A3: Low-frequency radio haloes around dwarf galaxies

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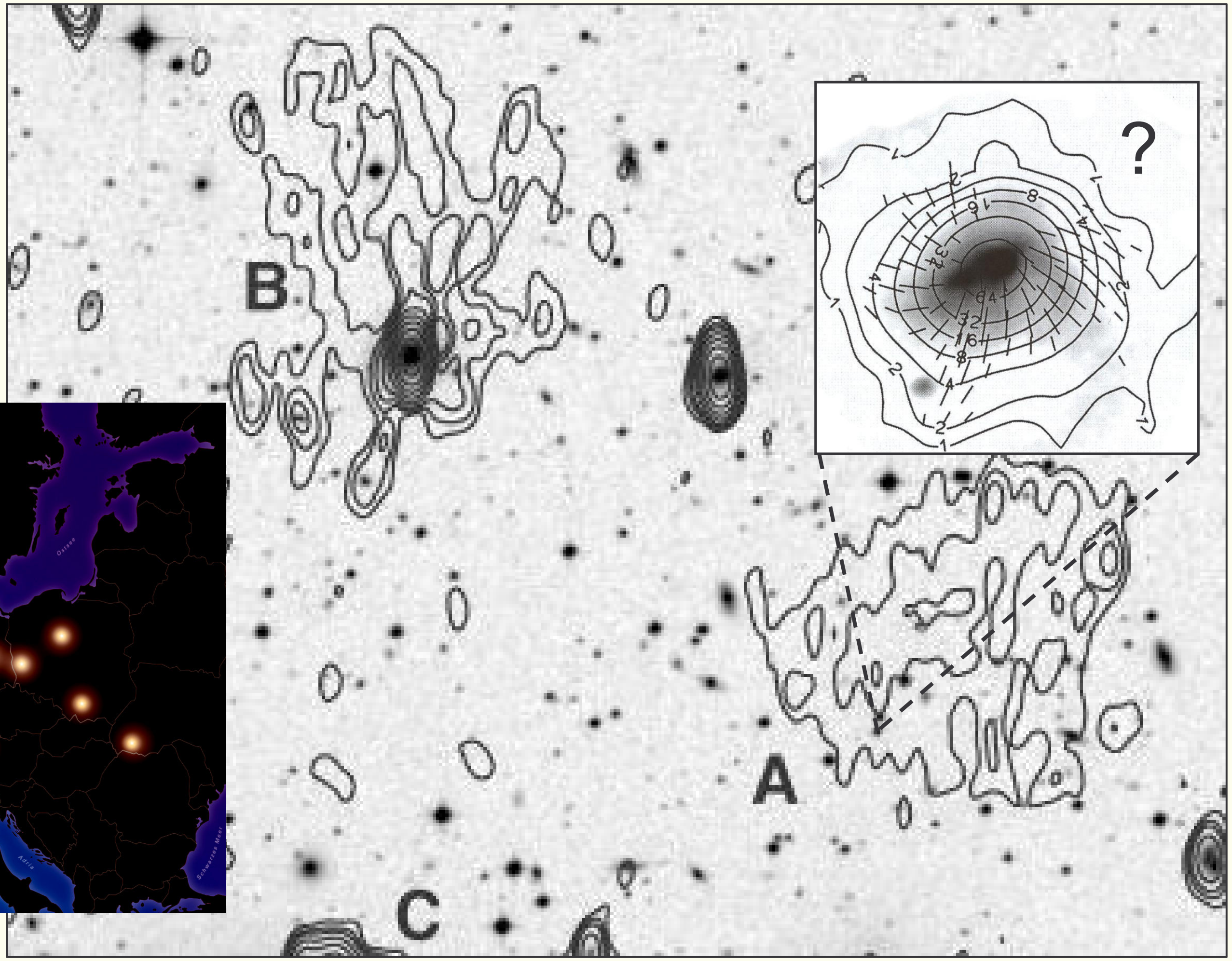
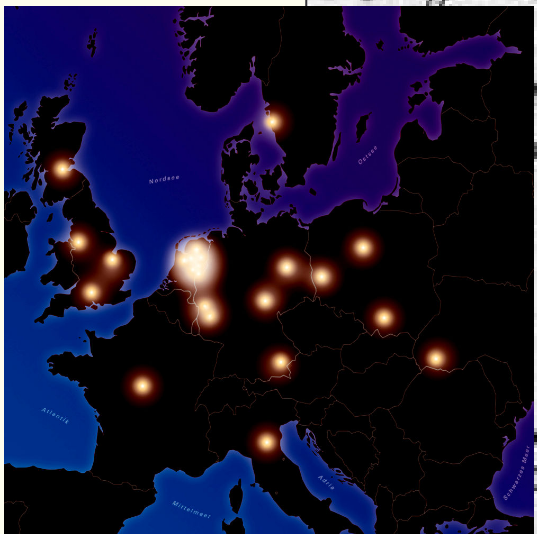
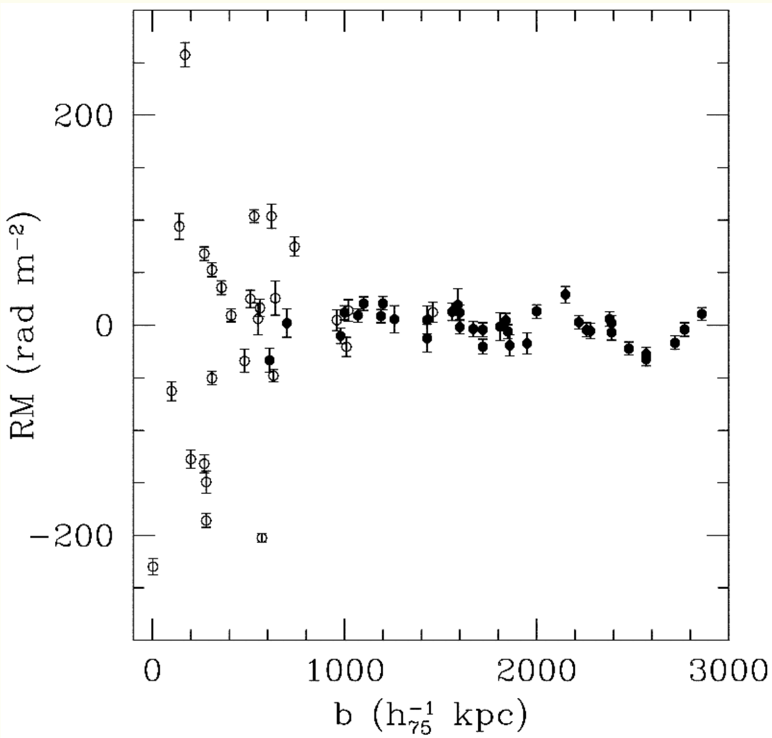




