Nearby Galaxies with LOFAR

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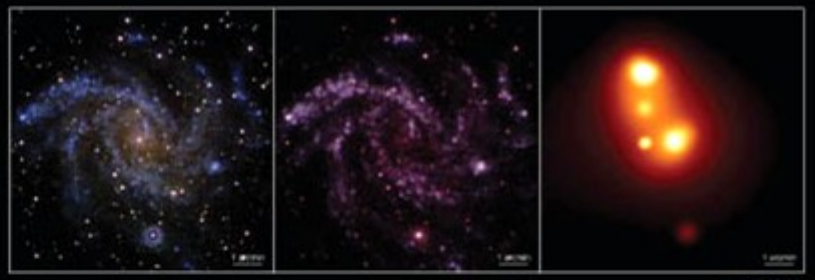
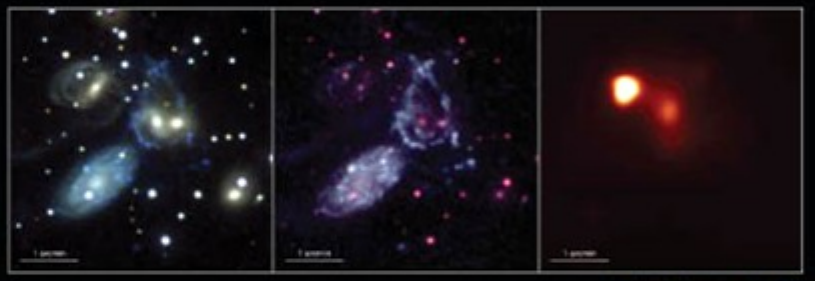




NASA

Cosmic rays propagation, sizes of galaxies

$$t_{1/2} = 1.59 \cdot 10^9 \cdot \frac{B^{1/2}}{B^2 + B_{cmb}^2} \left[\left(\frac{\nu}{\mathrm{GHz}} \right) (1+z) \right]^{-1/2}$$

$$B_{cmb} = 3.25\,(1+z)^2\,\mu\mathrm{G}$$

$$v_A = 2.2 \cdot \left(\frac{B}{\mu} \right) \left(\frac{n_e}{cm^{-} } \right)^{\cdot} \; km\,s^{-}$$

VLA 5 GHz

Outer disk: B=10 μG, n_e=0.01 cm^{-3}

→ t ≈ 23 Myr - loss time of cosmic-ray electrons

v_A ≈ 220 km/s - Alfvén speed, propagation speed of CR

L ≈ 5 kpc

LOFAR 50 MHz

Halo, IGM: B=3 μG, n_e=0.001 cm^{-3}

→ t ≈ 1.4 Gyr - lifetime of cosmic-ray electrons

v_A ≈ 210 km/s - Alfvén speed

L ≈ 300 kpc

IC losses → e can travel L≈ 200 kpc

Galaxies are expected to be immense at low frequencies!

How their sizes depend on the galaxy type, SFR, mass?

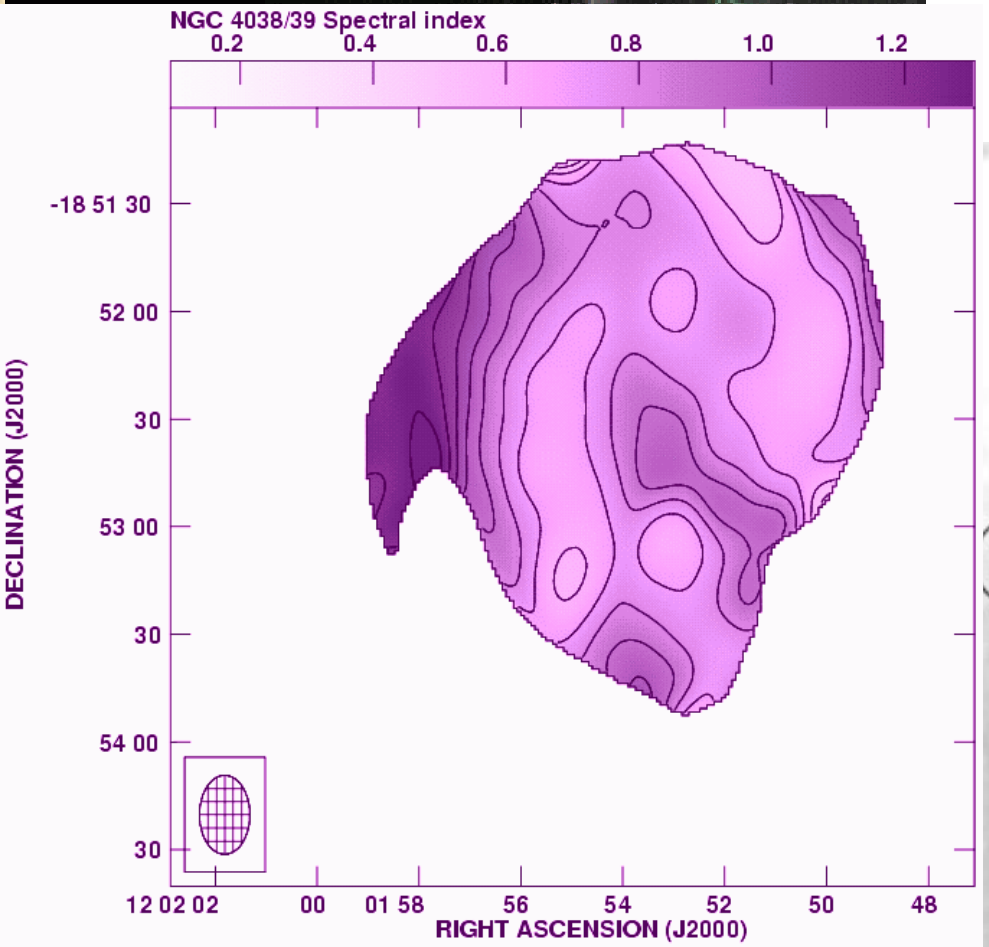
CRs can reveal events from the galactic past, merges, periods of SF activity.

