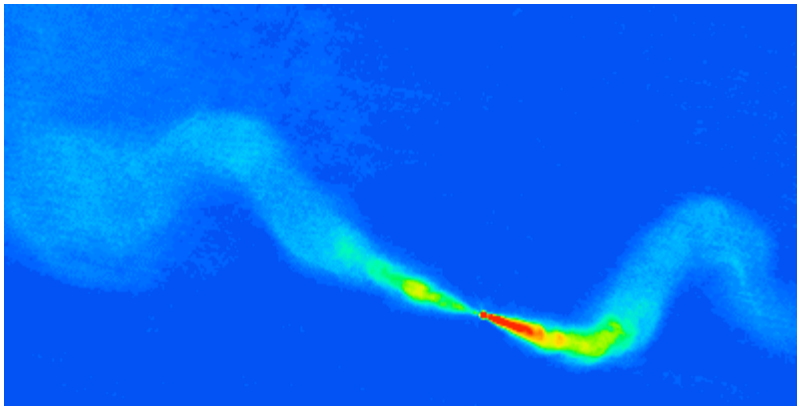
Interferometry at metre and centimetre wavelengths: the next five years

Robert Laing



Overview

- New and upgraded metre and centimetre-wavelength arrays becoming available ~2010.
- Arrays (not comprehensive):

  cm-wave: EVLA and e-MERLIN

  metre-wave: LOFAR
- Technology
- Survey science
- Complementarity with ALMA

Common themes: cm wavelengths

- Receivers are approaching quantum limits; antennas and site development are expensive.

  Increase the bandwidth for continuum observations (noise level is proportional to $\Delta\nu^{-1/2}$). Optical fibres + digital electronics..

- Observe many spectral lines (often redshifted)

  Continuous frequency coverage

- High frequency resolution, wide-field imaging and the need to get rid of interference.

  Many spectral channels; flexible frequency configuration (now possible with modern correlators and data-processing)

- Improvement of image fidelity for continuum imaging

  Multifrequency synthesis

Very Large Array – current status

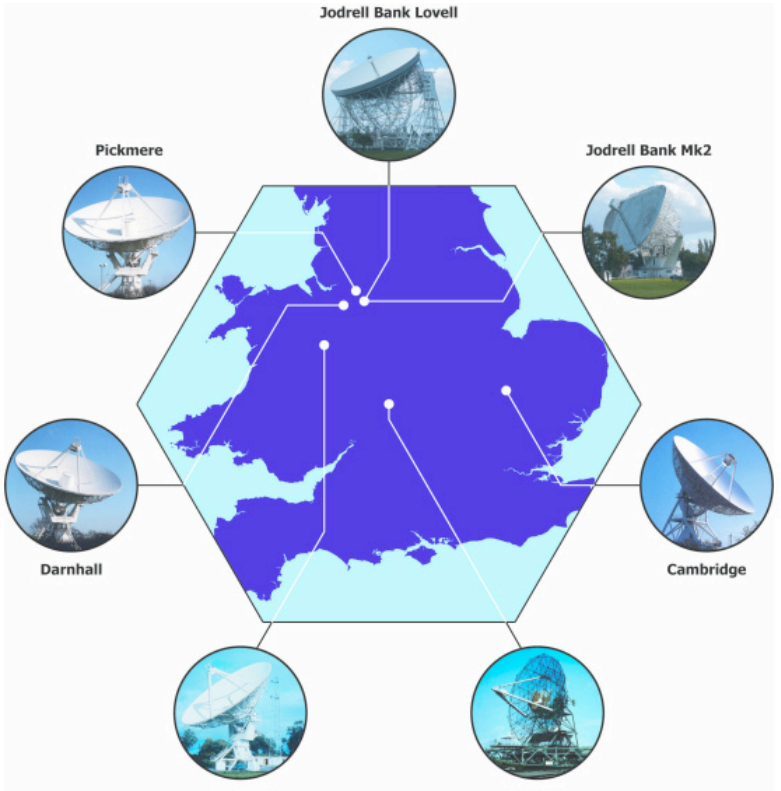
- Operated by NRAO
- 27 x 25m antennas, Socorro, New Mexico
- Maximum baseline 35km; 4 configurations
- 7 frequency bands in range 74MHz – 43GHz
- Maximum continuum bandwidth 100 MHz

