Dwarf Galaxies NGC1569 and NGC4449 at WSRT-92 cm

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Magnetic Fields in Galaxies

- Two mechanisms can explain the transport of magnetic fields produced in galaxies into the ICM/IGM
  - Jets and radio lobes emerging from powerful radio galaxies
  - **Galactic winds from star-forming galaxies**

Can Starburst Dwarfs Magnetize the IGM?

- Description of models by Kronberg et al (1999) and high-resolution simulations of galaxy formation Bertone et al. (2006) say YES.
- The two prime arguments for dwarf galaxies as agents (in competition with AGNs) are:
  - Large number, predicted in ΛCDM cosmology, and observed as well
  - Shallow gravitational potentials, rendering outflows of hot gas and relativistic plasma feasible

Synchrotron Halos Around Dwarf Galaxies

- Hard to detect at cm wavelengths
- Characterized by a break at some frequency ν_b
- In low frequencies, one should detect the flatter low-frequency part of the spectrum, hence find non-thermal halos wrapped around

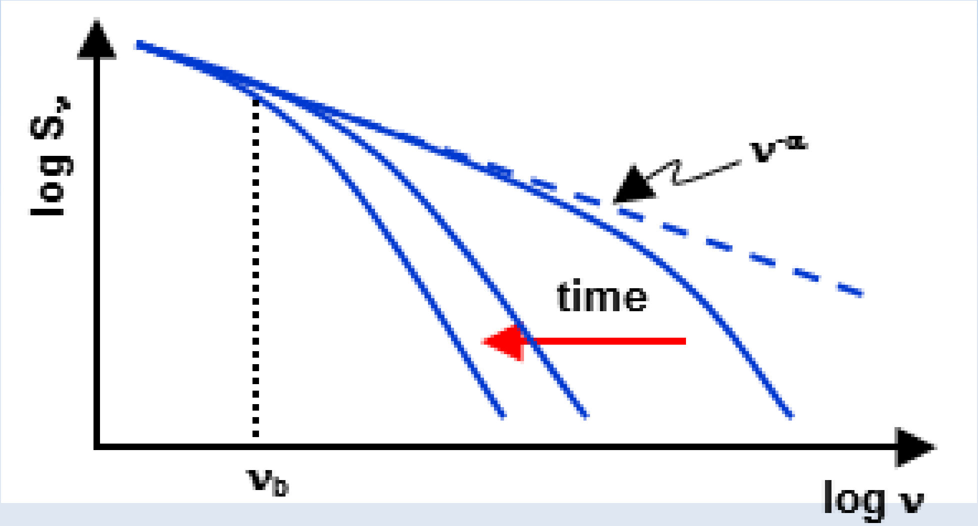
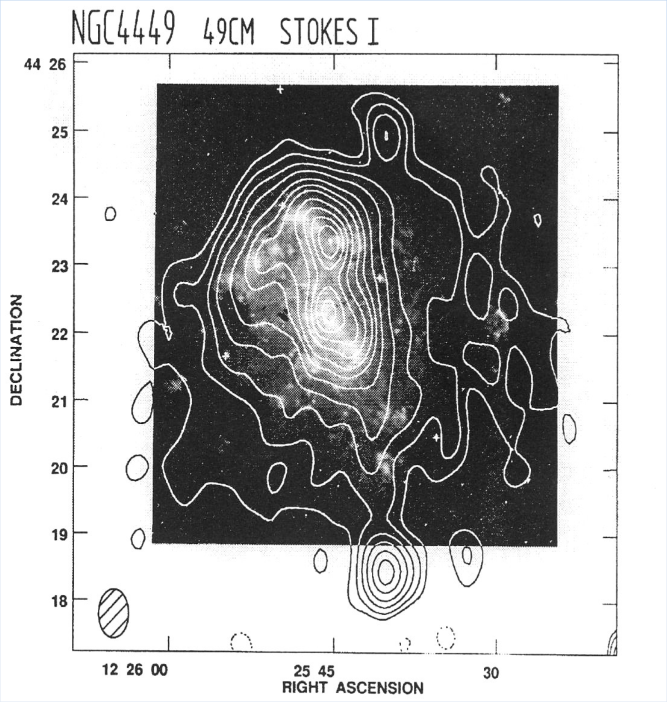
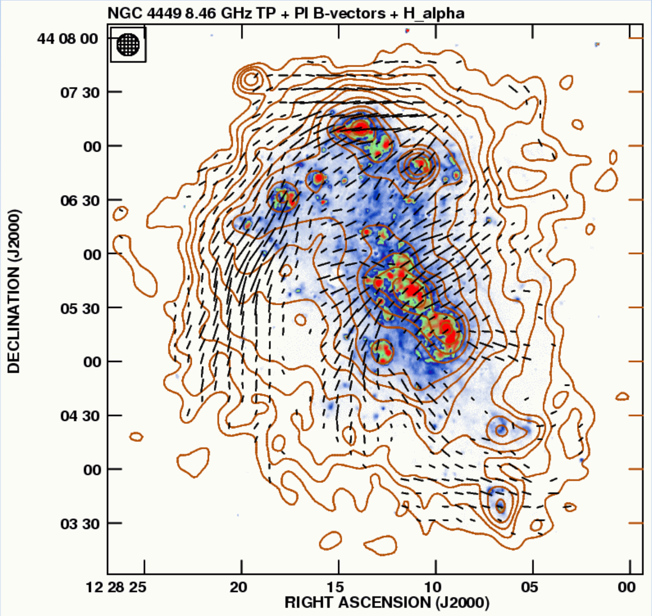