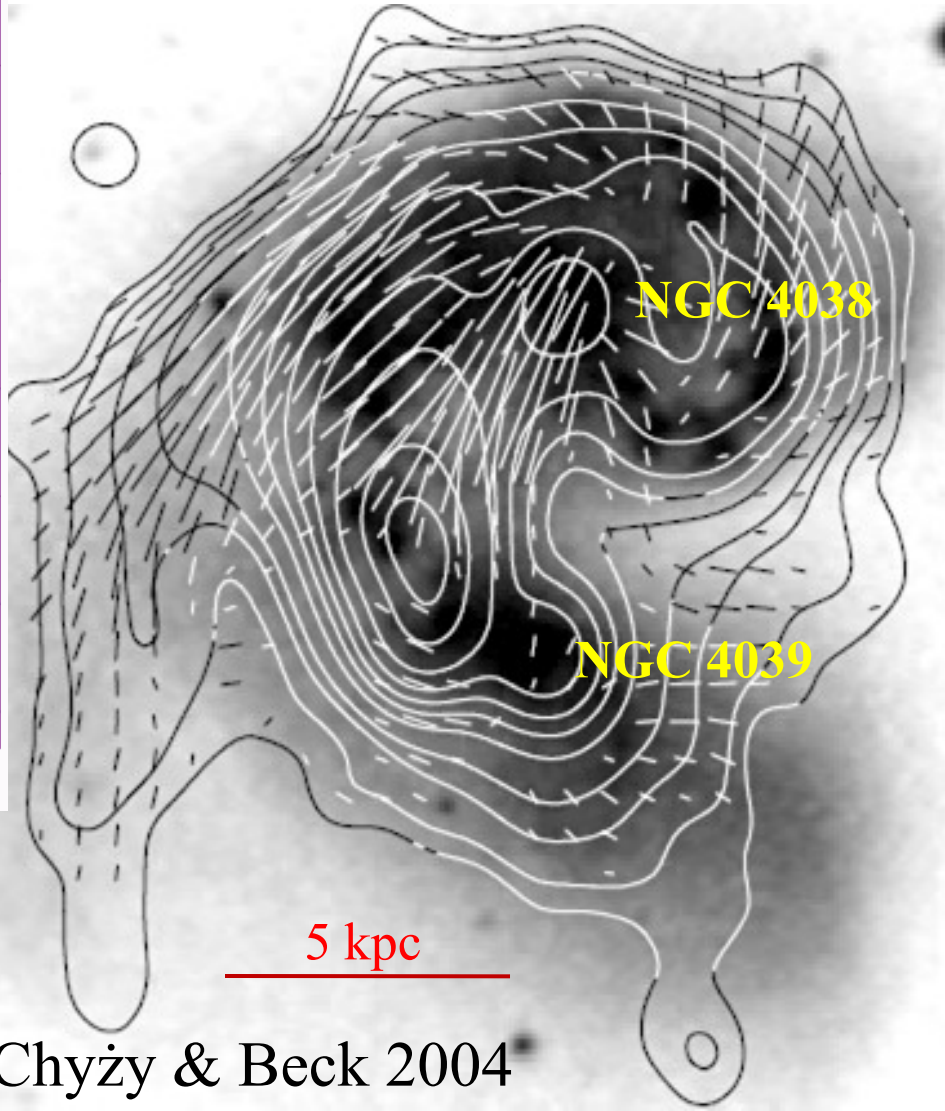
Polarization! CR propagation speed depends on the magnetic field geometry.

The Antennae

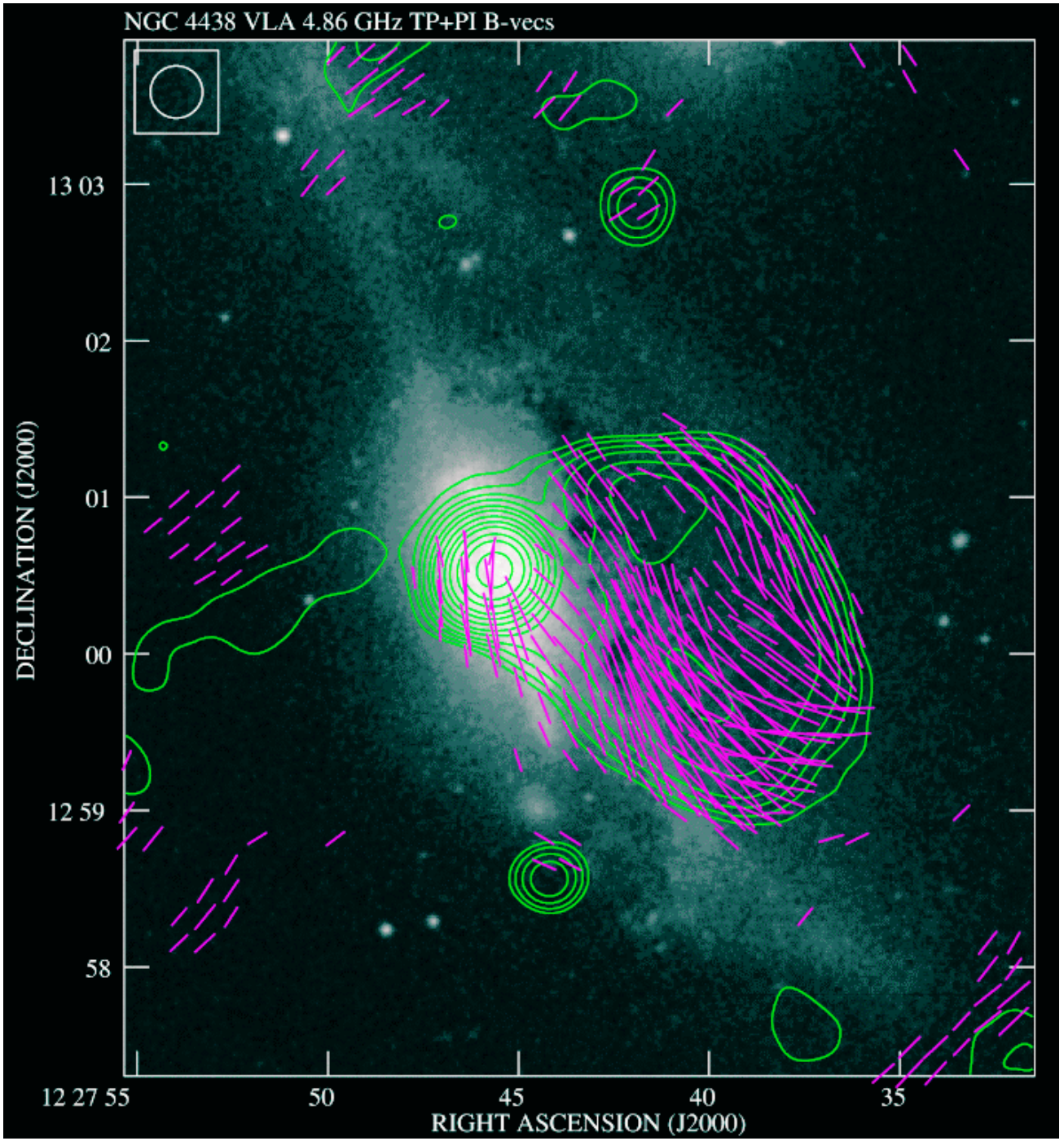
With the synchrotron spectrum we can study the history of the interacting system

