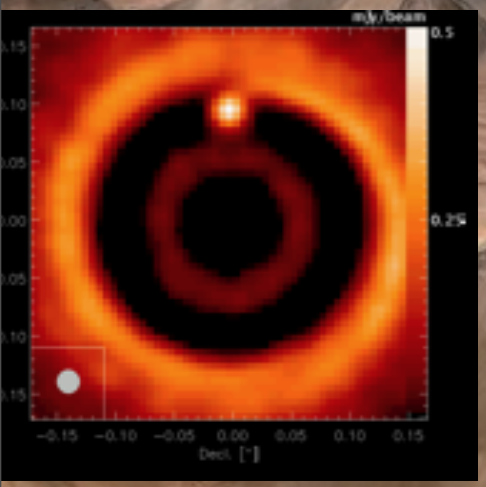
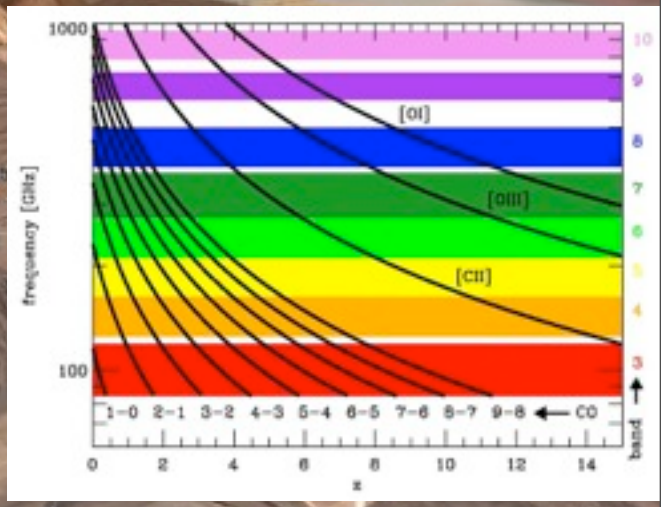
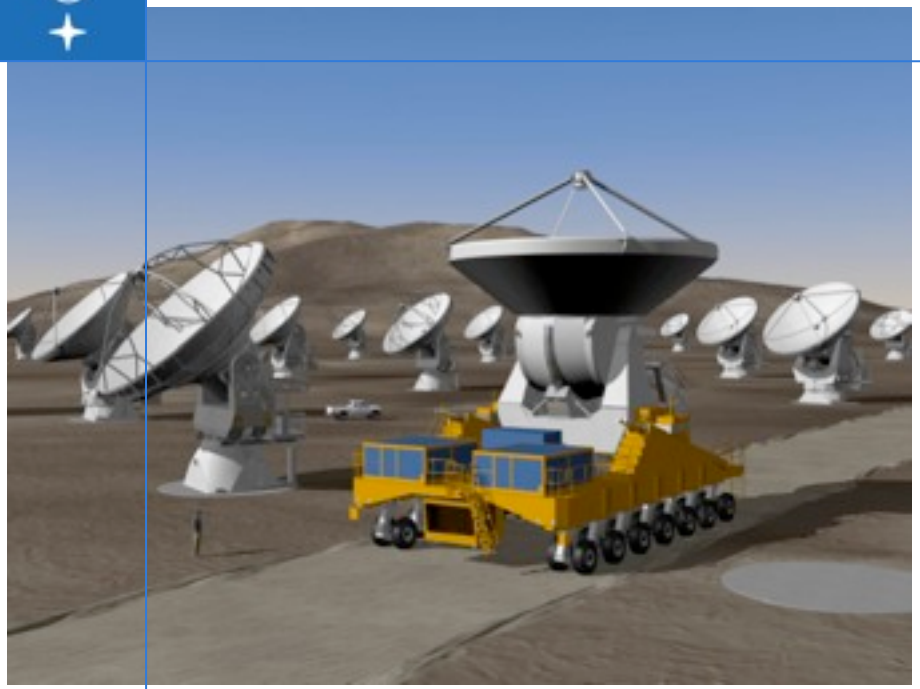
ALMA Science:
The Cool Side of the Universe





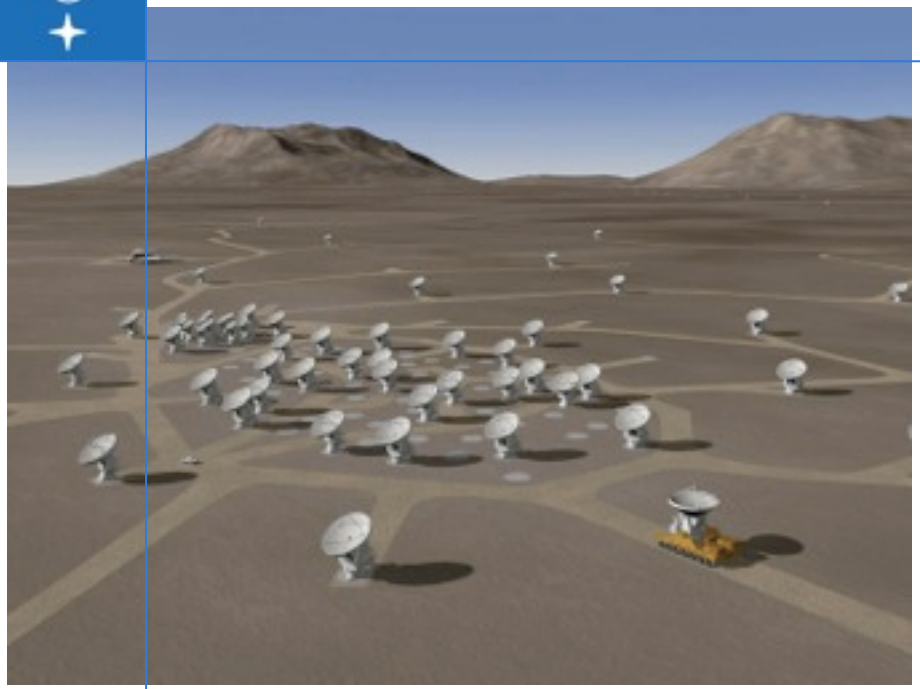
Leonardo Testi
ESO

Atacama Large Millimeter Array



- At least 50x12m Antennas
- Frequency range 30-1000 GHz (0.3-10mm)
- 16km max baseline (<10mas)
- ALMA Compact Array (4x12m and 12x7m)

Atacama Large Millimeter Array



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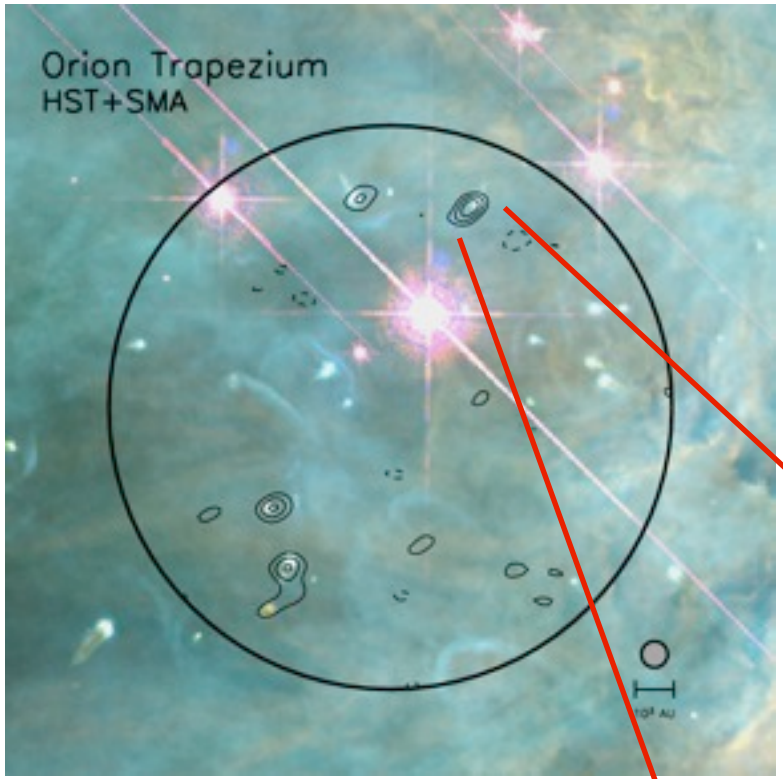
- ALMA Compact Array (4x12m and 12x7m)

