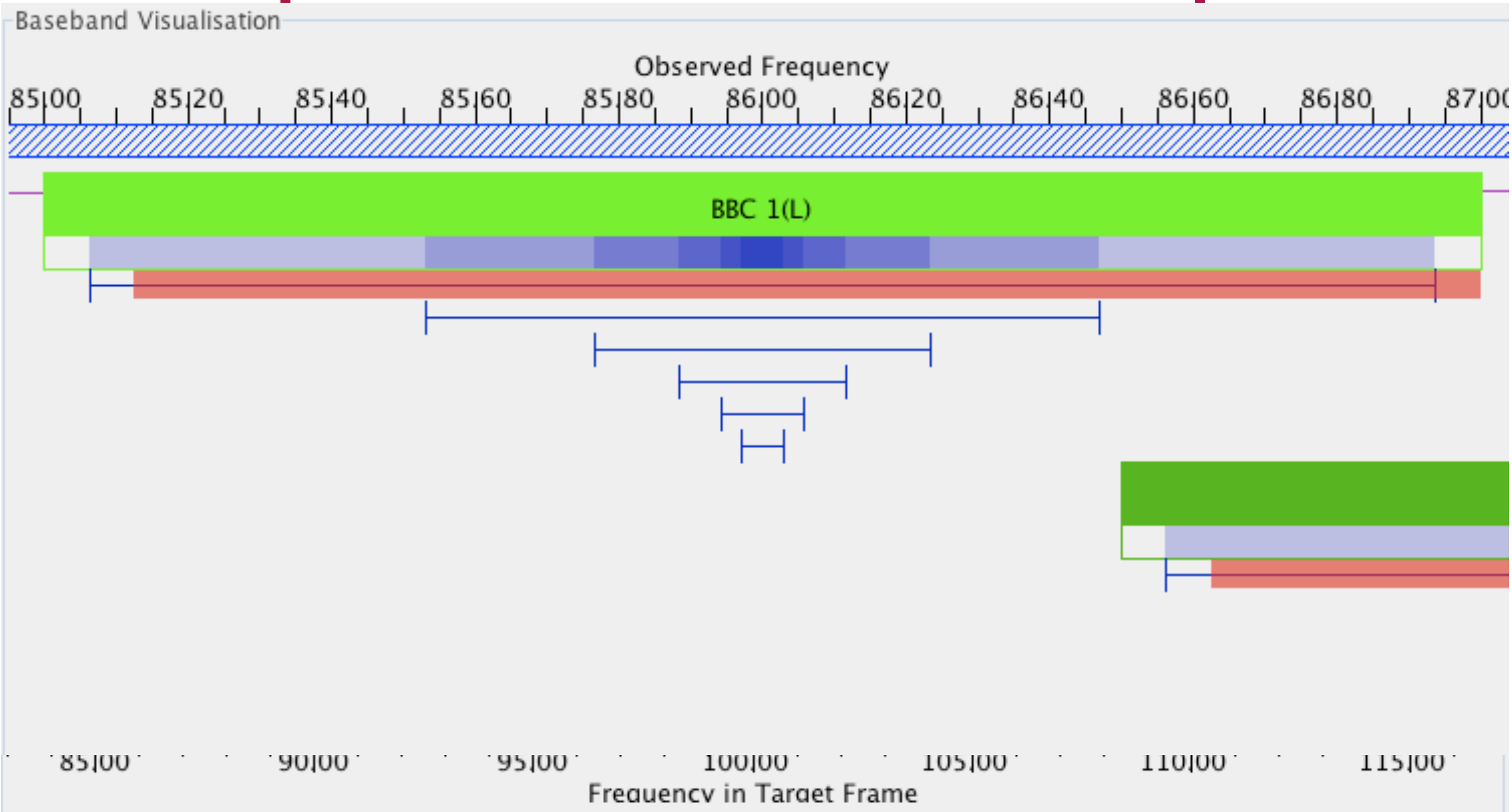


- Early Science
- Goal
- Construction
- Future
- ???