VLA 4.8 GHz TP + B + DSS





Chyży & Beck 2004



NGC 4438

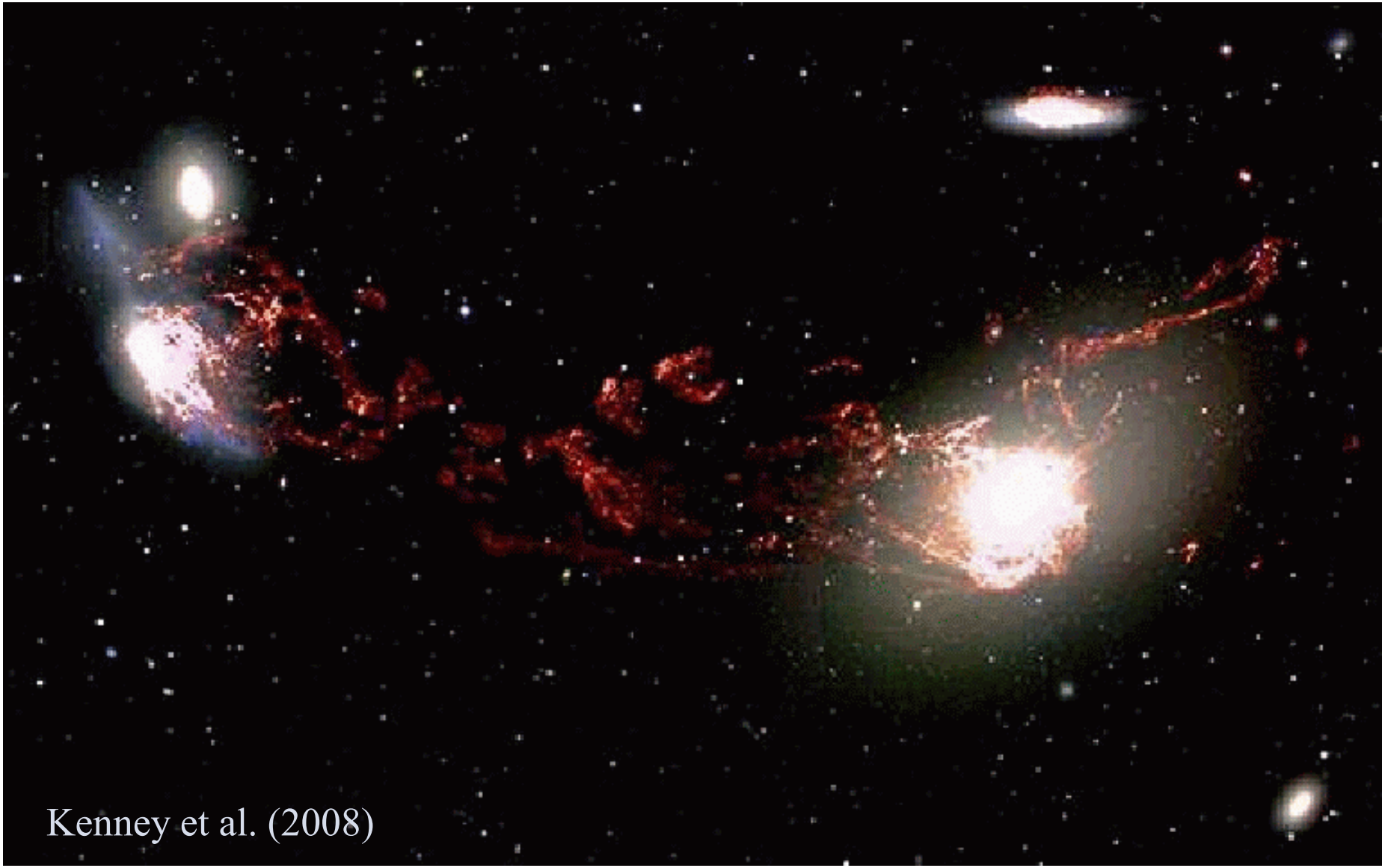
heavily perturbed

Virgo Cluster

Vollmer et al. 2007, 2009
MHD modelling: HI, TP, PI - constraints

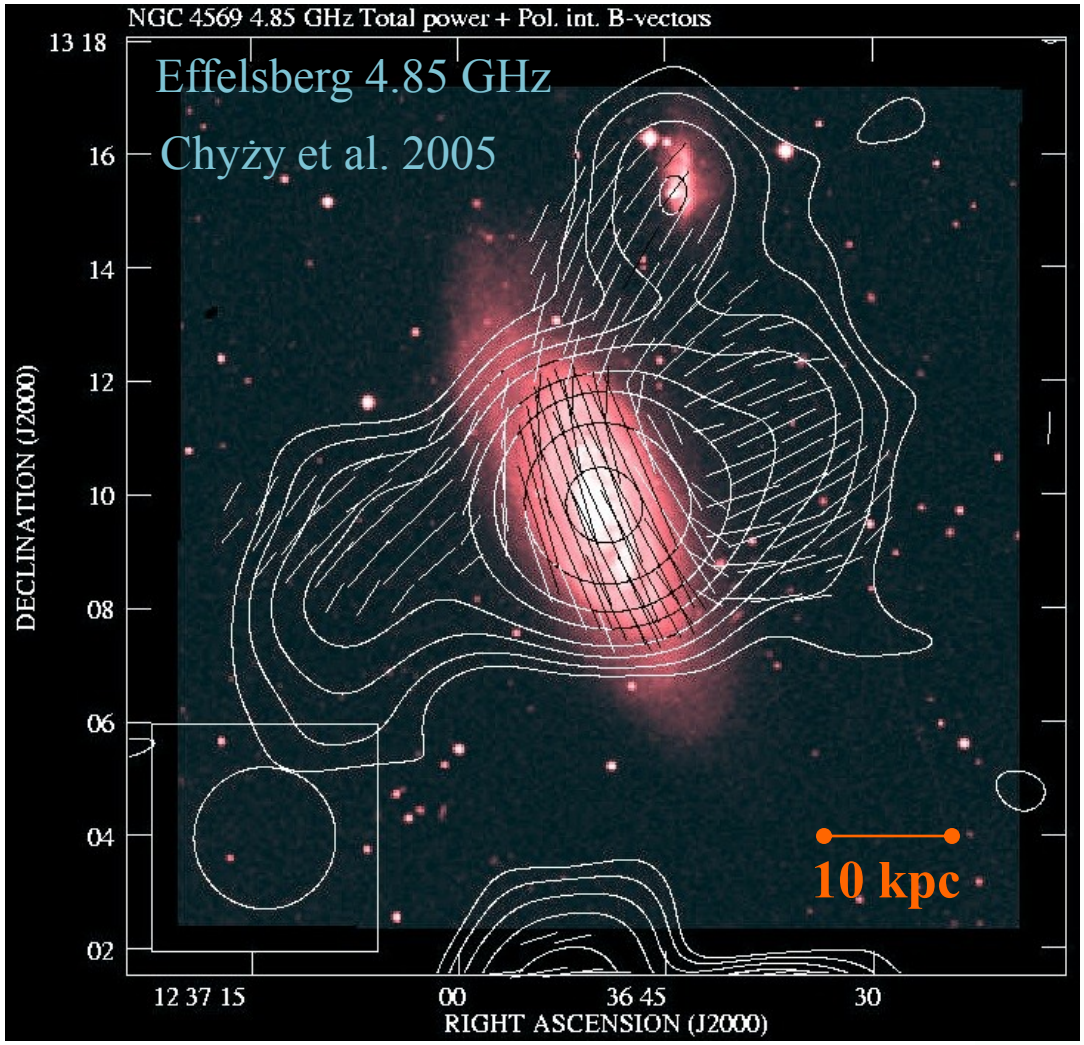