EVLA technology

- Continuous frequency coverage 1.0 – 50 GHz
- 8 GHz bandwidth with full polarization
- New receivers
- 1μJy continuum sensitivity in 12 hours at 2 – 40 GHz (factor of 5 – 20 improvement)
- 1 Hz frequency resolution; 16382 channels, 128 independently-tunable sub-bands
- Dynamic scheduling
- [EVLA Phase 2 – more antennas and longer baselines]

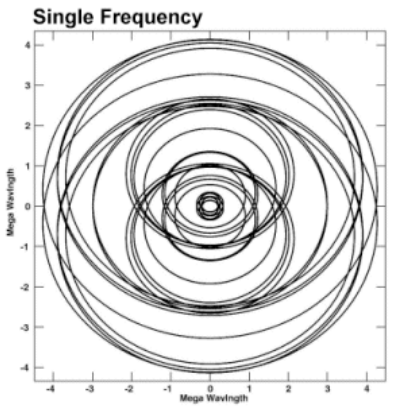
MERLIN

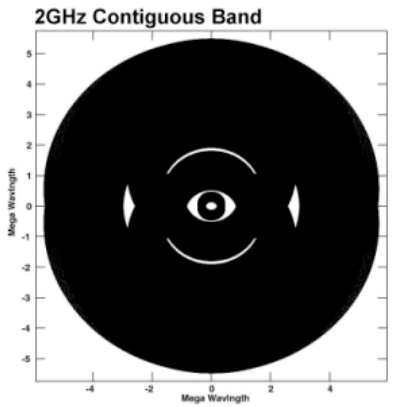
- United Kingdom, University of Manchester/PPARC
- 6/7 antennas up to 76m diameter
- Maximum baseline 217km (resolution 0.15 arcsec at 1.5 GHz - 0.01 arcsec at 22 GHz)
- Maximum bandwidth 16 MHz

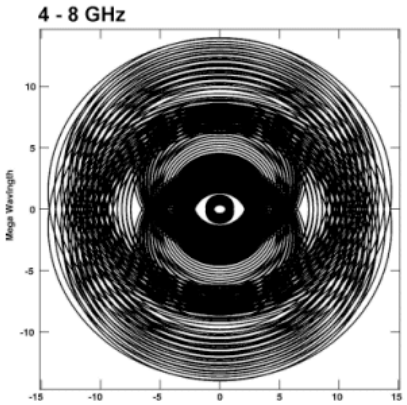


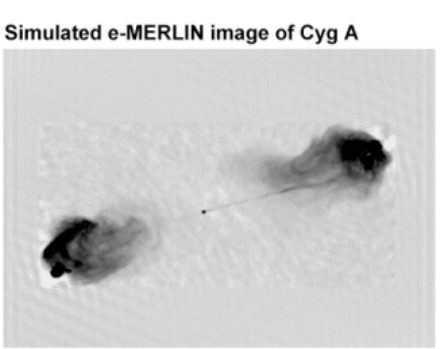
e-MERLIN technology

- 2 GHz bandwidth for full polarization
- 1.3 – 1.8, 4 – 8 and 22 – 24 GHz
- 1.4μJy rms in 12 hours at 5 GHz
- New correlator
- Multi-frequency synthesis





