



# Synergies of SPICA with radio, from cm to mm and submm



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# OUTLINE

## Main Scientific Topics

### Big radio projects:

Sardinia Radio Telescope (cm/mm)

ALMA (mm/submm)

GMVA (mm- VLBI)

EHT (submm-VLBI)

LOFAR (cm)

SKA & precursors (cm)

# Synergy between IR and radio on :

## Star formation - galactic and extragalactic

radio cm emission from relativistic electrons  
accelerated by SN

mm free-free emission from excited HII  
regions

mm and submm thermal em from cold objects

## Planetary disks

direct observations in mm/submm , high  
resolving power, ability to see fine details  
cm emission from giant planets like Jupiter,  
characterized by strong magnetic fields  
"water hole"

# Synergy between IR and radio (cont.) :

## Interstellar medium

radio: thermal emission of cold regions  
many complex molecules

## AGN

different components at different wavelengths  
radio: jets, regions close to the BH

## Early Universe

early objects, EoR (redshifted HI)

# Synergy between IR and radio (cont.) :

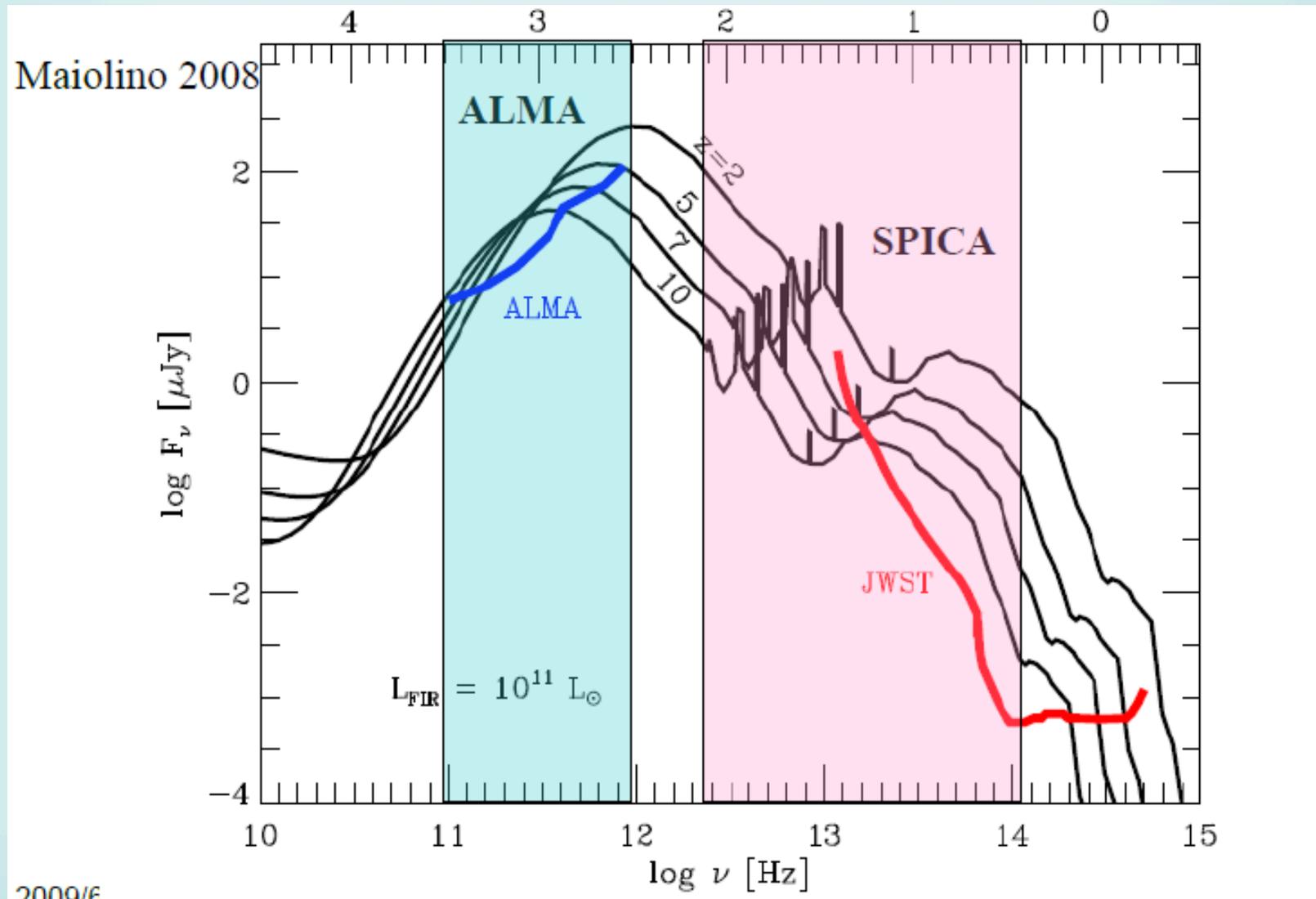
## Surveys

the microJy and nanoJy radio sky

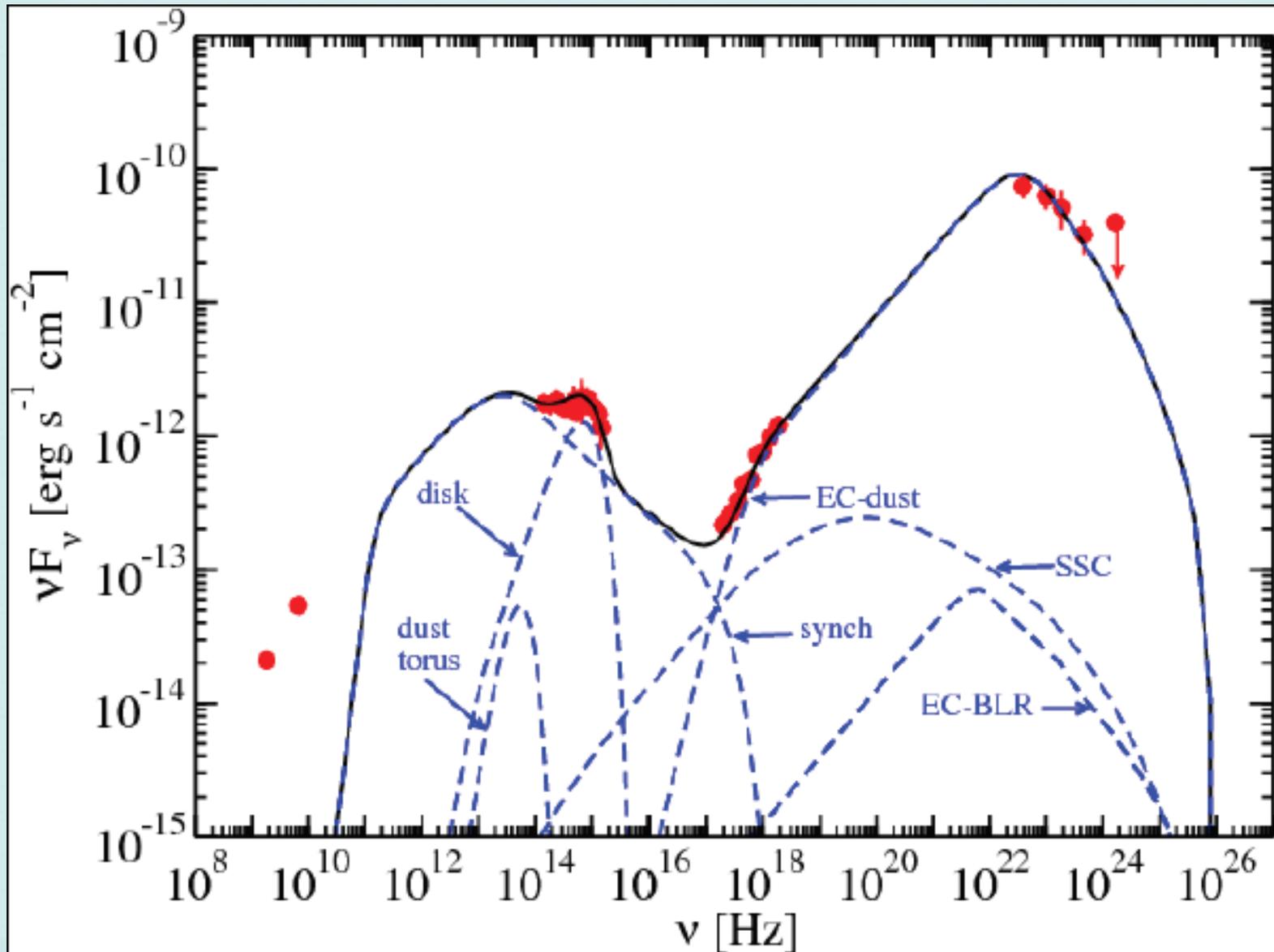
## Radio - infrared surveys:

- separate AGN from SFG
- what is the role of AGN in galaxy formation and evolution
- co-existence and co-evolution of AGN and star formation in galaxy evolution (trigger of SF in galaxy collisions, quench of SF due to AGN feedback)

# SED of a Star Forming Galaxy scaled from the SED of M82



# PKS 2123-463 : a gamma ray blazar at $z=1.67$



D'Ammando et al. 2012

# Radio Projects

# Sardinia Radio Telescope SRT

Fully steerable, 64m diameter, paraboloidal radio telescope.

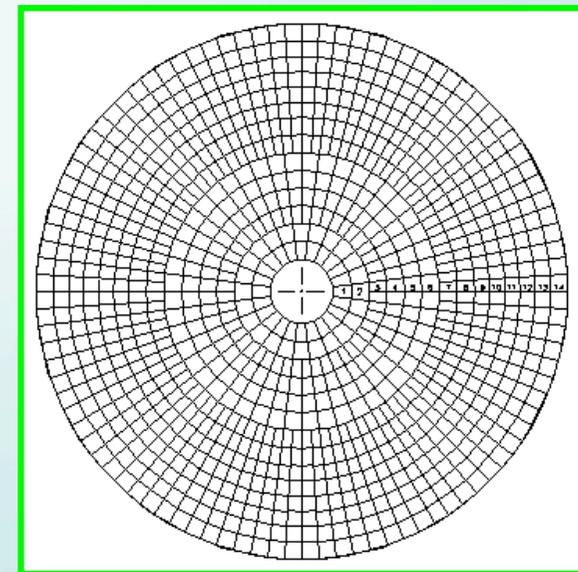
Alt- Azimuth mounting

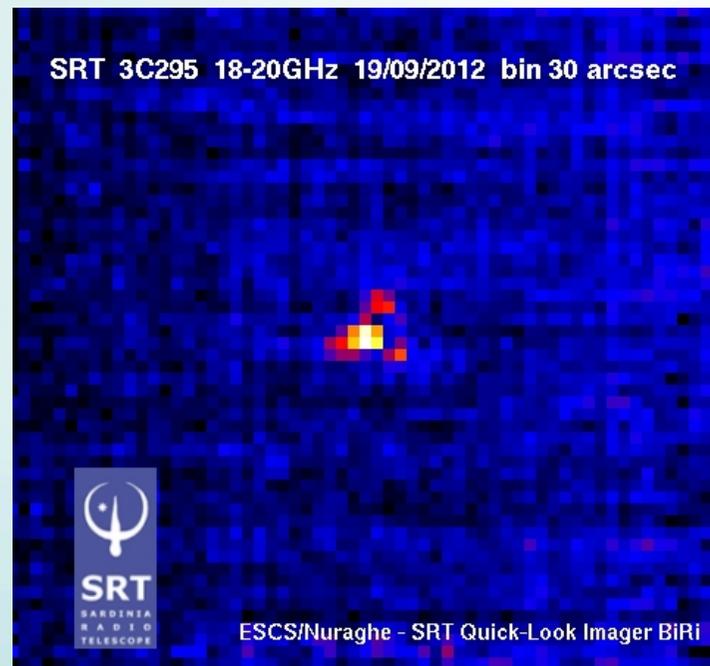
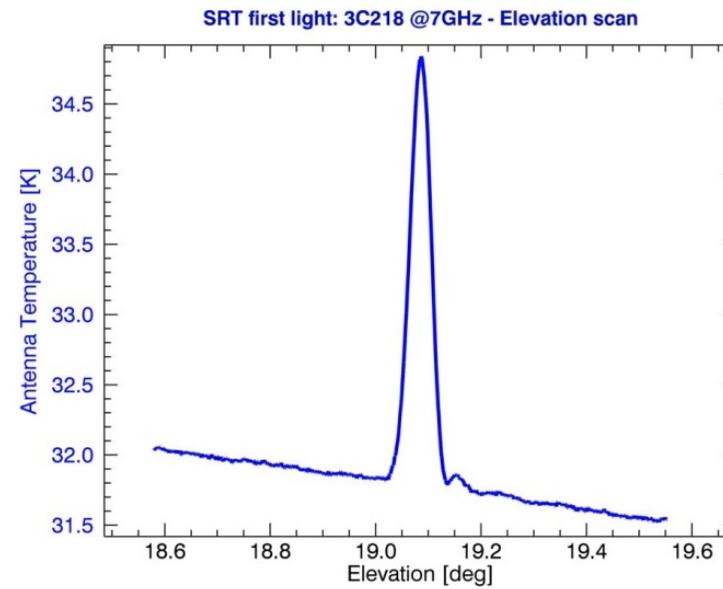
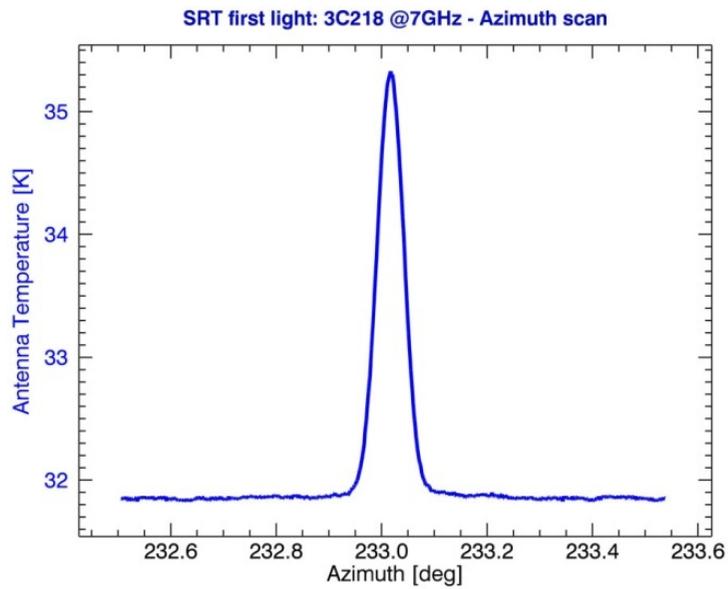
Fiber optic connection