Transformational Performance

- ALMA improves
  - Sensitivity: 100x
  - Spatial Resolution: up to 100x
  - Wavelength Coverage: ~2x
  - Bandwidth: ~2x
    - Scientific discovery parameter space is greatly expanded!
- ***ALMA Early Science*** begins the transformation
  - Sensitivity: ~10% full ALMA
  - Resolution: up to ~0.4" (0.1" goal)
  - Wavelength Coverage: 3-4 of final 8 bands (7 goal)
  - Bandwidth: ~2x improvement
  - Beginning the Discovery Space Expansion

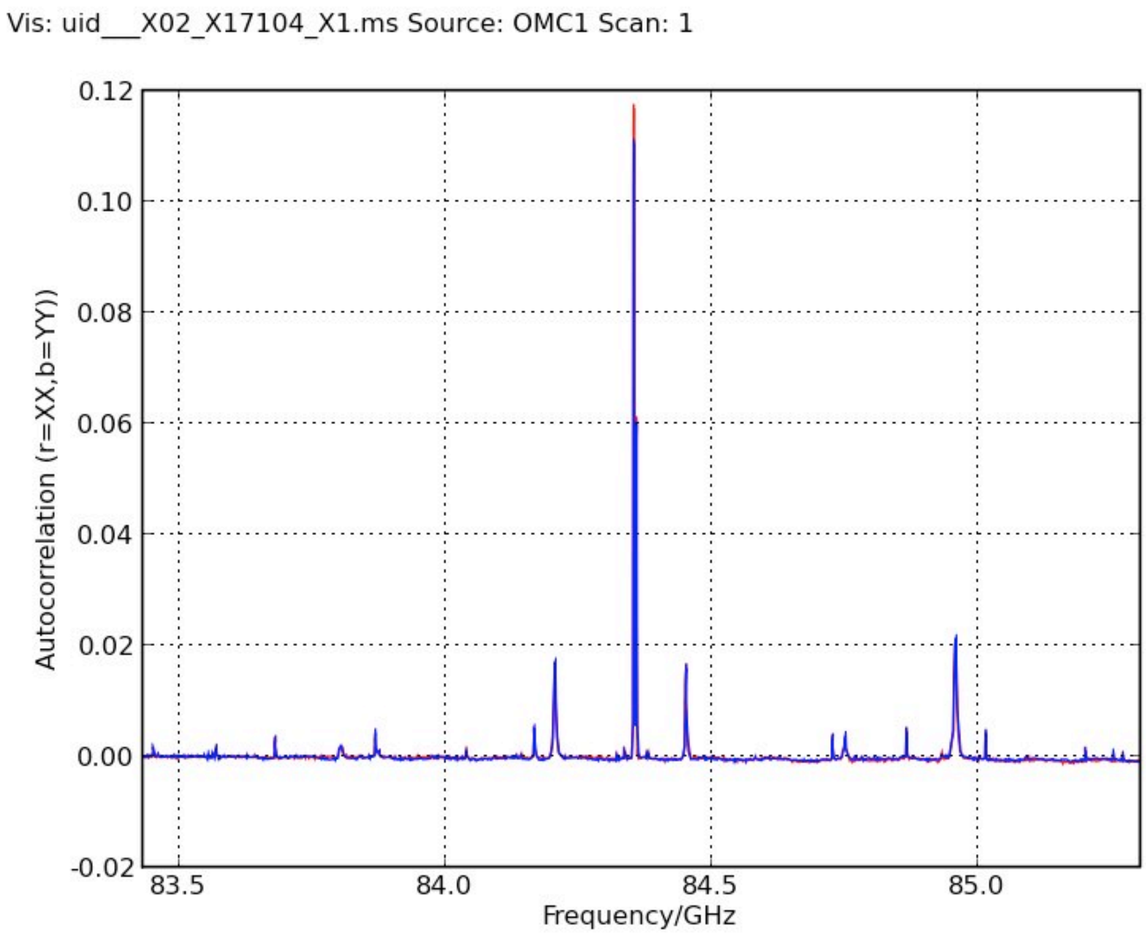
Example Correlator Window Setups



Correlator Modes

Mode 7

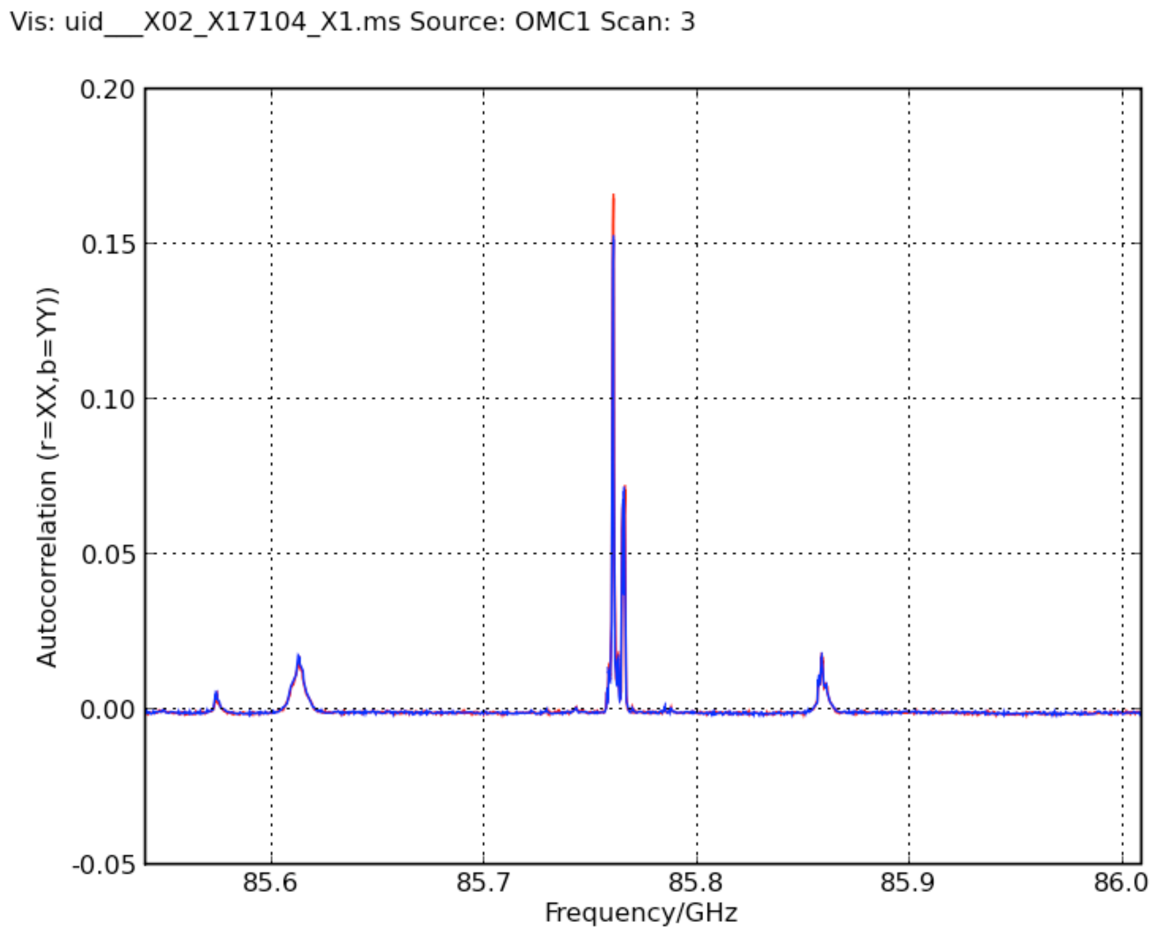
- 3840 channels
- 0.488 MHz resolution
- 1.875 GHz bandwidth
- ES Mode



Correlator Modes

Mode 9

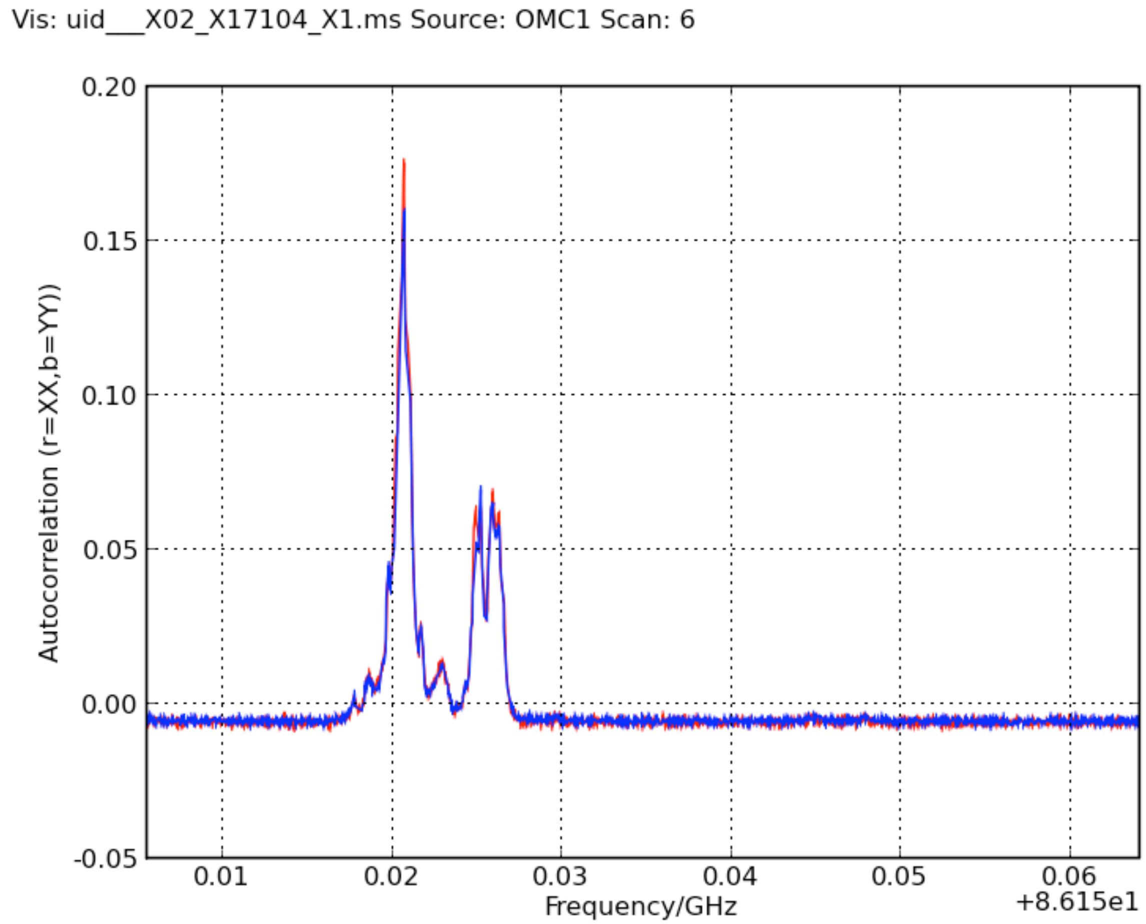
- 3840 channels
- 0.122 MHz resolution
- 0.4688GHz bandwidth
- ES Mode