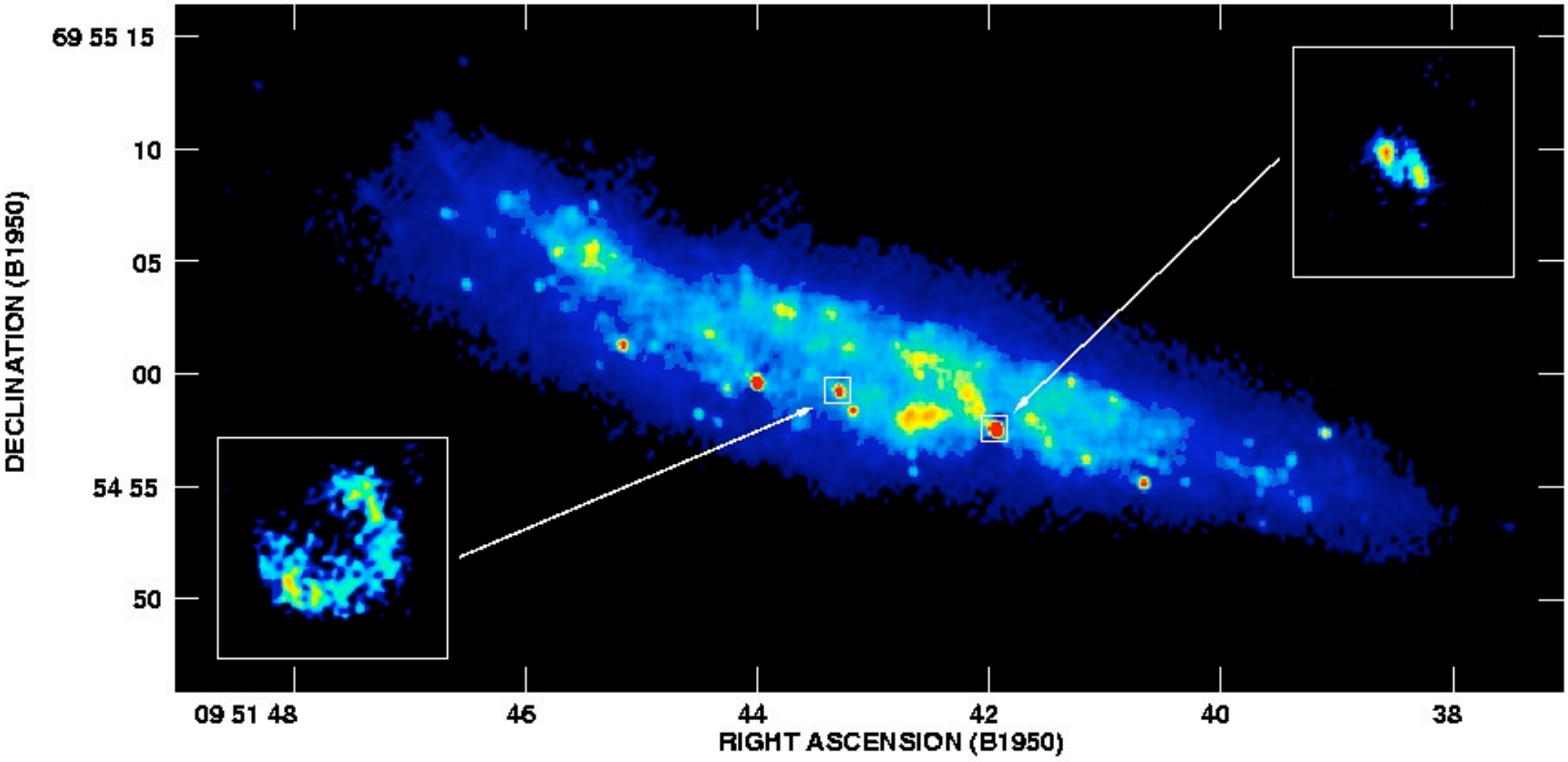




Complementarity

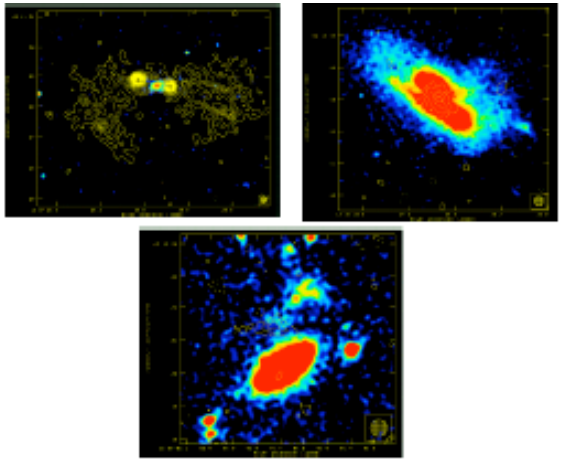
- ALMA - dust continuum, molecular line emission, SZ, …
- m/cm wavelength arrays – synchrotron and coherent emission, free-free emission and absorption; atomic hydrogen, OH, H_20, NH_3, …
- Ionized/relativistic vs cold, neutral gas
- Magnetic fields from synchrotron polarization and Faraday rotation vs scattering by aligned dust grains
- Continuity in frequency for redshifted lines, optically thick synchrotron radiation, different transitions for the same molecular species, …
- Comparable resolution

