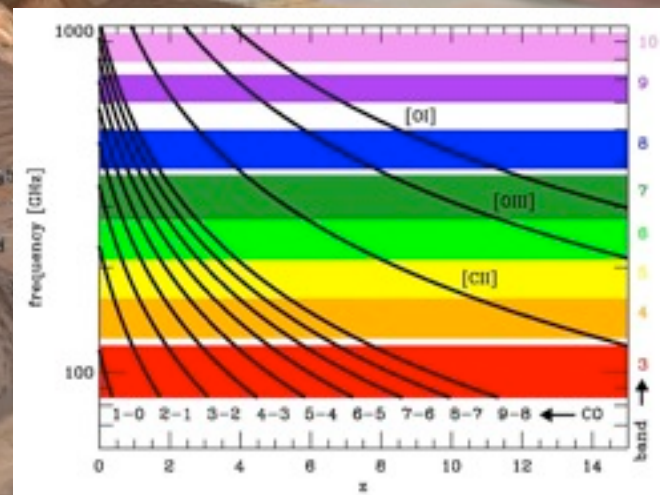
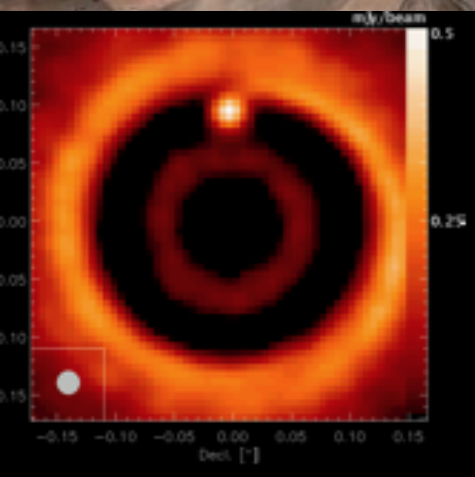


# ALMA Science

Leonardo Testi

ESO ALMA Program Scientist



- (Sub)mm astronomy in Italy was traditionally focused on CMB
  - Balloon, satellite, Antarctica
- Strong involvement in “classical” radio astronomy
  - IRA, big national facilities and VLBI network
- (mid and far) Infrared community developed around ESA missions
  - ISO, Herschel
  
- Radio astronomer vs Optical astronomer syndrome
  - OA: “If it has the beak like a duck and the paws like a duck, it has to be...”, RA: “...obvious: a platipus!” (@R.Gilmozzi)

# Italy and ALMA

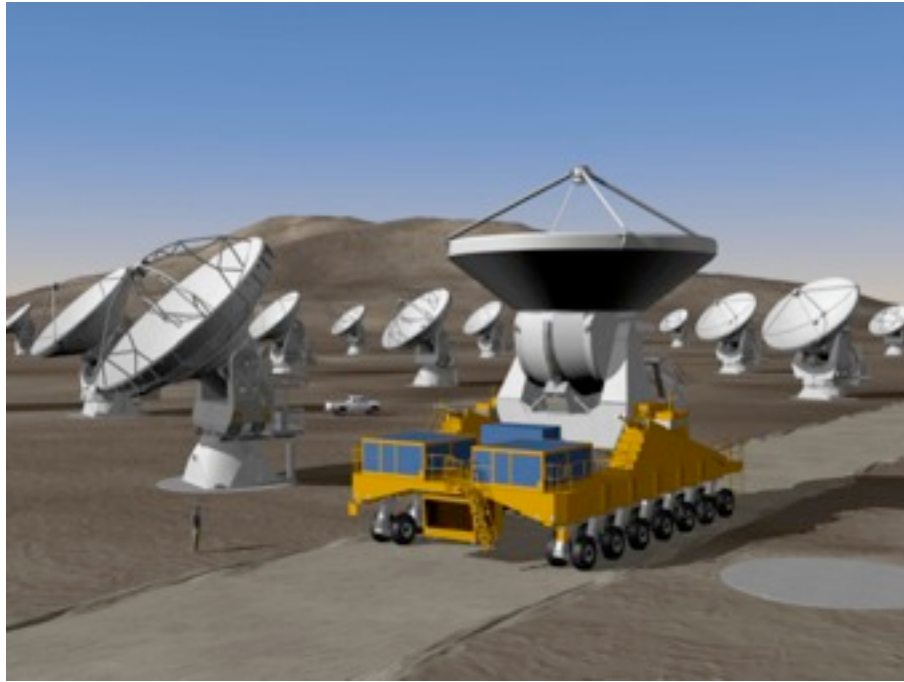
- The development in Arcetri of groups working on Star and Planet Formation, Astrochemistry, the Evolution of Galaxies and Active Galaxies was thanks to Franco Pacini in the 1979-2001 period
- As part of his plans, he kicked some of the most reluctant among us in the appropriate places to go and develop the required skills



# Italy and ALMA

- ALMA and italian institutes
  - Participation in software development (Trieste)
  - Initial designs of receiver optics (Arcetri)
  - Participation in correlator design (Arcetri)
- Science advisory committees
  - ESAC/ASAC participation (Walmsley, Testi, Maiolino)
- European ARC Network
  - INAF-IRA is hosting the Italian ARC node (Brand)

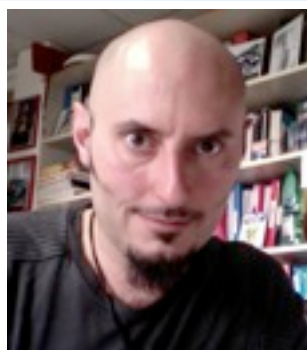
# Atacama Large Millimeter Array



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

- 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**
- 3. Provide high fidelity imaging in the (sub)millimeter at 0.1 arcsec resolution**

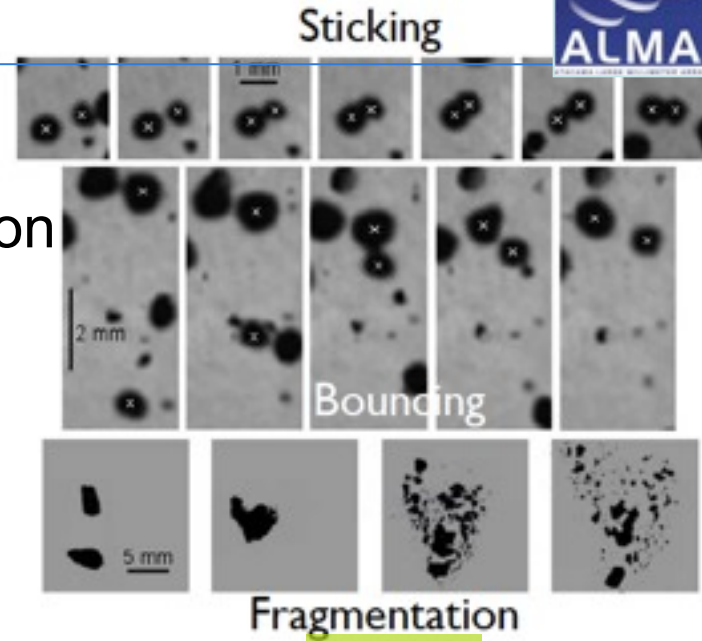
# Italy and Cycle 0



- No of proposals ~10%, high priority time ~12%
- 3 PIs from INAF plus 3 expatriates (17%)
  - Low Metallicity Starburst
  - Outflows-Low mass star formation
  - High Mass Star Formation
  - Astrochemistry
  - Planet formation
  - Nearby Galaxies

# Grain Growth the Dawn of Planets

- The core-accretion scenario
  - Dust growth and planetesimals formation
  - Formation of rocky cores
  - Gas accretion from disk



# Dust trapping in pressure maxima

- Pressure maxima in disks (arms, vortices...) can efficiently trap large particles allowing grains to growth and stay in the disk for long times



Migration + Fragmentation

Millimetre and infra observations

Models

Extrasolar planetary systems

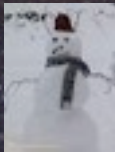
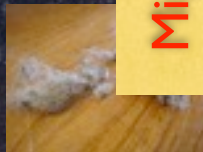
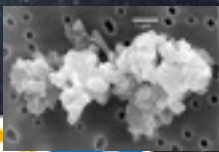
1µm

