



# ALMA – Development Programme



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# Why think about the Development Programme?

- ALMA will have a development programme, funded from the Operations budget.
- Ramps up slowly from 2010, in steady state from 2015. Roughly \$5M per partner.
- Long lead times for major upgrades (e.g. new receiver bands)
- We need community input on priorities quite soon.



# Initial priorities (my personal view)

- Phasing up ALMA to allow VLBI is low-cost, has a strong science case and is technically straightforward(ish)
- Completing the full complement of receiver bands is also important and has low(ish) technical risk
  - Bands 1 and 5 are currently seen as higher priority than Band 2
  - Strong science cases for both
  - Comparable costs (Band 1 intrinsically cheaper, but the EU-funded enhancement programme has done much of the development needed for Band 5 )
- Calibration improvements will have high priority, but probably low capital cost

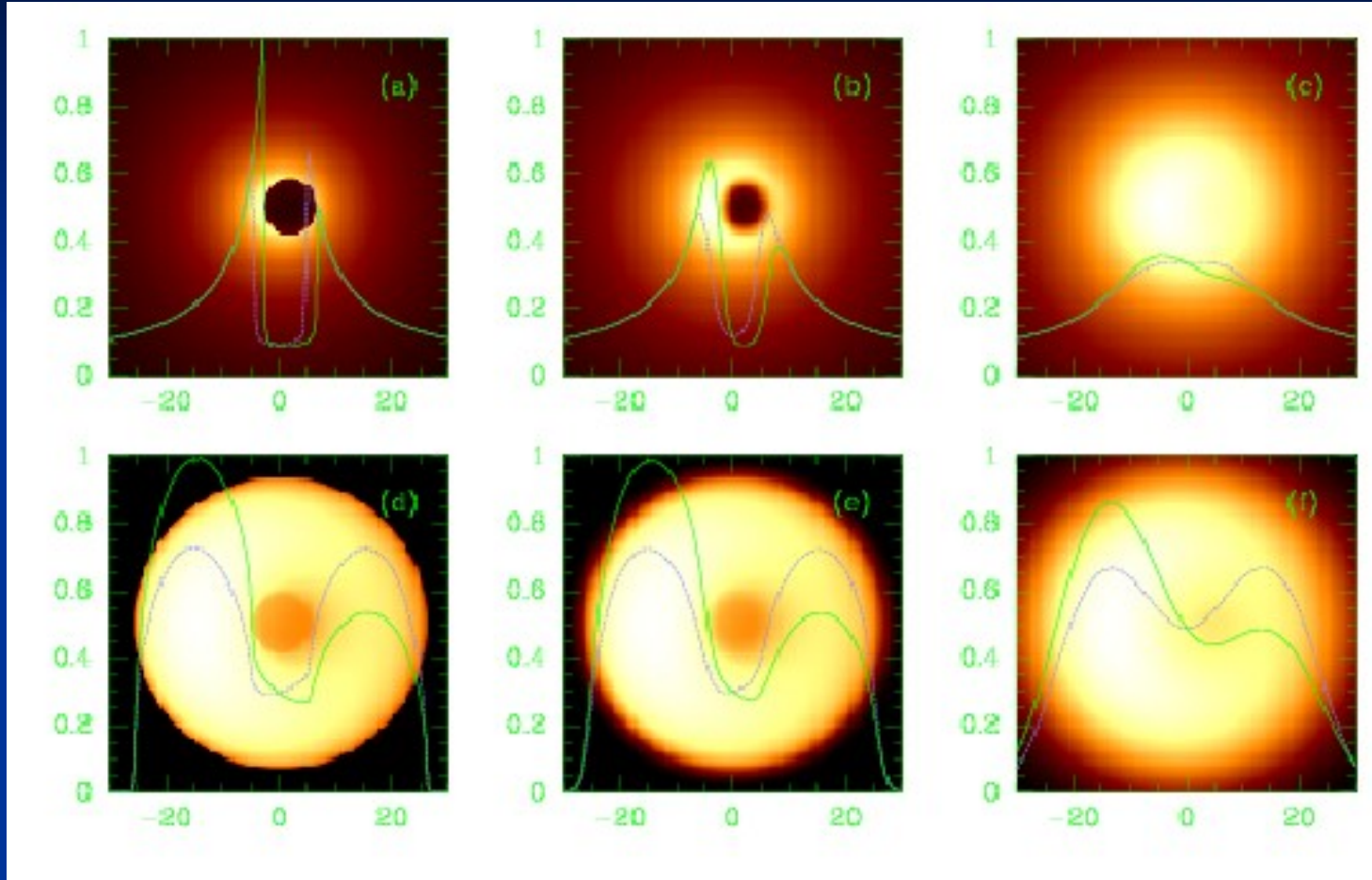


# ALMA as part of a VLBI Network



- ALMA has been designed to be used as a phased array
- Supported by correlator
- H maser, VLBI terminal, software not yet part of the construction programme (cost)
- No restriction on observing frequency
- Clearly harder at high frequencies and long baselines
- Should be possible to phase up compact configuration to at least 345GHz
- Other mm and sub-mm telescopes are needed too (e.g. LMT)