1. **Detect and map CO and [C II] in a Milky Way galaxy at z=3 in less than 24 hours of observation**
2. **Map dust emission and gas kinematics in protoplanetary disks at AU resolution**
3. **Provide high fidelity imaging in the (sub)millimeter at 0.1 arcsec resolution**

Birth of Planets

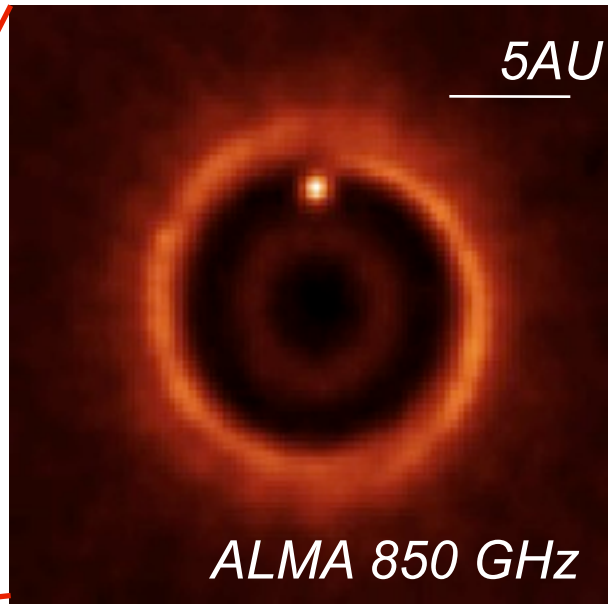


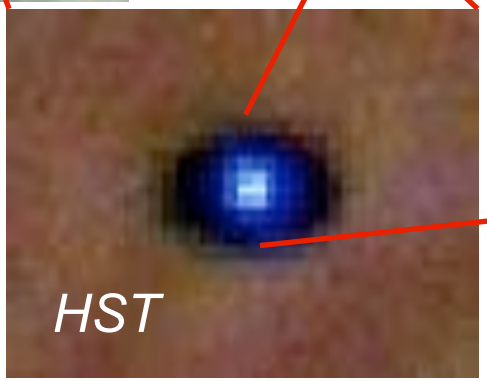
$M_{planet} = M_{Jup}$