NGC 4438 – M86 Hα filaments/bridge

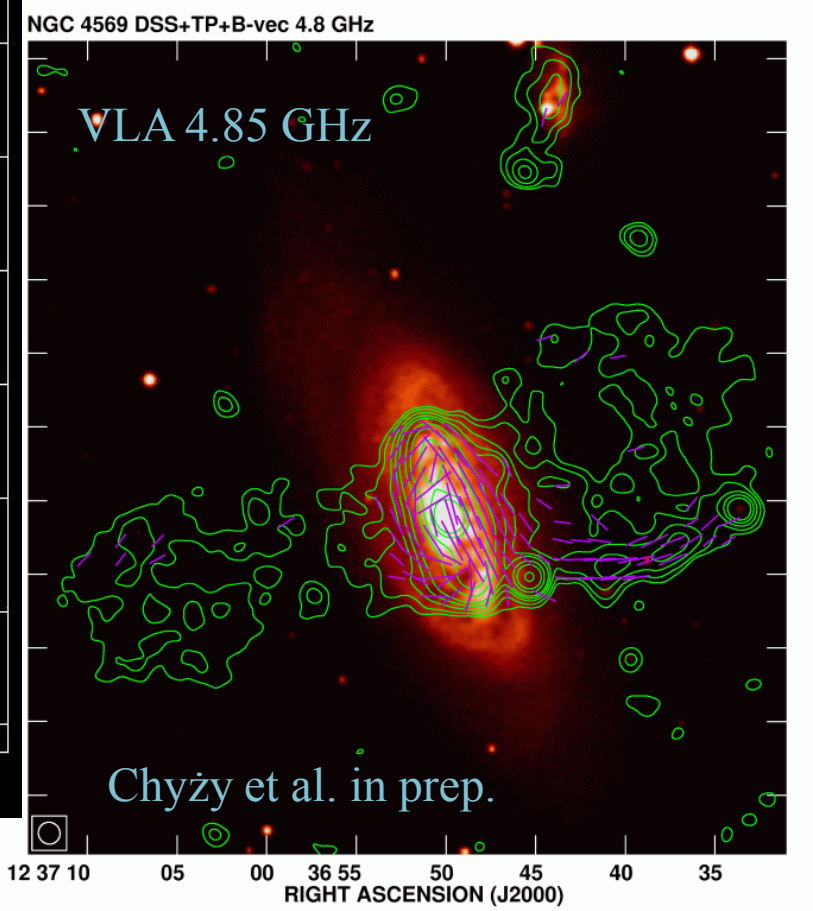
Is there a synchrotron counterpart?



NGC 4569 – galactic halo

Investigation of magnetic fields in low-brightness outer parts of haloes and in extraplanar outflows of spiral galaxies