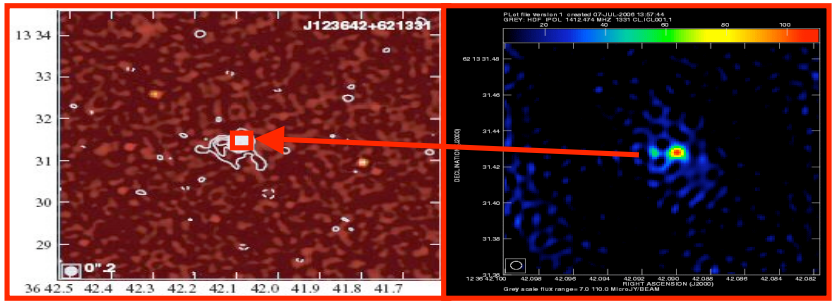
Starburst galaxy M82



MERLIN+VLA detect individual supernova remnants; VLBI resolves
ALMA will study dust and molecular lines

Wide-field imaging of faint radio sources





AGN, starbursts or both?

HST optical

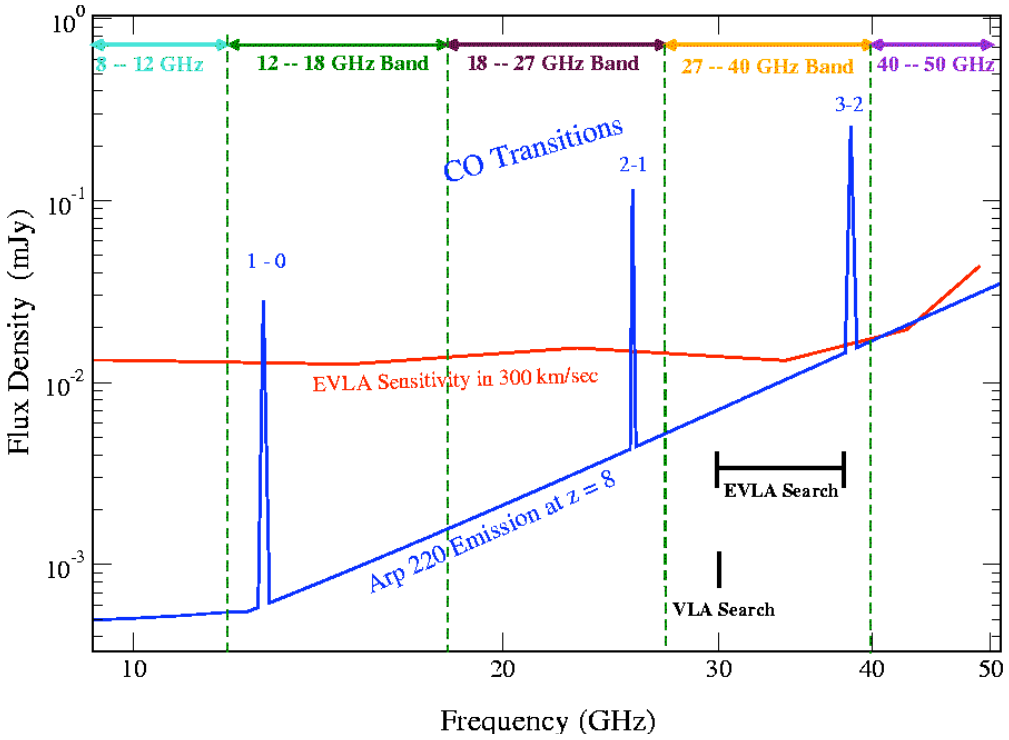
MERLIN + VLA
(Muxlow et al.)