$M_{star} = 0.5\ M_{sun}$

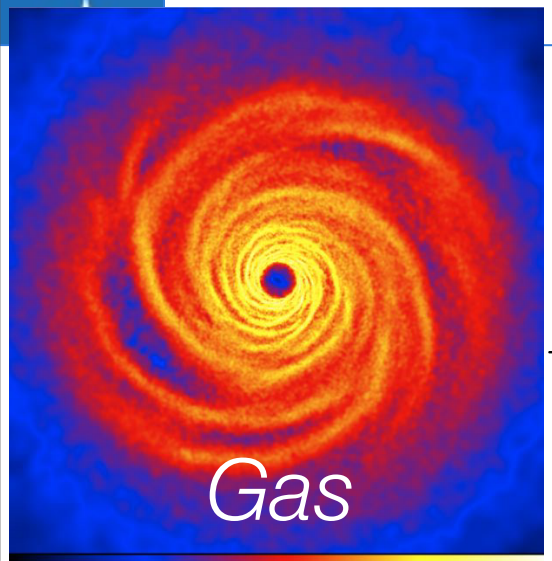
Orbiting at 5AU

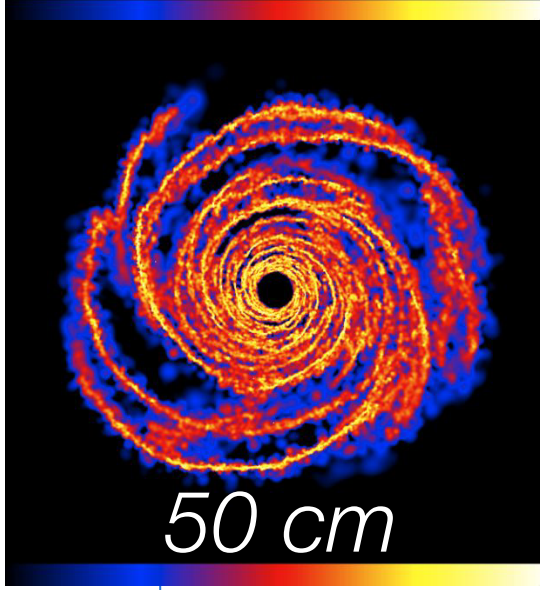
Distance 50pc

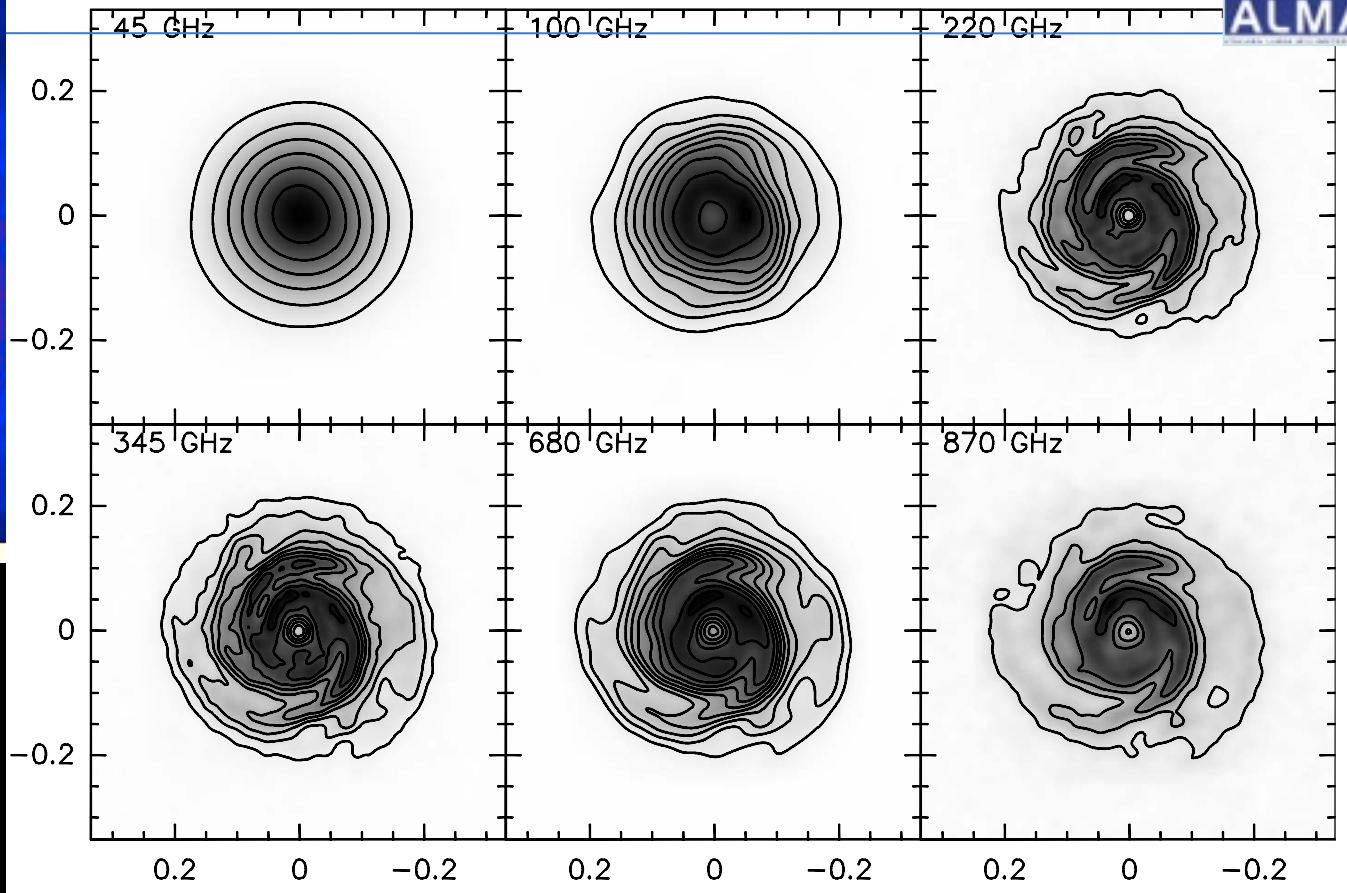




Gas density maxima and grain trapping

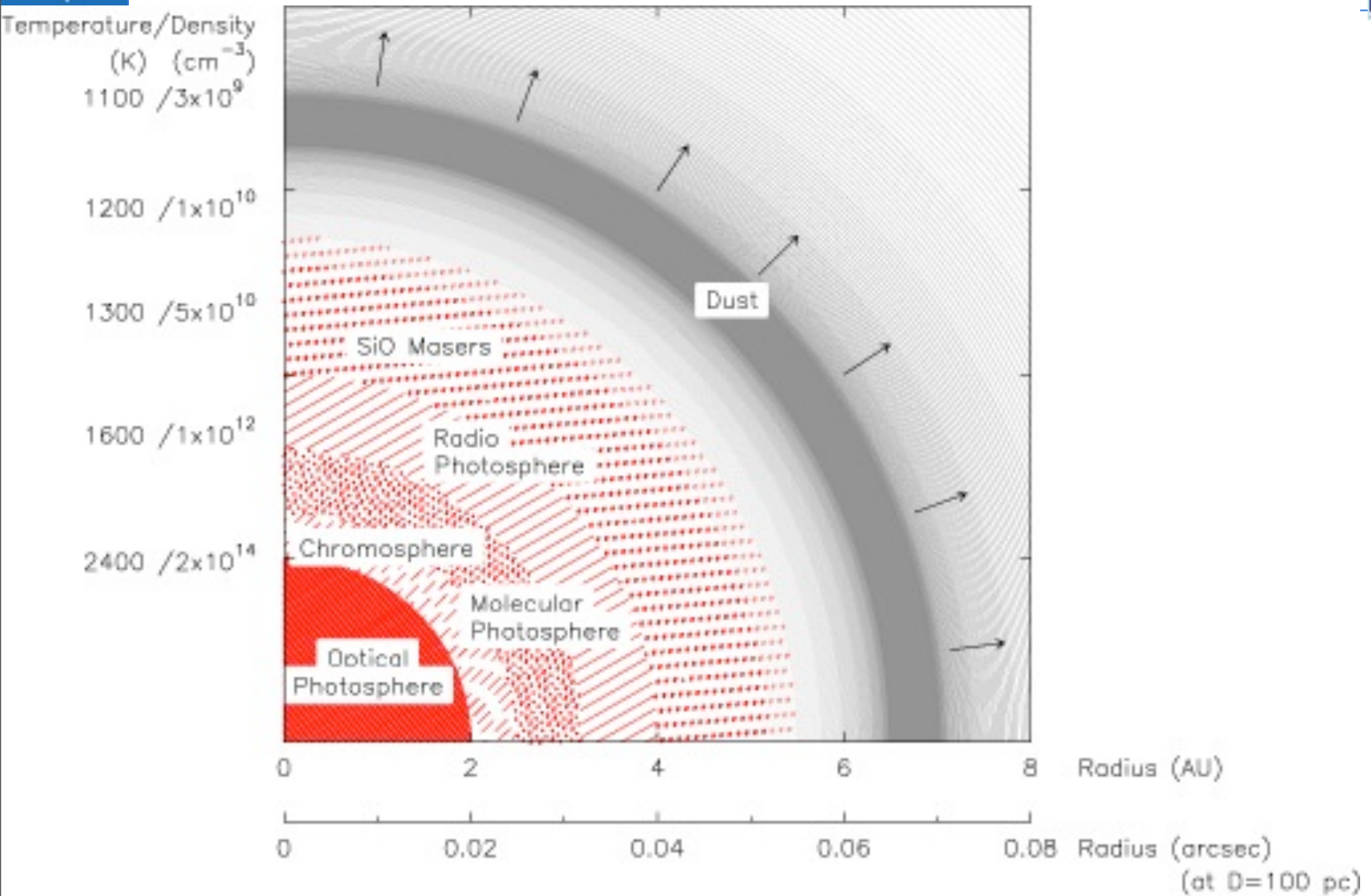




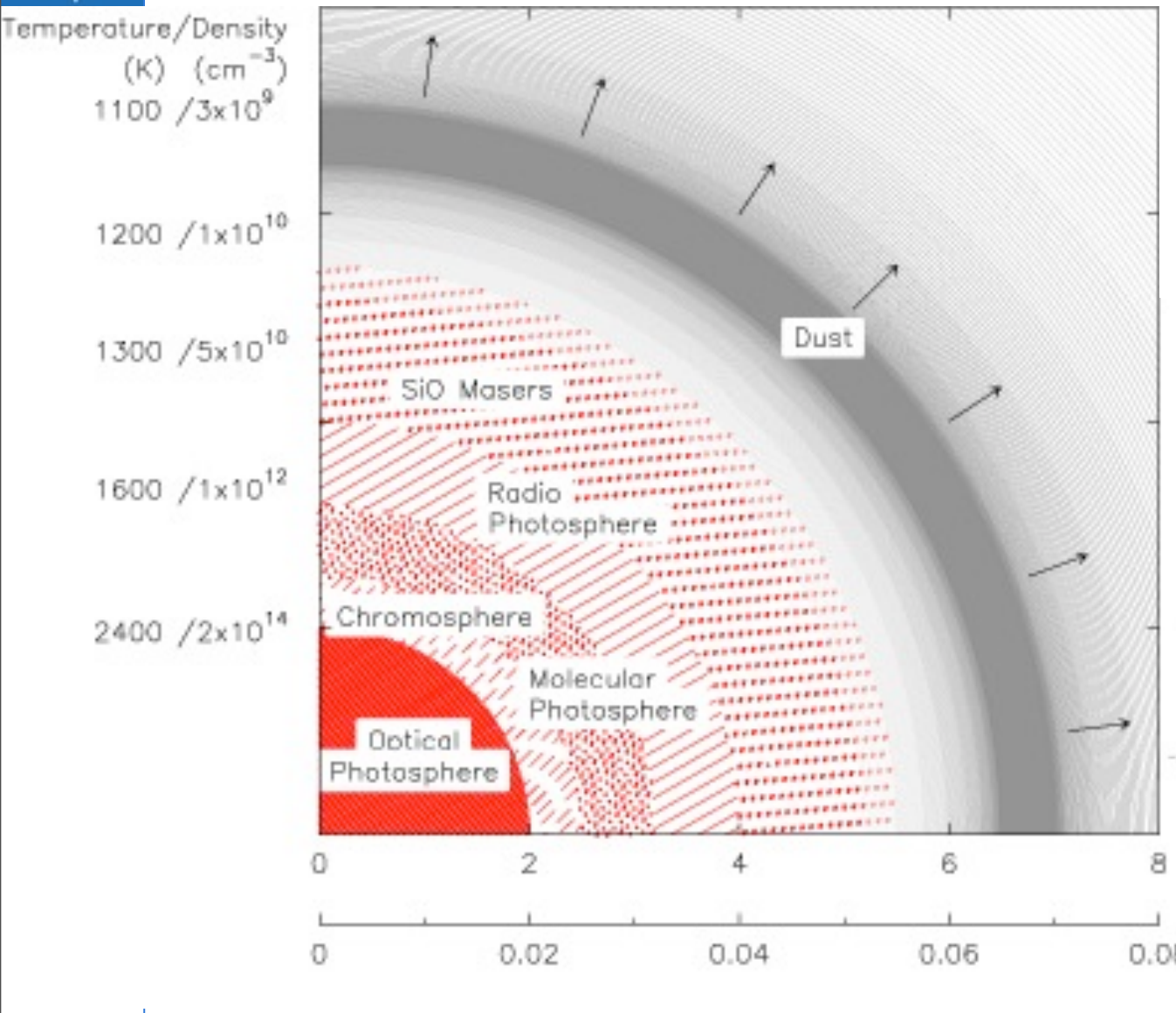


- Resolving disk structures with ALMA (simul from Cossins, Lodato & Testi 2010)