1mm

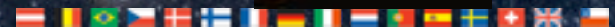
1m

1km

1000km



Leonardo Testi: The disks of dawn, Cambridge, May 10, 2012

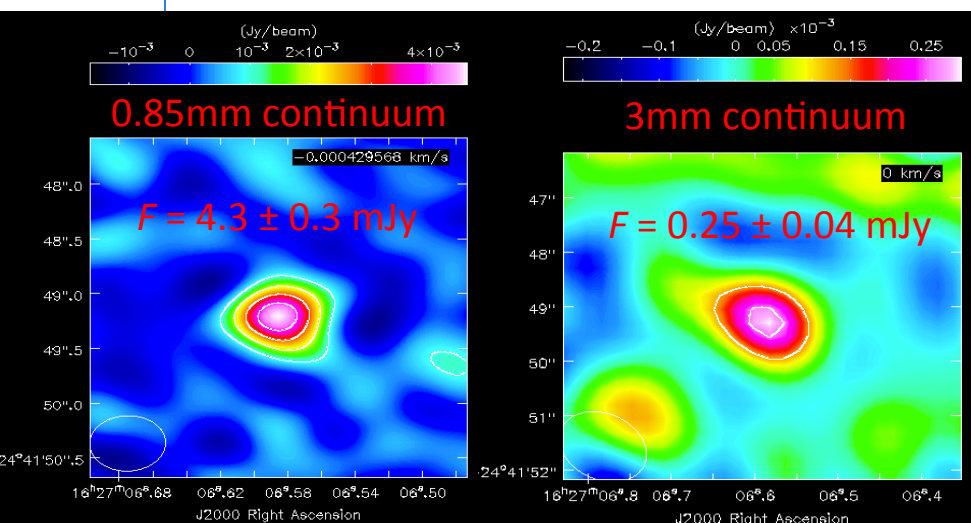


(Pinilla, Birnstiel, Ricci et al. 11, Ricci et al. 11)



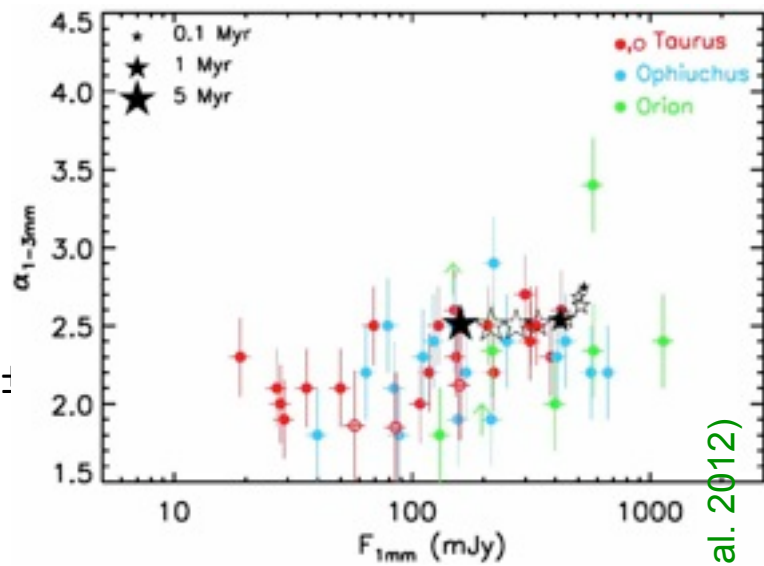
# Grain Growth the Dawn of Planets

- Testing BDs formation theories and dust evolution models in BDs

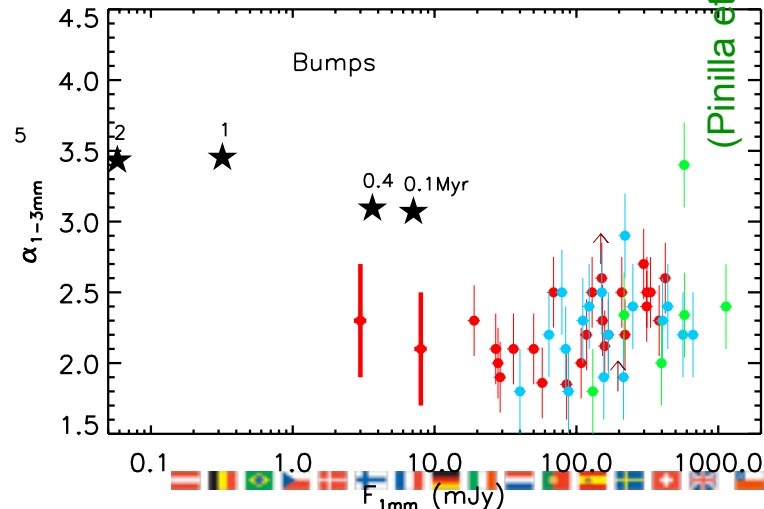
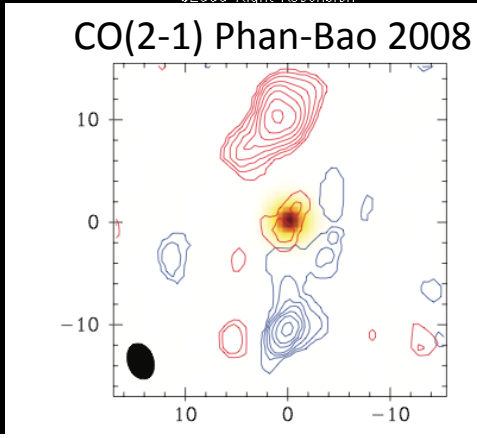
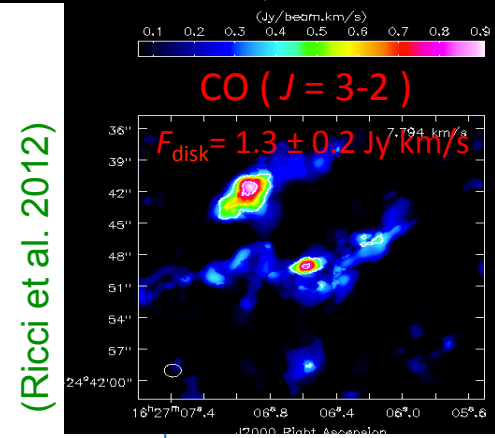


(Ricci et al. 2012)