Fig. 3: Sketch of the time evolution of a radio synchrotron spectrum.

The First Detection of a Synchrotron Halo: NGC4449



Total radio emission of NGC 4449 at 610 MHz, superimposed onto Hα (Klein et al. 1996)



Total radio emission of NGC 4449 at 8 GHz, and orientation of the magnetic field; the coloured image is Hα (Chyży et al. 2000)

Why choose these two targets?

- Sufficiently nearby:
  - NGC1569 → 3.36 ± 0.20 Mpc (Grocholski et al. 2008)
  - NGC4449 → 3.7 Mpc
- NGC1569 is a post-starburst dwarf, with a complex star formation history. The youngest starburst is likely to have ceased ~ 5 Myr ago (Grocholski et al. 2008, Angeretti et al. 2005, Greggio et al. 1998, Israel & de Bruyn 1988). NGC4449 has a strong ongoing starburst.
- Bright in the radio continuum, hence, observations possible, with good sensitivity and resolution using the WSRT

Observations with the WSRT

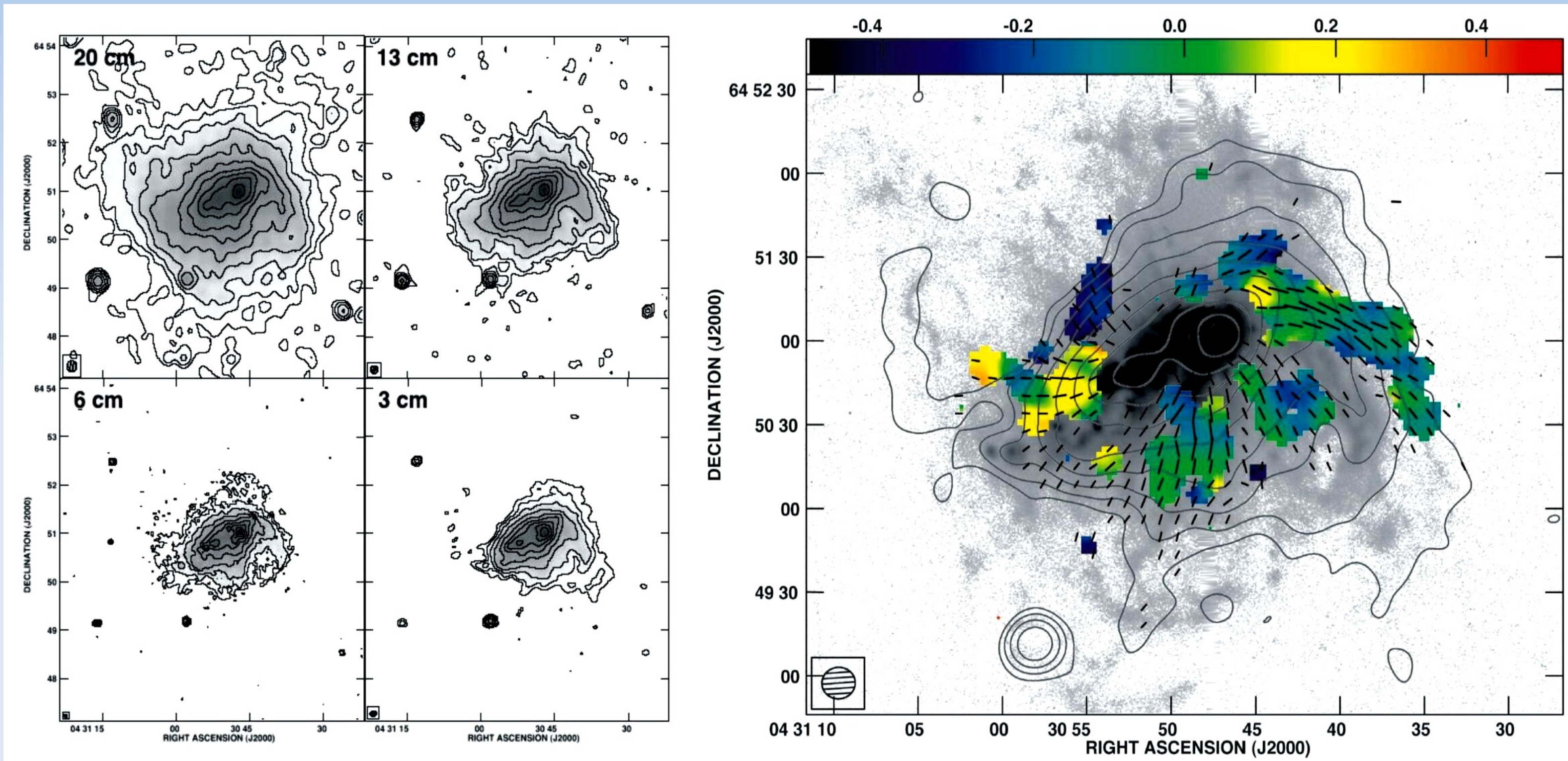
NGC1569
13 Nov 2010
92 cm, 350 MHz
12 hour run, maxi-short config
128 channels, 4 polarisations, 8 bands, 10Mhz bandwith
Calibrators: 3C48, 3C286 (both unpolarised at this frequency!). Obtained polarized calibrator DA240 from an observation 5 days later.

NGC4449
15 May 2011
92 cm, 350 MHz
12 hour run, maxi-short config
128 channels, 4 polarisations, 8 bands, 10Mhz bandwith
Calibrators: 3C147, DA240