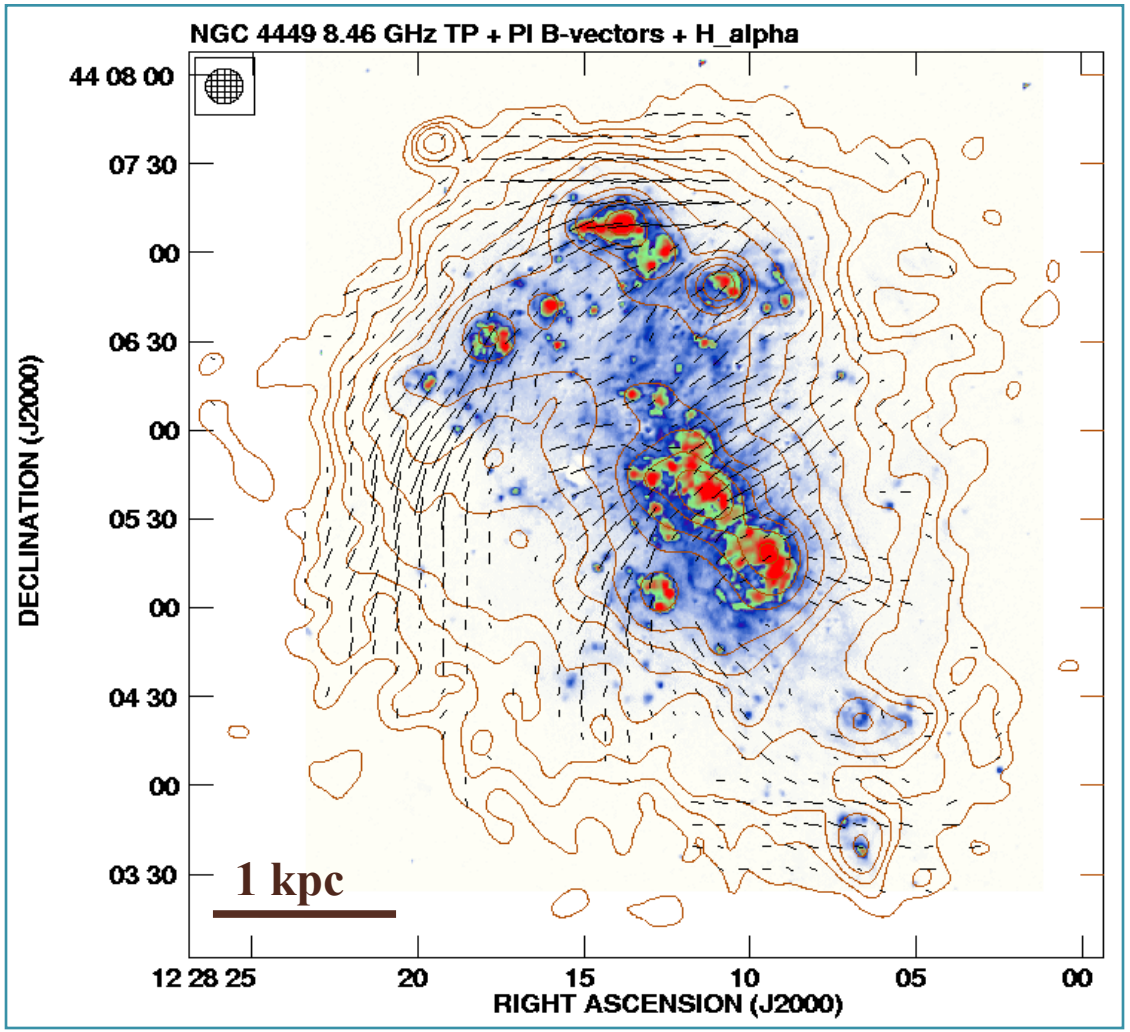


Lerche & Schlickeiser (1982) and Breitschwerdt et al. (1991) steepening depends on propagation process advection - difussion

Are dwarf galaxies radio-faint?

- NGC 4449, 5x smaller, 8x less massive than the Milky Way, no spiral arms
- Slow (30 km/s), almost chaotic rotation
- But B=14μG !
- Fast dynamo (Parker 1992)?

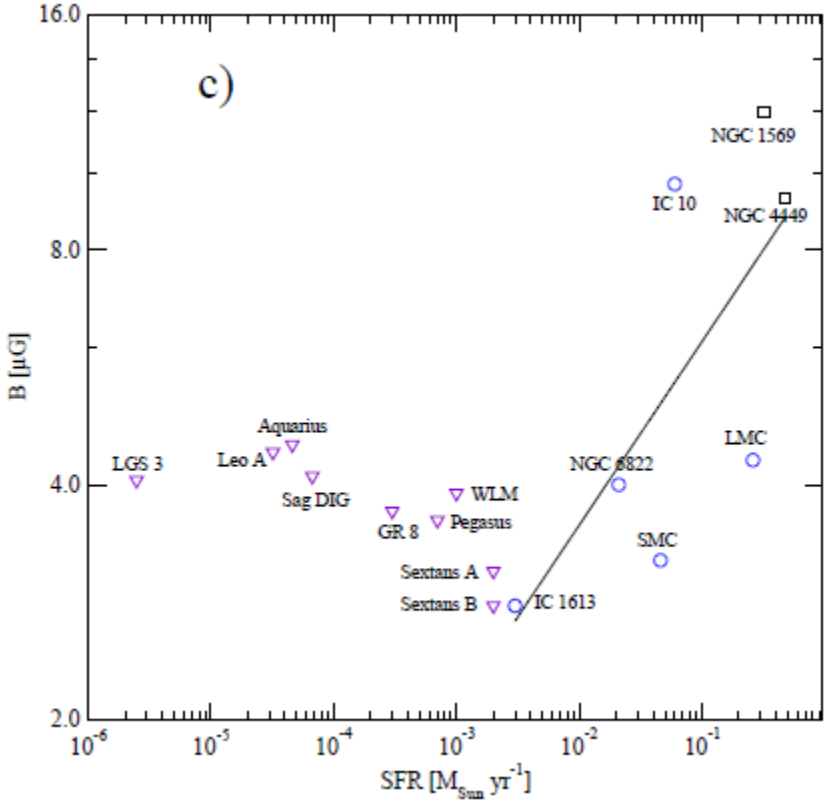
Shallow gravitational potential, galactic winds more effective (the extent – LOFAR)
At early epochs, injection of CRs and magnetic fields into IGM by dwarf galaxies at $10 < z < 6$ (Kronberg et al. 1999) - magnetization of the IGM