VLBI
Garrett et al.

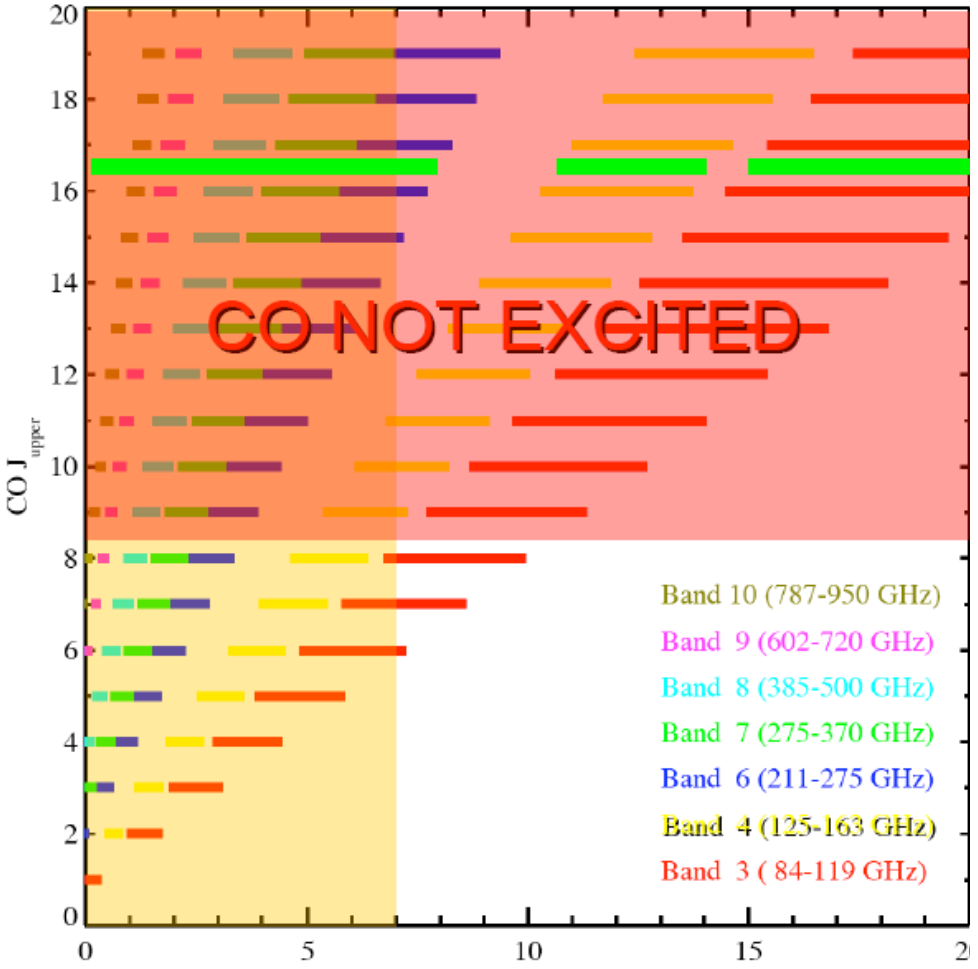
eMERLIN, EVLA and eVLBI will image >1000 starburst/AGN sources to 4μJy in a single field.