NGC1569: Previous work

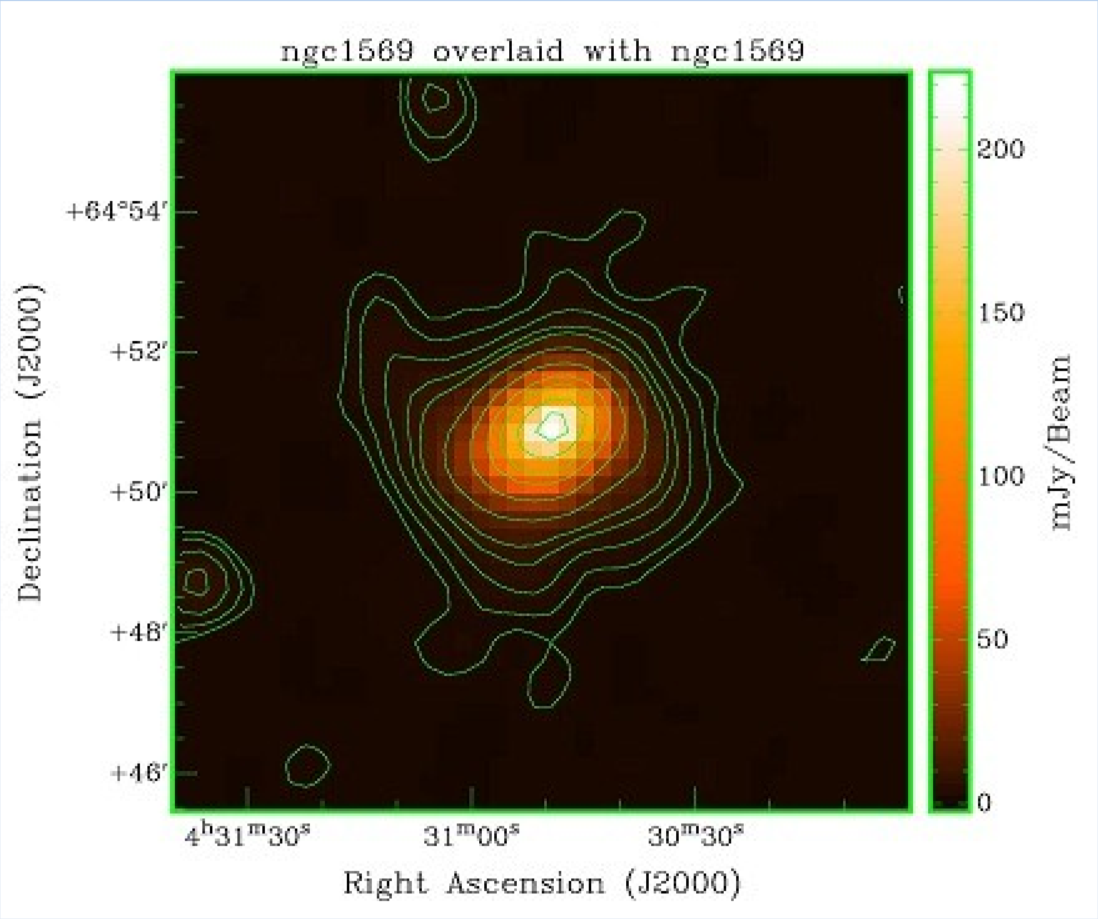
- The transport of a relativistic plasma out of this post-starburst galaxy was suggested by two observations (Mühle 2003):
  - NGC1569 has a radio halo, extending out to about 2 kpc at 20 cm
  - The projected orientation of its magnetic field is radial throughout

NGC1569: Previous work



Radio images of NGC1569. Left: Continuum maps at four wavelengths (VLA, WSRT). At 20 cm, the first contour is at 50 μJy/b.a. Right: Magnetic field structure obtained at 3.6 cm (VLA), along with the rotation measure (colour wedge in units of 10^3 rad m−2), superimposed onto an Hα image (from Kepley et al. 2010).