Transmitting capabilities



Main reflector active surface:  
1008 panel + 1116 mechanical actuators

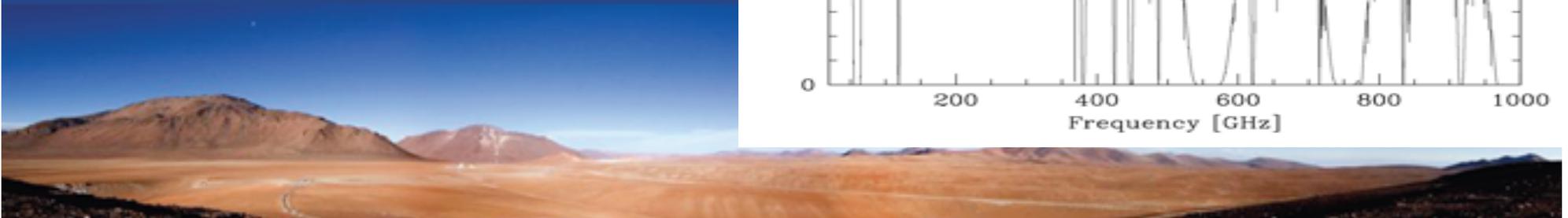
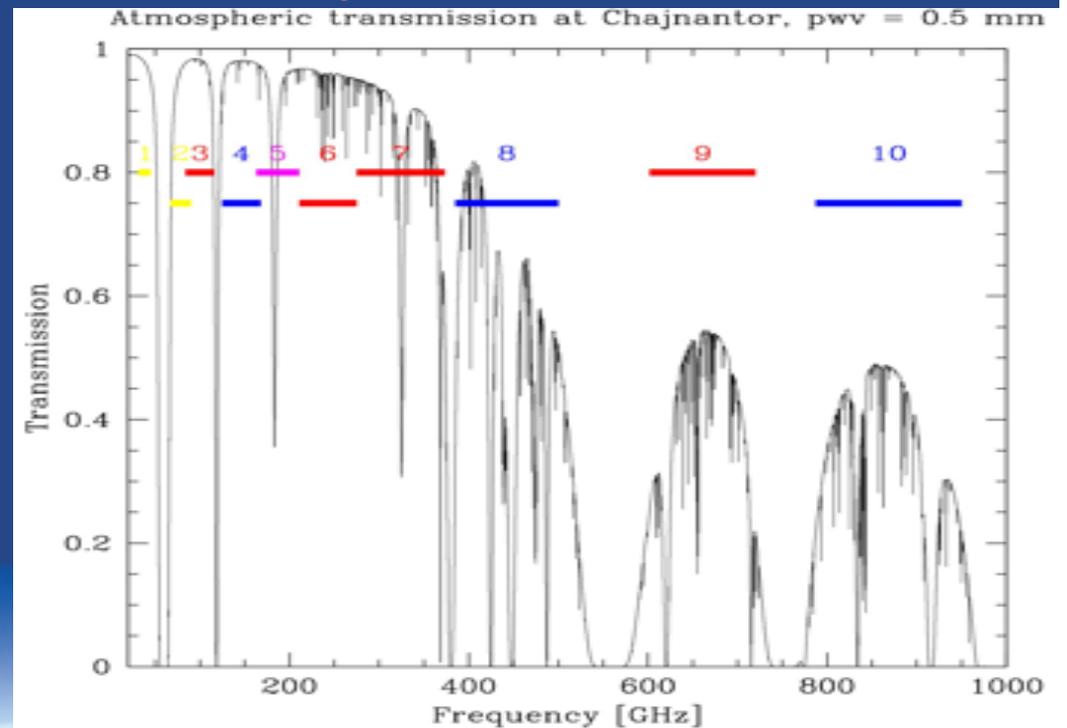