AGB Stars


Temperature/Density
(K) (cm^{-3})
1100 /3x10^{9}
1200 /1x10^{10}
1300 /5x10^{10}
1600 /1x10^{12}
2400 /2x10^{14}
Dust
SiO Masers
Radio Photosphere
Chromosphere
Molecular Photosphere
Optical Photosphere
0
2
4
6
8
Radius (AU)
0
0.02
0.04
0.06
0.08
Radius (arcsec)
(at D=100 pc)

AGB Stars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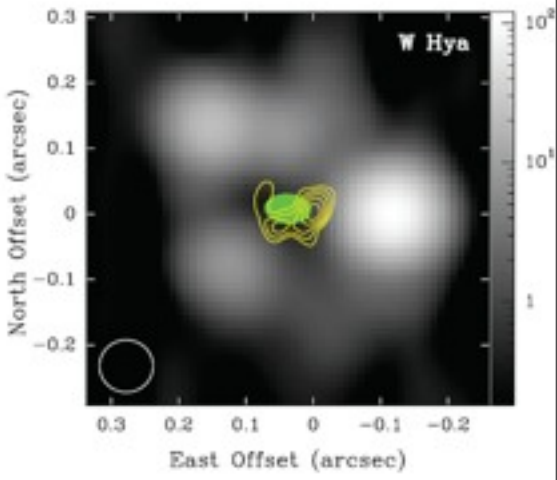
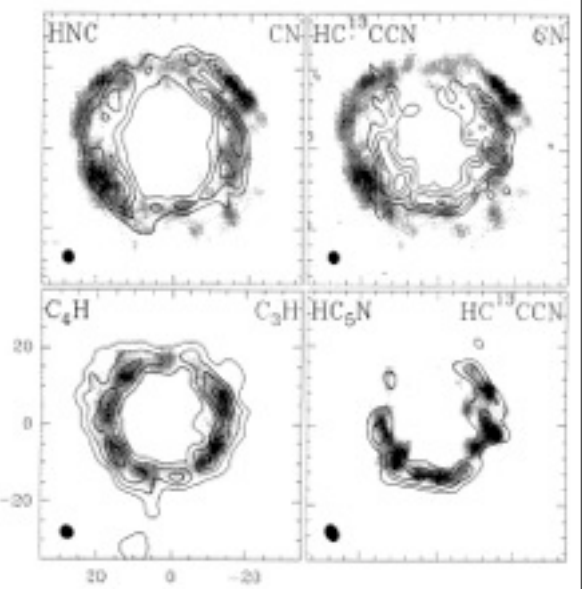
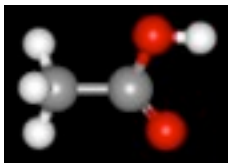

W Hya
North Offset (arcsec)
East Offset (arcsec)
0.3
0.2
0.1
0
−0.1
−0.2

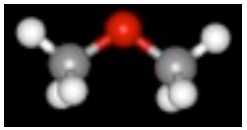

HNC
CN
HC^{13}CCN
SiN
C$_4$H
C$_3$H
HC$_5$N
HC^{13}CCN
20
0
−20

Complex Organic Molecules

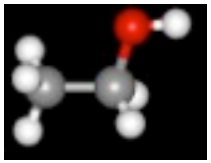
Detected



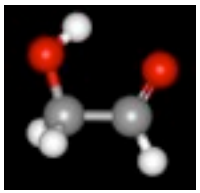
Acetic acid



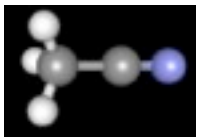
Di-methyl ether



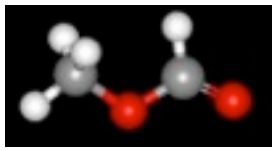
Ethanol



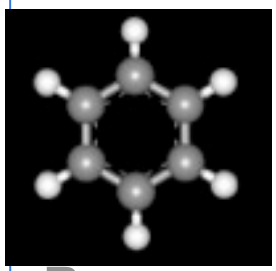
Sugar



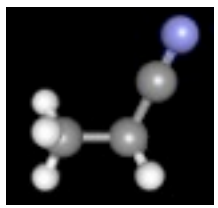
Methyl cyanide



Methyl formate

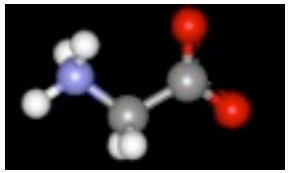


Benzene

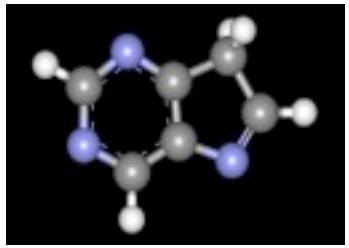


Ethyl cyanide

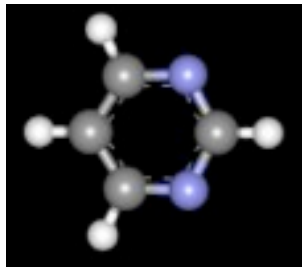
Not (yet) detected



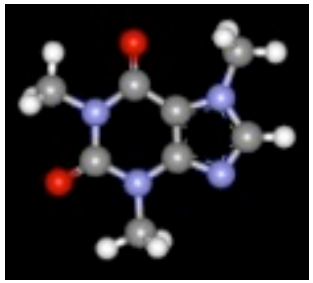
Glycine



Purine



Pyrimidine

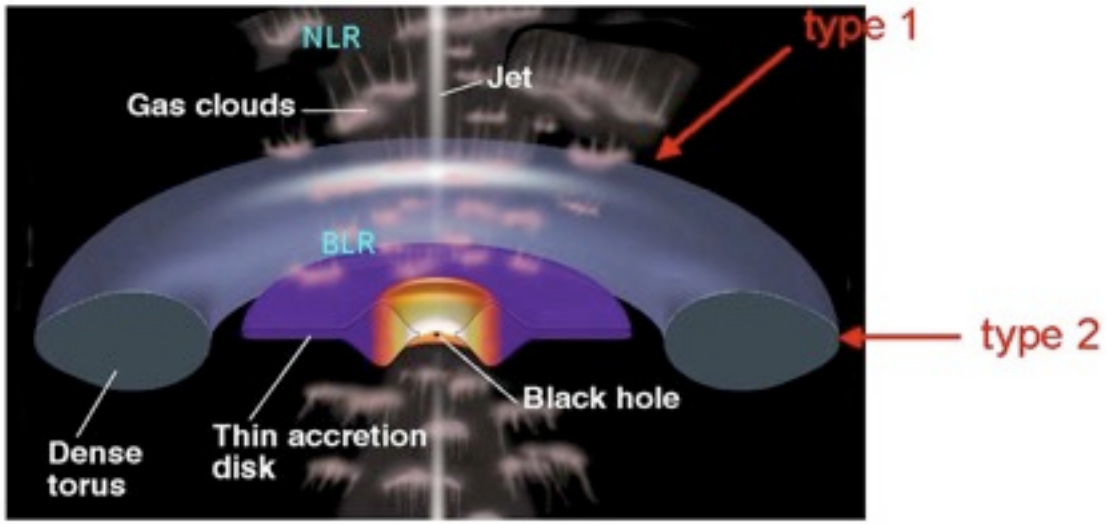


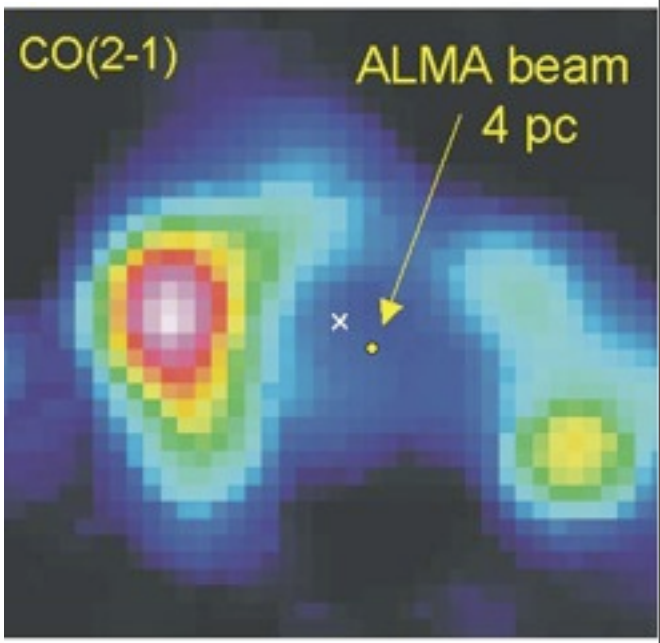
Caffeine

How far does chemical complexity go?
Can we find pre-biotic molecules in Disks?