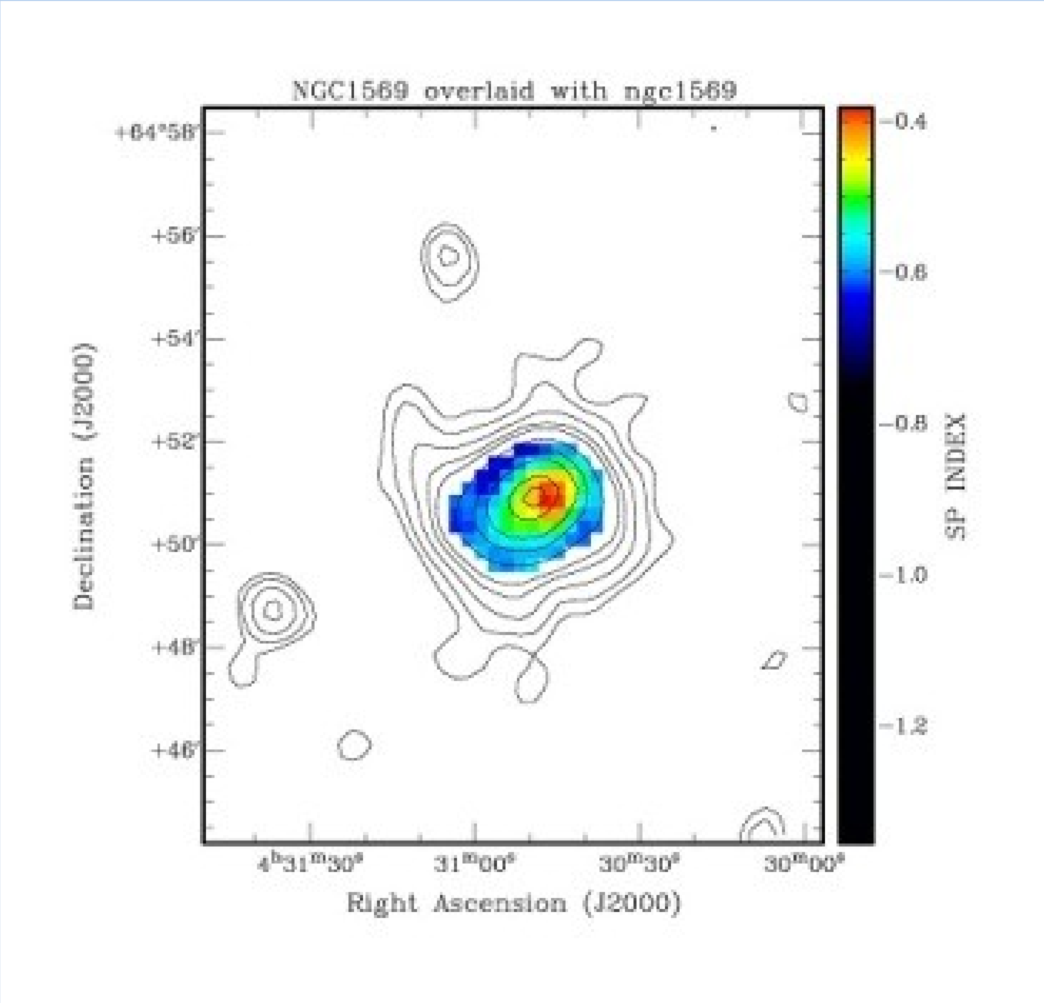
Results so far: NGC1569



Radio Continuum image of NGC1569 at 92 cm (WSRT).

- RMS in the image is ~ 0.3 mJy/beam.
- The first contour is at 1 mJy.
- “boxy” structure, which is reminiscent of the morphology seen in X-rays and Hα.
- The extent of the radio halo is approx 6 kpc, at 20 it was 4.4 kpc
- Western Hα arm not visible anymore