Search for redshifted CO

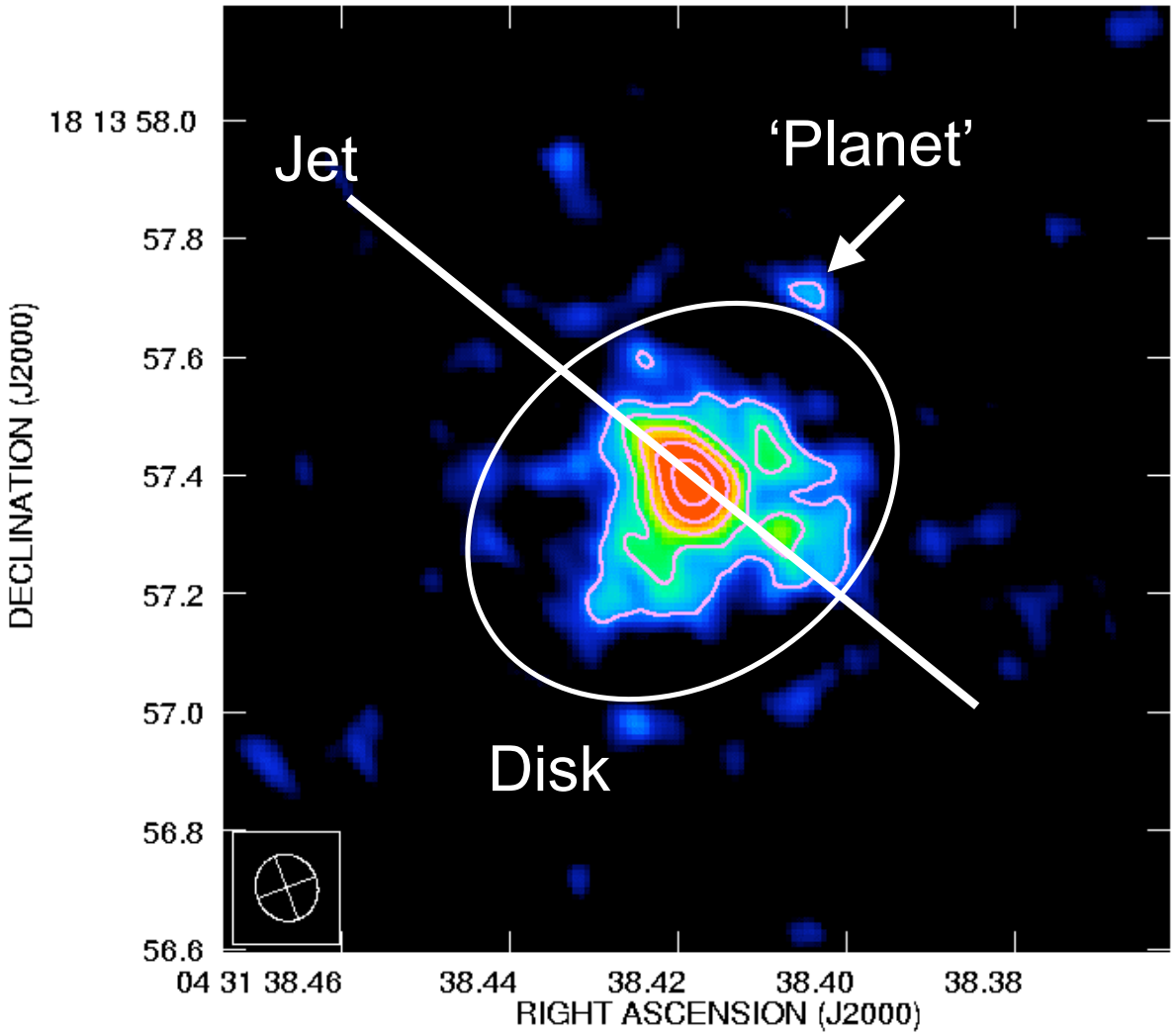
Arp 220 at z = 8 (R. Perley)



ALMA CO and CII (F. Walter)



HL Tau



Greaves, Richards, Muxlow, Rice

22 GHz VLA+Pie Town

Need sub-mm – cm images to separate jet, dust and pebble emission.