# VLBI observations of Sgr A\*



Kerr (spinning)  
black hole

Schwarzschild  
(non-rotating)  
black hole

GR ray tracing

0.6mm VLBI

1.3mm VLBI



# Band 1

- One of the original ALMA bands, lost in a descope ~2002
- Space allocated for Band 1 cartridge in the ALMA cryostats
- 31.3 – 45 GHz (extension to >50 GHz anticipated)
- $T_{rx} < 17$  K (SSB) across >80% of the band; HEMT
- Optics designed (in outline)
- CO at high redshift
  - 1-0 at  $z = 1.6 - 2.7$
  - 2-1 at  $z = 4.1 - 6.4$
  - 3-2 at  $z = 7.6 - 10.0$
- Sunyaev-Zeldovich Effect
  - High- $z$  clusters
  - Substructure due to shock fronts, radio-source interactions
- Planet formation: need lower frequencies to see large grains (Jane Greaves, yesterday)

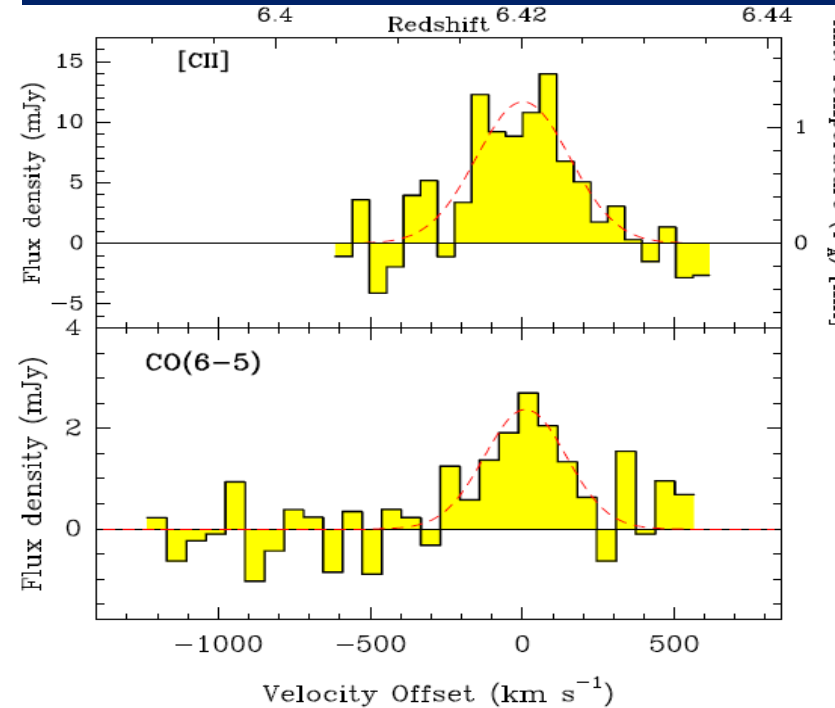
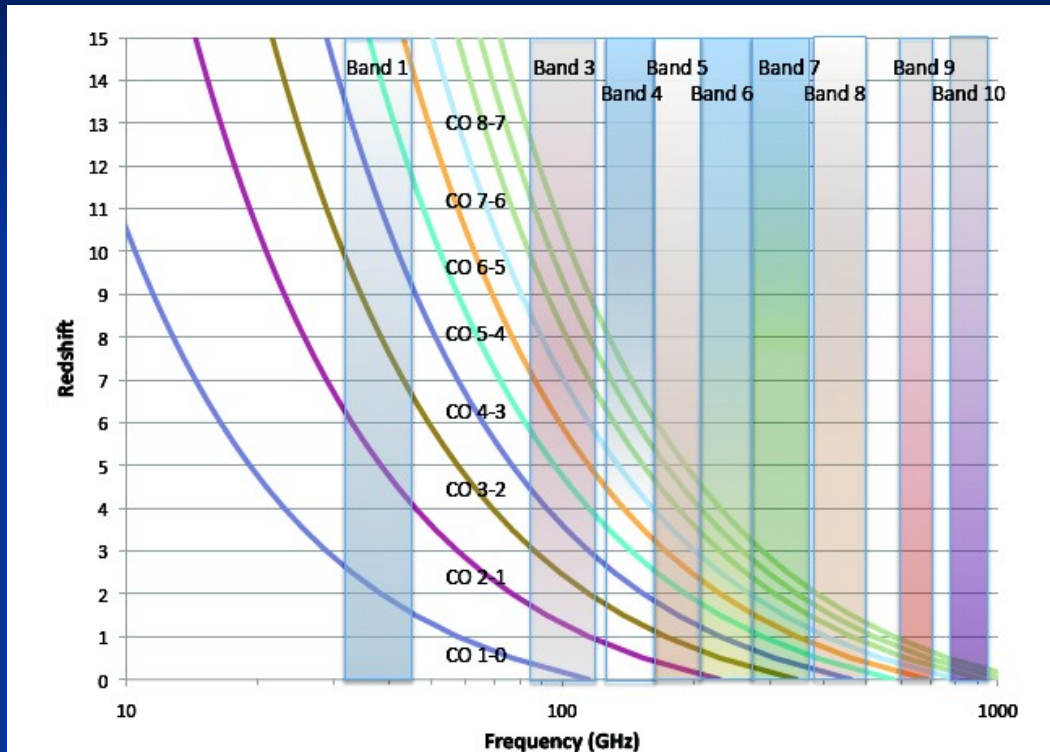
Meetings on Q-band Science held at HIA and JBCA 2008/9