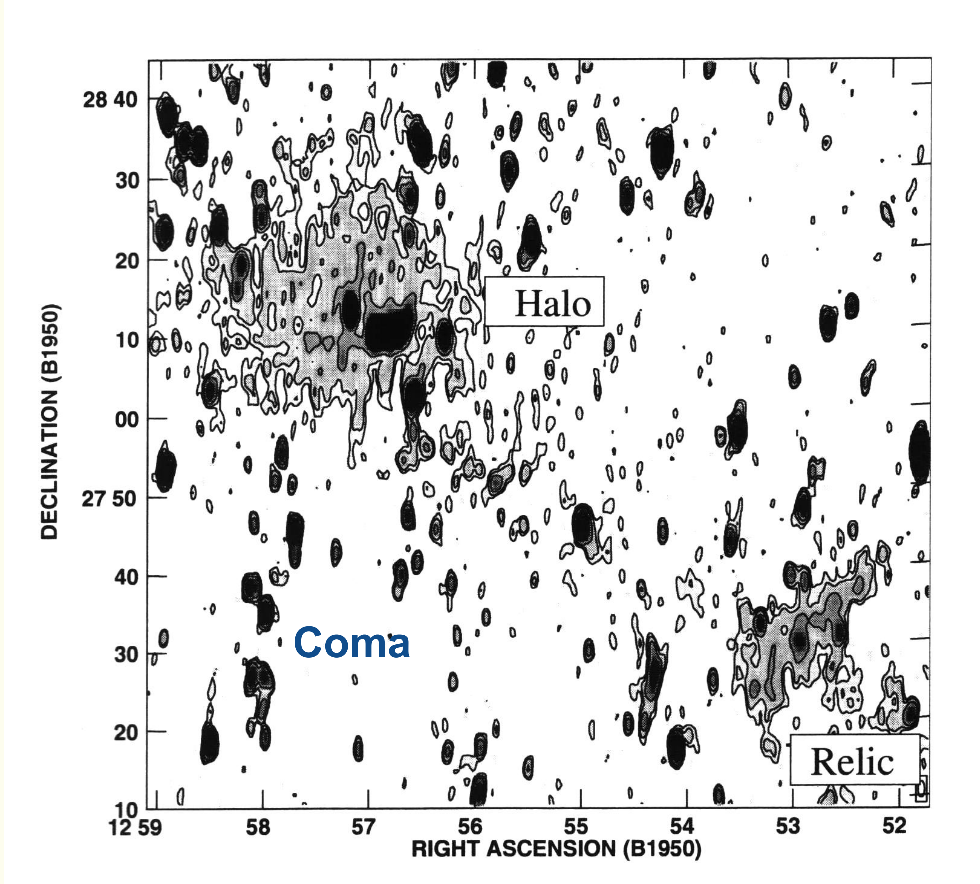
ICM is magnetized (throughout?)

Galaxy clusters exhibit:

- radio halos
- Faraday rotation
- peripheral radio structures



Clarke et al. (2001)



Giovannini et al. (1993)

relativistic electrons have short lifetimes

$$t_{1/2} = 8.97 \cdot 10^{8} \cdot \frac{B^{1/2}}{B^{2} + B_{cmb}^{2}} \cdot \left[\left(\frac{\nu}{\mathrm{GHz}} \right) (1 + z) \right]^{-1/2} \ \mathrm{yr}$$

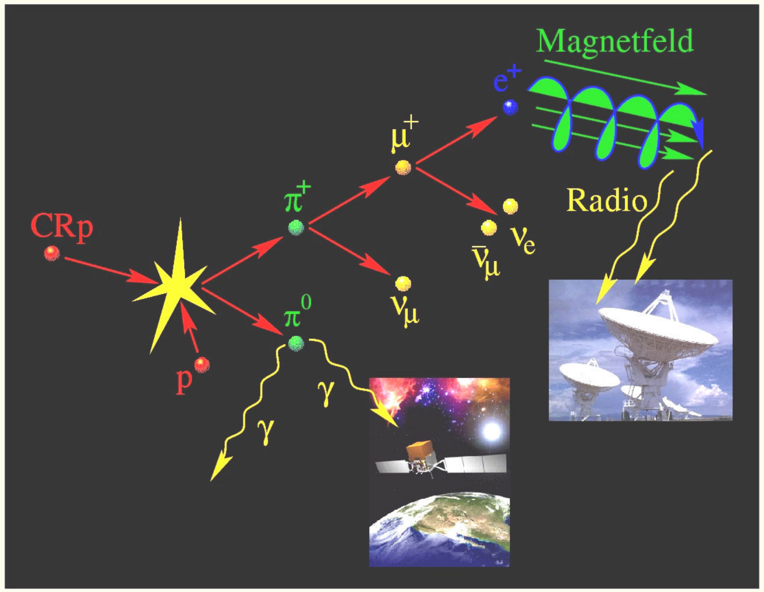
$$B_{cmb} = 3.25\,(1 + z)^{2} \ \mu\mathrm{G}$$