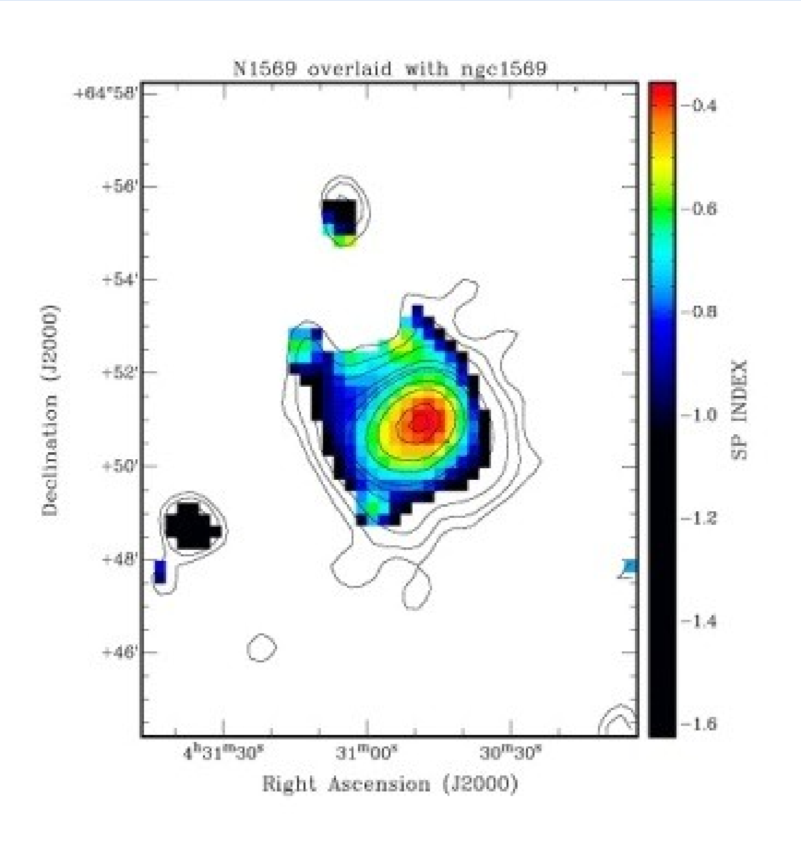
Results so far: NGC1569



Spectral index map between
92 cm and 20 cm

Artifacts in the 20 cm map caused problems

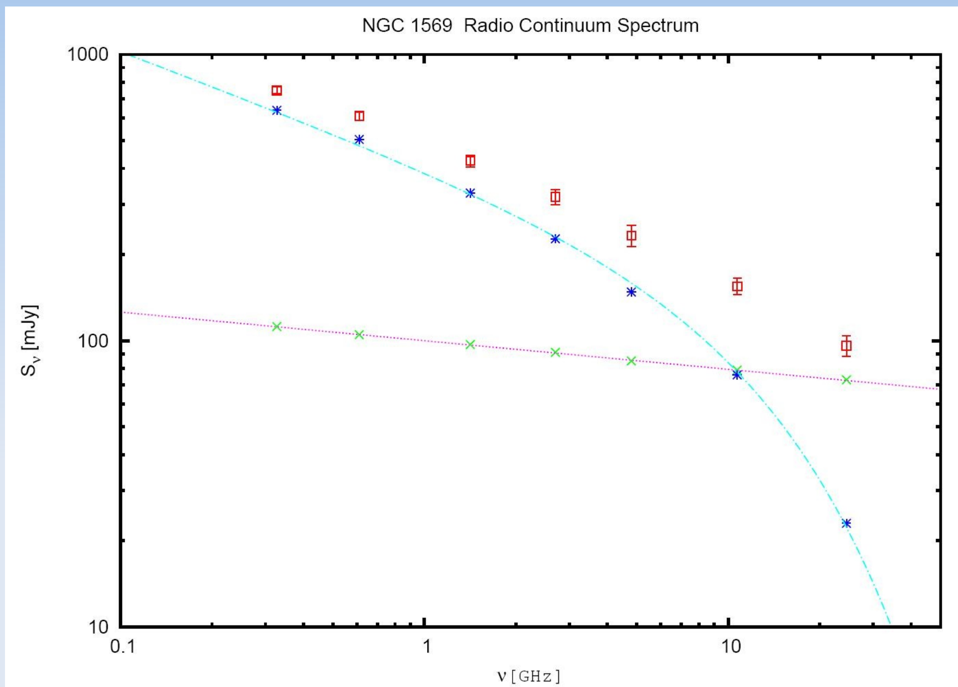
Results so far: NGC1569



Spectral index map between 92 cm and 6 cm

- Spectral indices in the galactic disk are close to thermal
- As one moves along the minor axis of the galaxy, away from the disk, the spectral indices become steeper, reaching a value of around -1 at the southern edge