$$\alpha = 2.3 \pm$$

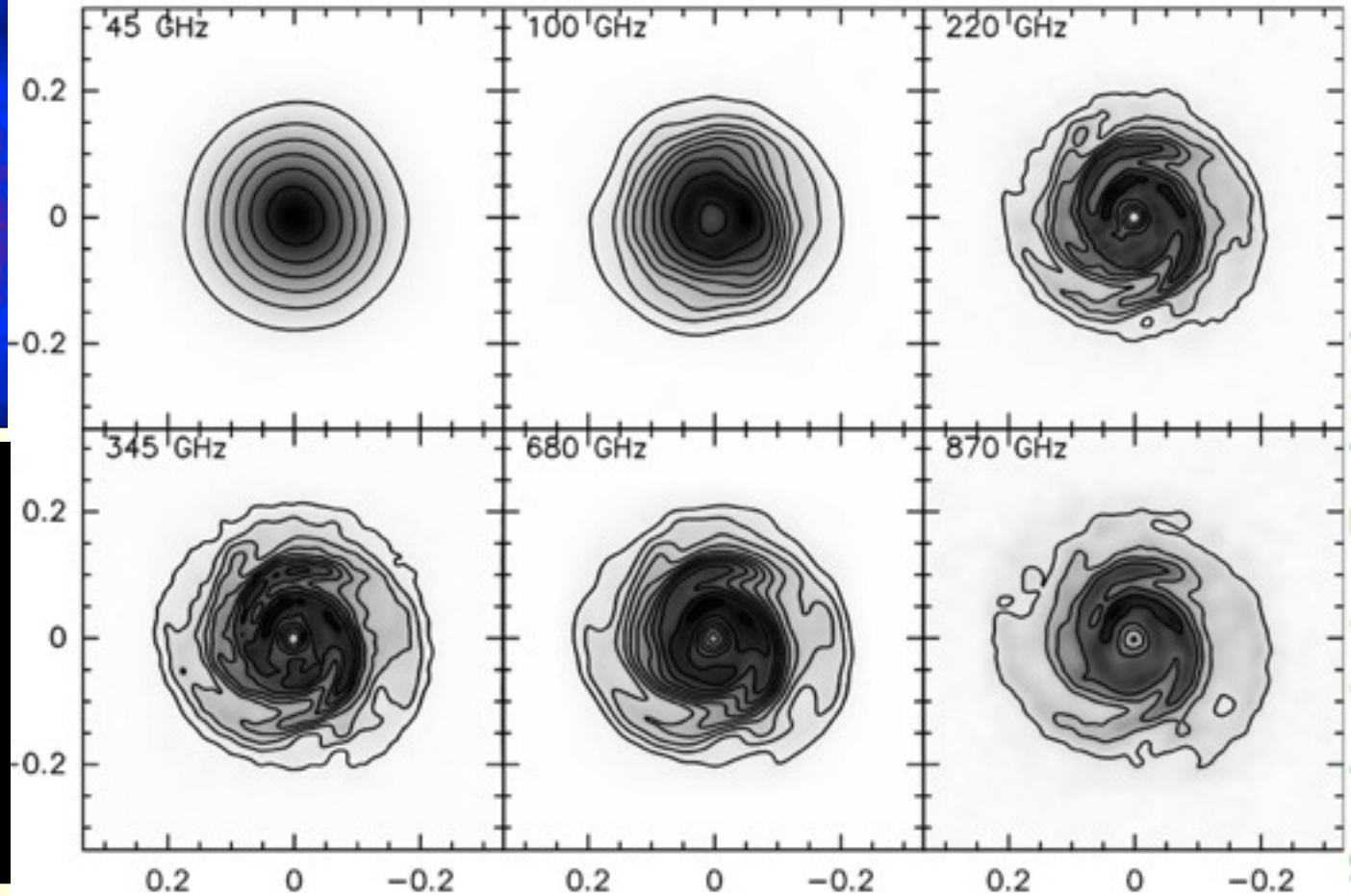
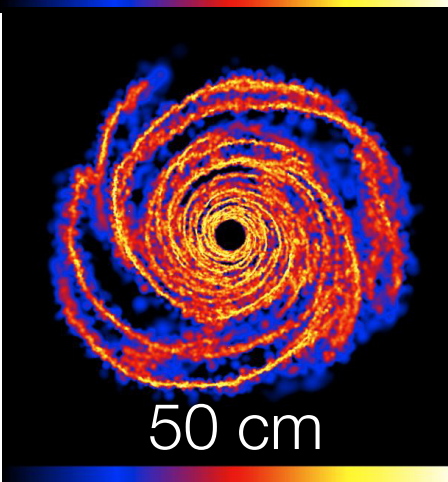
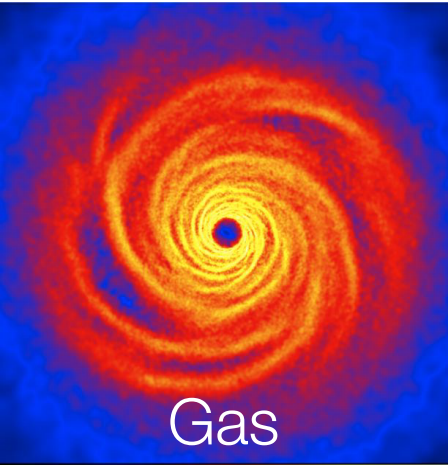


(Pinilla et al. 2012)



(Pinilla et al. 2012)

# Slowing down radial drift: grain trapping

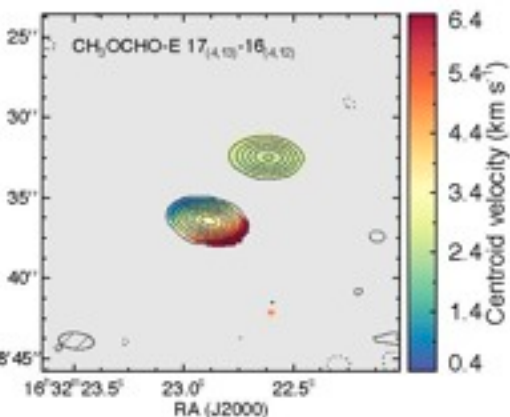
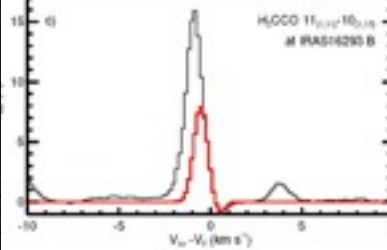
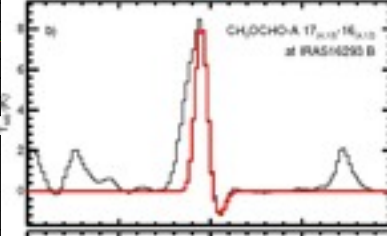
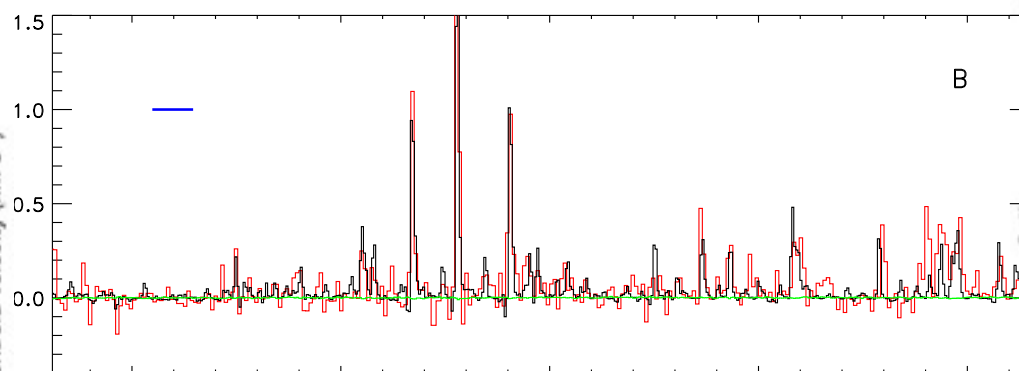
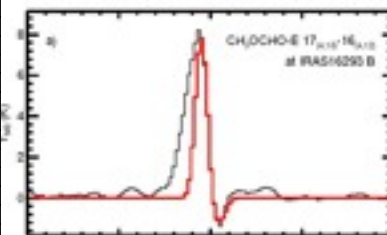
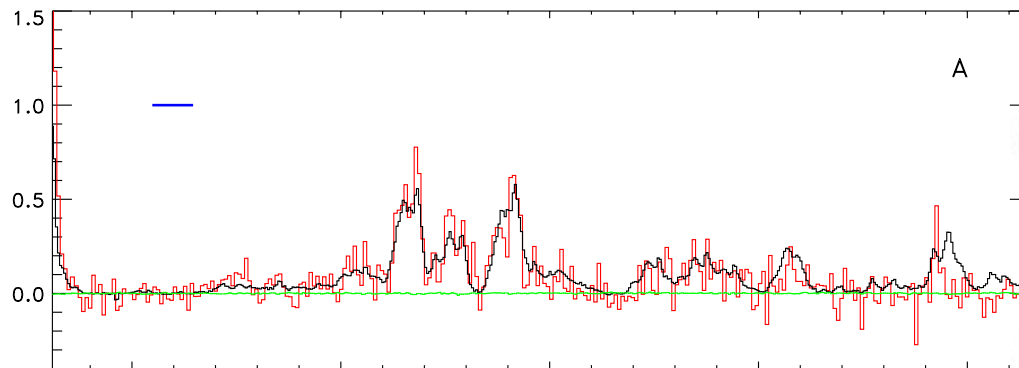
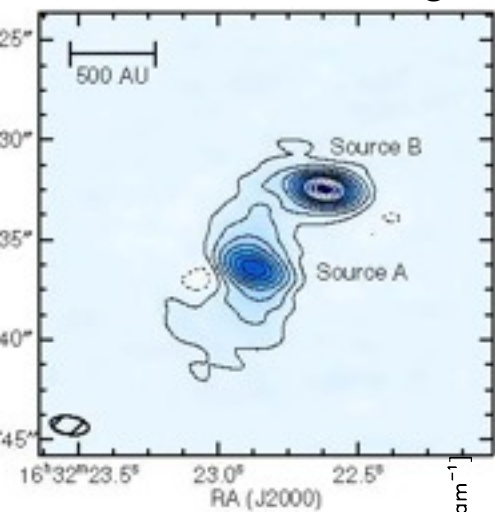


