

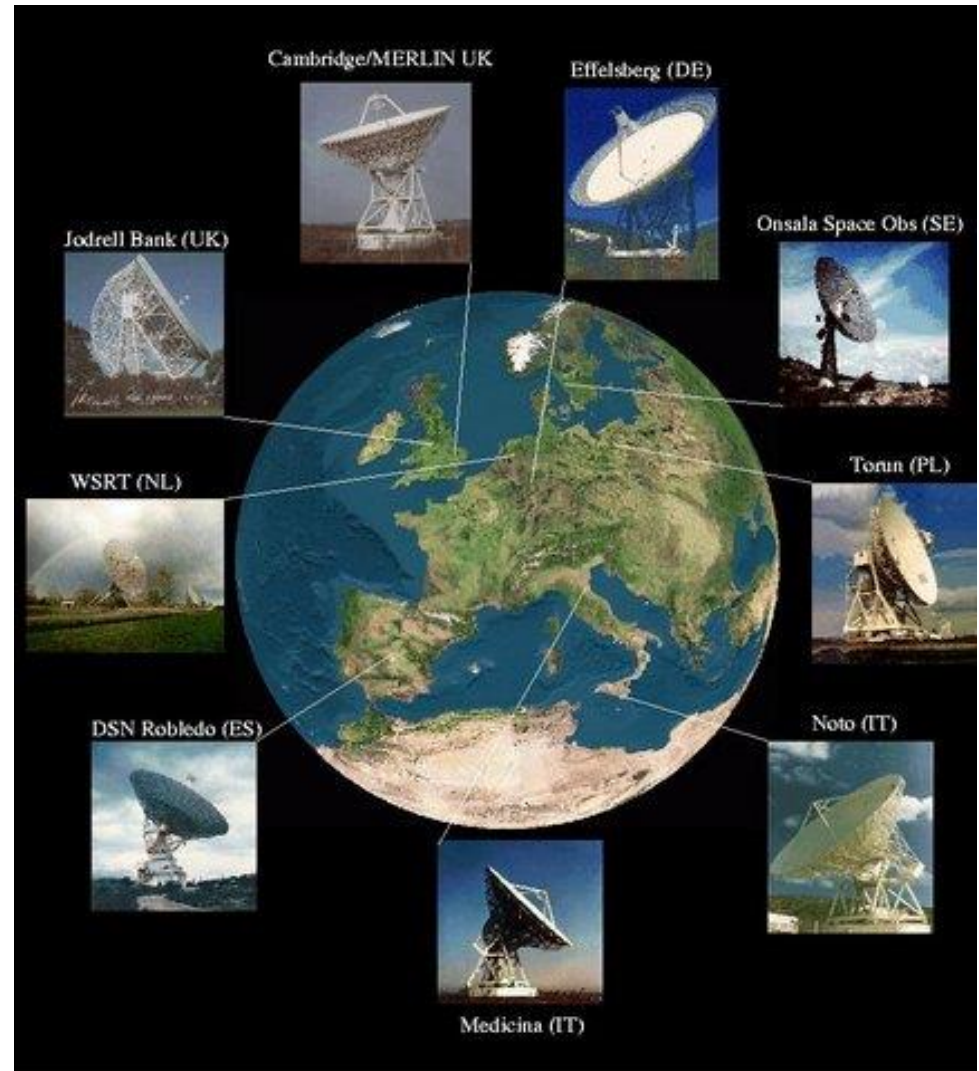
# New Radio Telescopes

- e-Very Long Baseline Interferometry
- e-Merlin
- e-Very Large Array
- Atacama Large Millimeter/sub-millimeter Array
- LOFAR
- Square Kilometer Array
- Sardinia Radio Telescope

# VLBI

([www.evlbi.org](http://www.evlbi.org))

The European VLBI Network (EVN) is an interferometric array of radio telescopes (18) spread throughout Europe (and beyond) that conducts unique, high resolution, radio astronomical observations of cosmic radio sources. It is the most sensitive VLBI array in the world, thanks to the collection of extremely large telescopes that contribute to the network.



Global VLBI - Space VLBI

# RadioAstron (10m antenna)

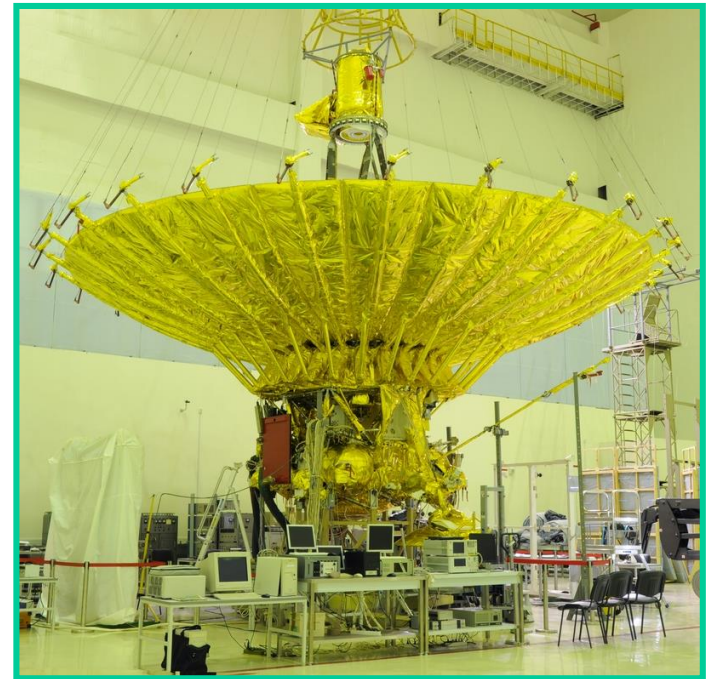
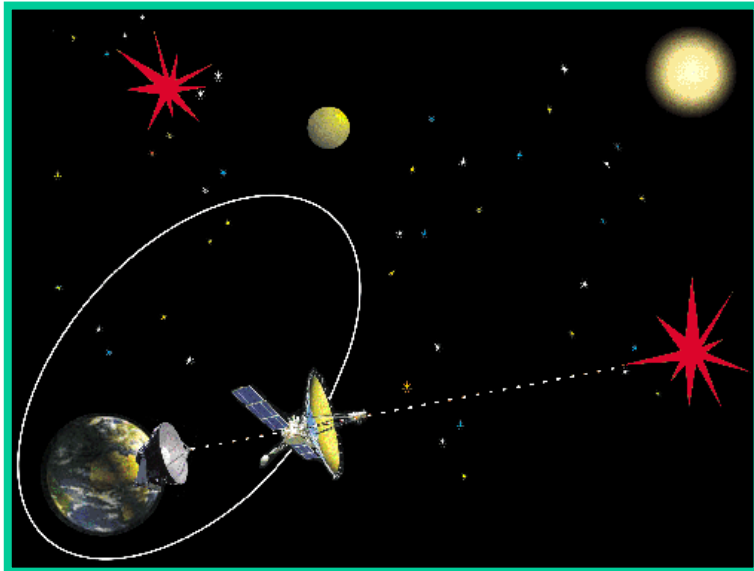
The RadioAstron project is designed by the Astro Space Center of the Russian Academy of Science.