B = 1 μG, ν = 1.4 GHz $\Rightarrow$ $t_{1/2} = 10^8$ yr @ z = 0

$\Rightarrow$ primary electrons require continuous injection, e.g. via

- merger shocks
- galactic wakes

secondary electrons: hadronic collisions of relativistic protons with thermal gas



in both cases: particle pools required

how did the relativistic plasma get there?

two alternatives:

- primordial magnetic fields; requires extremely efficient amplification
- galactic evolution with injection by

early starbursts

(Kronberg et al. 1999; Bertone et al. 2006)

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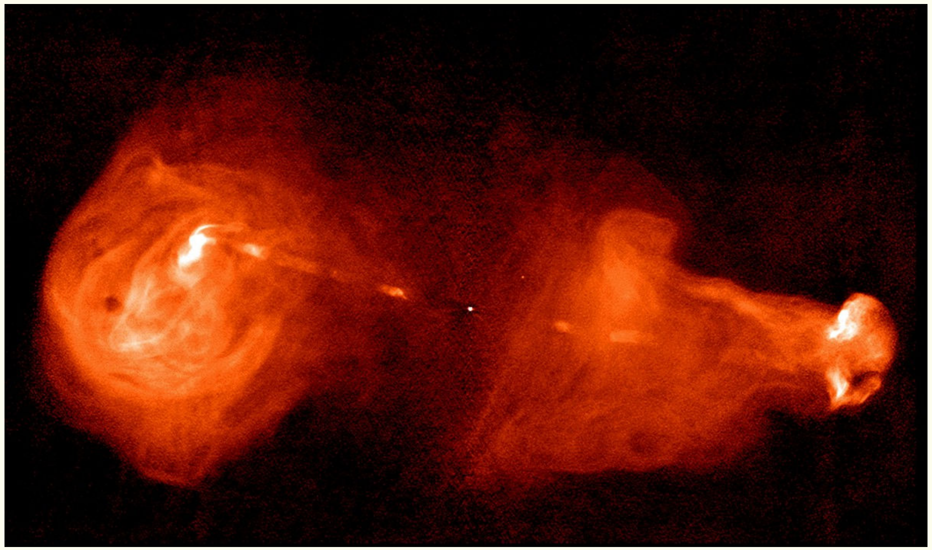


FR I/FR II radio galaxies:

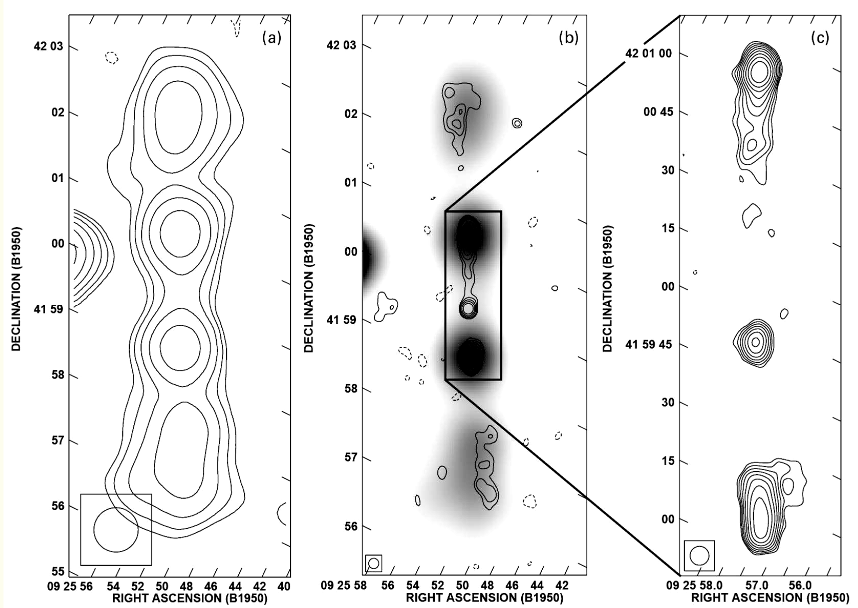
$P_{1.4GHz}(FRI/II) \approx 10^{24.7}$ W Hz^{-1}

starburst dwarf galaxies:

$P_{1.4GHz}(dwg) \approx 10^{20.5}$ W Hz^{-1}

$\Rightarrow P_{1.4GHz}(FRI/II) \approx 15000 \cdot P_{1.4GHz}(dwg)$

ΛCDM helps …



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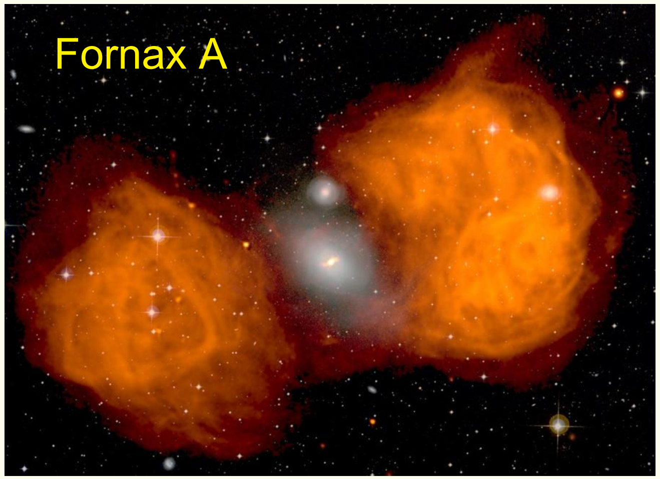
lifetime of radio galaxy (Bird et al. 2008):