(Cossins, Lodato, Testi 2010)

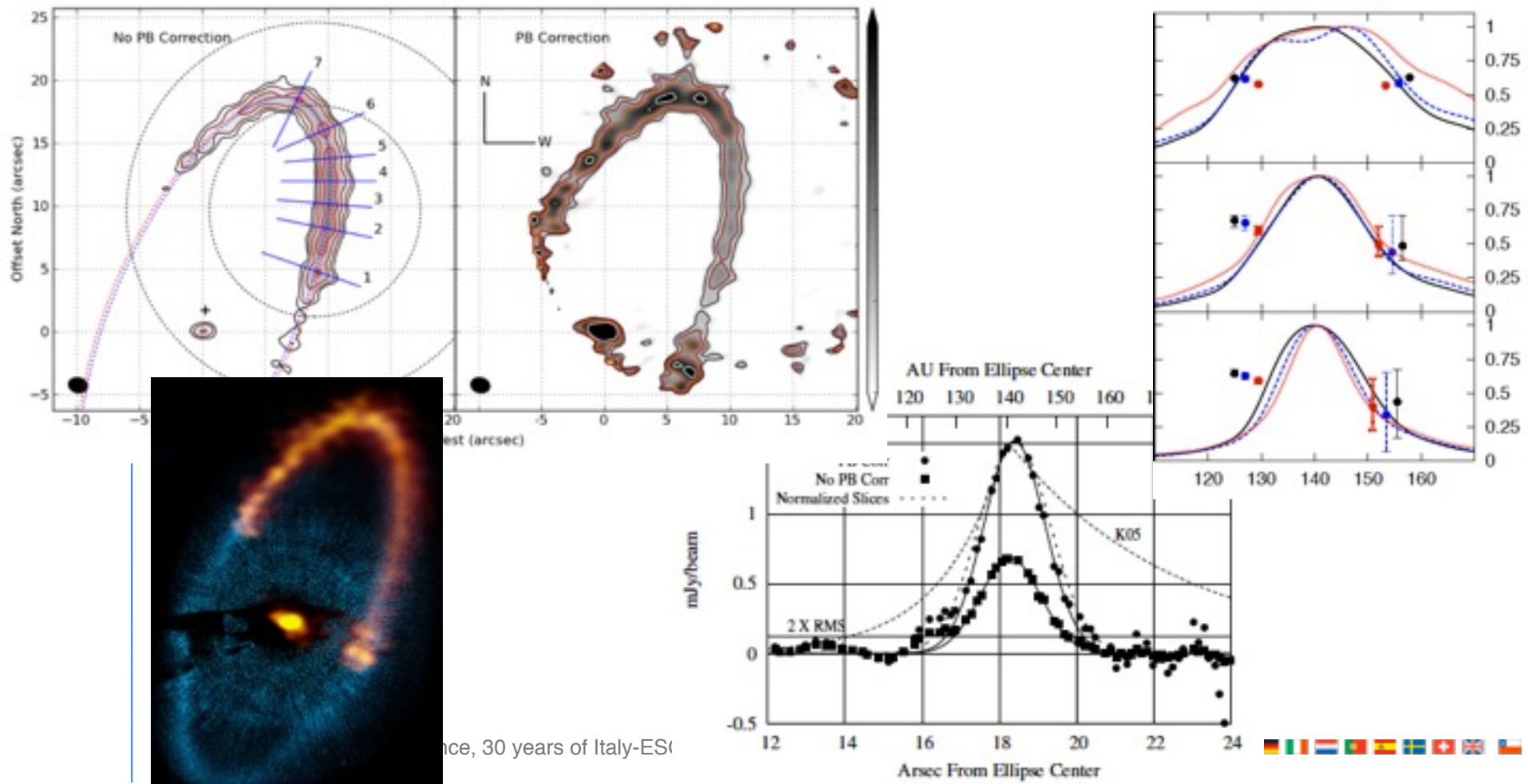
- Grain Trapping: e.g. spiral arms, vortices, density enhancements
- Predictions will be tested observationally

## ■ The multiple solar-mass protostellar system IRAS16293

➤ Jorgensen et al. 2012; Pineda et al. 2012

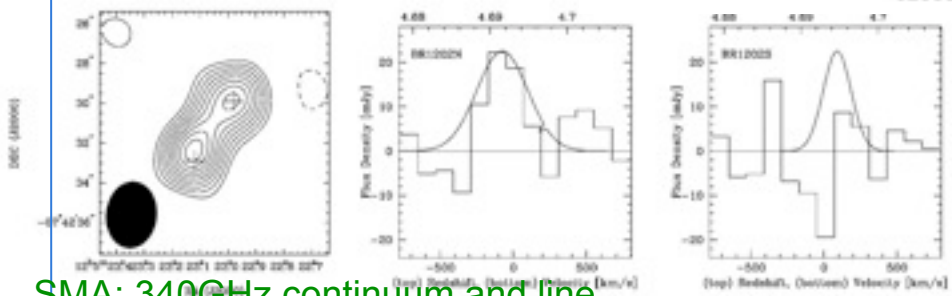
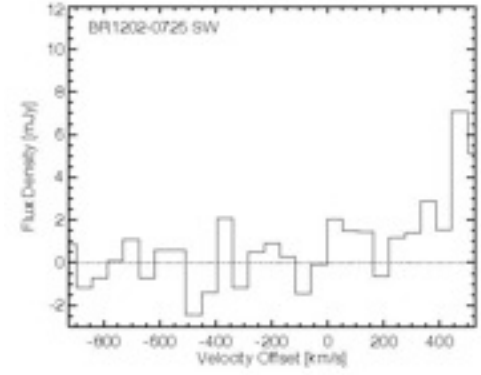
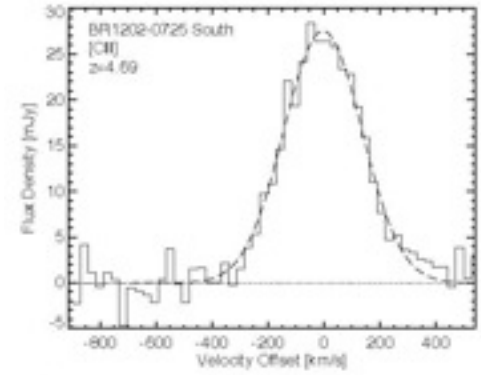
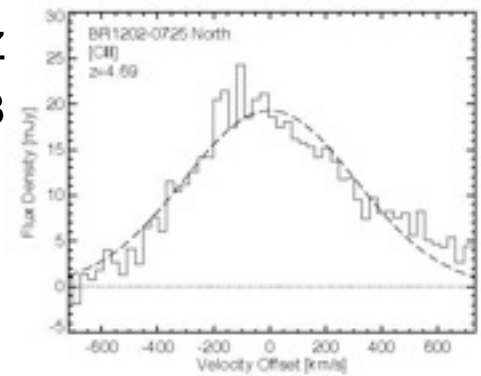
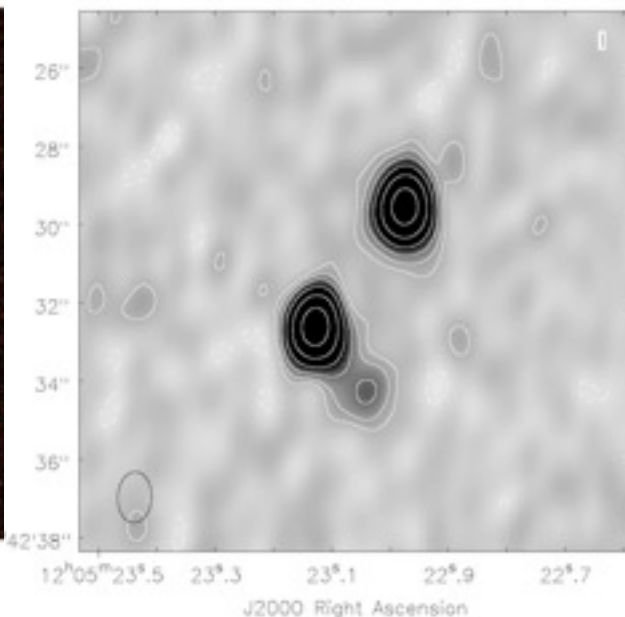
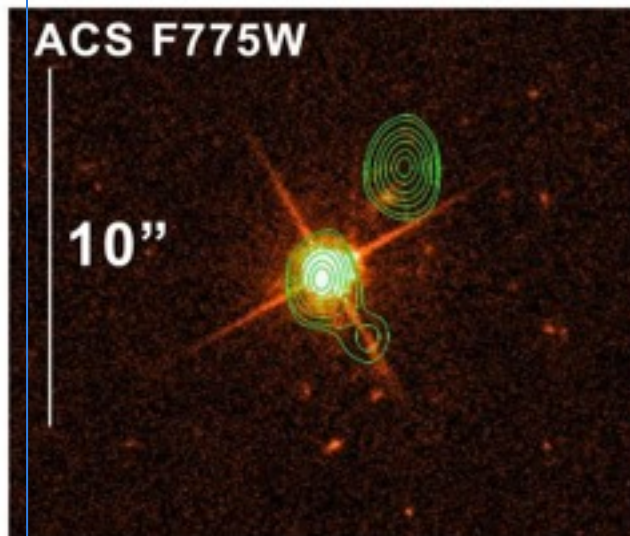