Launched in July 18, 2011 from Baikonur

Period 7-10 days

Major semi-axis 189000 km

Frequency 0.327, 1.665, 483, 18-25 GHz



# RadioAstron

Scientific goals:

Galactici nuclei (supermassive BH, event horizon, particle acceleration, Faraday rotation, Magnetic fields, cosmic rays, superluminal motion)

Cosmology effects: redshift dependance of various physical parameters of galactic nuclei; dark matter and dark energy effects

Star and planetary systems formation, masers and Megamasers

Interstellar and interplanetary media

Astrometry

High precision model of the Earth gravitational field

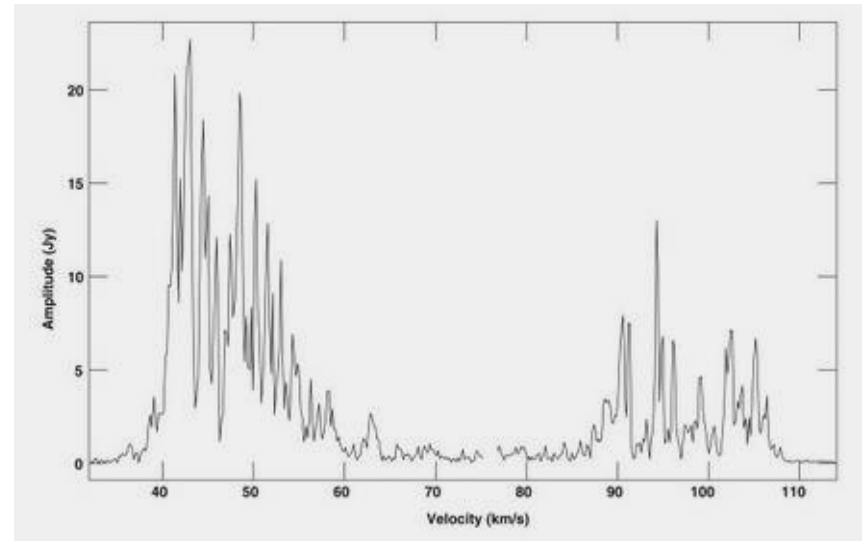


# e-VLBI

The 20-hour long observations, performed on 22nd September 04 using the EVN, involved radio telescopes in the UK, Sweden, the Netherlands, Poland and Puerto Rico. The maximum separation of the antennas was 8200 km, giving a resolution of at least 20 mas. The 9 Terabits of data, at 32 Mbits/second per telescope, were fed in real-time into a specialised supercomputer, called a 'correlator', and combined.

IRC+10420 is a supergiant star with a mass about 10 Msol and at about 15,000 light year. One of the brightest infrared sources in the sky, it is surrounded by a thick shell of dust and gas thrown out from the surface of the star. The total velocity width of the emission shows that the shell is expanding at about 40 km/s.

Amplitude (Jy)



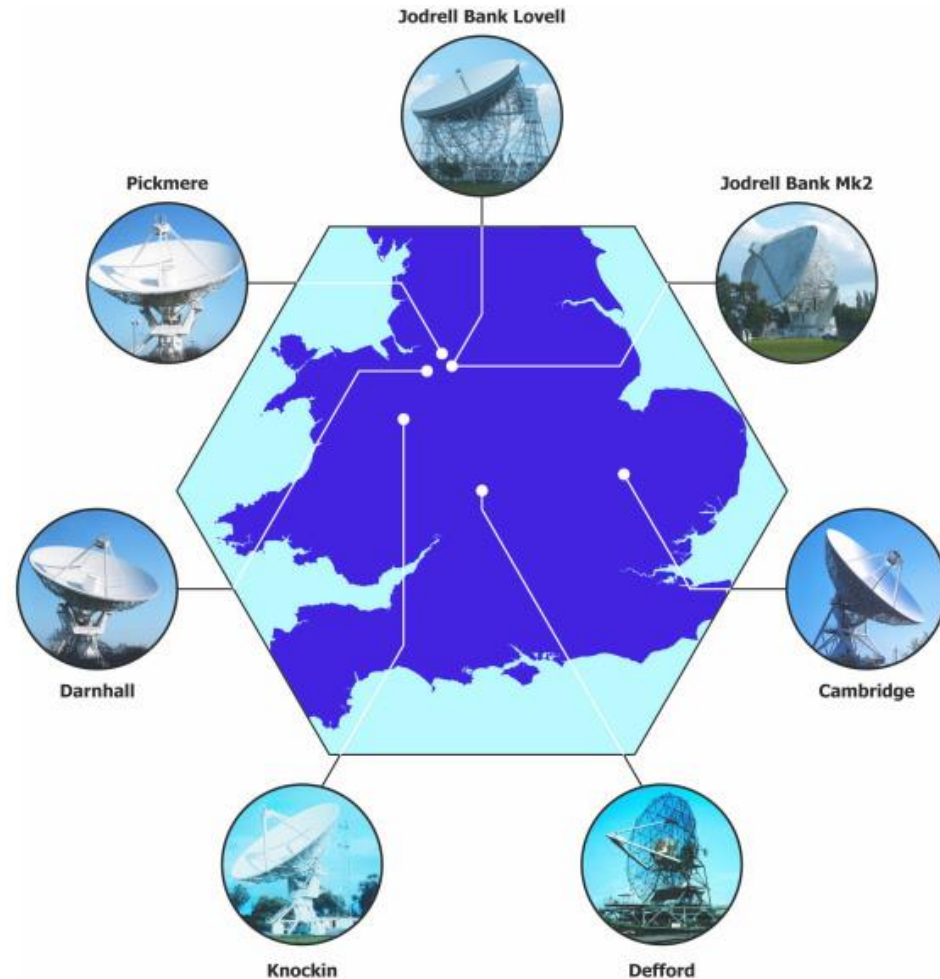
Velocity (km/s)



# e-Merlin ([www.merlin.ac.uk/e-merlin/](http://www.merlin.ac.uk/e-merlin/))

The e-MERLIN telescope array provides an increase in observing sensitivity by a factor of 30. It provides radio imaging, spectroscopy and polarimetry **with 10-150 milliarcsecond resolution and microJansky sensitivity at centimetre wavelengths.**

The fundamental infrastructure of six radio telescopes distributed across England has been enhanced by the installation of a dedicated 210 Gb/s optical fibre network and new receivers; a powerful new correlator and new telescope electronics have been installed.



# e-VLA

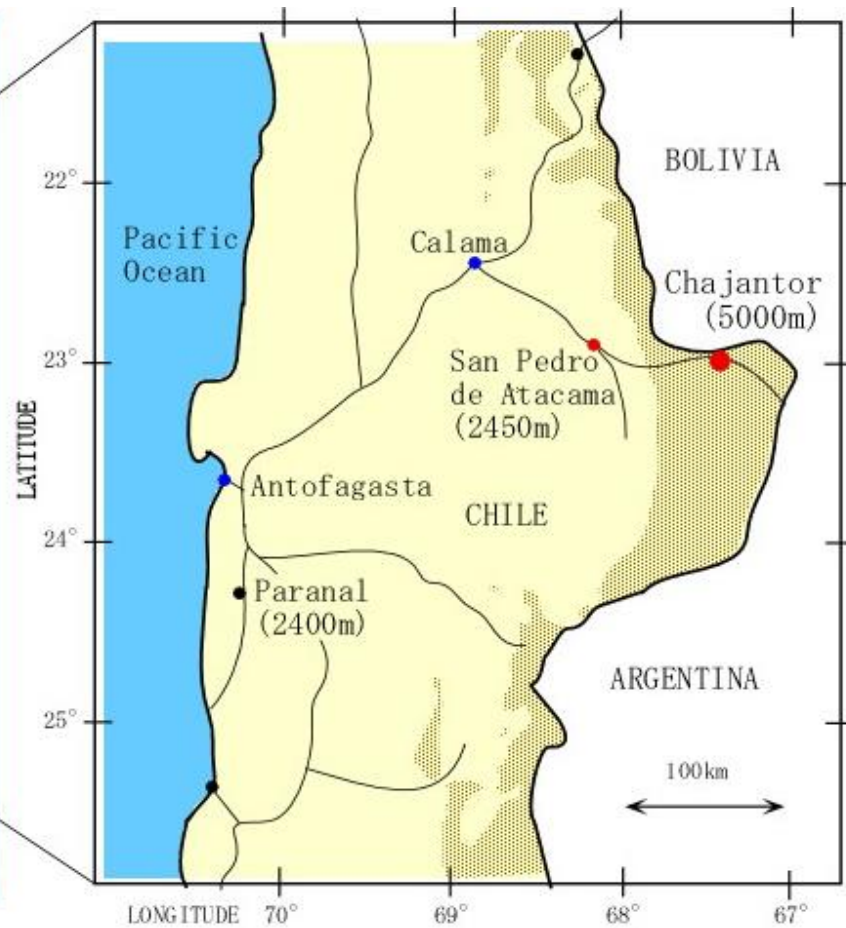
([www.vla.nrao.edu/](http://www.vla.nrao.edu/))