Correlator Modes

Mode 12

- 3840 channels
- 0.0153 MHz resolution
- 0.0586 GHz bandwidth
- ES Mode

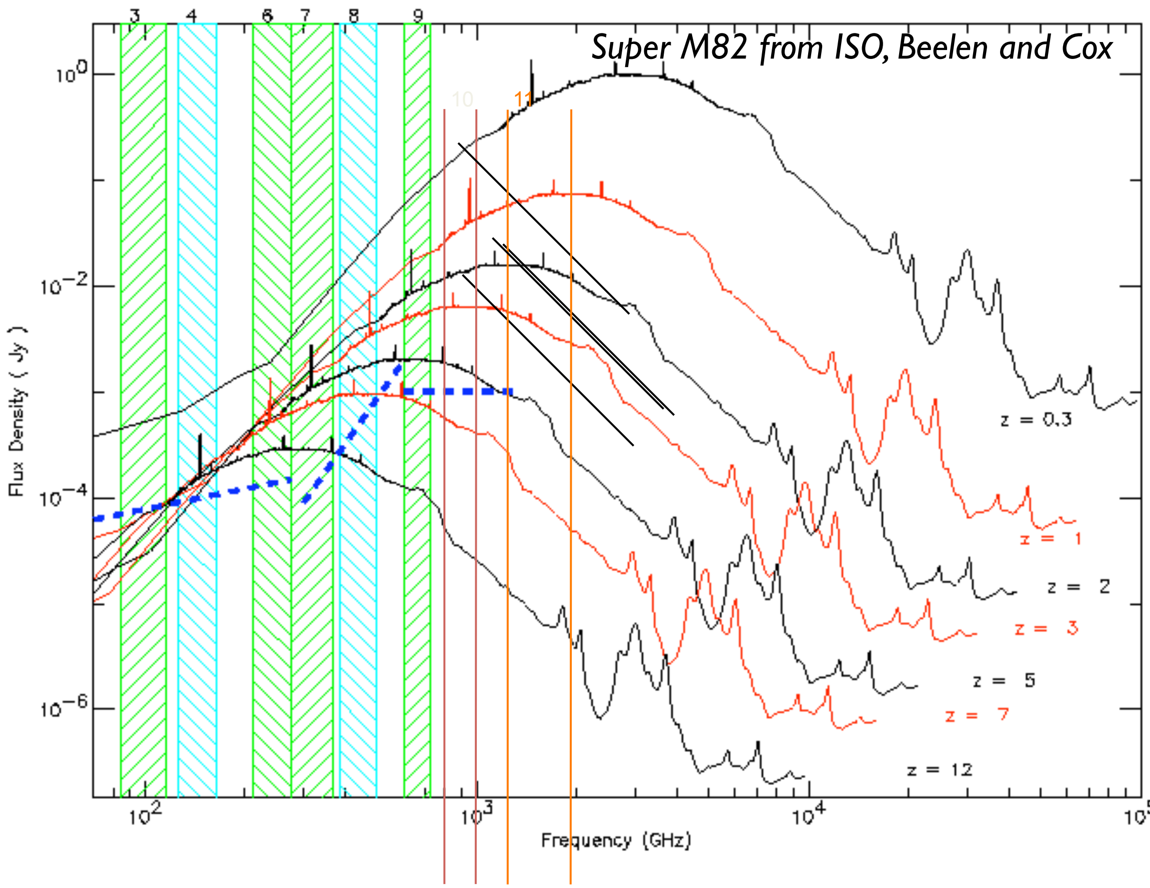


DRSP Examples: Early Science

- Design Reference Science Plan
- Among the examples:
  - A Deep Field Object
  - Protoplanetary disks
- Consider possibilities for Early Science
  - Excellent sensitivity—better than any current array—witness the 3-element spectra shown here
  - Excellent imaging—imaging quality goes as N^2 for a given antenna size; for the ES array we have 120 baselines; 1225 up to 2016 for full science, plus total power.