- ALMA Observations of the Debris Disk around Fomalhaut
  - Boley et al. 2012, ApJL, in press (see PR in April)
  - Sharp ring in mm-size grains, indirect evidence for shepherding planets



- Star formation in the Early Universe: [CII] at high z
  - Wagg et al. 2012, ApJ Letters, submitted, arXiv:1205.3498

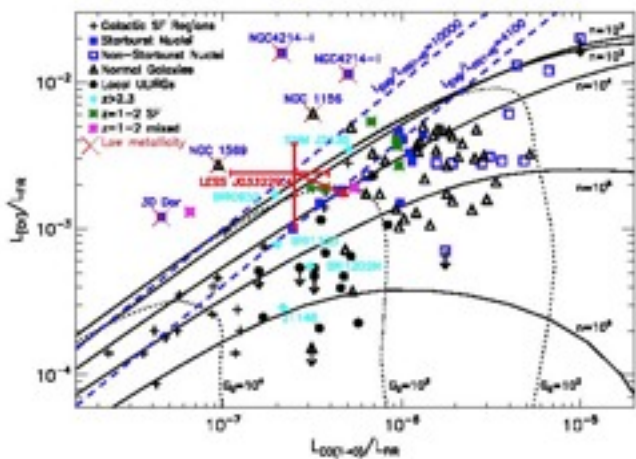
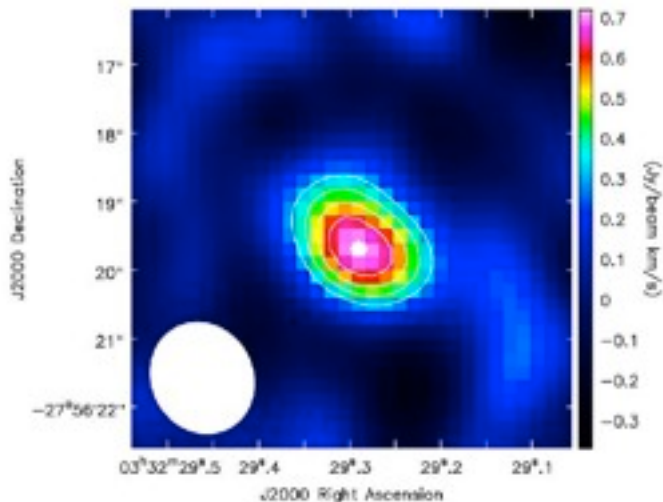
<http://almascience.eso.org/alma-data/science-verification>



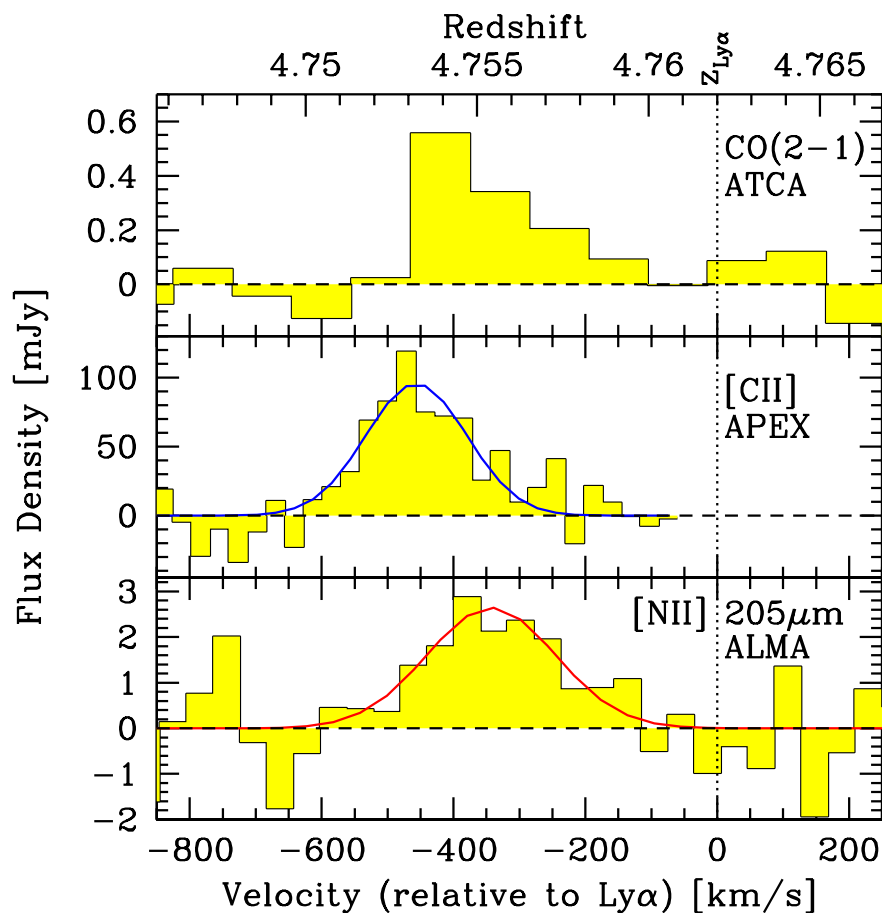
$z=4.69$

SMA: 340GHz continuum and line  
Iono et al. (2006), [CII] (N only)+cont

- ALMA Observations of the high-z galaxy LESS J03322
  - Nagao et al. 2012, A&A, in press
  - Detection of [NII] at  $z \sim 4.76$ , first estimate of [CII]/[NII] at high-z