Based on Ehrenfreund 2005

The Engine of nearby AGNs



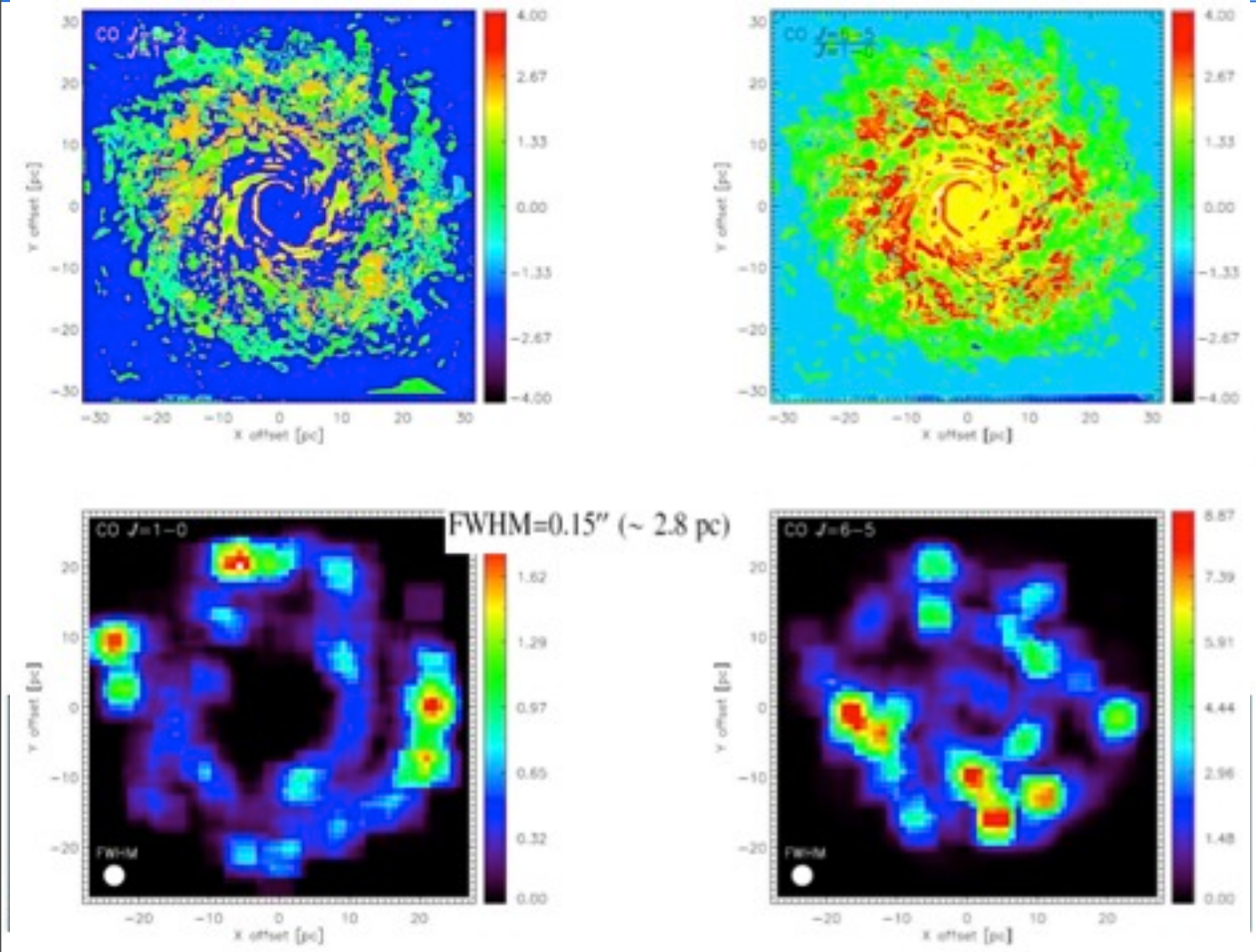


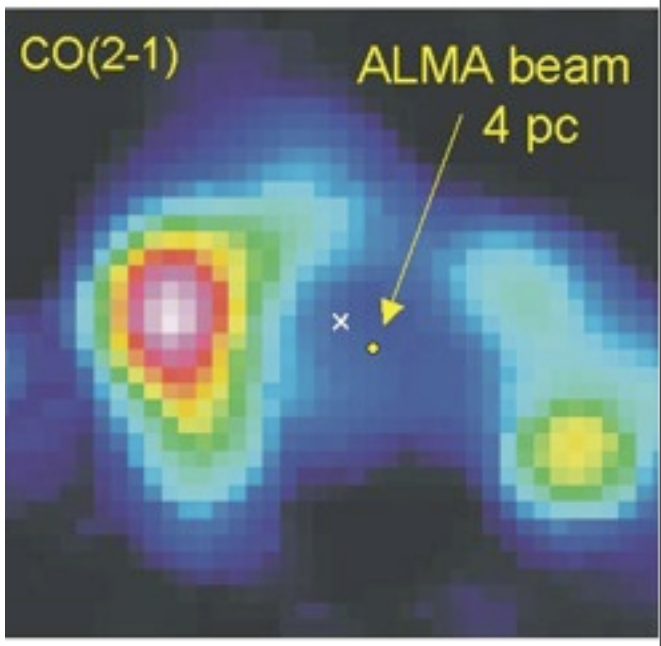
Several (competing) models:

Geometry		Dynamics		Structure	
large ~100 pc	small ~1 pc	rotation	rotation and outflow	cont./diff. medium	clumpy medium
(observed)	(ALMA)	(ALMA)		(ALMA)	