The EVLA provides the following capabilities:

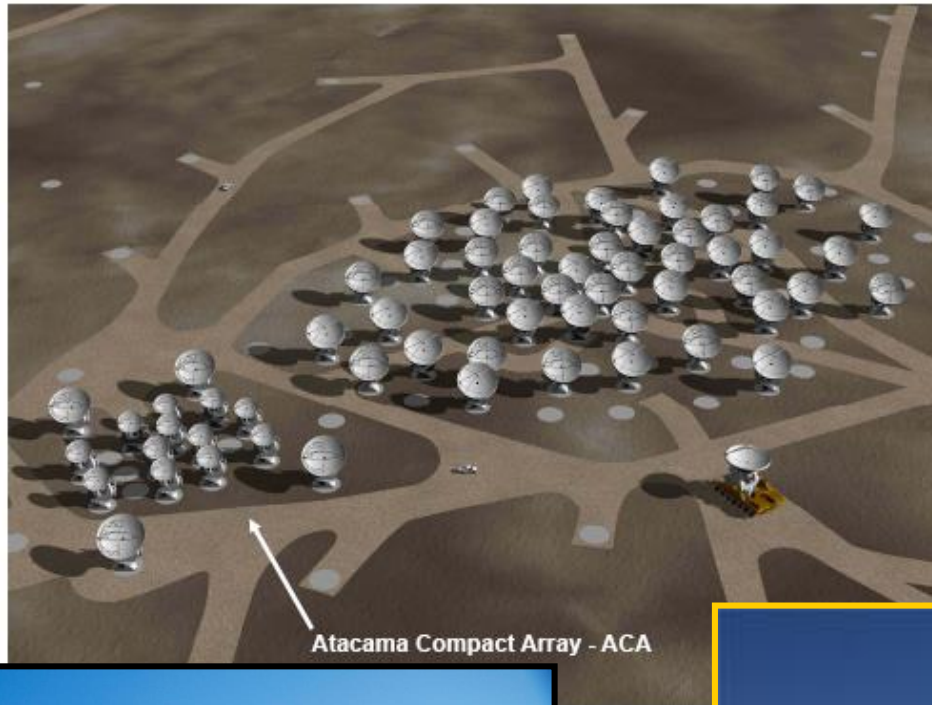
- **Sensitivity:** Continuum sensitivity improvement over the VLA by factors of 5 to 20, to give point-source sensitivity better than 1 microJy between 2 and 40 GHz.
- **Spectral Capability:** Full polarization (8 GHz bandwidth per polarization), with a minimum of 16,384 channels, frequency resolution to 1 Hz.
- **Resolution:** Angular resolution up to  $200 / (\text{frequency in GHz})$  milliarcseconds with tens of Kelvin brightness temperature sensitivity at full resolution.
- **Low-Brightness Capability:** Fast, high fidelity imaging of extended low-brightness emission with tens of arcsecond resolution and microKelvin brightness sensitivity.
- **Operations:** Dynamic scheduling, based on weather, array configuration, and science requirements. "Default" images automatically produced, with all data products archived.



# ALMA site







Atacama Compact Array - ACA

December 2010



April 2011, the first EU antenna

# ALMA timeline

- Mid 2006: European ARC activities begin
- Late 2007: First antennas arrive in Chile
- Late 2008: Two antenna interferometry
- Early 2009: Commissioning and science verification starts
- 2010/2011: Early science (16 ants + 4 rec. bands)
- Late 2013: Full science operations starts

## Operations Support Facility - 2900m



12m and 7m antennas

# All atmospheric windows between 30 and 950 GHz

**Initial priority to band**

**3= 84 to 116 GHz,**

**4= 125 to 169 GHz,**

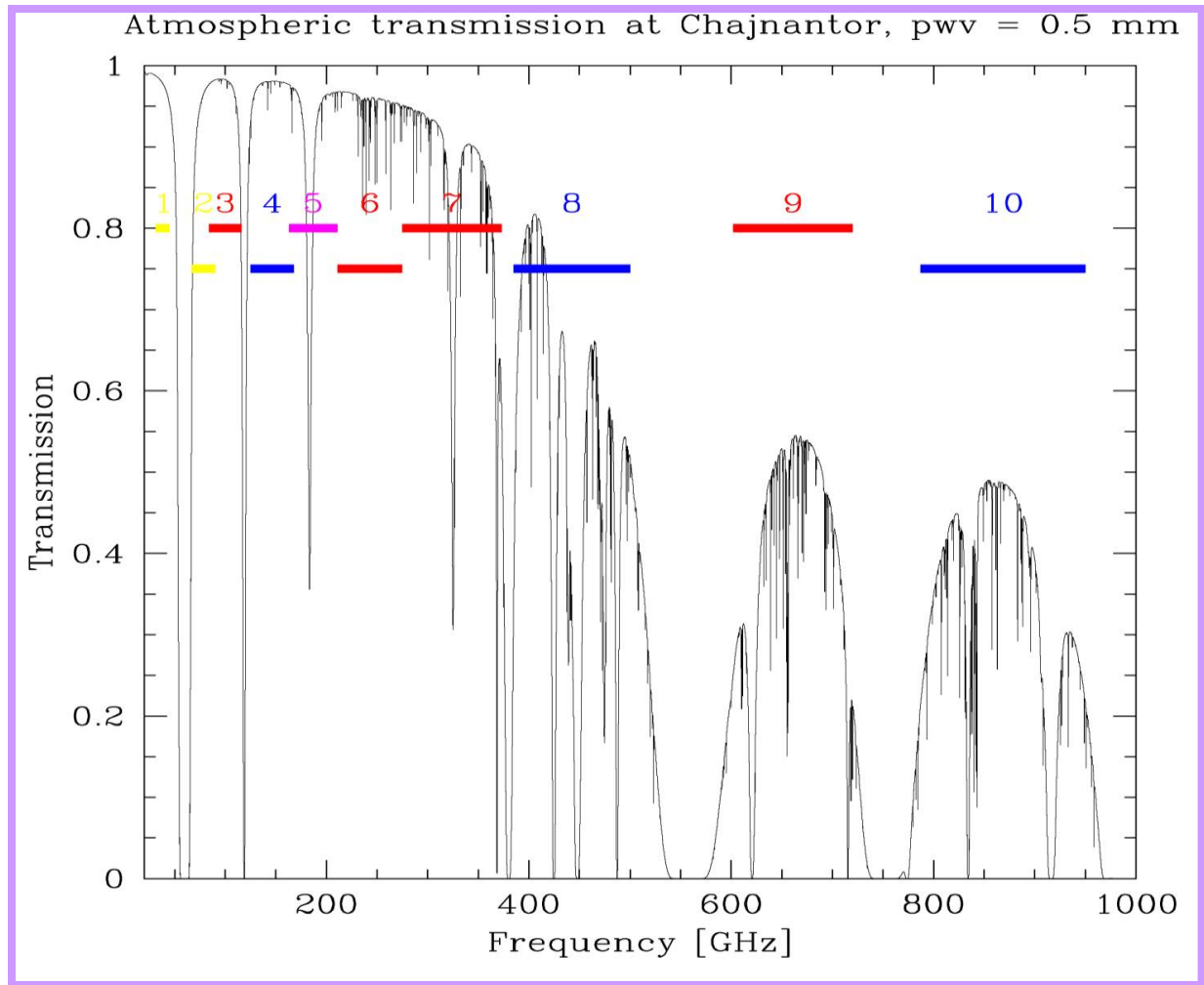
**6= 211 to 275 GHz,**

**7= 275 to 373 GHz,**

**8= 385 to 500 GHz,**

**9= 602 to 720 GHz**

**<0.1 pwv measured  
with APEX**





# ALMA Science Requirements

- High fidelity imaging
- Precise imaging at 0.1 arcsec resolution
- Routine sub-mJy continuum sensitivity
- Routine mK spectral sensitivity
- Wideband frequency coverage
- Wide field imaging mosaicing
- Submillimeter receiver capability
- Full polarization capability
- System flexibility