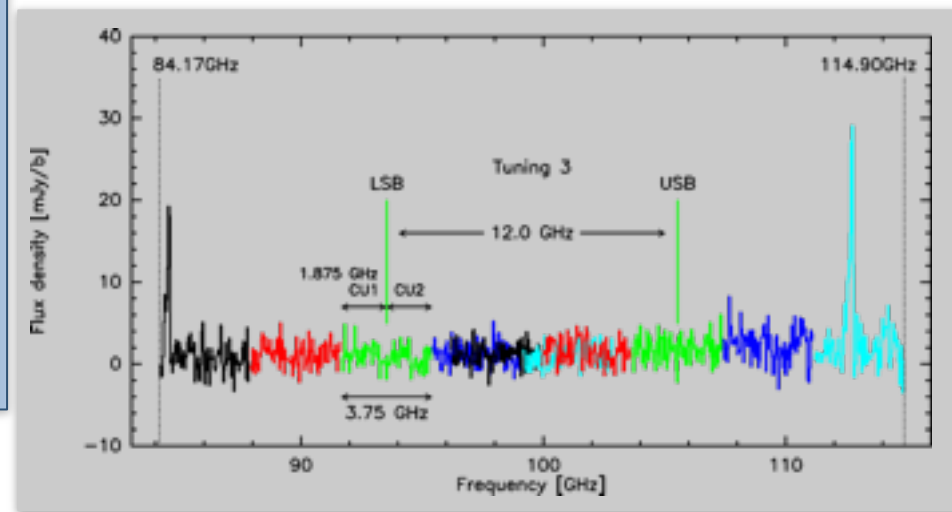
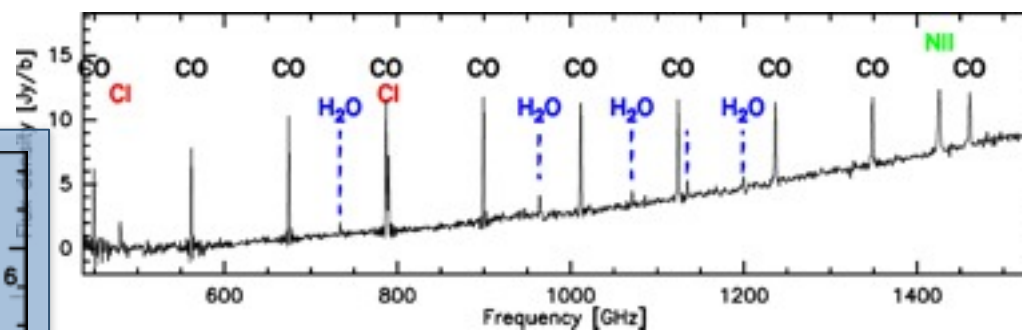
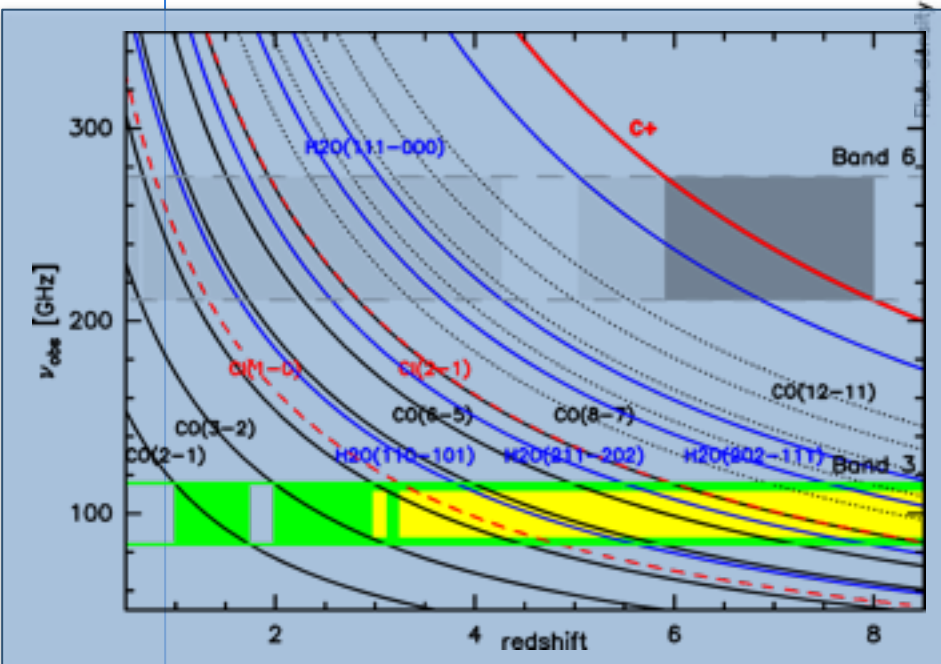


ESO



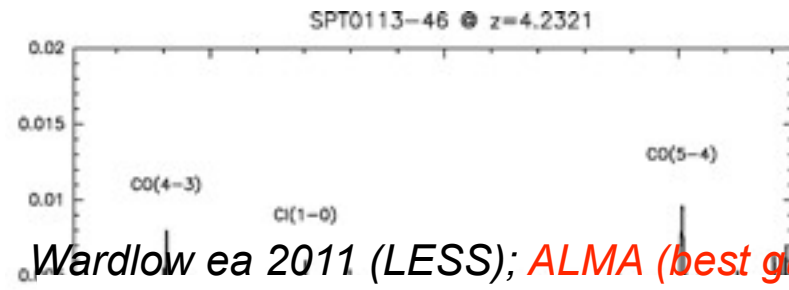
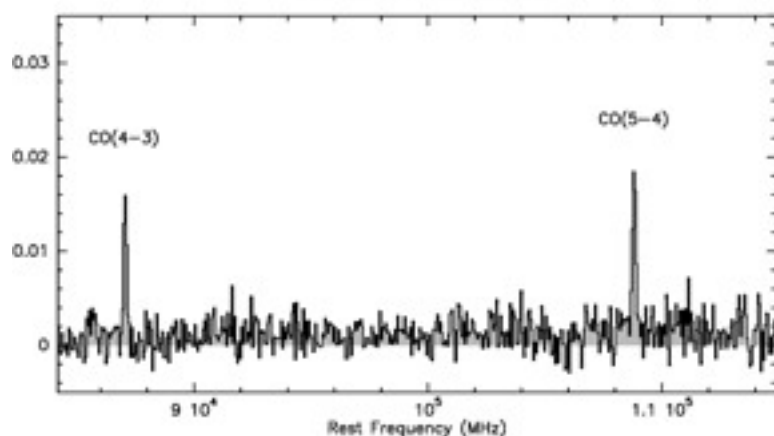
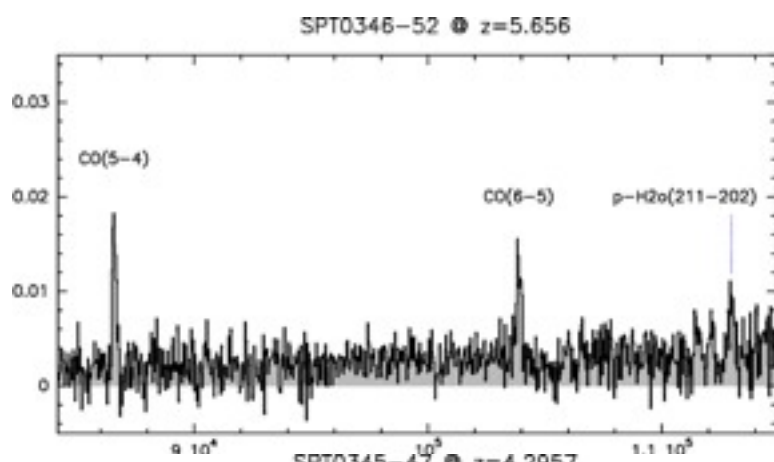
(de Breuck et al. 2011, APEX [CII])

- SPT submillimetre galaxies; B3 spectral survey
  - Weiss et al. 2012, in prep

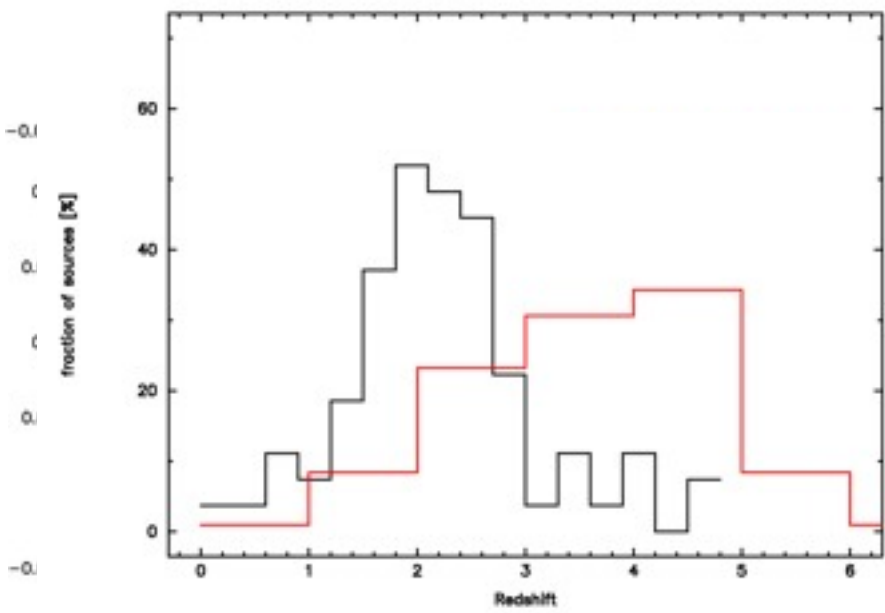


# Early Science Results

- SPT submillimetre galaxies; B3 spectral survey
  - Weiss et al. 2012, in prep



Wardlow et al 2011 (LESS); ALMA (best guess)