Integrated Radio Continuum Spectrum



Integrated radio continuum spectrum of NGC1569, with the most reliable data culled from the literature, and the new measurement at 327 MHz included. Shown are the total flux densities (red squares), the free-free radiation (green crosses), and the synchrotron fluxes (blue stars), the latter obtained by subtracting the thermal from the total fluxes.

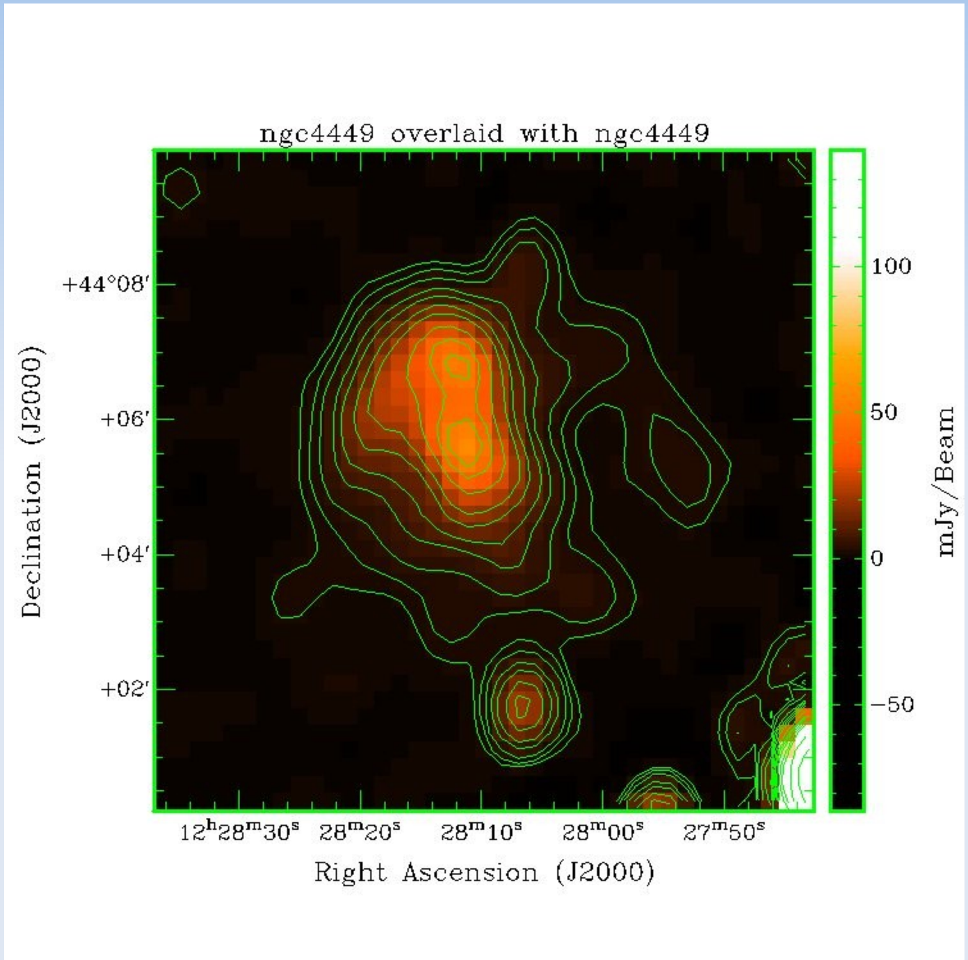
Thermal (free-free) flux density of 100 mJy at 1 GHz (Lisenfeld et al. 2004).