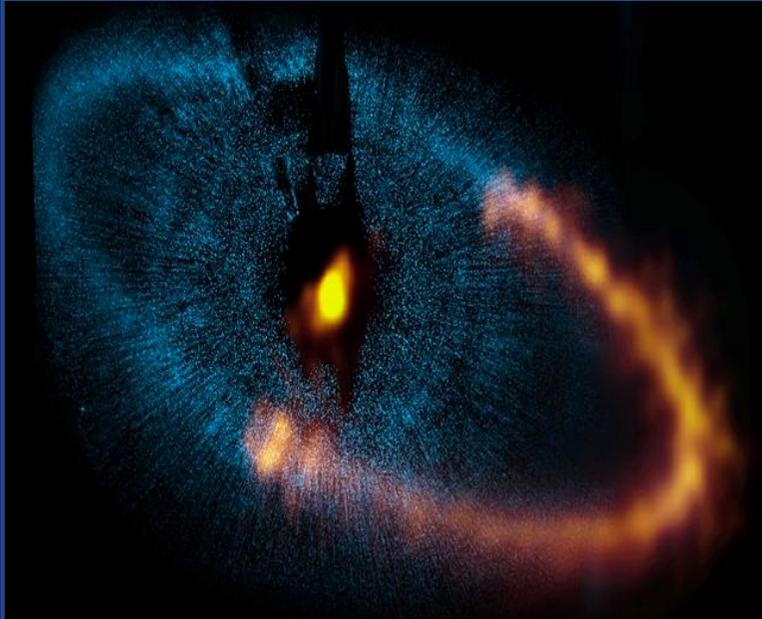
First light  
First image

## ALMA numbers

- The Atacama Large Millimeter Array is a **mm-submm reconfigurable interferometer**
- Under construction on the Chajnantor plain (**5000m**, Chile)
- Frequency range: **10 bands between 30-900 GHz** (0.3-10 mm)
- Antennas: **50x12m** main array + **(12x7m + 4x12m)** ACA
- Baselines length: **15m ->150m-16km** + **9m->50m**
- Resolution: **0.2" x (300/freq\_GHz)x(1km/max\_baseline)**
- FOV 12m array: **20.3"/(300/freq\_GHz)**
- Bandwidth: **2 GHz x 4basebands for each of 2 polarisations**
- **World wide collaboration:**
  - ■ Europe: ESO (14 countries),
  - ■ North America: NRAO (USA, Canada),
  - ■ East Asia: NAOJ (Japan, Taiwan),
  - Chile
  - Contributors share the observing time



# A taste of what was already done: Cycle 0



## ALMA Reveals Workings of Nearby Planetary System observing a ring around the bright star Fomalhaut

This view shows a new picture of the dust ring around the bright star Fomalhaut from the Atacama Large Millimeter/submillimeter Array (ALMA). The underlying blue picture shows an earlier picture obtained by the NASA/ESA Hubble Space Telescope. The new ALMA image has given astronomers a major breakthrough in understanding a nearby planetary system and provided valuable clues about how such systems form and evolve. Note that ALMA has so far only observed a part of the ring.