$\tau_{life} \approx 1.5 \cdot 10^7$ yr

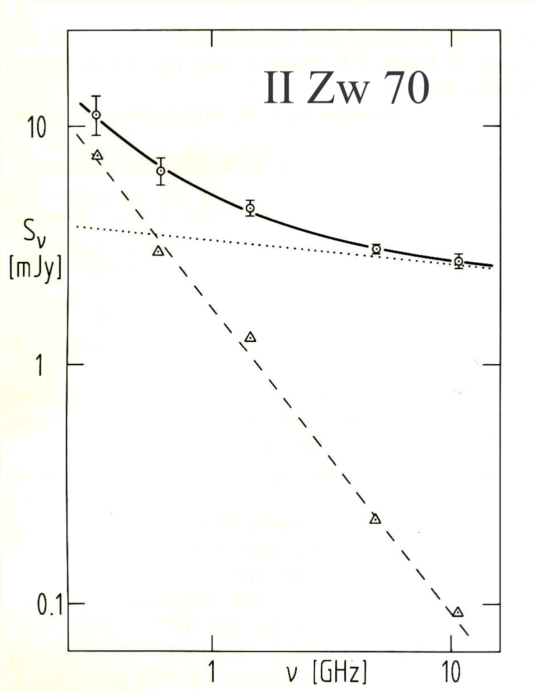
duty cycle:

$\tau_{duty} \approx 8 \cdot 10^8$ yr

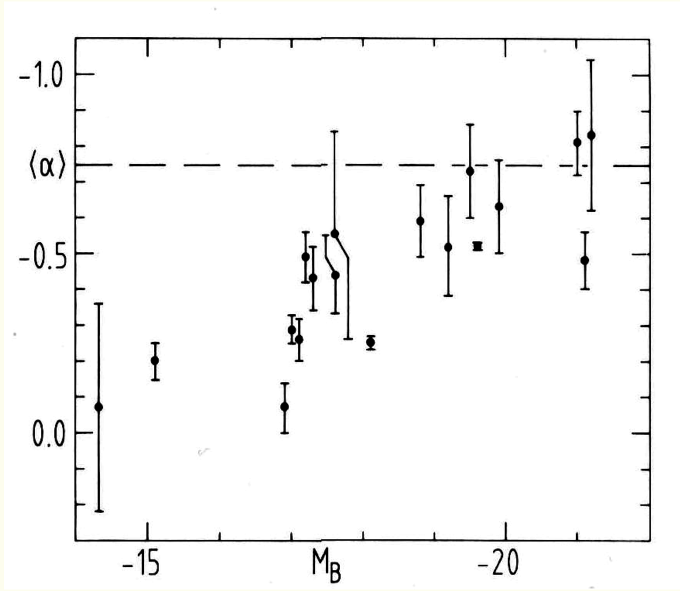


Dwarf galaxies:

deficiency of synchrotron radiation (at GHz frequencies)



Skillman & Klein (1988)



Klein, Weiland, Brinks (1991)