- ALMA will resolve the molecular gas structure and dynamics around nearby AGNs

The Engine of nearby AGNs

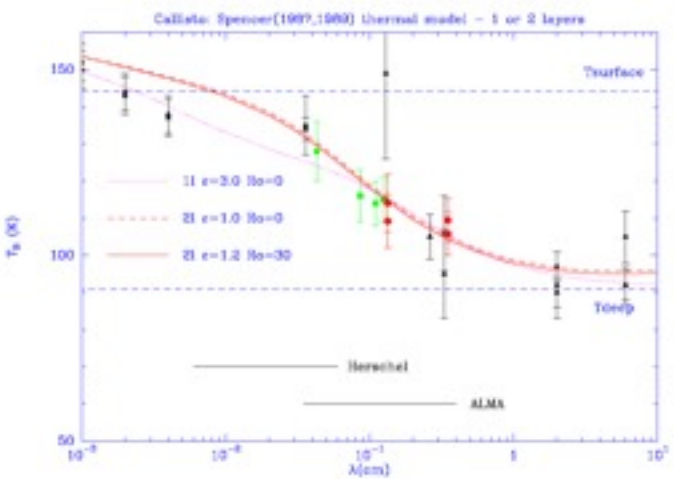




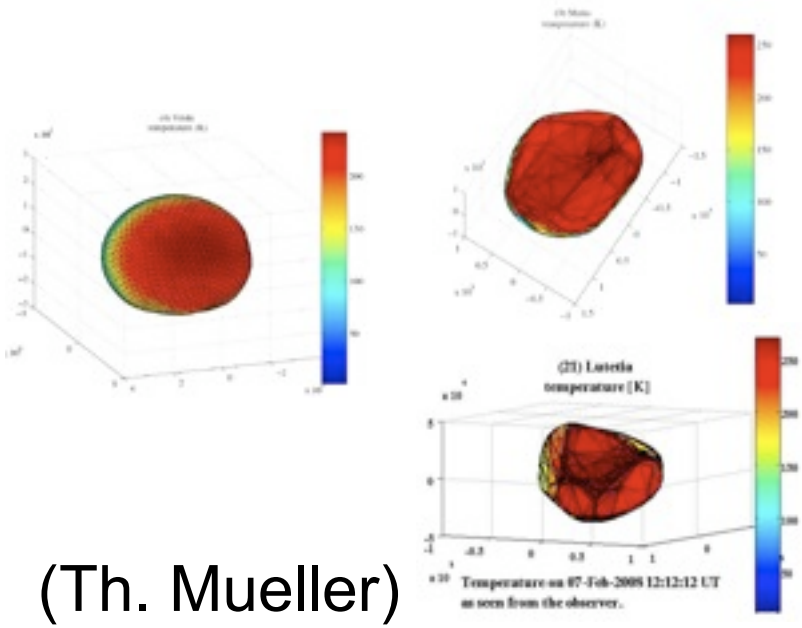
- ALMA will resolve the molecular gas structure and dynamics around nearby AGNs

Small Solar System bodies

- Surface properties and thermal structure
- Atmosphere composition
- Multiplicity
- The well characterized ones are very interesting also as calibrators



(R. Moreno)



(Th. Mueller)

ALMA Science

- Star Formation, Proto-planets in nearby disks
- Astrochemistry
- Interstellar medium (Galaxy, Local Group)
- High-redshift deep fields

- *+130 projects in first 3yrs – DRSP 2.0*
  - http://www.eso.org/sci/facilities/alma/documents/drsp.html

- **ALMA Science is for everyone**
  - High resolution/sensitivity 3D instrument at mm-wl
  - 100% service observing with full dynamic scheduling
  - Complete e2e data flow system
  - Science quality images (cubes) delivered to the users
  - Raw, calibrations, pipeline processed data and recipes in archive
  - Friendly and widespread User Support through ARCs

The ALMA configurations

- Current mm interferometers offer typically ~10^4 visibility measurements in several hours, the VLA delivers ~10^5 visibilities per hour
- ALMA will improve by almost two orders of magnitude

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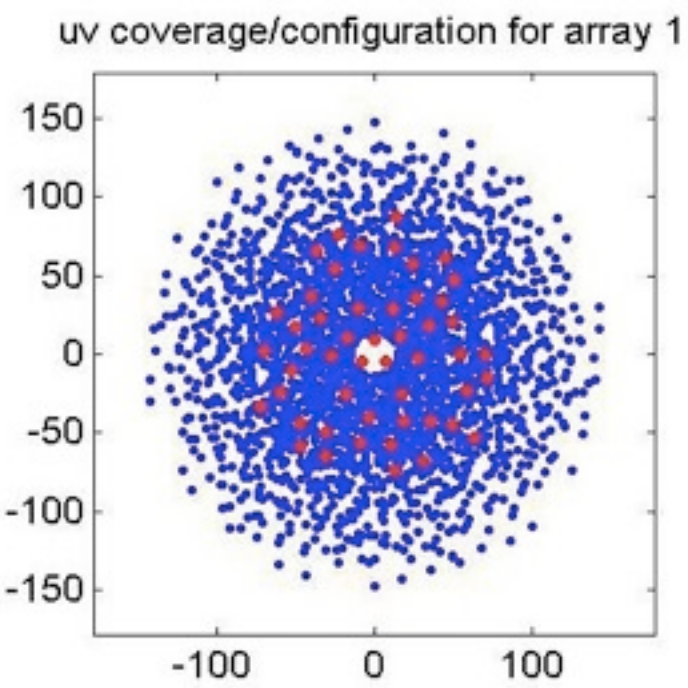

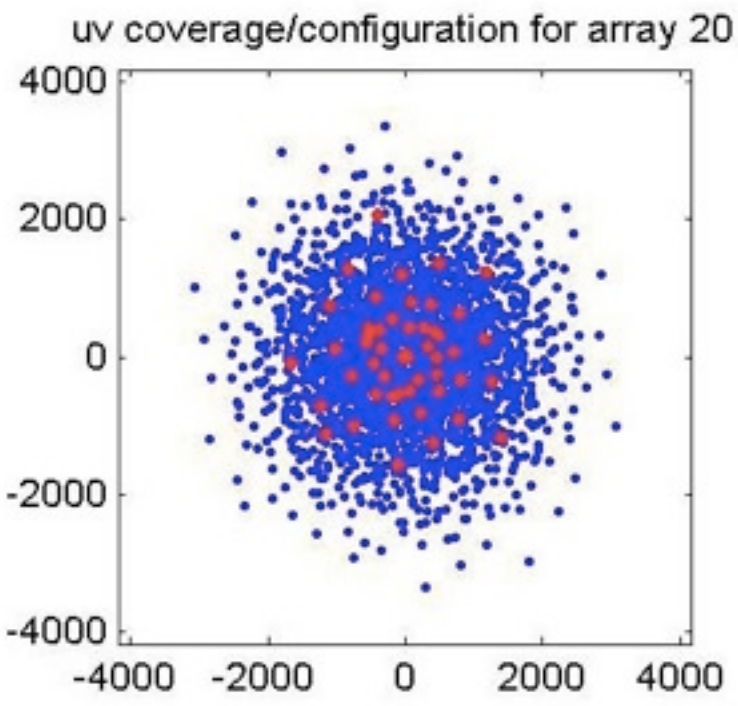

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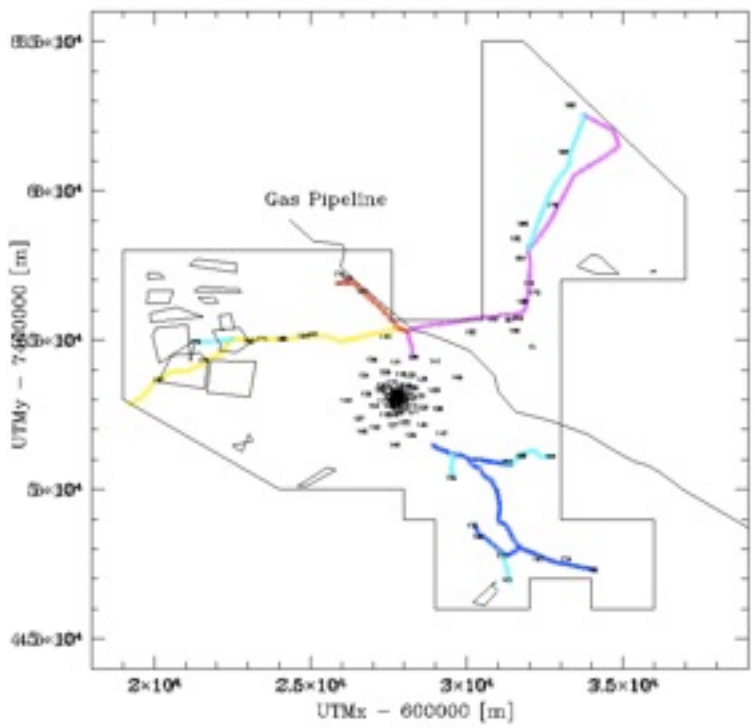