**ALMA resolution is comparable to  
HST**

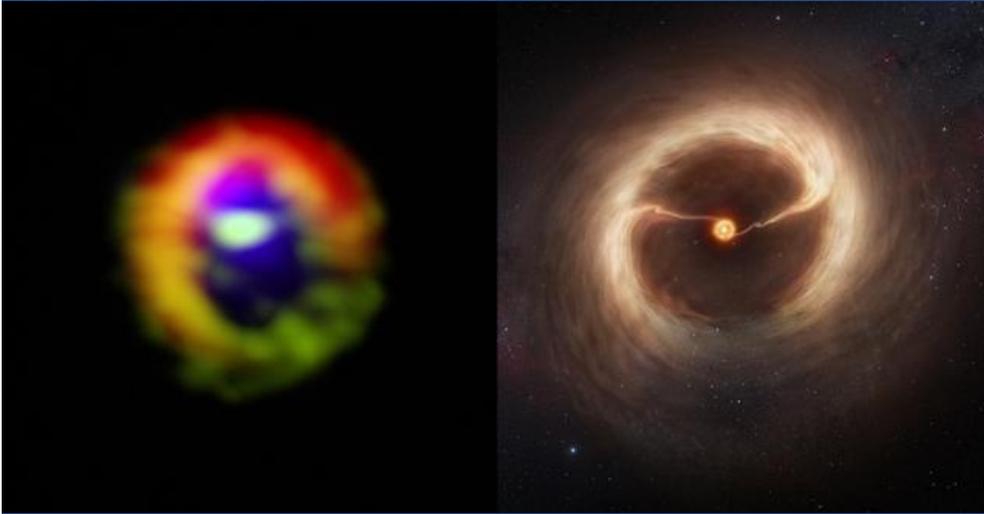
## Curious spiral spotted by ALMA around red giant star R Sculptoris

Observations using the Atacama Large Millimeter/submillimeter Array (ALMA) have revealed an unexpected spiral structure in the material around the old star R Sculptoris. This feature has never been seen before and is probably caused by a hidden companion star orbiting the star. This slice through the new ALMA data reveals the shell around the star, which shows up as the outer circular ring, as well as a very clear spiral structure in the inner material.



# A taste of what was already done: Cycle 0

## Side-by-side comparison of ALMA observations and artist's impression of the disc and gas streams around HD 142527



Left: observations made with the Atacama Large Millimeter/submillimeter Array (ALMA) telescope of the disc of gas and cosmic dust around the young star HD 142527, showing vast streams of gas flowing across the gap in the disc. These are the first direct observations of these streams, which are expected to be created by giant planets guzzling gas as they grow, and which are a key stage in the birth of giant planets.

The dust in the outer disc is shown in red. Dense gas in the streams flowing across the gap, as well as in the outer disc, is shown in green. Diffuse gas in the central gap is shown in blue. The gas filaments can be seen at the three o'clock and ten o'clock positions, flowing from the outer disc towards the centre. The dense gas observed is HCO<sup>+</sup>, and the diffuse gas is CO. The outer disk is roughly two light-days across. If this were our own Solar System, the Voyager 1 probe — the most distant manmade object from Earth — would be at approximately the inner edge of the outer disk.

Right: artist's impression of the disc and gas streams, for illustration.