$$S_\nu = S_{0,ff} \cdot \nu^{-0.1} + S_{0,syn} \cdot \nu^{\alpha_{syn}}$$

weak synchrotron emission at low-mass end

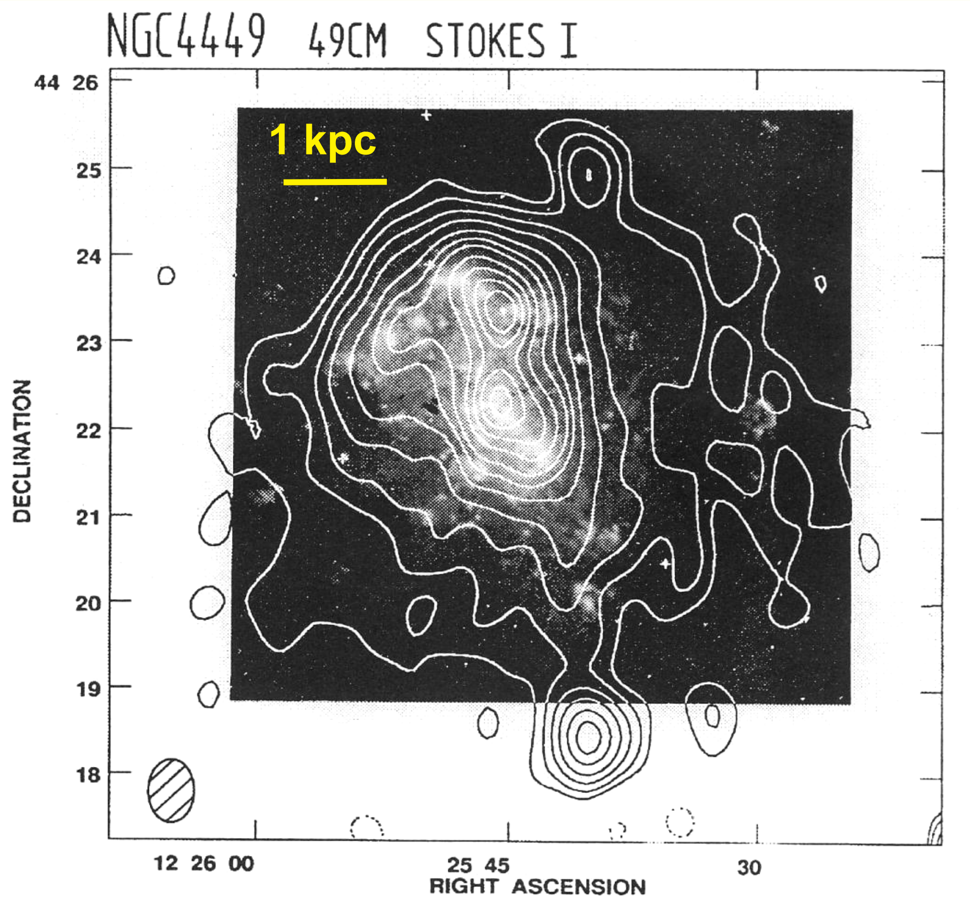
lack of CR containment

nearby template: NGC 4449

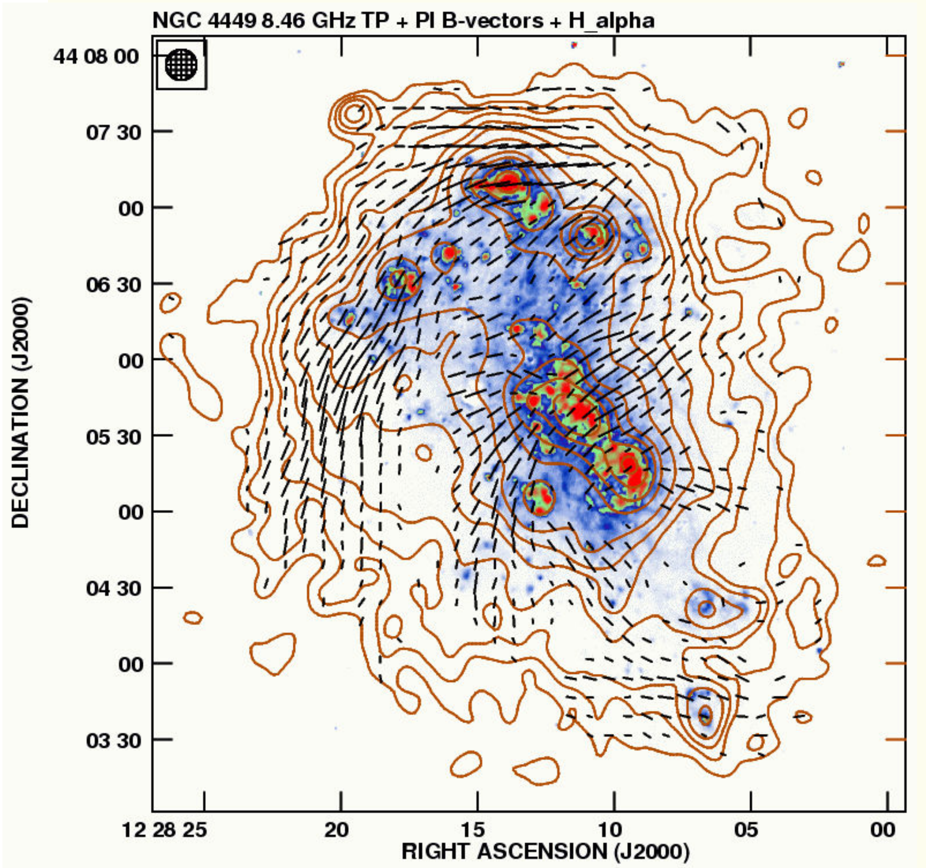
$M_{tot} = 5 \cdot 10^{10} M_\odot$

$D = 3.7$ Mpc

- (partly) radial B-field structure
- synchrotron halo

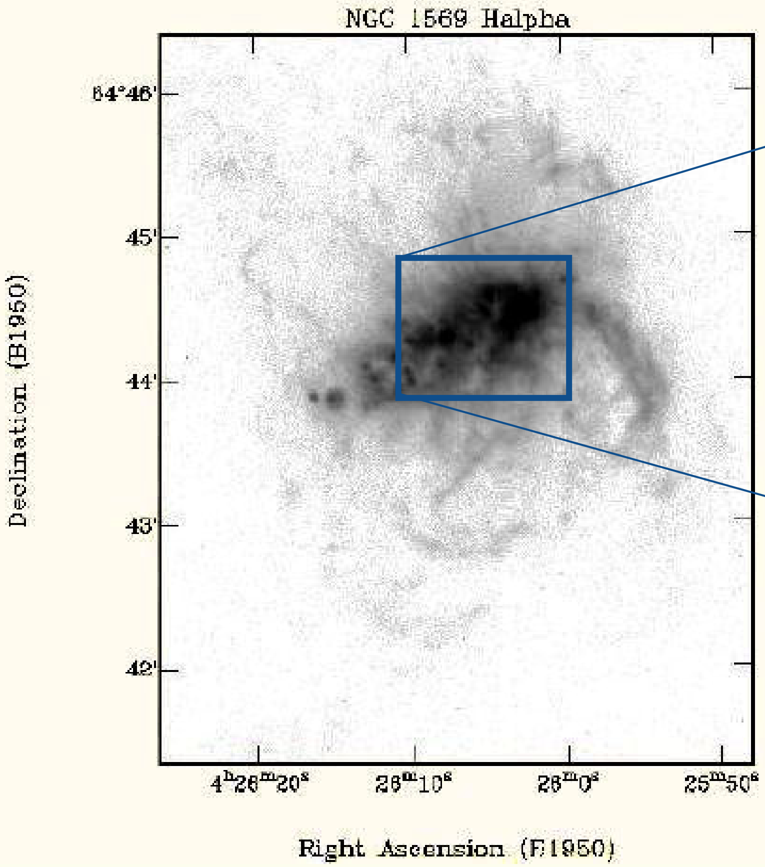


Klein et al. (1996)



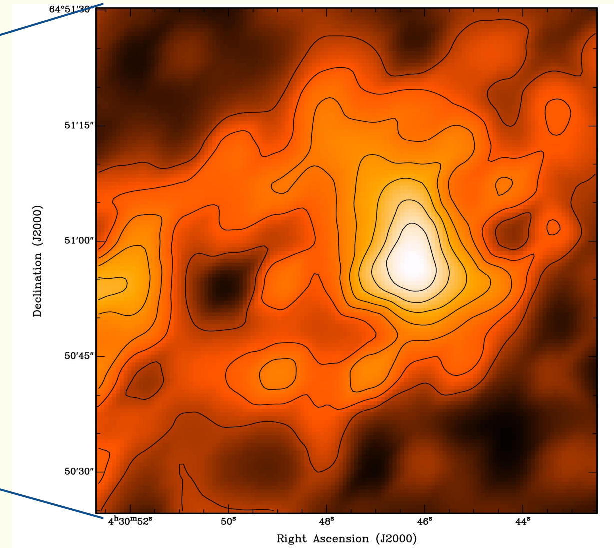
Chyży et al. (2000)

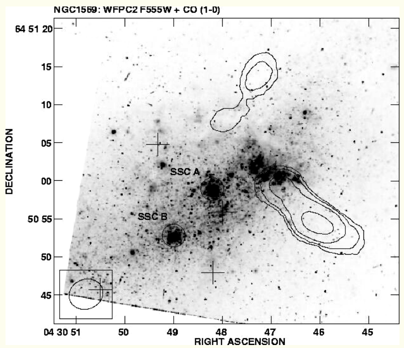
… and another one: NGC 1569: D = 2.2 Mpc, $M_{tot} \leq 10^{10}\,M_\odot$