1. The ability to provide high-quality and high resolution imaging in the millimeter and submillimeter bands to match that of HST and ground-based AO-equipped telescopes
2. Detecting CO and [C II] in a Milky Way galaxy at  $z=3$  in less than 24 hours of observation
3. To map dust emission and gas kinematics in protoplanetary disks

# ALMA

## Imaging molecular material in the vicinity of AGNs

**Map the CO (2-1) line emission in 2 nearby AGN**

(NGC1068, NGC1097)

- Band 6 (220 GHz)
- With a resolution of  $\sim 0.06$  arcsec (corresponding to 5pc at 17Mpc distance)
- Sensitivity sufficient to detect  $T > 20\text{K}$  gas close to AGN with  $\sim S/N \sim 10$
- Total integration time  $\sim 64\text{h}$

# ALMA

## Nuclear Dense Gas in AGN

**Map the HCN line emission in 6 nearby AGN-Starburst Galaxies to identify the excitation source**

(NGC1068, NGC2273, Arp220...)

- Band 6 (265 GHz)
- With a resolution of  $\sim 0.1$  arcsec
- Total integration time  $\sim 96$ h



# ALMA

## Ability to provide high-quality and high resolution imaging

SURVEY: GOODS-N with SCUBA

by Borys et al. 2003; Blake et al. 2006

10x16.5 arcmin

~480 h

~ 30 sources

### With ALMA

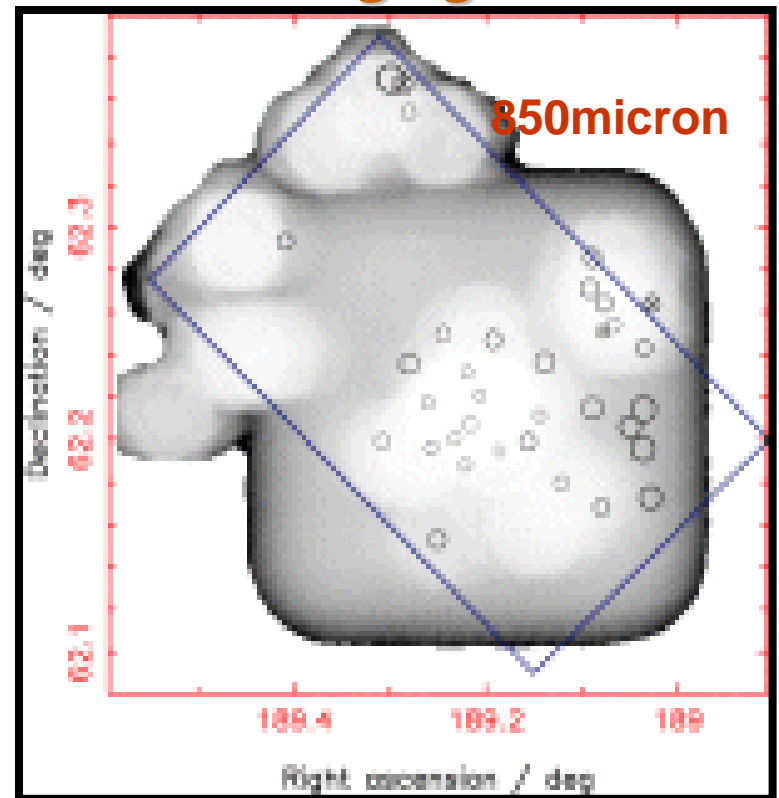
Band 6/7 280GHz

~ (1500 pointings) 900 h

~ 0.1 arcsec resolution

~ noise 0.02 mJy

~ 3000 sources



The grey-scale represents the noise level, which is at the positions of the extracted sources in the range from 0.3 to 4.3 mJy/beam. The circles indicate the positions of the secure sample of 34 counterparts extracted from the sub-mm map.

# ARC - EUROPE

## ESO+Regional nodes

Bonn-Bochum-Cologne (D)

IRAM (Grenoble; F, E)

IRA, Bologna (I)

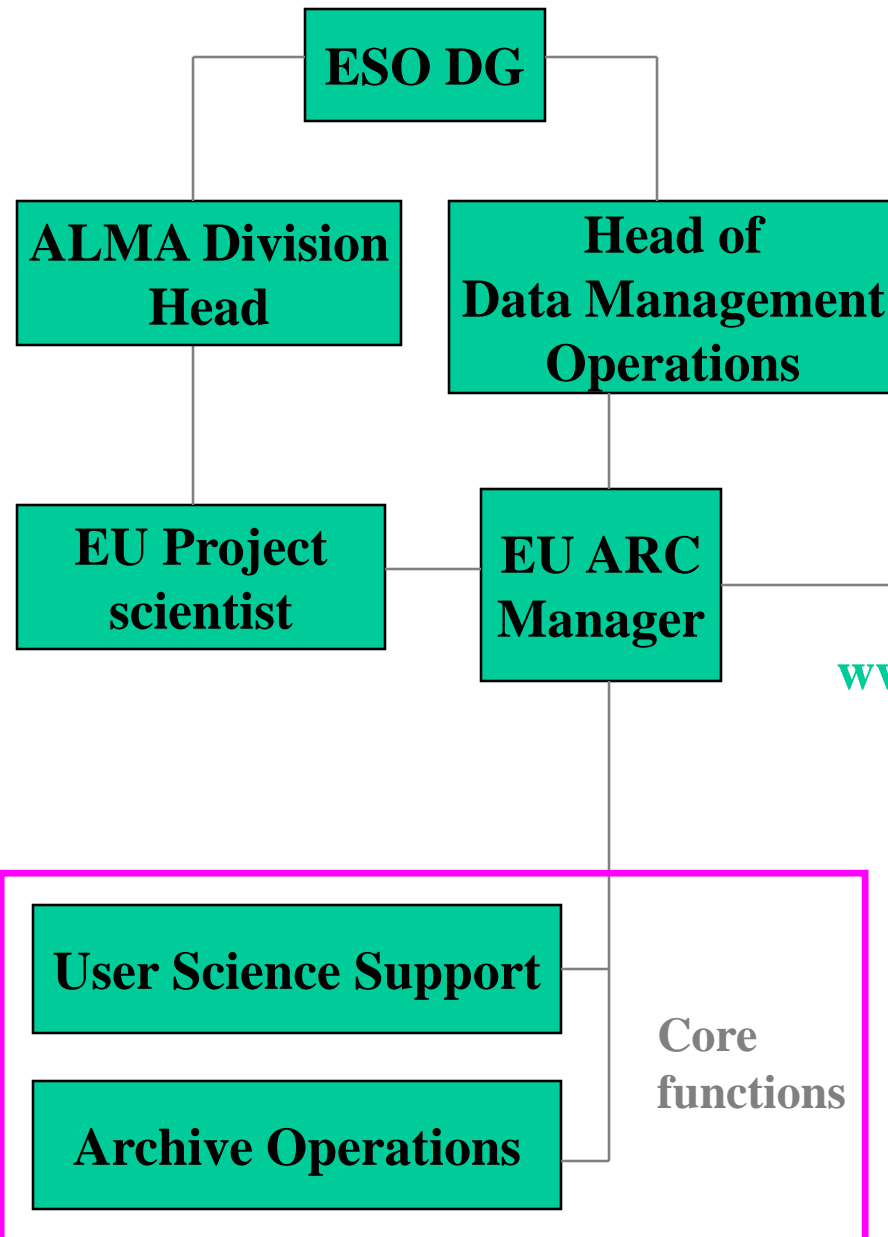
[www.ira.inaf.it/inaf\\_ira/ARC-ALMA.html](http://www.ira.inaf.it/inaf_ira/ARC-ALMA.html)