## Contact details

Follow the ALMA news on <http://www.alma.info/en/home>

Enter the ALMA world through the Science Portal [www.almascience.org](http://www.almascience.org)

Send your request to the Italian ARC [www.alma.inaf.it](http://www.alma.inaf.it)

[help-desk@ira.inaf.it](mailto:help-desk@ira.inaf.it)



# The Global Millimeter VLBI Array (GMVA)

Imaging with  $\sim 40 \mu\text{as}$  resolution at 86 GHz

## Baseline Sensitivity

in Europe:

30 – 300 mJy

in US:

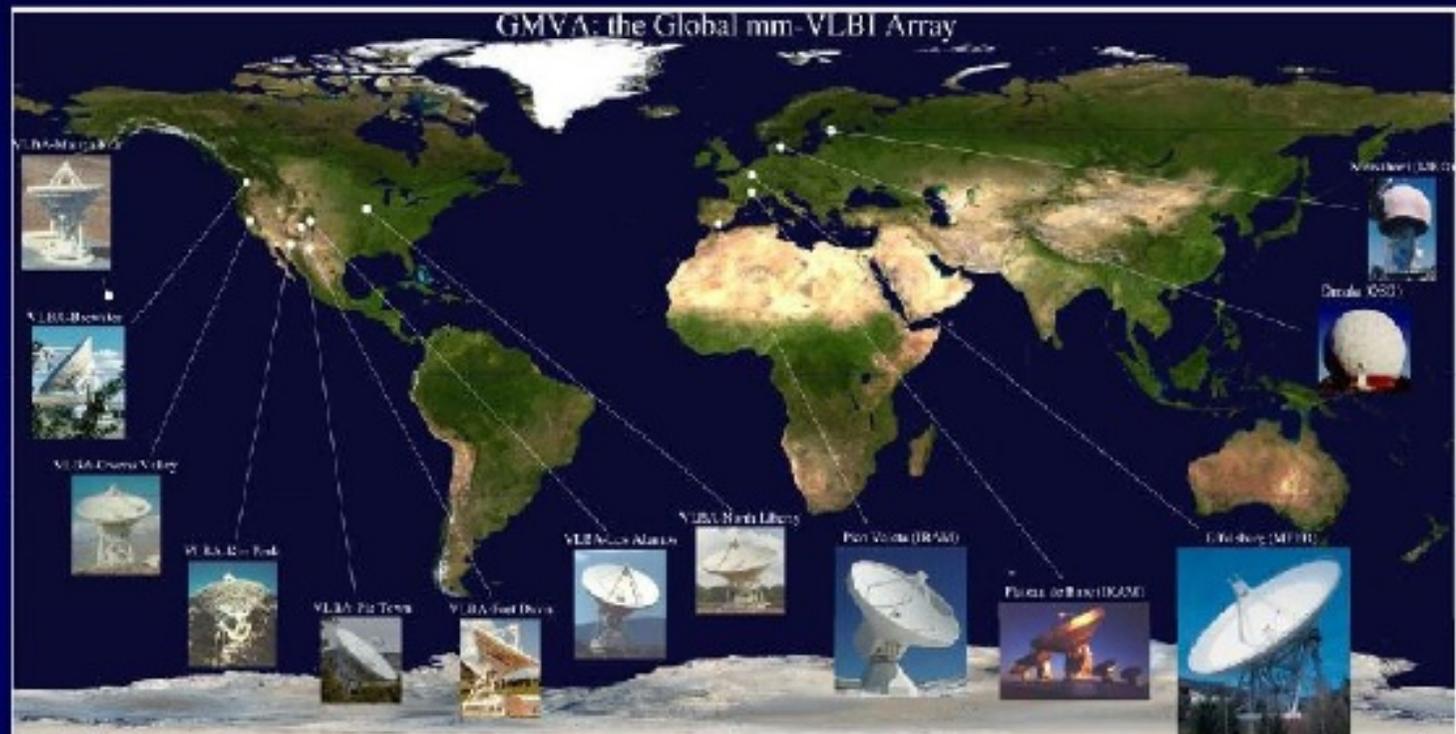
100 – 300 mJy

transatlantic:

50 – 300 mJy

Array:

1 – 3 mJy / hr



(assume  $7\sigma$ , 100sec, 512 Mbps)

<http://www.mpifr-bonn.mpg.de/div/vlbi/globalmm>

- Europe: Effelsberg (100m), Pico Veleta (30m), Plateau de Bure (35m), Onsala (20m), Metsähovi (14m), Yebes (40m), planned: GBT (100m), KVN, SRT, ALMA, ...
- USA: 8 x VLBA (25m)