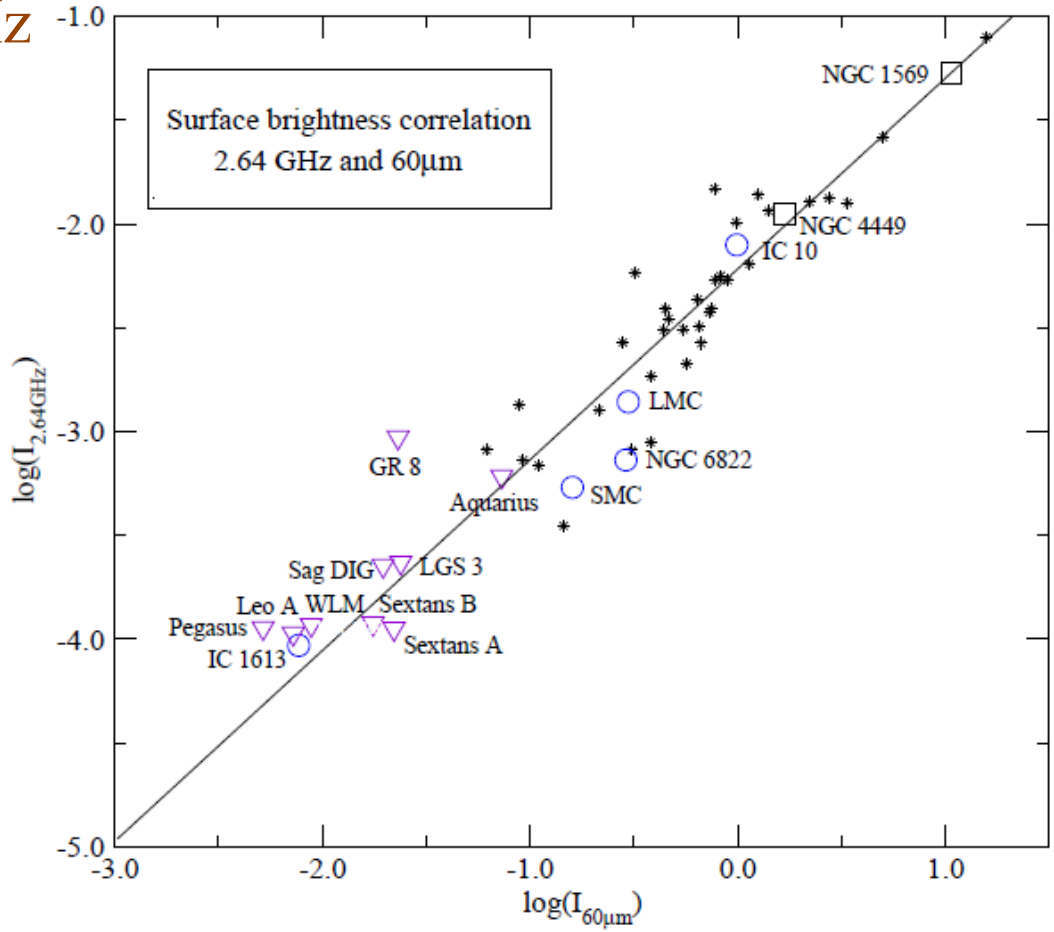
VLA 8.46 GHz, Chyży et al. 2000

Local Group Dwarfs

Effelsberg, 2.64 GHz, 4.86 GHz



Chyży, Weżgowiec, Beck, Bomans (in prep)

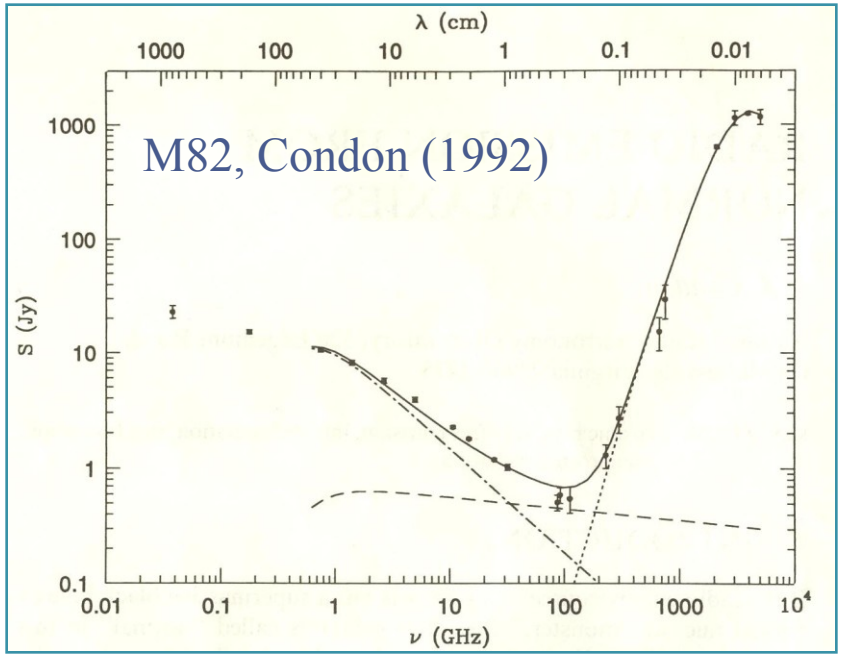


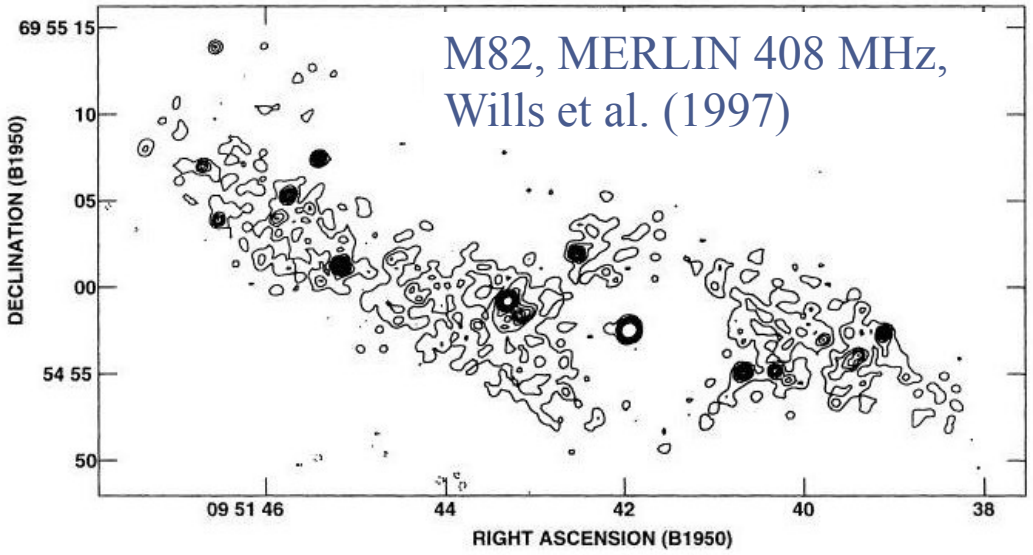
NGC 4449, IC10 – exceptions, majority of LGD undetected. Is there a dynamo treshold?

LOFAR observations of LGD needed

High-z dwarfs should have strong, regular fields (Arshakian et al. 2009)