Inverse K-correction: the magic of the submillimeter

As galaxies get redshifted into the ALMA bands, dimming due to distance is offset by the brighter part of the spectrum being redshifted in. Hence, galaxies remain at relatively similar brightness out to high distances.



Hubble Deep Field (HDF)

Rich in Nearby Galaxies, Poor in Distant Galaxies

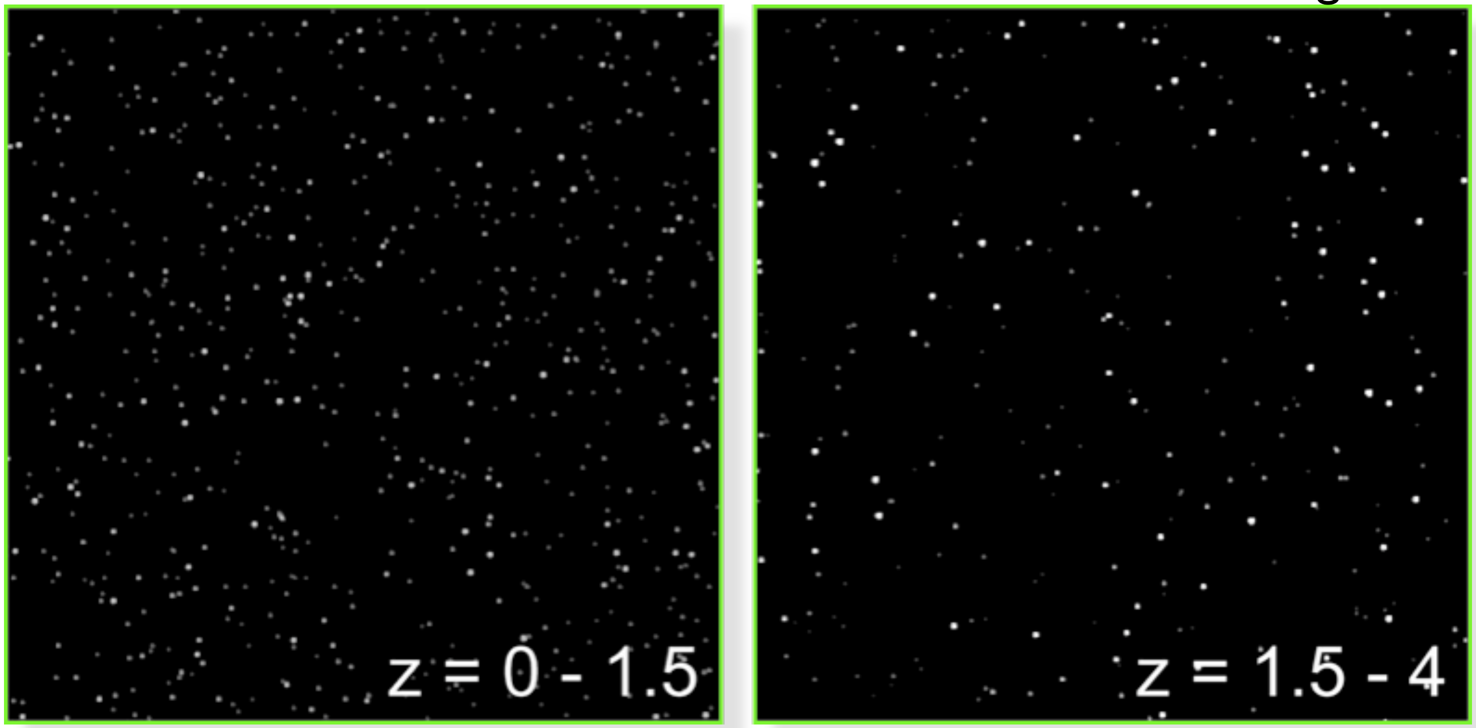
Source: K. Lanzetta, SUNY-SB

Nearby galaxies in HDF

Distant galaxies in HDF

Submm Sources
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)