Hunter et al. (1993)

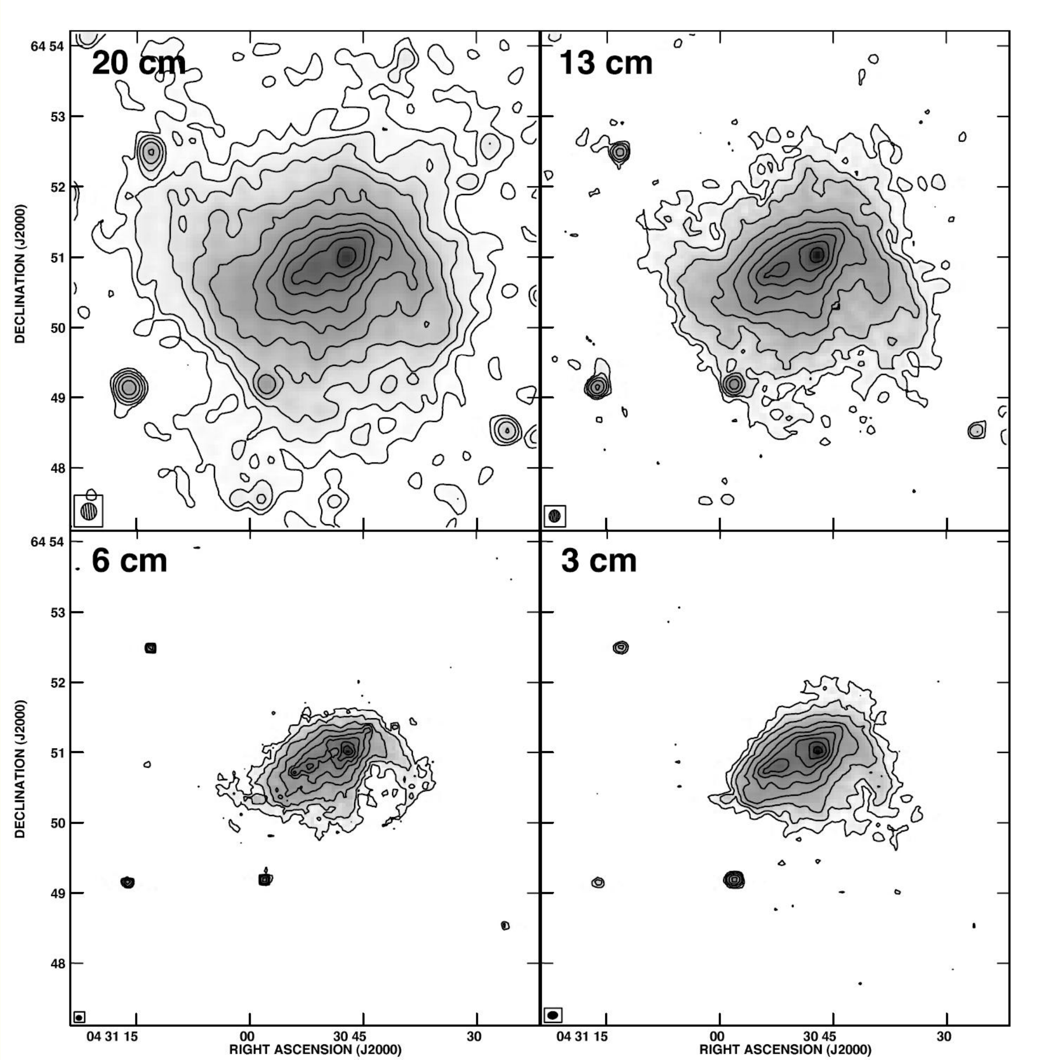
Mühle (2003)

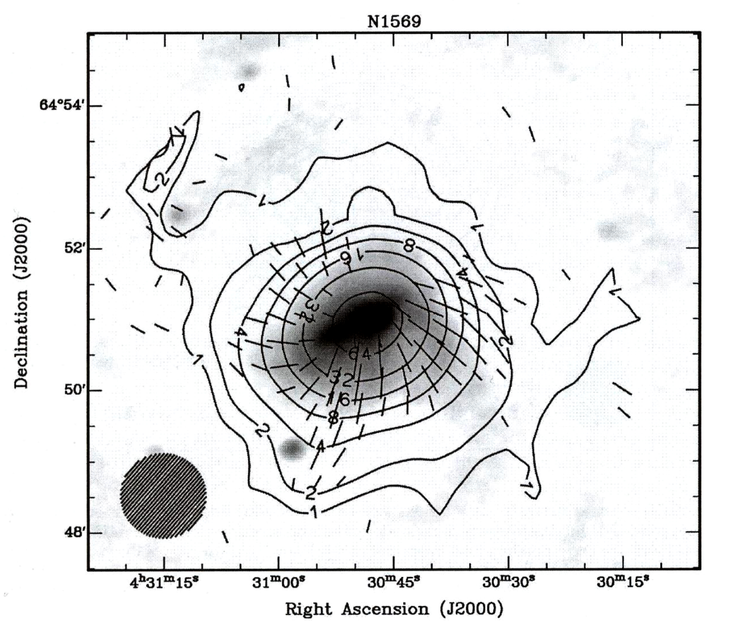


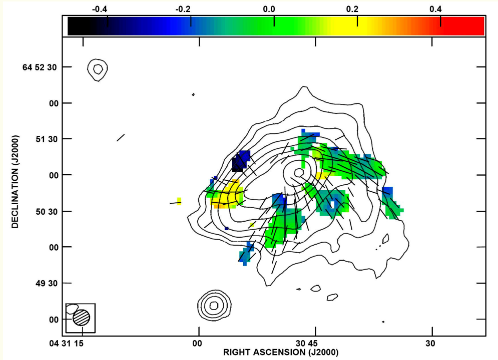


Taylor et al. (1999)