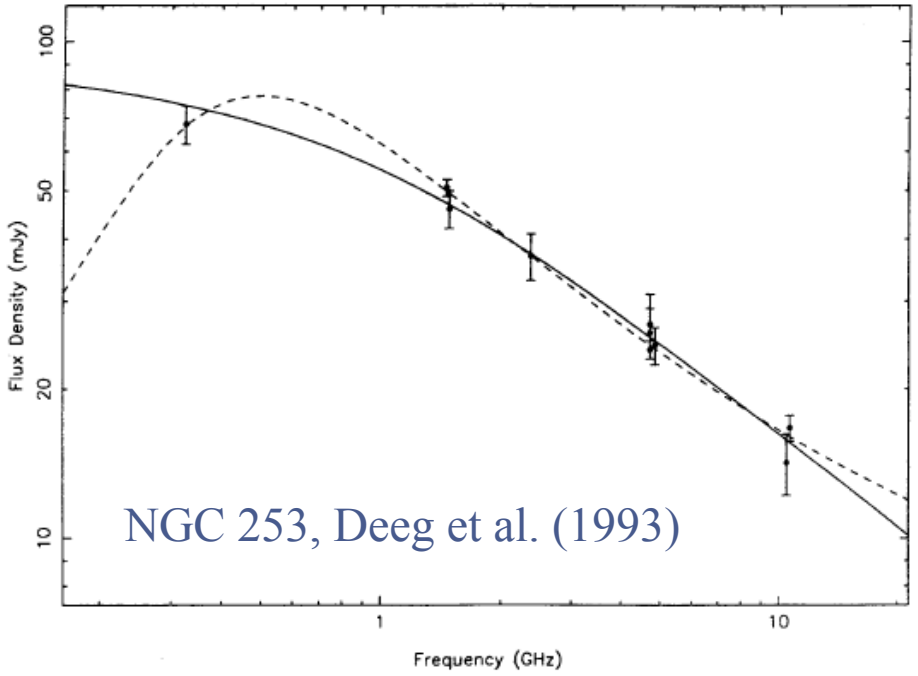
Free-free emission





- Studying MF is not easy (depolarization, f-f), f-f separation with LOFAR
- another problem - thermal absorption, may affect radio fluxes of unresolved distant galaxies

A sensitive survey of galaxies is needed!

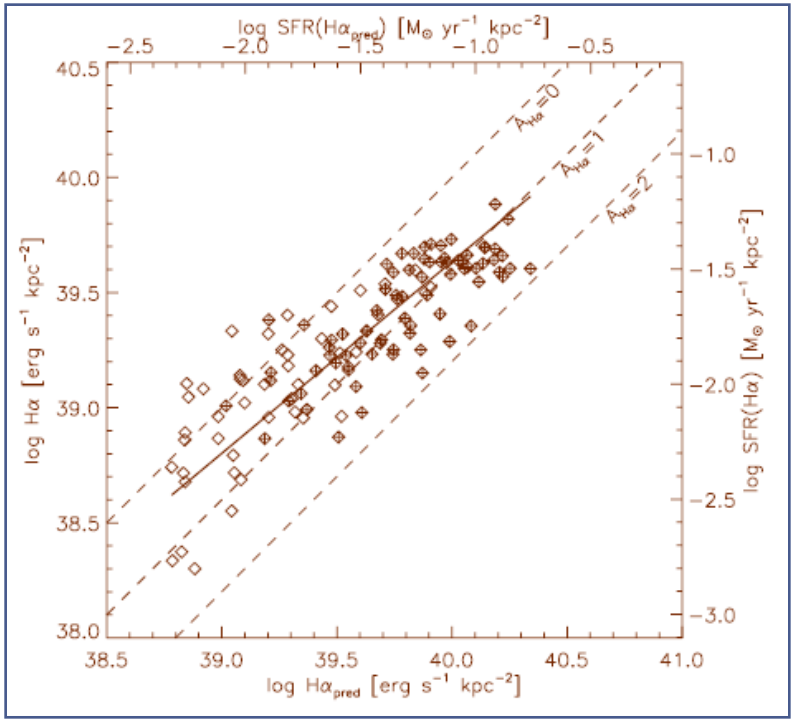


Separation of thermal, nonthermal emision

NGC 4254:

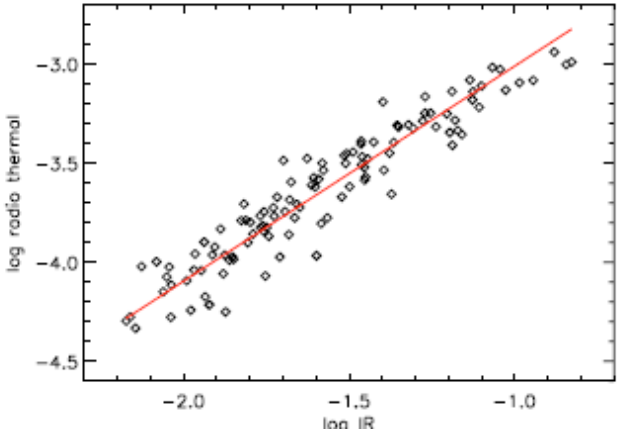
- separation with α_{nth}=const
- radio thermal emission the best SFR indicator
- predict Hα emission and estimate extinction
- estimate radio-infrared relation WITHIN galaxies separately for th, nth emission

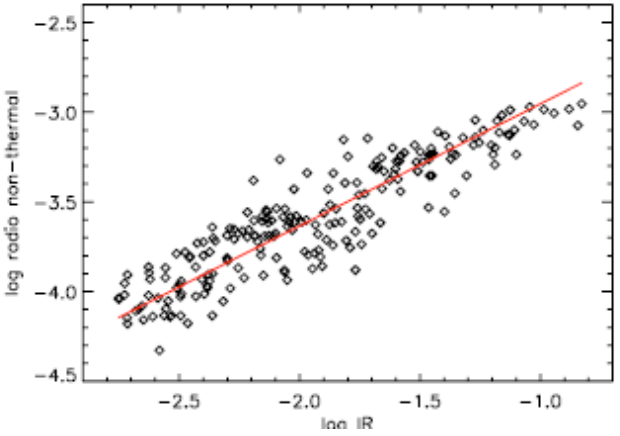
We can do it in a reliable way with LOFAR

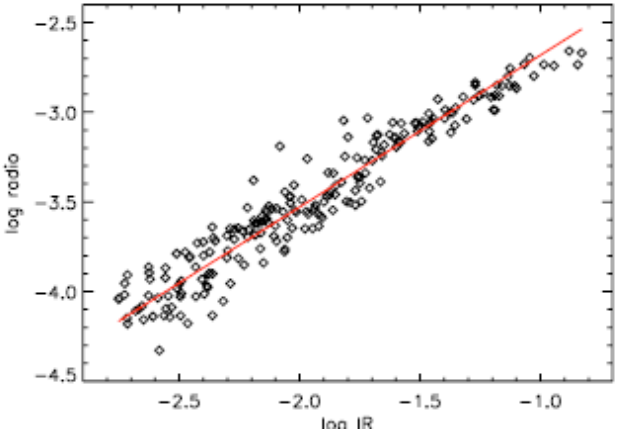


Chyży, Ehle, Beck (2008)