## Band 5

- 163 – 211 GHz. Lower priority because of atmospheric water line at 183 GHz, but conditions at Chajnantor better than expected.
- Main science:
  - Water: chemistry of life and origin of water on Earth (synergy with Herschel)
  - Redshifted atomic lines from the first galaxies, especially CII from redshifts between 7 and 10
- Sideband separating SIS mixer,  $T_{\text{SYS}} < 65 \text{ K}$  across 80% of the band
- Manufacture of 6 receivers funded by EU under FP6 ALMA Enhancement Programme

# The first galaxies in CO and CII – probing the epoch of reionization



[CII] in  $z = 6.42$  quasar  
256.2 GHz (ALMA Band 6)

(Maiolino et al.)



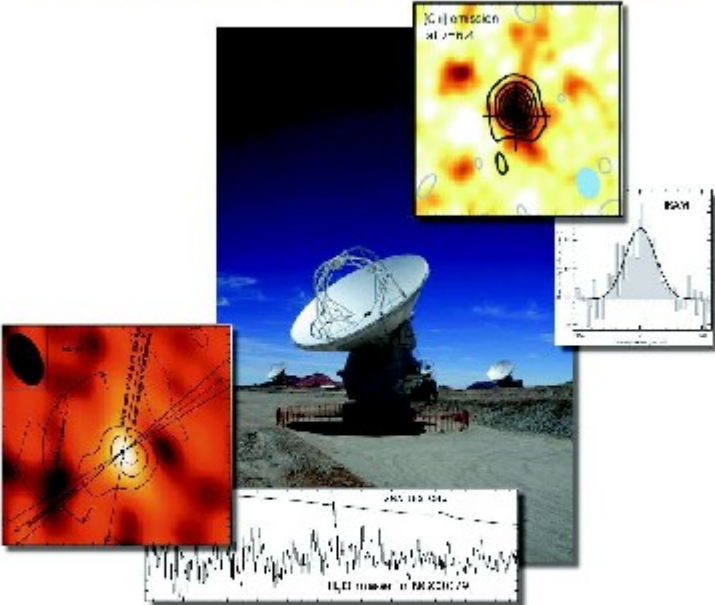
# What happens now (probably)?

- ESO: call for studies (costs)
- ALMA Board: call for proposals
- Small number of high-priority projects + longer-term R&D?
- Important to be ready with:
  - science case (meetings are happening now)
  - technical proposal
  - managerial, product assurance and financial details
- Key technical expertise: SIS mixer and HEMT receivers; digital electronics, software (maybe photonics)




# Band 5 Workshop

SCIENCE WITH ALMA BAND 5 (163 - 211 GHz)  
Osservatorio Astronomico di Roma, May 24 - 25, 2010



The poster features a central image of an ALMA radio telescope dish in a desert landscape. Surrounding this central image are several smaller panels: a spectral plot with a peak labeled "SiO emission at 170.4 GHz", a spectral plot labeled "SiO", a spectral plot labeled "SiO emission at 170.4 GHz", and a spectral plot labeled "SiO emission at 170.4 GHz".



At the bottom of the poster are three logos: the ESO logo, the ERTN (European Radio Telescope Network) logo, and the IAC (Instituto de Astrofísica de Canarias) logo.

<https://www.oa-roma.inaf.it/meetings/AlmaBand5/Home.html>