Distant Galaxies with ALMA Early Science

- Continuum Sensitivity: Better than 1 mJy 1 minute most bands; ~3mJy .4 mm
  - Weakest sources ever seen in submm emit ~few mJy
  - With many more antennas, deep surveys will be more effective with full ALMA
- Spectral line sensitivity: ~3 Jy km s^{-1} in 1 minute at .4mm
  - ~30x better than current ~10m submm telescopes in one hour
  - Whole-band search, requiring ~15 tunings, feasible to good sensitivity
- Imaging performance, but ~10x better with full ALMA
- Conclusion: Excellent sensitivity
  - Spatial surveys should await full ALMA
  - Line surveys practical with ALMA Early Science array on targeted objects

J1148+5251

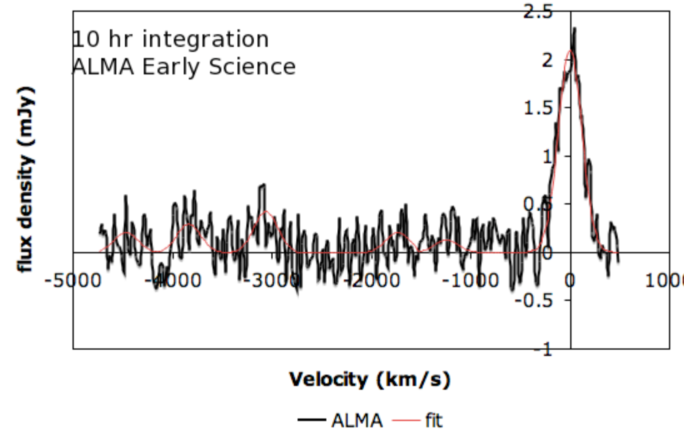
An EoR paradigm with ALMA

ALMA

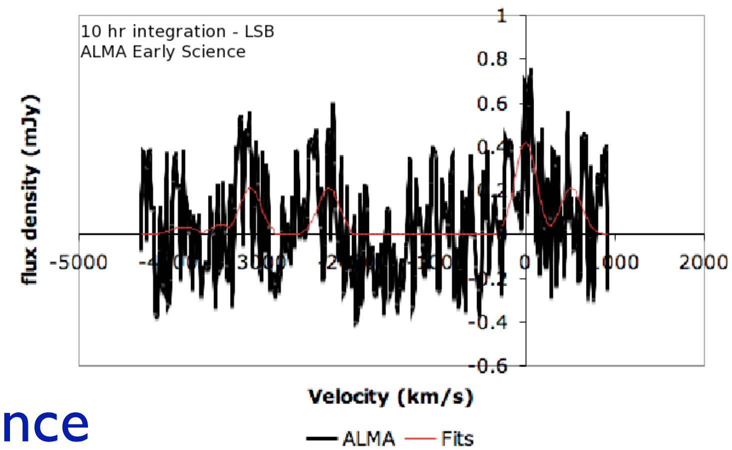
Secure redshifts
Molecular astrophysics

z=6.4 CO J=6-5

Top: USB, 3mm or 94.8 GHz
CO 6-5
HCN 8-7
HCO+ 8-7
H2CO lines



Lower: LSB, 86.8 GHz
HNC 7-6
H2CO lines
C18O 6-5
H2O 658GHz maser?