Leiden (NL)

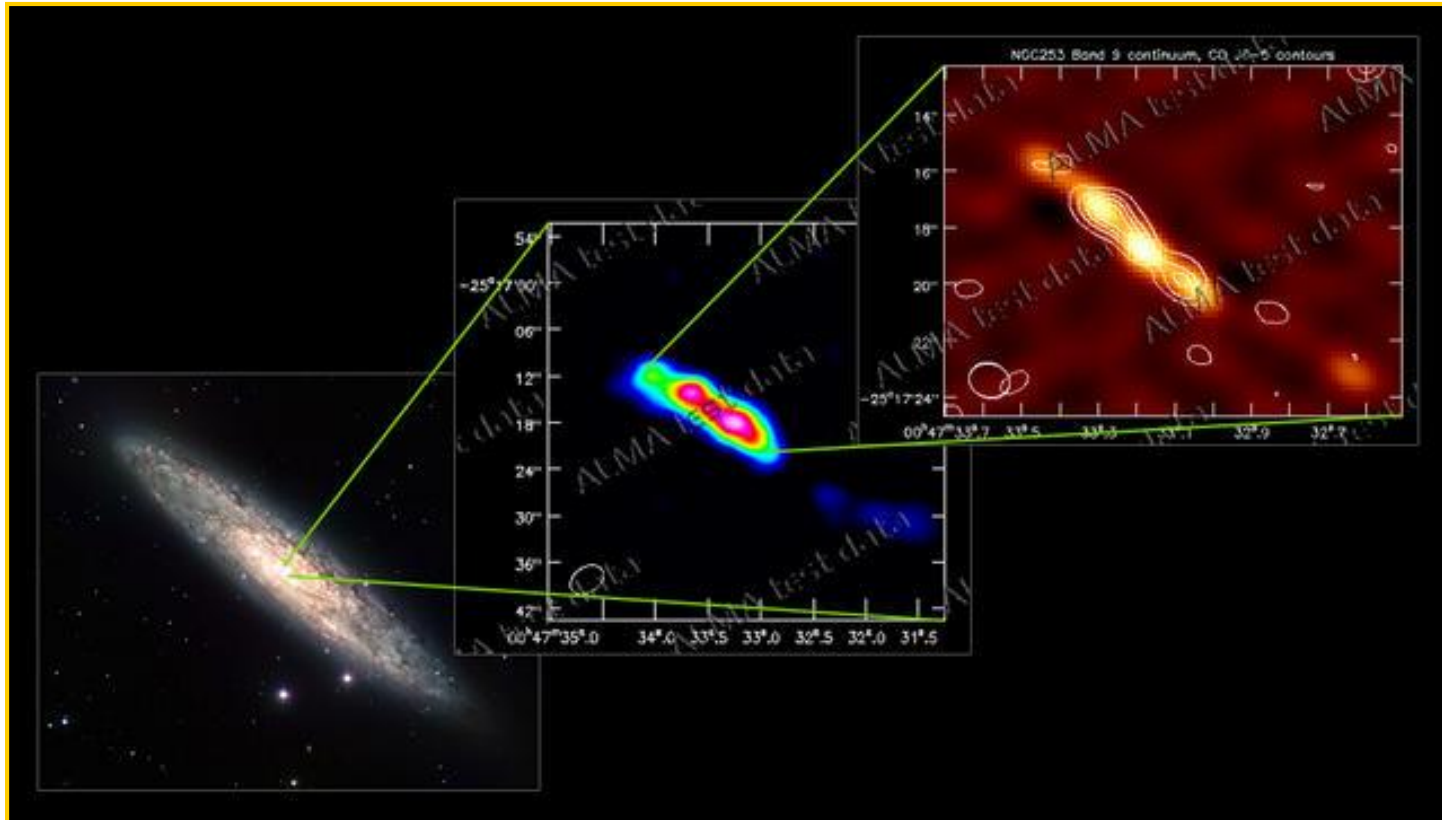
Nordic (Onsala; DK, S, SU)

Manchester (UK)

Lisbon (P); Zürich (CH); Prague (CZ)



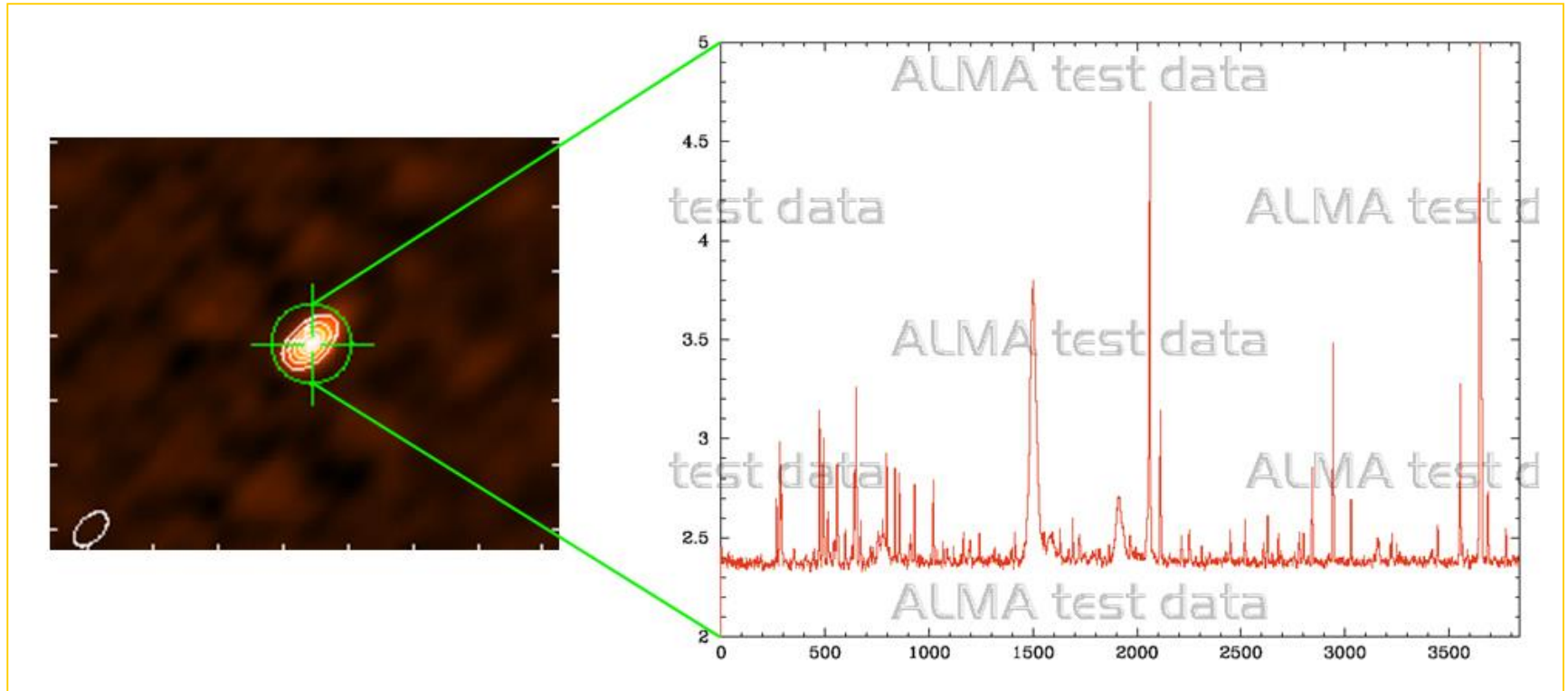
# TEST results (11/2010)