Proposal deadlines: February 1<sup>st</sup>, August 1<sup>st</sup>

# Event Horizon Telescope

Carma 6 x 10m + 9 x 6m



ALMA Kitt Peak, 12m



SMTO, 10m



Pico Veleta, 30m



Plateau de Bure 6x15m

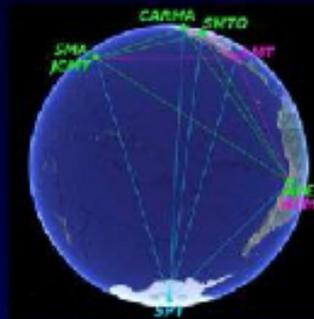


image: EHT collaboration

CSO, 10m



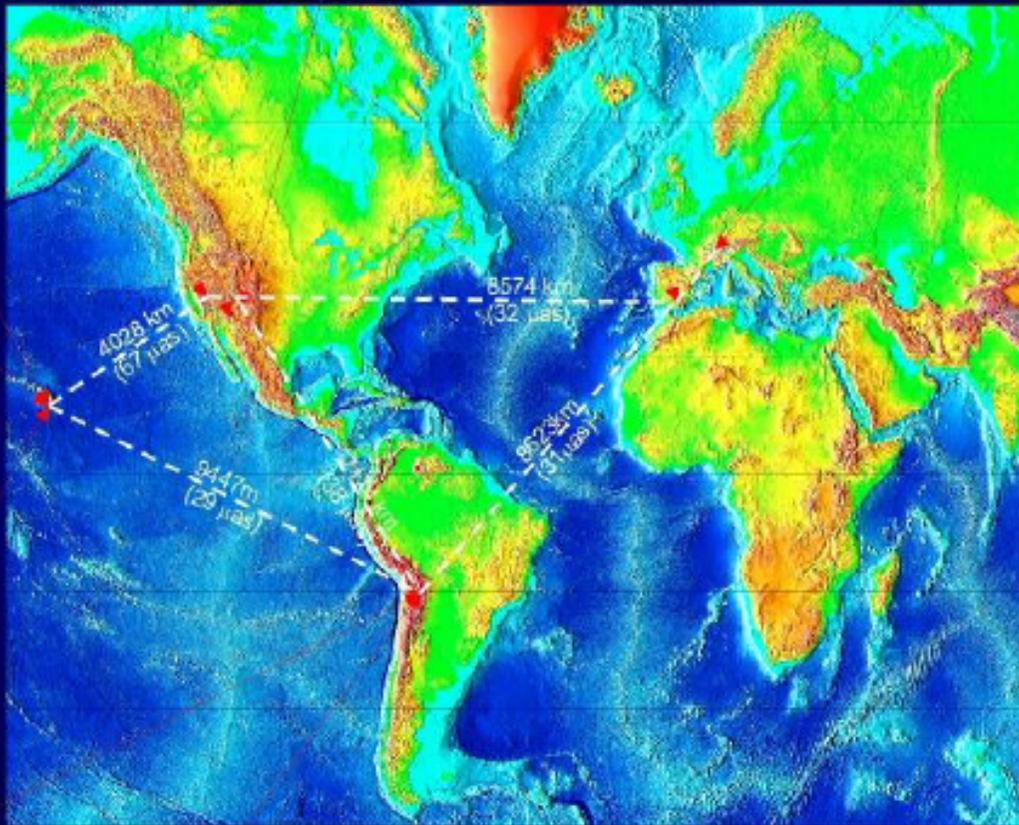
JCMT, 15m



SMA, 8x6m



APEX, 12m



ALMA, 50 x 12m

(angular resolutions calculated for 230 GHz)

Angular Resolution:

25-30  $\mu$ as @230 GHz

16-20  $\mu$ as @345 GHz



image: Broderick.

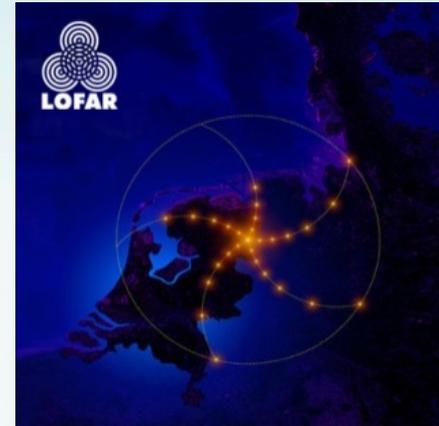
Imaging Black Holes with global mm-/sub-mm VLBI

(now called Event Horizon Telescope)

# LOFAR: Low Frequency Array



10-240 MHz



120-240 MHz

30-80 MHz