# The First Year of ALMA Science

Puerto Varas, Chile  
December 12-15, 2012

Exciting results from ALMA Early Science observations,  
from the Solar System to the high-redshift Universe,  
with an outlook to the future

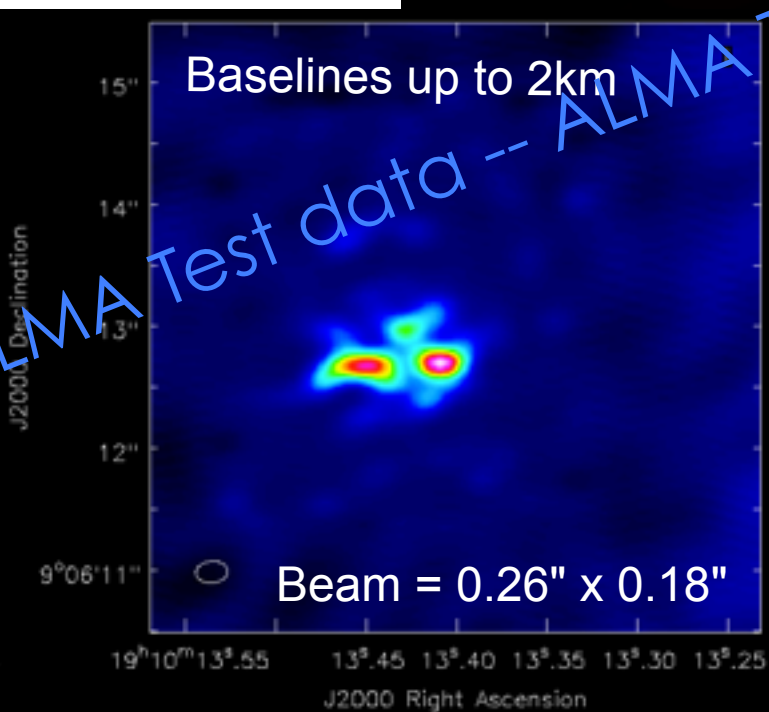
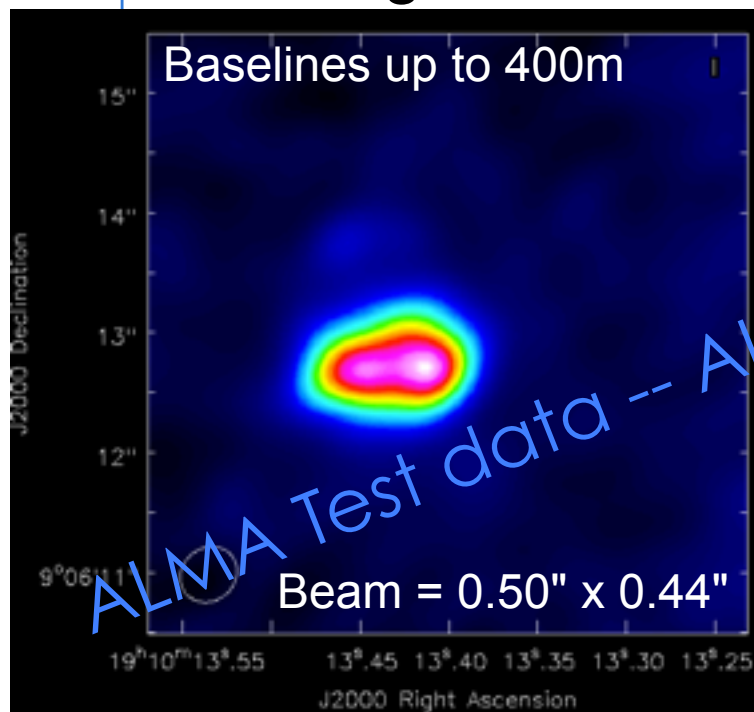
## Scientific Organising Committee

Leonardo Testi (ESO, Chair)  
Paola Andreani (ESO)  
Lewis Ball (JAO)



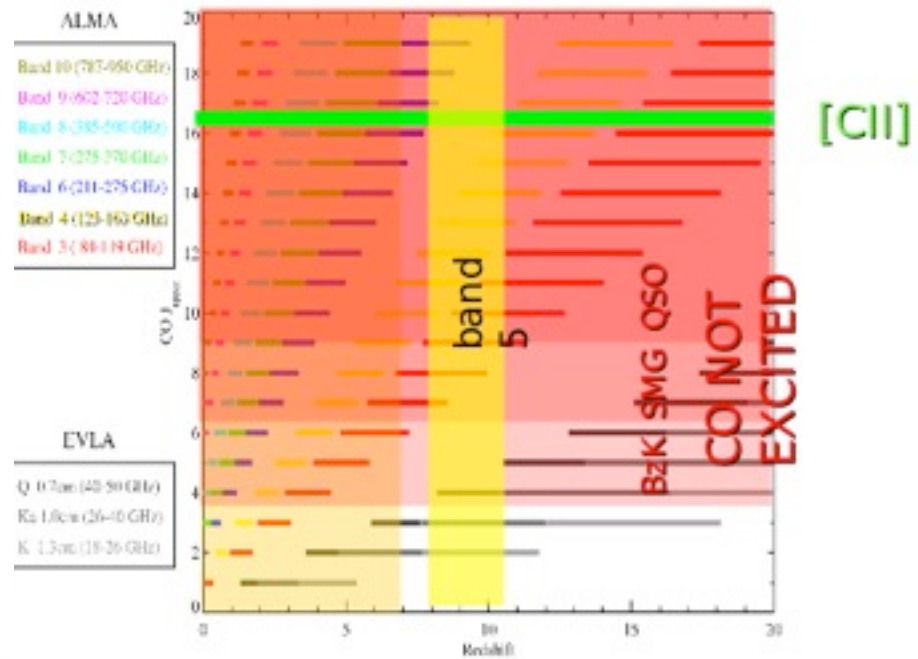
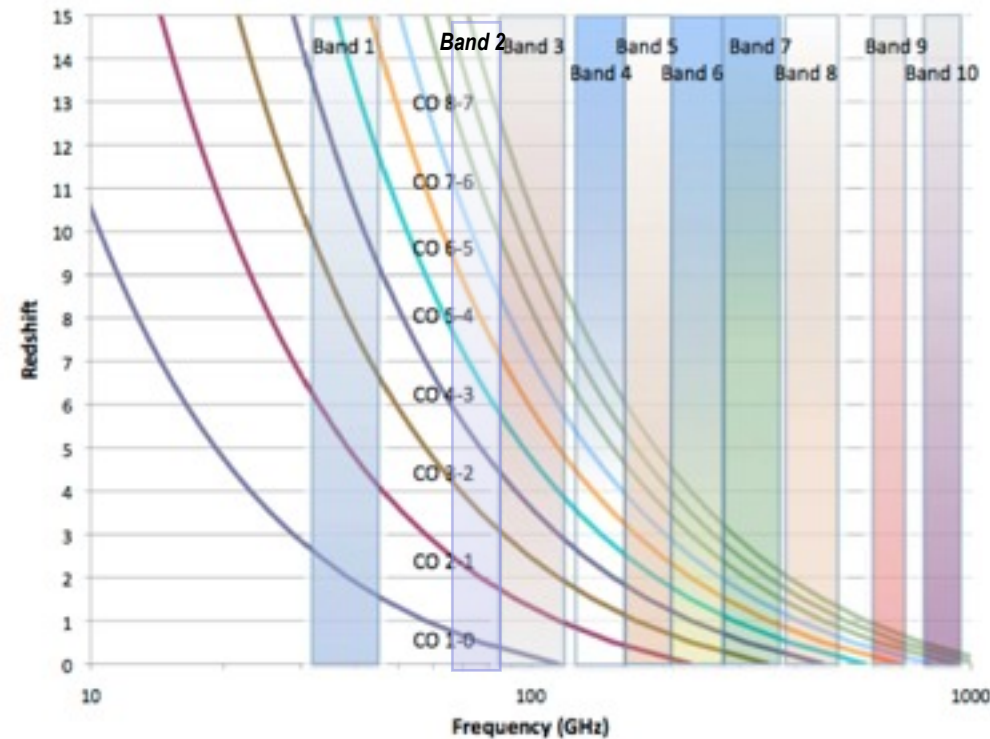
# On the horizon