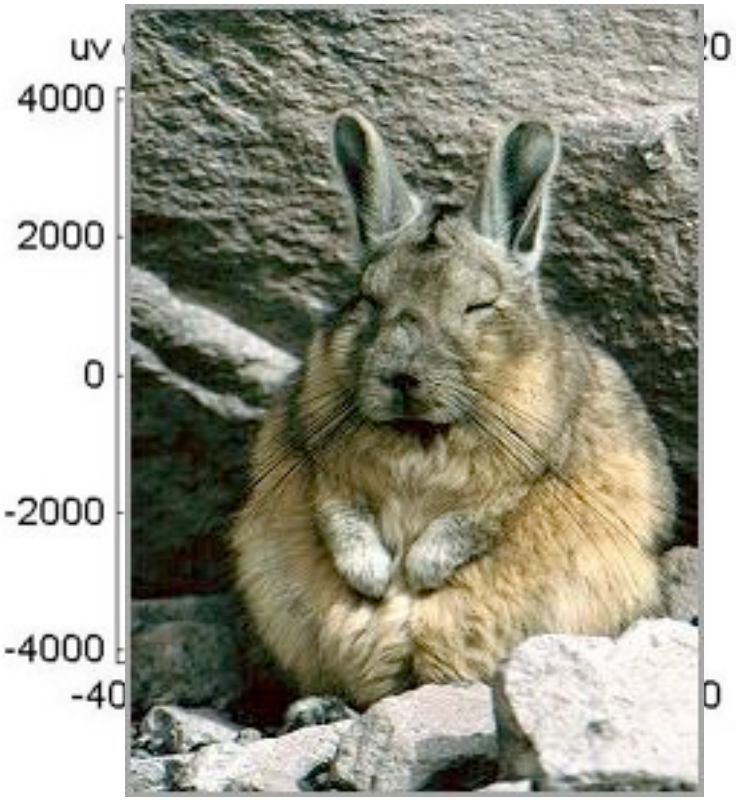

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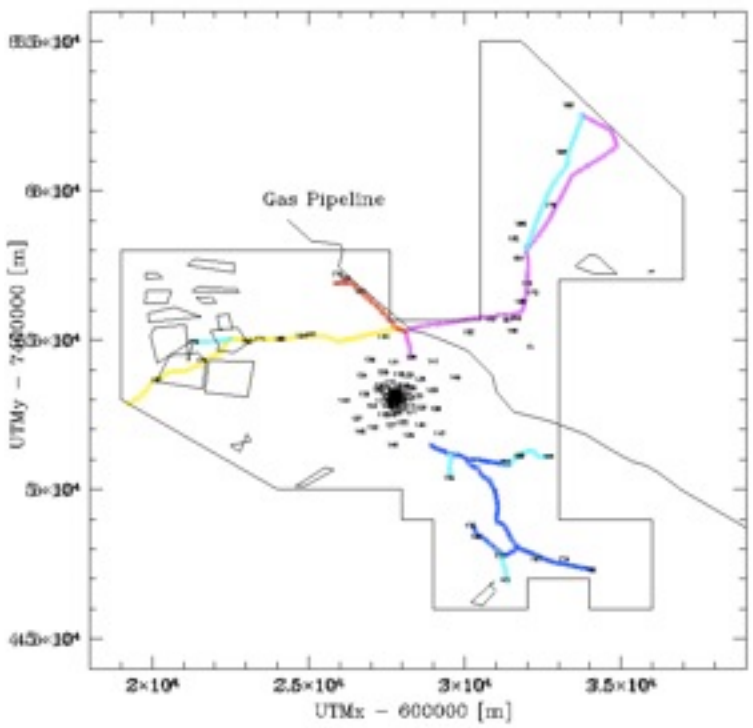
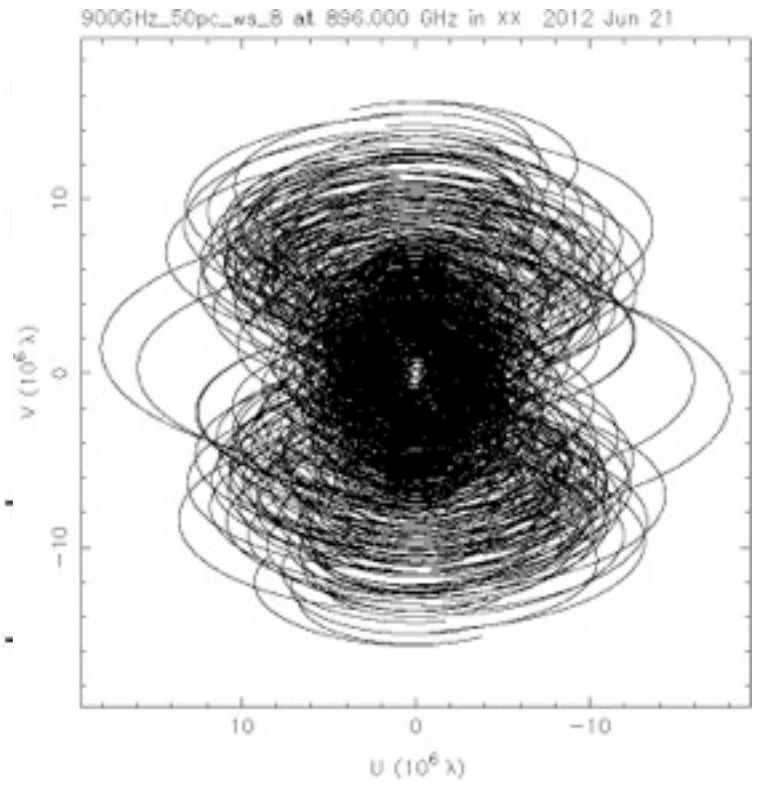




ALMA Early Science

- Call for Proposals (Cycle 0): 30 Mar 2011
  - Limited capabilities
    - 16 antennas, 4 receiver bands, 400m max baseline
    - no polarization, no complex correlator setup, no solar
- Response
  - 900+ proposals received by Jun 30 deadline
  - Proposal scientific/technical review over summer

Early Science – ESO Press Release

eso1137 — Organisation Release

Choose your language:

SPACE SCOOP

ALMA Opens Its Eyes

The most powerful millimetre/submillimetre-wavelength telescope in the world opens for business and reveals its first image

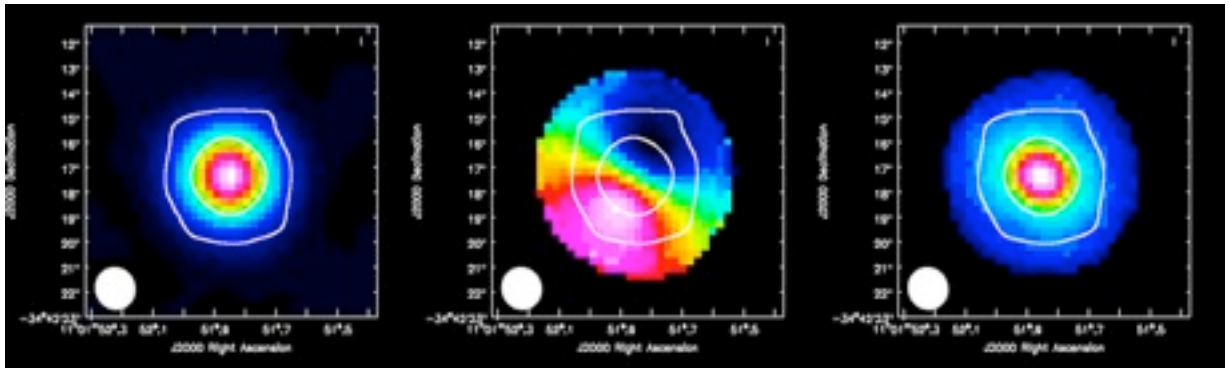
3 October 2011

Click to Enlarge

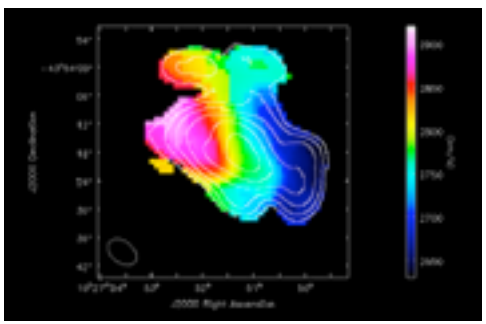
Humanity's most complex ground-based astronomy observatory, the Atacama Large Millimeter/submillimeter Array (ALMA), has officially opened for astronomers. The first released image, from a telescope still under construction, reveals a view of the Universe that cannot be seen at all by visible-light and infrared telescopes. Thousands of scientists from around the world have competed to be among the first few researchers to explore some of the darkest, coldest, furthest, and most hidden secrets of the cosmos with this new astronomical tool.