The spiral galaxy NGC253: left: optical image

ALMA test images show dense cloud of gas in the central regions of the galaxy;  
(middle) the CO J=2-1 line at 230 GHz, (right) the continuum and CO J=6-5 at  
690GHz

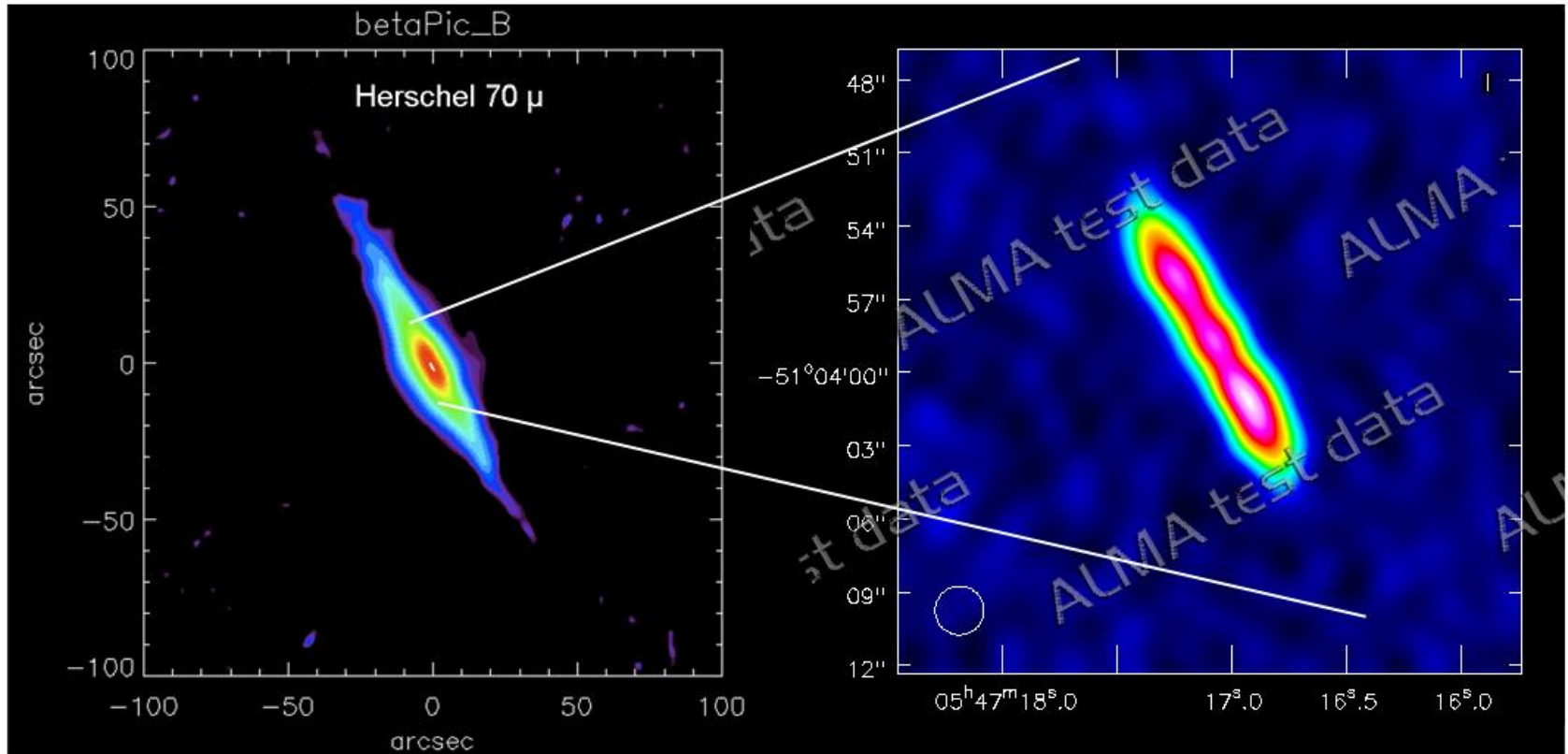
# TEST results (11/2010)



Spectroscopic capabilities of ALMA: Molecular hot core G34.26+0.15, which is unresolved with the short baselines that are presently using, whereas a section of the spectrum near 100 GHz shows a “forest” of molecular lines.

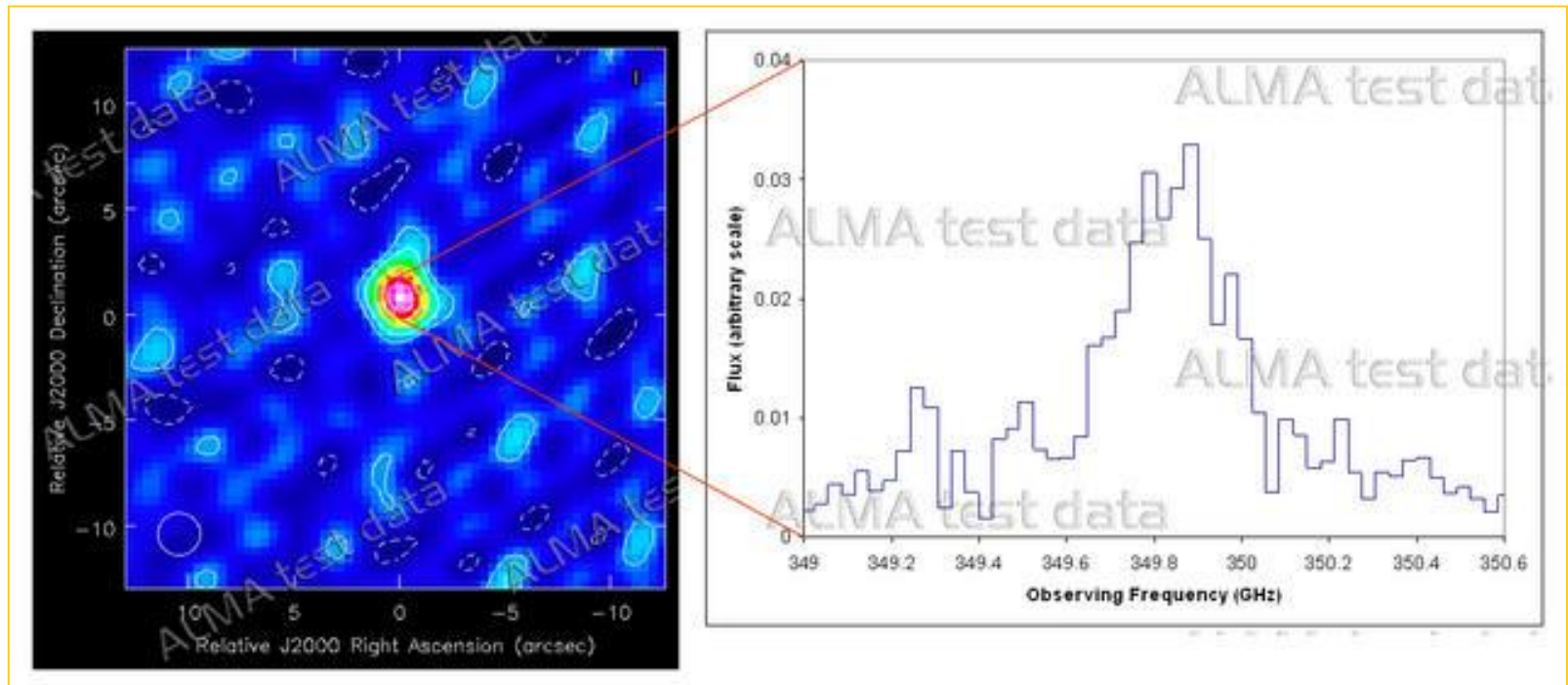


# TEST results (11/2010)



The emission from the disk of dust surrounding the star Beta-Pictoris.(left) image at 70 microns from Herschel, (right) ALMA test data at 870 microns showing the denser material in the central region.