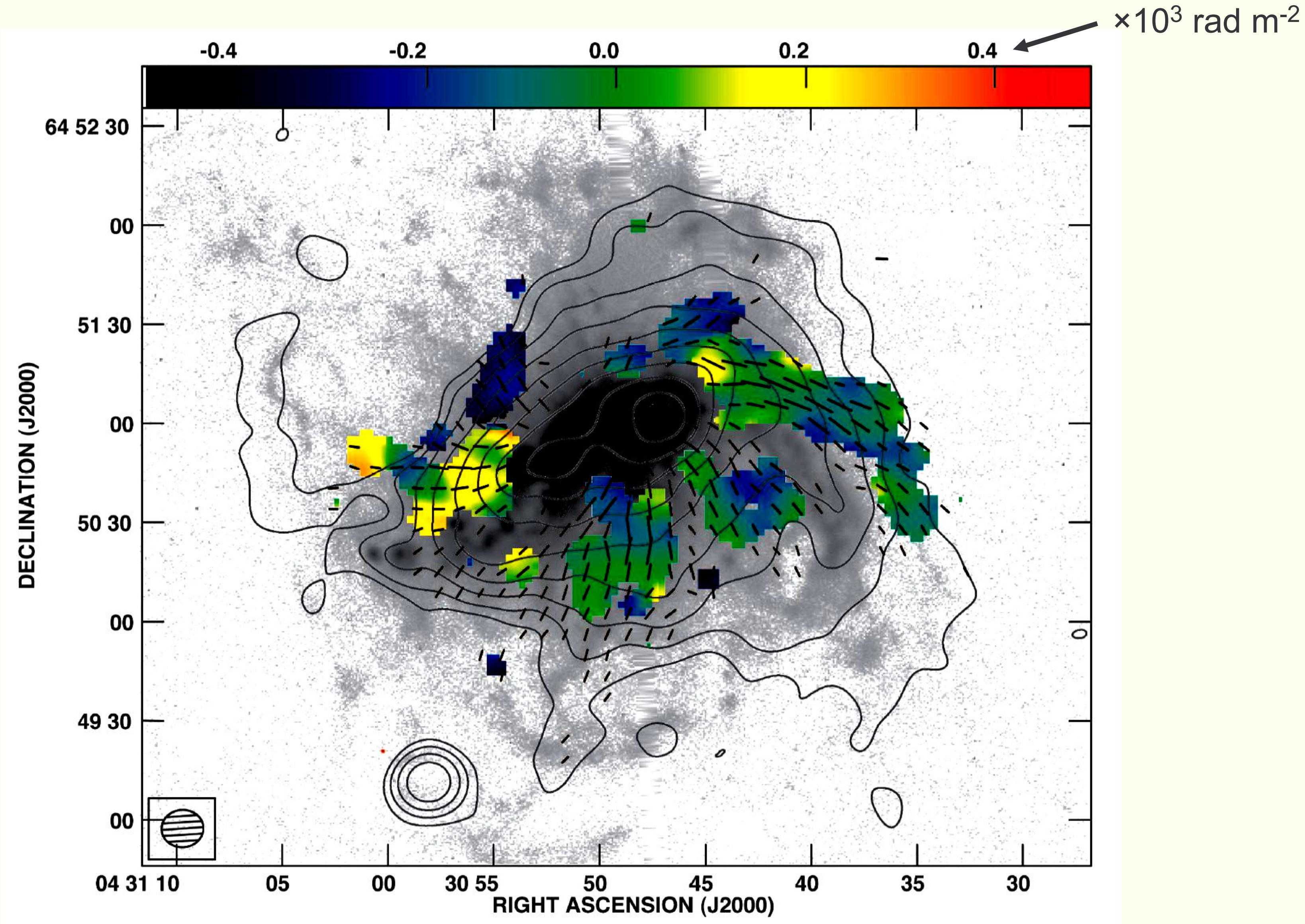
Kepley et al. (2008)







template: NGC 1569

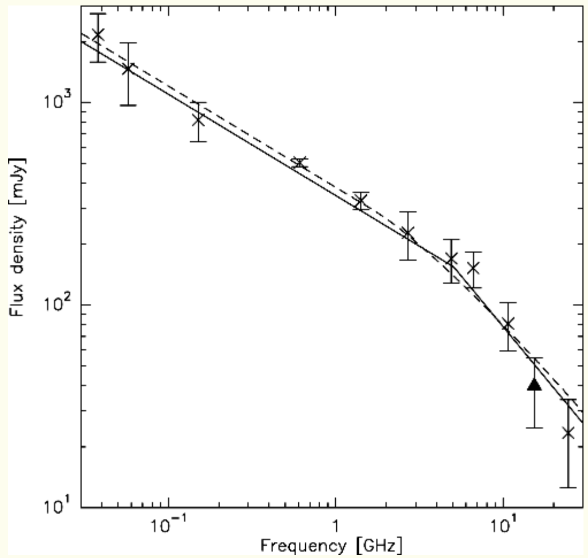


Kepley et al. (2010)

- break in synchrotron spectrum: cease of SF burst several Myr ago
- radio halo
- radial magnetic field
- B ≈ 40 μG (central region)

Israel & de Bruyn (1988)