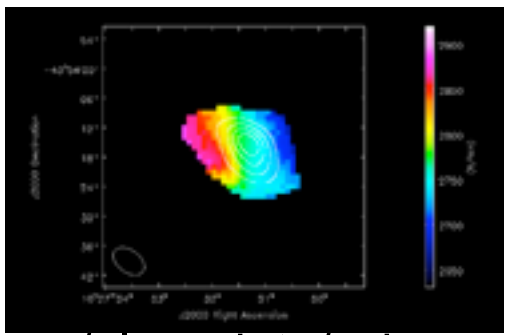
Science Verification

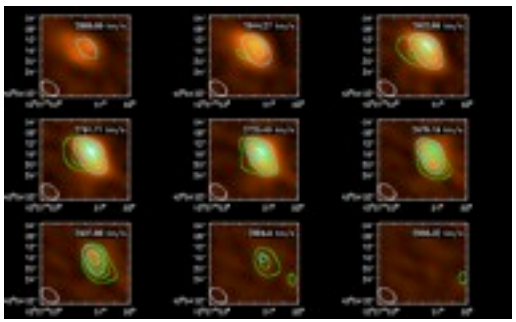
- TW Hya – protoplanetary disc – Bands 3, 6 and 7
  - http://casaguides.nrao.edu/index.php?title=TWHydraBand7



- NGC3256 – Nearby luminous galaxy
  - http://casaguides.nrao.edu/index.php?title=NGC3256Band3



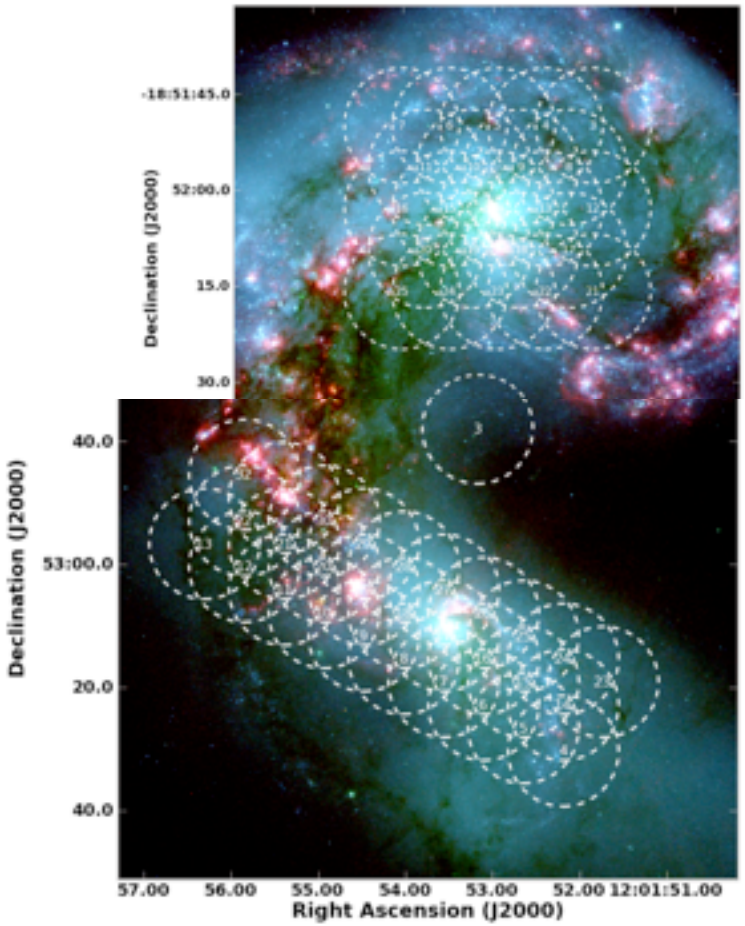


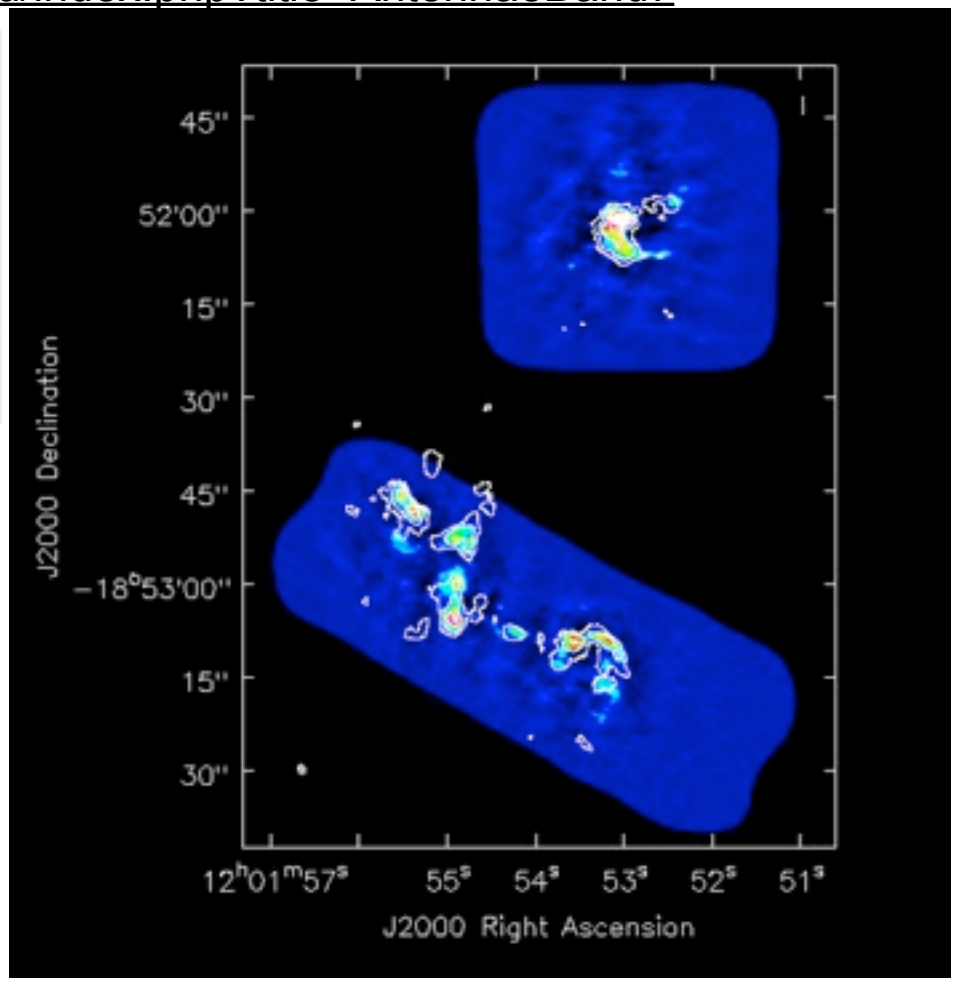


- http://almascience.eso.org/alma-data/science-verification

Science Verification

- Antennae mosaic – Galaxies merger – Bands 7
  - http://casaguides.nrao.edu/index.php?title=AntennaeBand7





Summary

- ALMA is here!
  - Early Science observing has started
  - Cycle 0: Oct 11 - Jun 12
- ALMA ES is just at the beginning!
  - Cycle 1 - Deadline Q1 2012 - will already be a huge step in sensitivity and other capabilities (resolution, observing modes, etc.)
  - Full Science Operations - End of Construction in 2013
- ALMA & VLTI
  - a perfect match!

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ALMA:
The cool side
of the Universe

VLTI:
The hot side
of the Universe