~10 hr ALMA Early Science

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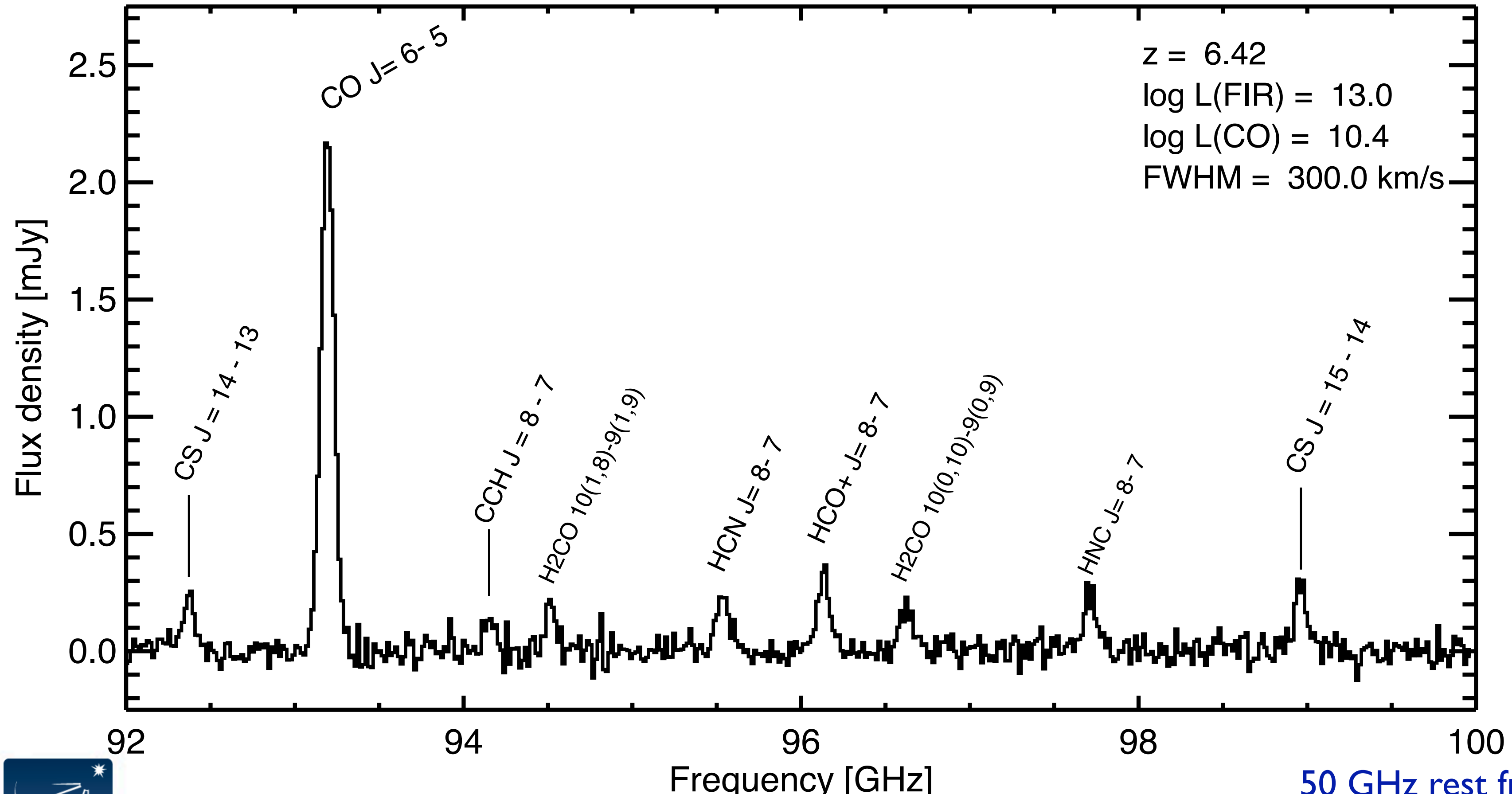
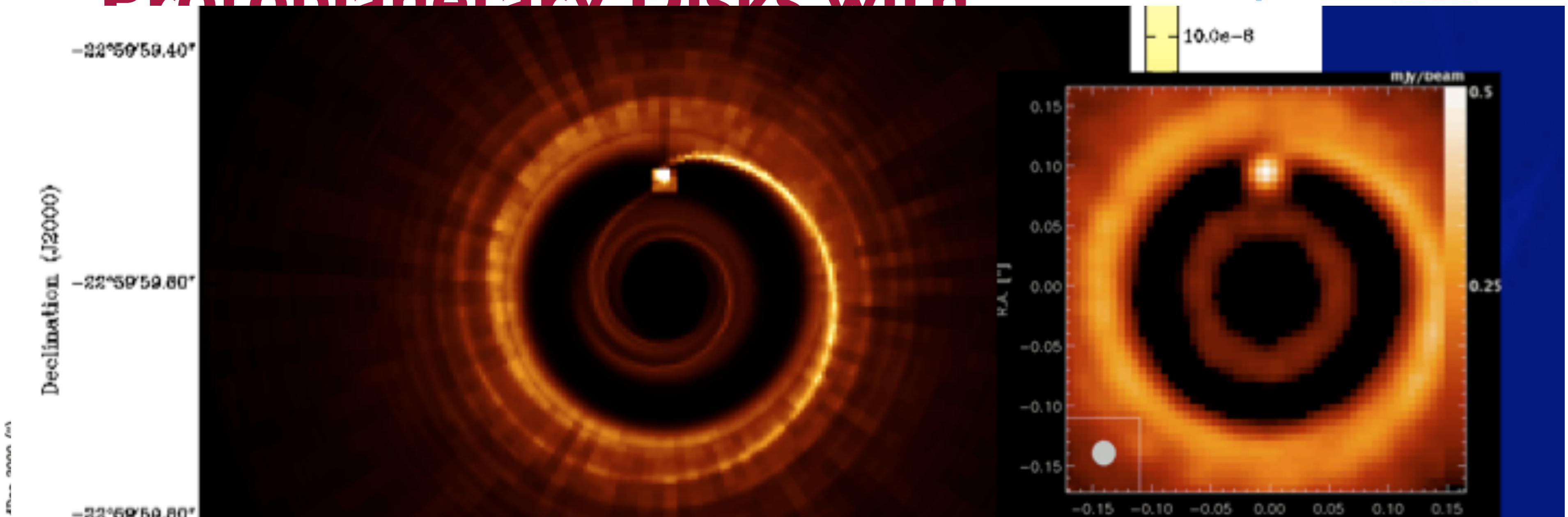
Full ALMA ~24 hr