- more Ant, ACA (Cycle 1)
- New Bands
- Solar observing
- Polarization
- Long Baselines



ALMA Test data -- ALMA Test data -- ALMA Test data

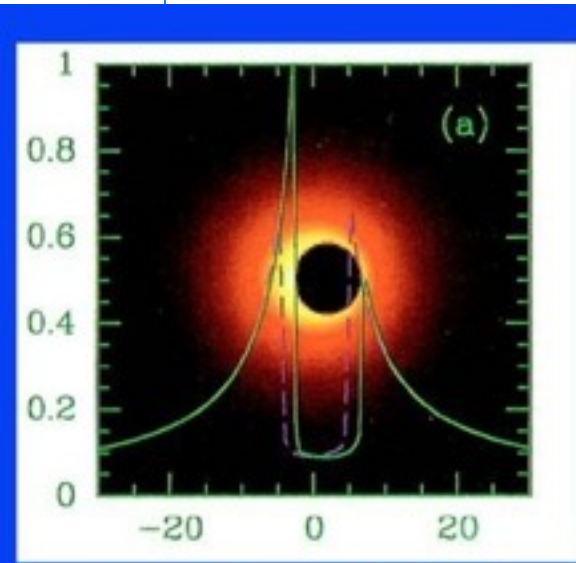
# On the horizon



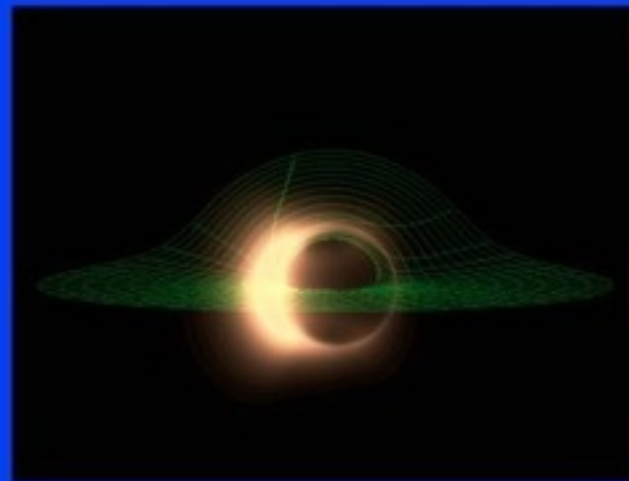
- Band 1&2 critical for low excitation molecular gas at high redshift
- Band 5 for [CII] in  $z \sim (8-10.5)$  range

# Phasing ALMA for VLBI

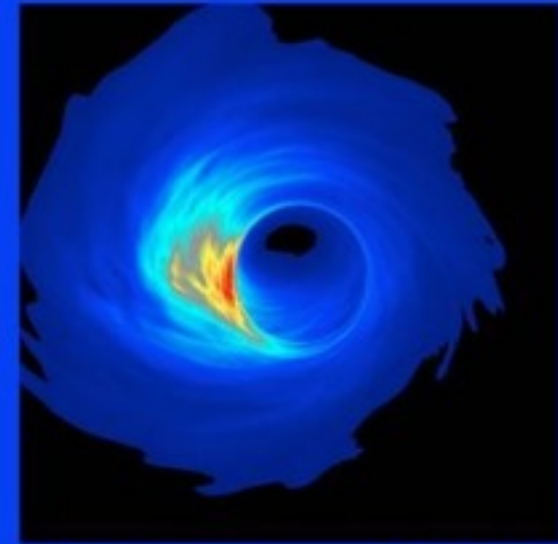
- The Event Horizon Telescope and Sgr A\*



Falcke et al 2000



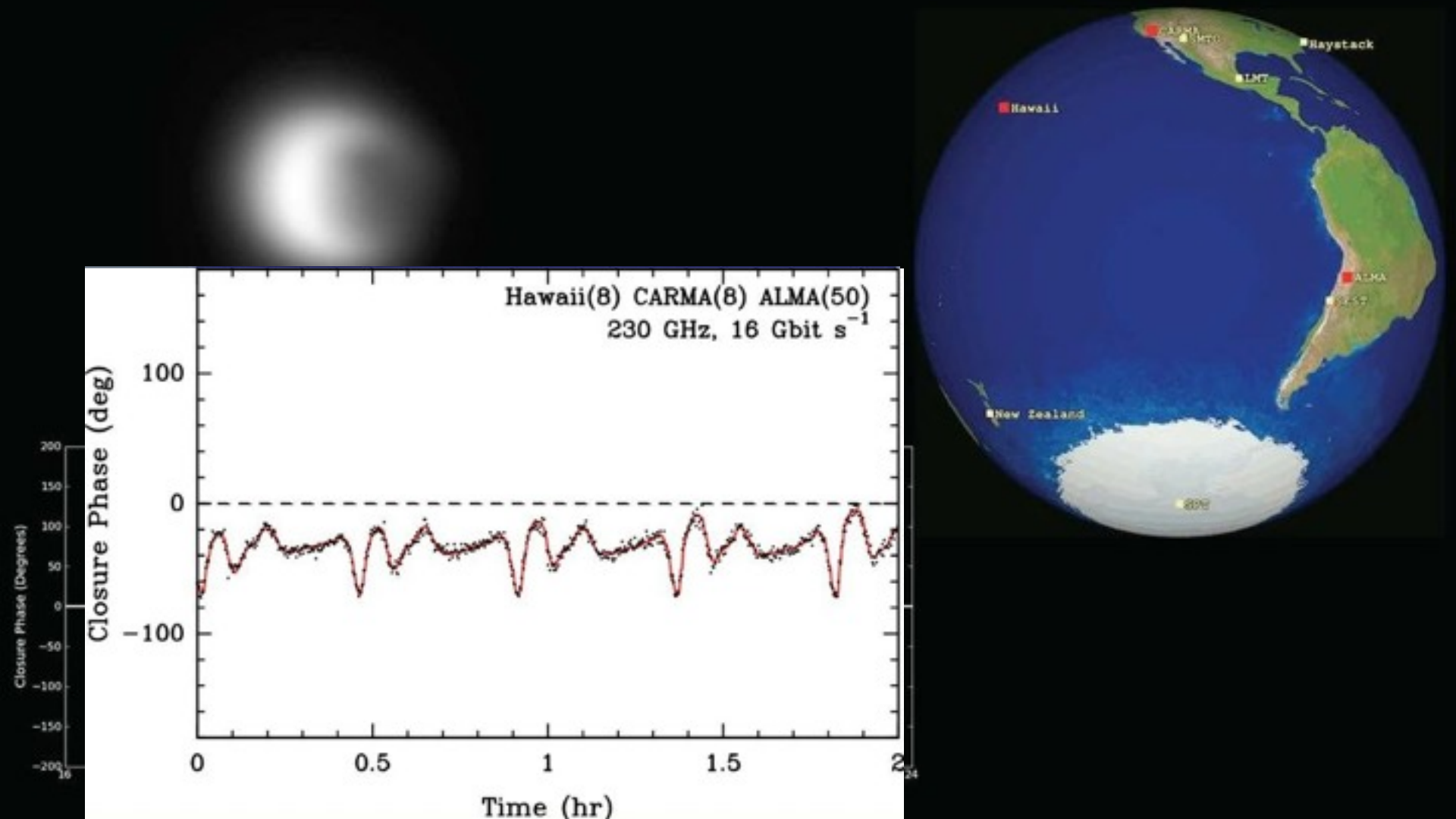
Broderick & Loeb 2009



Noble & Gammie 2007

# Phasing ALMA for VLBI

- The Event Horizon Telescope and Sgr A\*



- ALMA Phasing for mmVLBI
  - Strong scientific interest (mainly, but not only, IRA)
  - Participation in some of the workpackages led by MPIfR
- ALMA Band 2(/3) development study
  - Responsible for passive optics wp (Arcetri, UniMi)
  - Responsible for cryogenics wp (IASF-Bo)
  - Participation in OMT design wp (IASF-Bo)
  - Participation in Science wp (Arcetri/IASF-Bo)
  - Possible participation Cagliari
- Next generation correlator
  - Strong interest in Arcetri