ALMA can measure proper motion

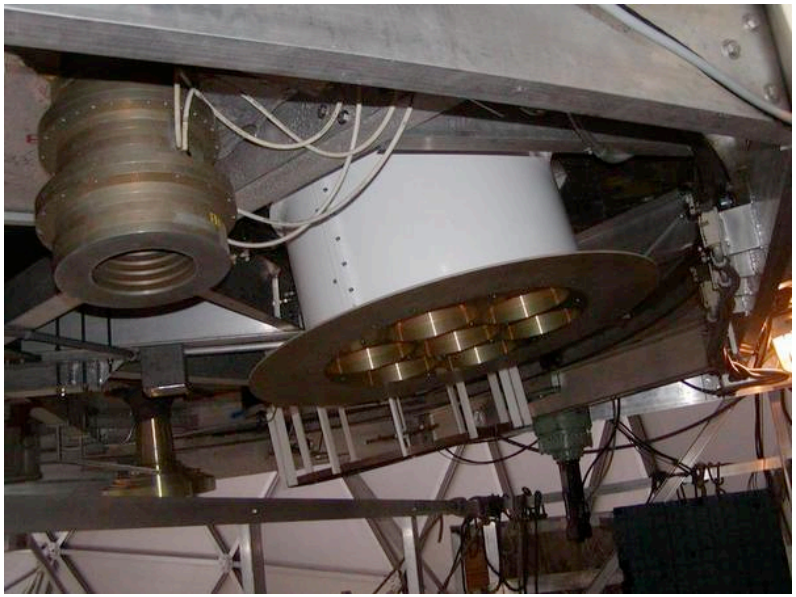
Other cm-wave developments

- eVLBI – broad band, near-real-time correlation and wide field
- Allen Telescope Array (SETI, 0.5 – 11 GHz, 350 6m dishes)
- Focal-plane arrays
  - HI multibeam surveys (HIPASS, HIJASS, ALFA)
  - Continuum (OCRA)
- Phased arrays
- Square Kilometre Array pathfinders
  - (Meer)KAT
  - ASKAP