# TEST results (11/2010)



Quasar BRI 0952-0115 at  $z=4.43$

The object is again unresolved on short baselines, but the 158 micron line from ionized C is clearly detected with only 1 hour observing time.

# LOFAR ([www.lofar.org](http://www.lofar.org))

LOFAR observes at radio-frequencies 10 - 240 MHz. The core is in Dutch.

LOFAR is a sensor platform not only for astronomers but also for geophysicists and agricultural scientists; there are seismic geophones, bio-sensors and weather instruments.

In Europe, groups at universities and research institutes in Germany, France, Sweden and the UK have been participating in defining and refining the science program.



# LOFAR

The simple antennas (about 15000) are arranged in clusters that are spread out over an area 350 km in diameter.

The sites for the approximately 45 separately situated antenna stations, each of approximately 4 hectares, were placed along the 5 imaginary arms radiating from the central core, and were selected on the basis of the technical requirements set by LOFAR and the local situations.

The key science projects are:

Epoch of reionisation

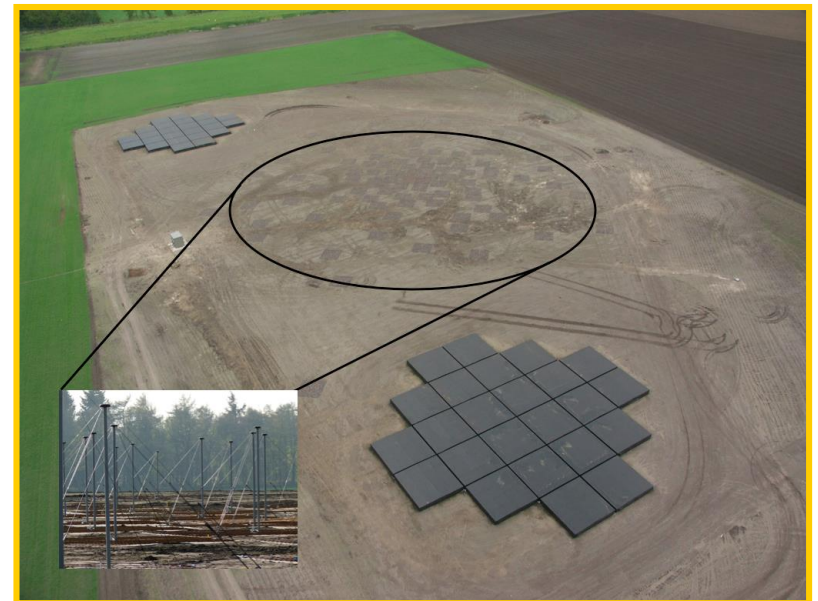
Deep extragalactic surveys

Transient sources

Ultra high energy cosmic rays

Solar science and space weather

Cosmic magnetism



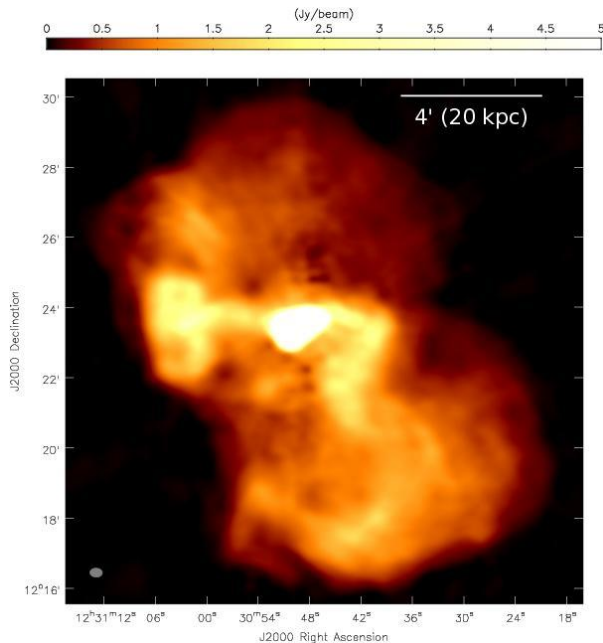
A LOFAR station with the low band Antennas in the inset



# LOFAR

International LOFAR stations:

Chilboton in UK - Jülich, Potsdam, Tautenburg, Effelsberg and Garching in Germany - Nancay in France - Onsala in Sweden -



Effelsberg Station

M87 observed at 140 MHz, noise  
20mJy/beam, beam = 21x15 arcsec

de Gasperin et al. 2012, A&A 547, A56

# Square Kilometre Array – SKA

(to be built by 2024)

Frequency range: 70 MHz and 10 GHz

Angular resolution:  $<0.1$  arcsec

Spectral (frequency) channels: 16384 per band per baseline

Final processed data output; 10 GB/second



Members: Australia, Canada, China, Germany, Italy, Netherlands, New Zealand, South Africa, Sweden, UK

# Australia and ASKAP precursor

**Australia will host the SKA's survey telescope and its low frequency aperture array antennas.**

As part of SKA Phase one, Australia's existing 36 dish ASKAP survey telescope will be expanded out to 96 dishes (Survey Telescope). Equipped with phased array feed (PAF) technology, this element of the SKA will be able to survey large areas of the sky in great detail.

In Phase one, Australia will host several hundred thousand smaller 'dipole' antennas (each about a metre in height) which will intercept low frequency radio waves. This array will be expanded to several million antennas in Phase two (Low frequency aperture array).



Four of new ASKAP antennas at the Murchison Radio-astronomy Observatory

# South Africa and the MeerKAT precursor

**In SKA Phase one, the addition of 190 SKA dish antennas will expand the 64-dish MeerKAT precursor array. South Africa and eight African partner countries will host the dish array in Phase two of the SKA and will also host the Phase two mid frequency aperture array antennas.**

South Africa's SKA Project is building the MeerKAT telescope, located at the SKA site. MeerKAT will be incorporated into Phase one of the SKA.

The MeerKAT telescope will comprise 64 offset Gregorian dishes each 13.5 m in diameter. The first seven dishes of MeerKAT are now complete and are known as KAT-7.