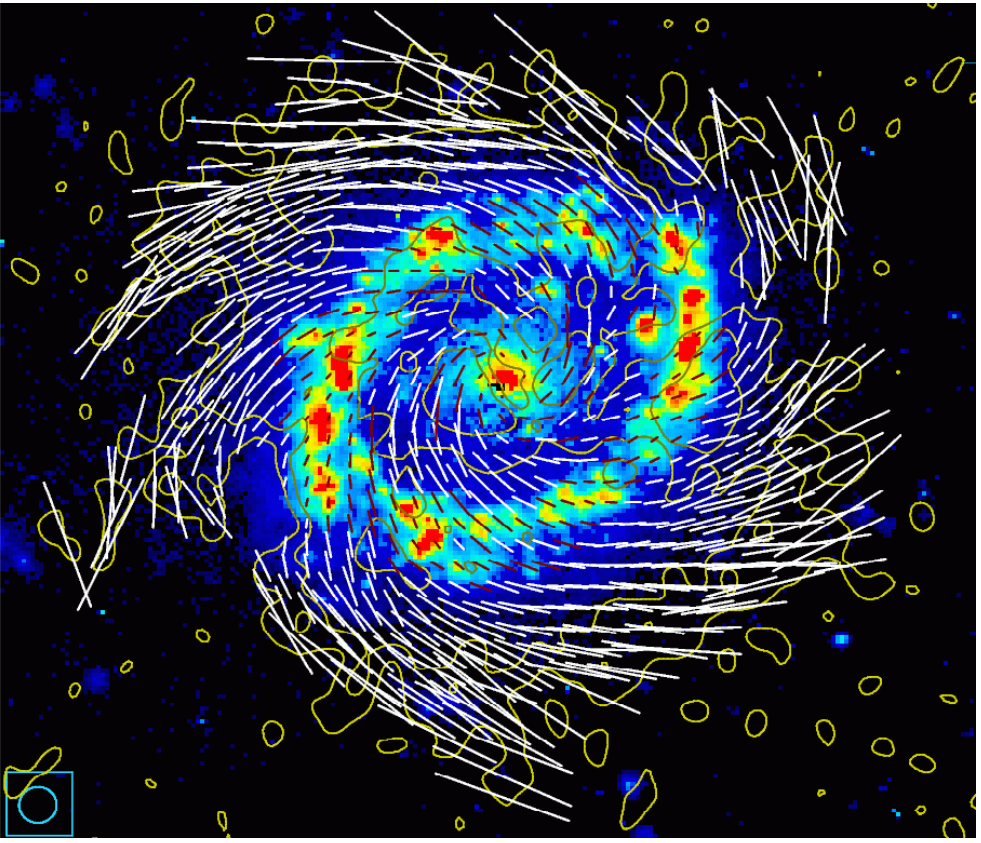
Radio-infrared relation within NGC 4254



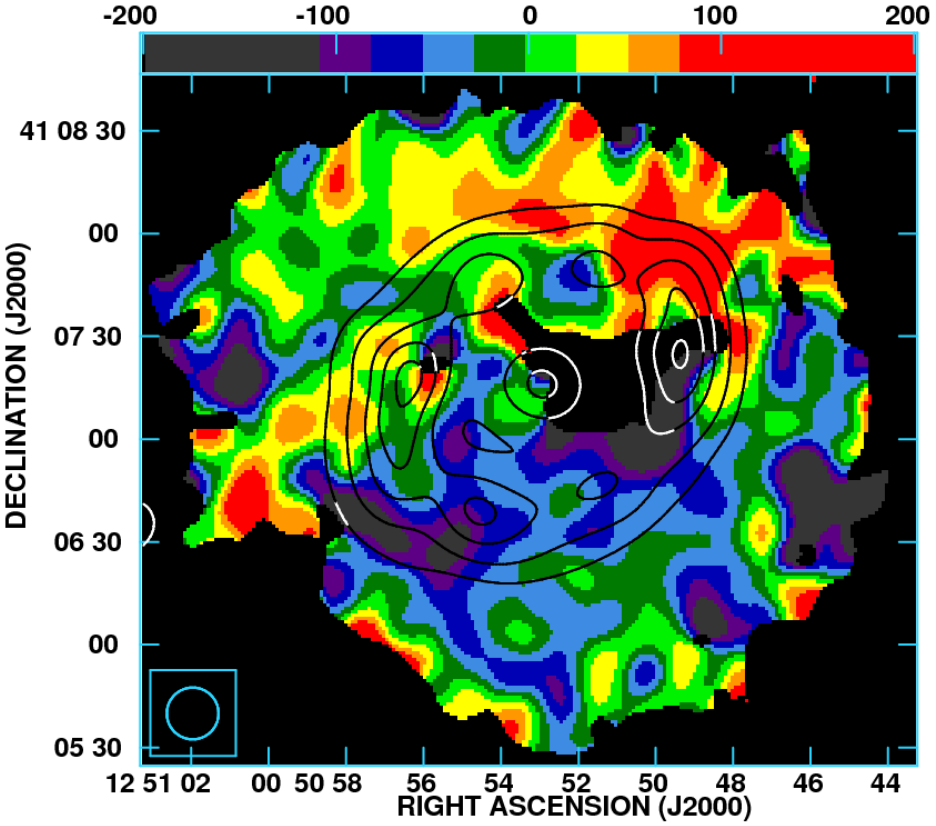




Ringed galaxy NGC 4736



VLA 8.4 GHz, PI+Hα 8”x8”, Chyży & Buta (2008)



RM, axisymmetric B

Thermal-synchrotron separation

→ detailed modelling of CR difussion from the starbursting ring, dynamo process

RM synthesis needed

(a cube of Q,U images in ‘Faraday depth’ space) to identify multiple ‘Faraday’-layers

Faraday screens , the Milky Way

NGLS – Nearby Galaxies Lofar Survey

60 galaxies – Local Volume Legacy (<11 Mpc) + most interesting galaxies to the distance of the Virgo Cluster

Science Case:

- **radio envelopes**, tidal tails, old outflows, disk-halo interaction, detection of LG dwarfs, sizes of galaxies at low wawelengths – how do they depend on the galaxy type, SFR, mass?
- **spectral index** studies – CR propagation studies, thermal absorption – trace which ISM component?
- **separation** of thermal and nonthermal components (large spread of frequencies needed), star formation studies, prediction of Hα absorption, SFR radio-calibrator, radio-infrared relation of thermal and nonthermal components within galaxies
- **magnetism** – determination of B, RM synthesis – solving RM mysteries, origin of B in IGM and ICM, dynamo models for galaxies
- **cosmological issues** – understanding the ISM content and radio emission in galaxies of the local volume - compare with global radio properties of galaxies of distant Universe
- and many others proposed by members of the NG group