Allen Telescope Array

Arecibo

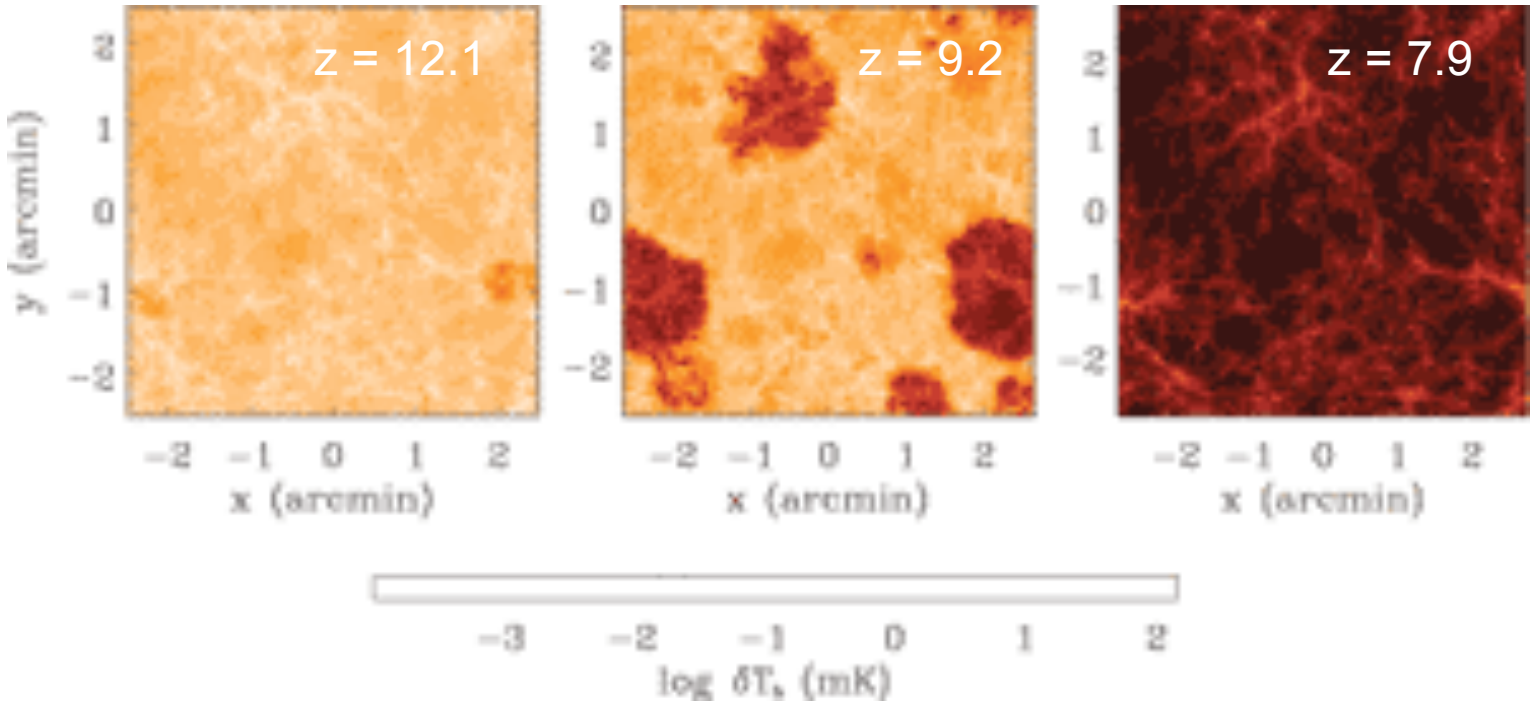
ALFA



Long-wavelength science (λ > 1m)

- Steep-spectrum synchrotron emission from low-energy (aged) electrons
  - Dying radio sources, cluster halos and relics
  - Energy input into the intracluster medium
  - Distant radio galaxies with highly redshifted spectra
- Surveys, selection by isotropic emission
- Particle acceleration, propagation effects and turbulence in the ISM
- Absorption processes
- Coherent emission
- Cosmic rays
- Epoch of reionization, observed via redshifted neutral hydrogen. Entirely new field – a main science driver for LOFAR.

HI and the epoch of reionization



Simulation (Furlanetto et al.): bright = neutral; dark = ionized)

Three stages: global signal (what is the redshift?)
power spectrum (what is the structure?)
imaging reionization

ALMA will observe the first galaxies; low-frequency arrays will

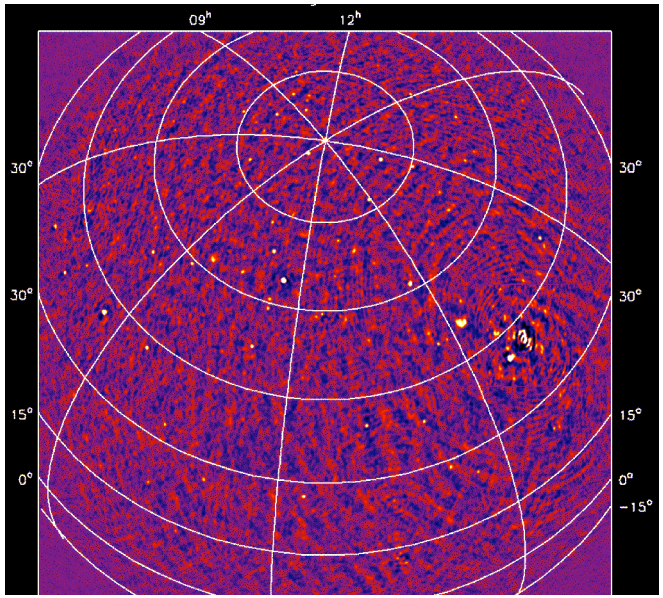
LOFAR et al.

- Under construction in the Netherlands
- 10 – 90 and 110 – 240 MHz. Two types of antenna, optimized for low and high frequency bands, excluding FM
- Large collecting area – designed for Epoch of reionization science. Core + extended array (>400 km)
- Design sensitivity 3.0 mJy at 10 MHz / 0.03 mJy at 200 MHz
- Phased array stations capable of producing one or more beams
- First images with a few stations
- Operational ~2009
- Also Long Wavelength Array (New Mexico); Mileura Widefield Array (Australia)

LOFAR

Low frequency

High frequency



First LOFAR image

Summary

- Major new centimetre and metre-wavelength facilities will become operational over the next few years.
- Most of them have significant wide-field and survey capabilities
- Big improvements in sensitivity, spectral flexibility and frequency range
- Complementary to ALMA