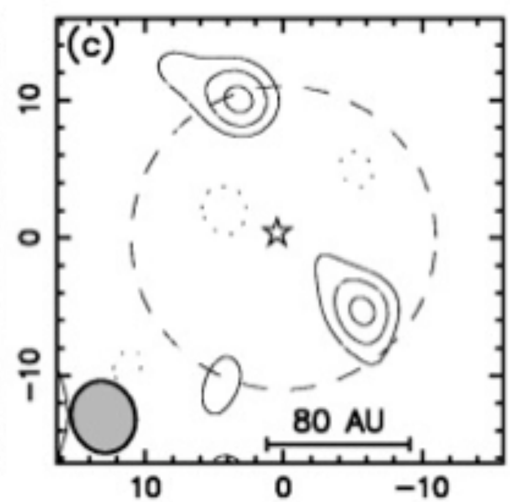
- Bandwidth compressed by (1+z) => many lines



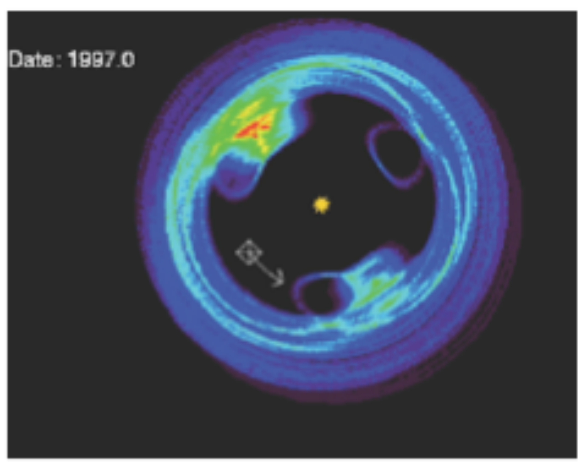
50 GHz rest frame

Protoplanetary Disks with ALMA

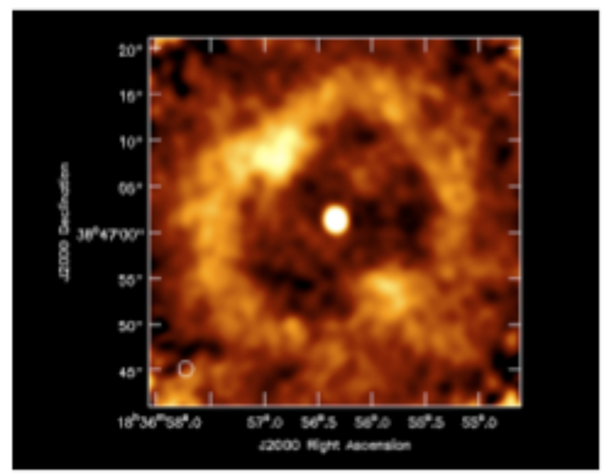




Wyatt 2???



Reid et al 2008



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  - Resolution: up to ~0.4" (0.1" goal)
  - Wavelength Coverage: 3-4 of final 8 bands (7 goal)
  - Bandwidth: ~2x improvement
- ***Begins next year***

www.almaobservatory.org

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).

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