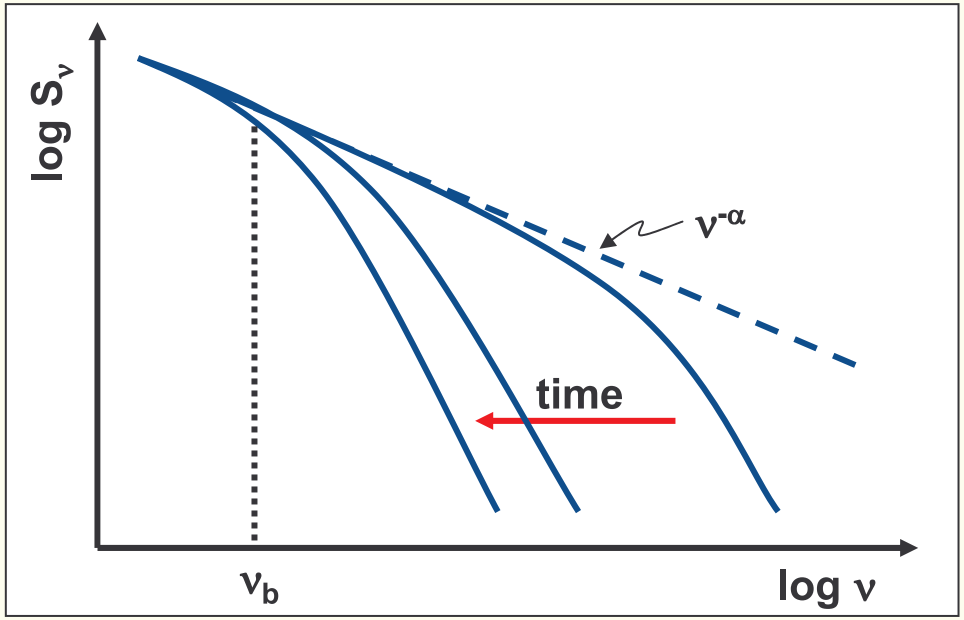
Lisenfeld et al. (2004)



synchrotron and IC aging (fast in BCDGs!)

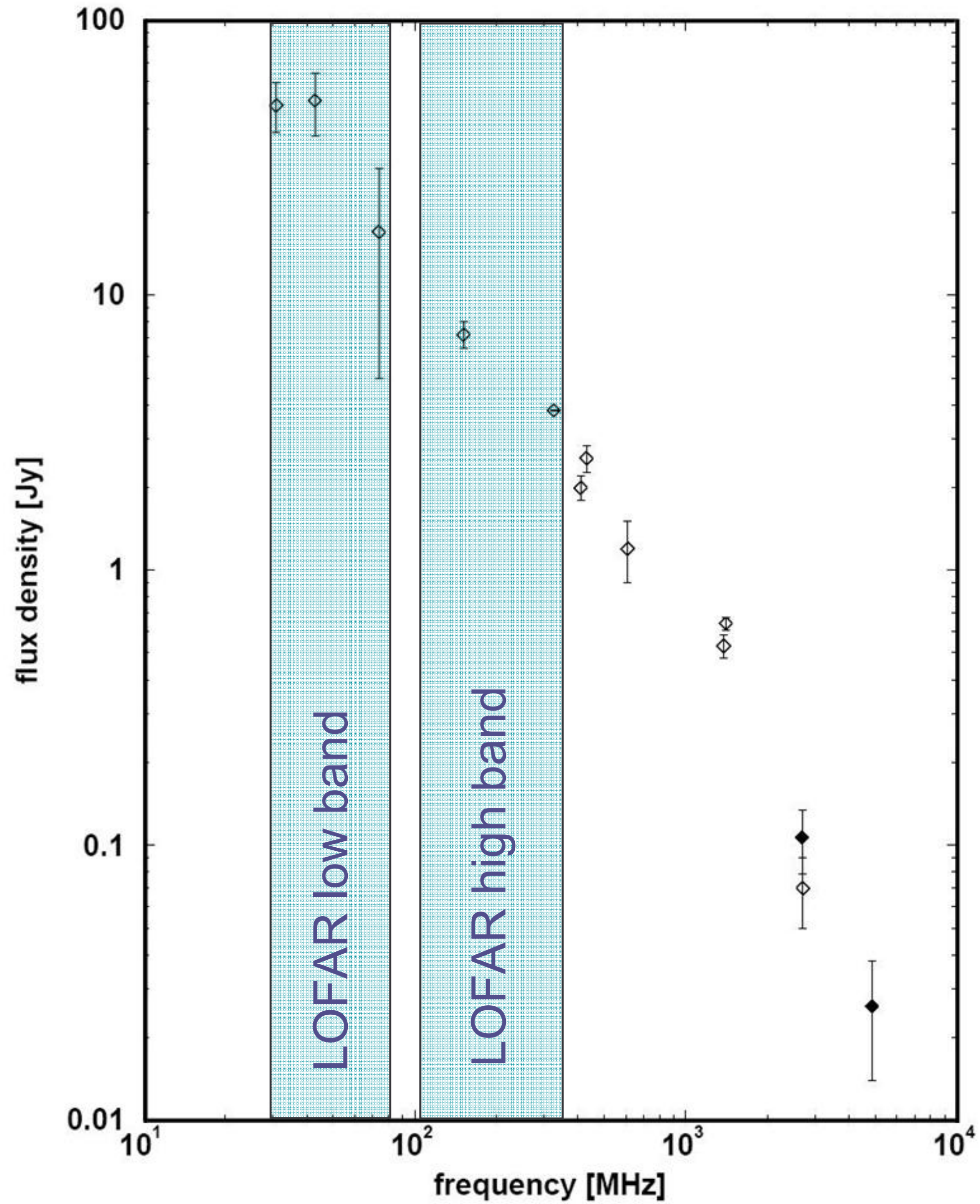
low-frequency halos will be detectable with **LOFAR**!

10 … 90, 110 … 240 MHz



e.g. spectrum of total radio continuum from the Coma Cluster halo

ν_b = 0.5 … 1.0 GHz



Thierbach et al. (2003)

numerous dwarf galaxies should be surrounded by low-frequency halos of synchrotron radiation

should be detectable with LOFAR; for B = 3 μG

ν = 50 MHz $\rightarrow$ $t_{1/2} = 3.6 \cdot 10^8$ yr (centre of low band)

ν = 175 MHz $\rightarrow$ $t_{1/2} = 1.9 \cdot 10^8$ yr (centre of high band)

ν = 20 MHz $\rightarrow$ $t_{1/2} = 5.6 \cdot 10^8$ yr

should also find lots of ‘idle’ dwarf galaxies!