The blue line superimposed onto the nonthermal flux densities represents the function

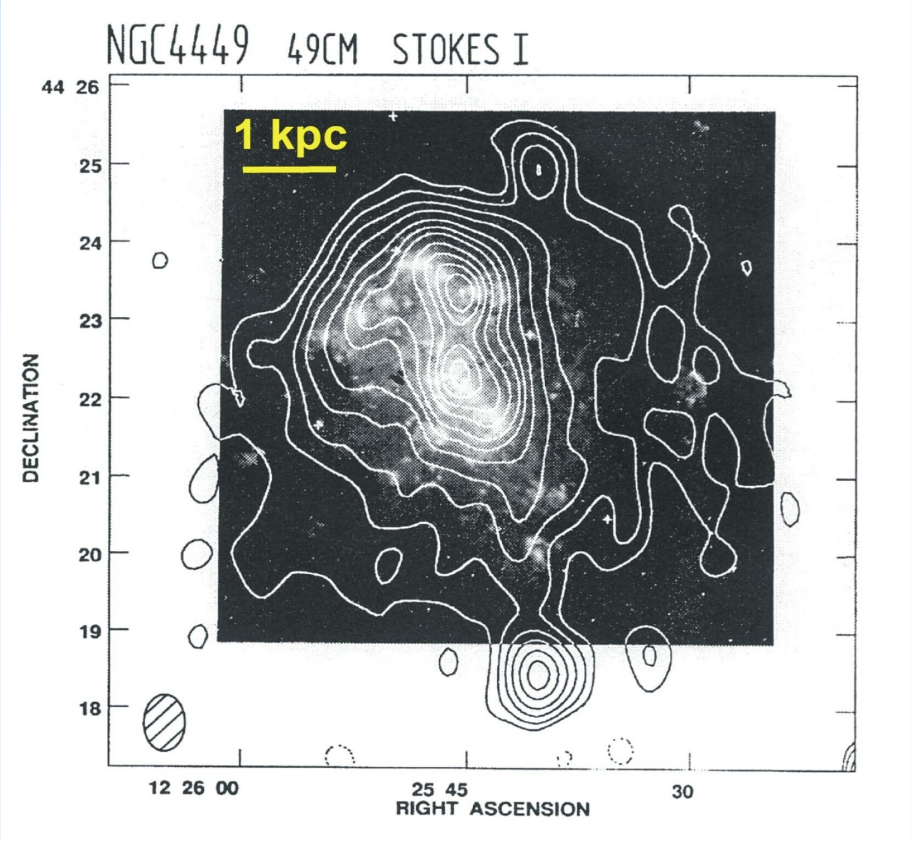
$$S_\nu = S_{nth} \cdot \left(\frac{\nu}{\nu_b}\right)^{\alpha_{nth}} \cdot e^{-\left(\frac{\nu}{\nu_b}\right)}$$

where ν_b = 15 GHz is the break frequency beyond which the spectrum drops off exponentially. The low-frequency spectrum is defined by the nonthermal spectral index α_{nth} = -0.4. The spectral break, which had also been found in earlier studies, is evident.

Results so far: NGC4449



Total radio emission of NGC4449 at 350 MHz. RMS in the image is ~0.5 mJy/beam. First contour is at 1.5 mJy/beam.



Total radio emission of NGC4449 at 610 MHz, superimposed onto Hα (Klein et al. 1996)

Polarisation and Magnetic Fields

- Calibration done on CASA – polarization leakage solution (D-term) and polarization angle (X-term) obtained for the source for each frequency channel (128x8)
- Initial RM Synthesis on NGC1569 gave disappointing results, but......
- Trying out better calibration techniques. Patience please!

Goals in Brief

Bridging the gap between the higher frequencies and future observations with LOFAR:

- Size of the synchrotron halos → find the relativistic particles
- Spectral index as a function of galacto-centric distance → ages of the relativistic particles.
- Perform a rotation-measure analysis → magnetic field structure around the dwarf galaxy → RM Synthesis

Thank you for listening!