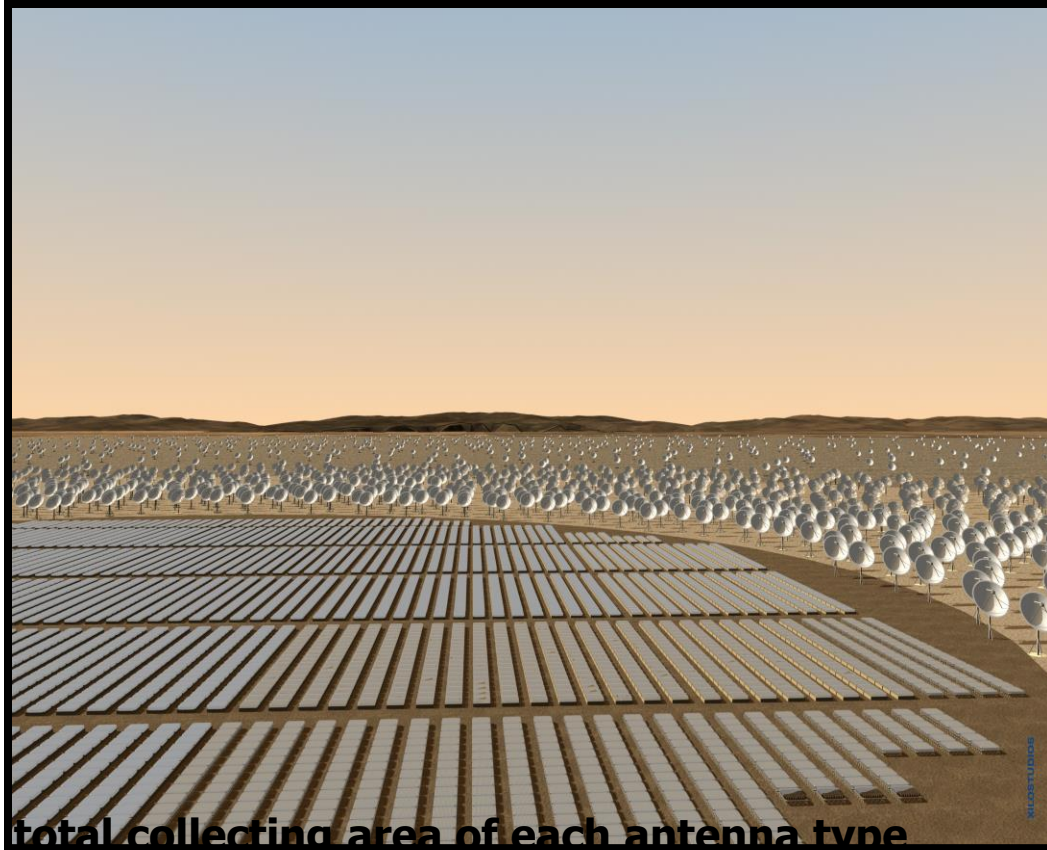
The first 7 dishes at the SKA site.



The Square Kilometre Array



# SKA



- **50% of the total collecting area of each antenna type concentrated in 3 central cores each 5 km in diameter**
- **Maximum baselines at least 3000 km from the central core region**
- **50 times the sensitivity and 1000 times the survey speed of current imaging instruments**
- **Life span of at least 50 years**

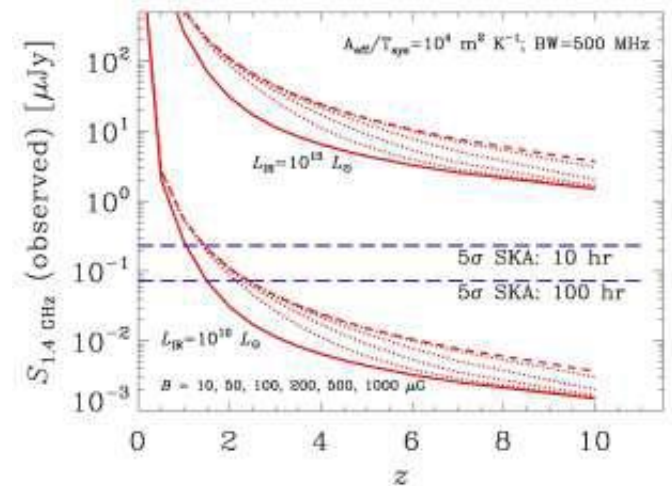


# SKA

The SKA will detect synchrotron emission from Milky Way-type galaxies at redshifts of  $z \leq 1.5$  and their polarized emission to  $z \leq 0.5$  (assuming 10% polarization).

Bright starburst galaxies could be observed at larger redshifts, but are not expected to host ordered or regular fields. Total synchrotron emission, signature of total magnetic fields, could be detected with the SKA out to large redshifts for starburst galaxies, depending on luminosity and magnetic field strength.

The SKA will be able to detect  $1 \mu\text{Jy}$  sources and measure about 104 RMs per square degree at 1.4 GHz within 12 h integration time. The SKA Magnetism Key Science Project plans to observe an all-sky RM grid with 1 h integration per field (Gaensler et al. 2004) which should contain about 20 000 RMs from pulsars in the Milky Way with a mean spacing of  $30'$  and several 100 extragalactic pulsars.



Total synchrotron emission at 1.4 GHz as a function of redshift  $z$ , total magnetic field strength  $B$  and total infrared luminosity  $L_{\text{IR}}$ . The  $5\sigma$  detection limits for 10 h and 100 h integration time with the SKA are also shown (Murphy 2009).

# Sardinia Radio Telescope (SRT)

([srtproject.ca.astro.it/welcome](http://srtproject.ca.astro.it/welcome))



SRT

64m diameter

Frequency range: 0.3 to 100 GHz



Commissioning starting feb. 2012

(2011)

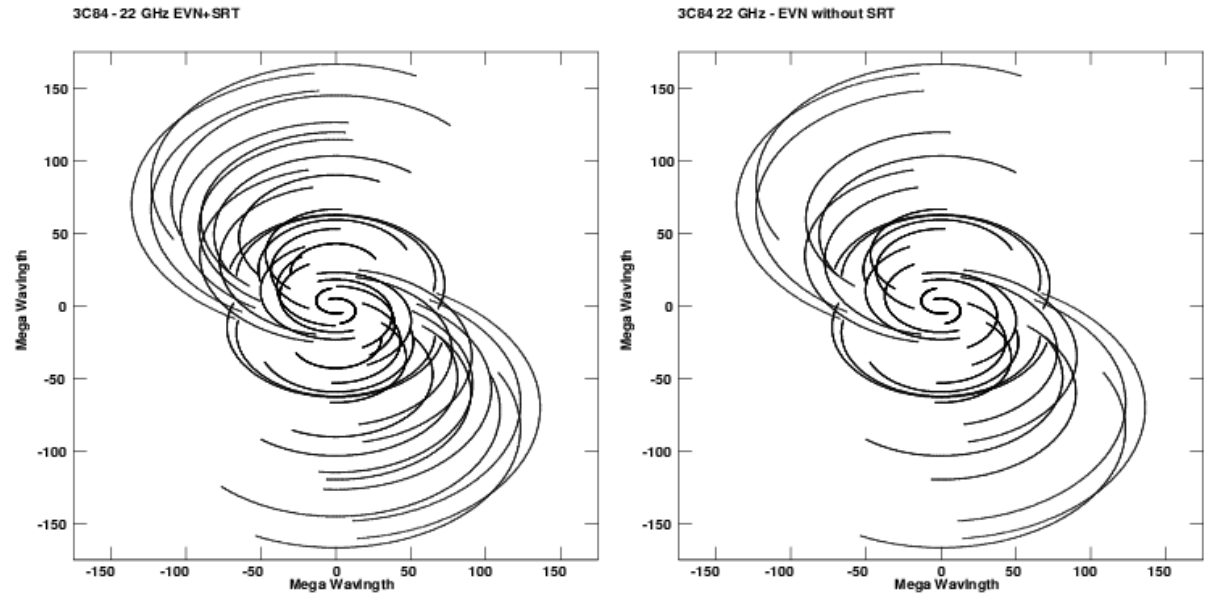


# SRT: new receiver



New generation Low Noise Amplifier using monolithic technology: 18 - 26 GHz cryogenic multifeed system.

# SRT: VLBI



u-v coverage with SRT (left) and without SRT (right) in the European VLBI network for a simulated observation of 3C84.