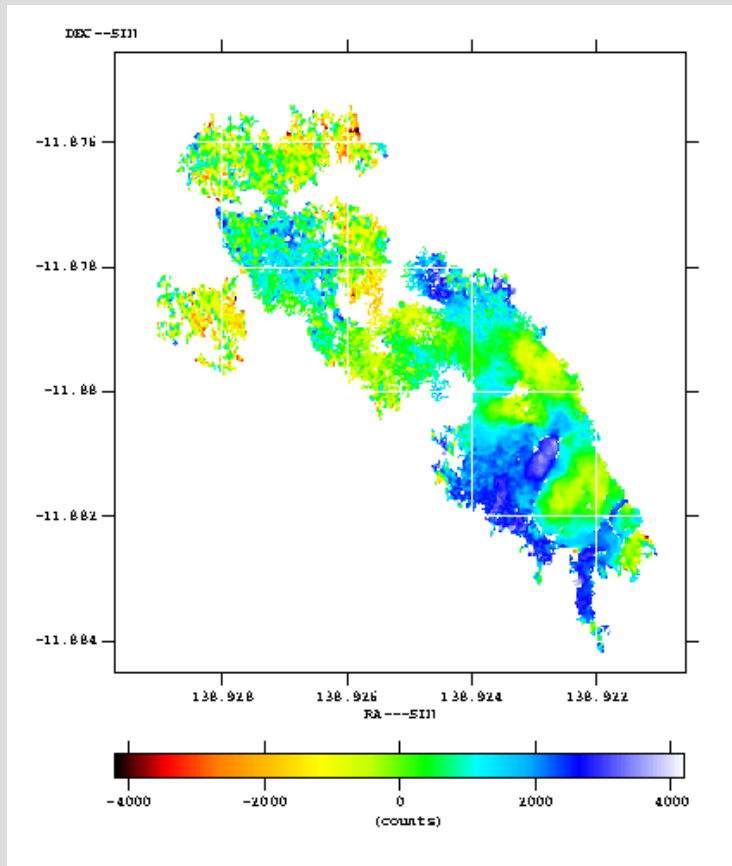


# Measuring MHD turbulence using polarised synchrotron emission and its Faraday rotation



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PACERMAN Faraday Rotation map of northern radio lobe  
credit: Radio:Taylor & Perley (VLA); Klaus Dolag

# Motivation

Magnetic fields exists throughout the universe!

★ Strength?

★ Structure?

★ Origin?

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Magnetic fields exist throughout the universe!

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- ★ Structure?
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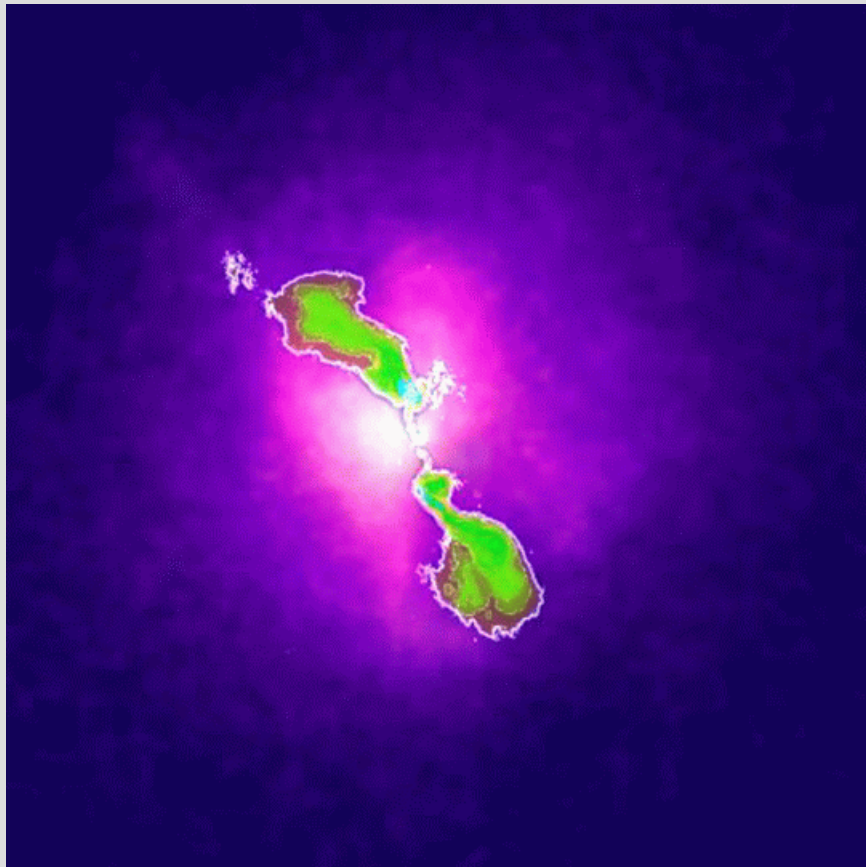
Important tools to study them:

Synchrotron emission from relativistic electrons moving in a magnetic field

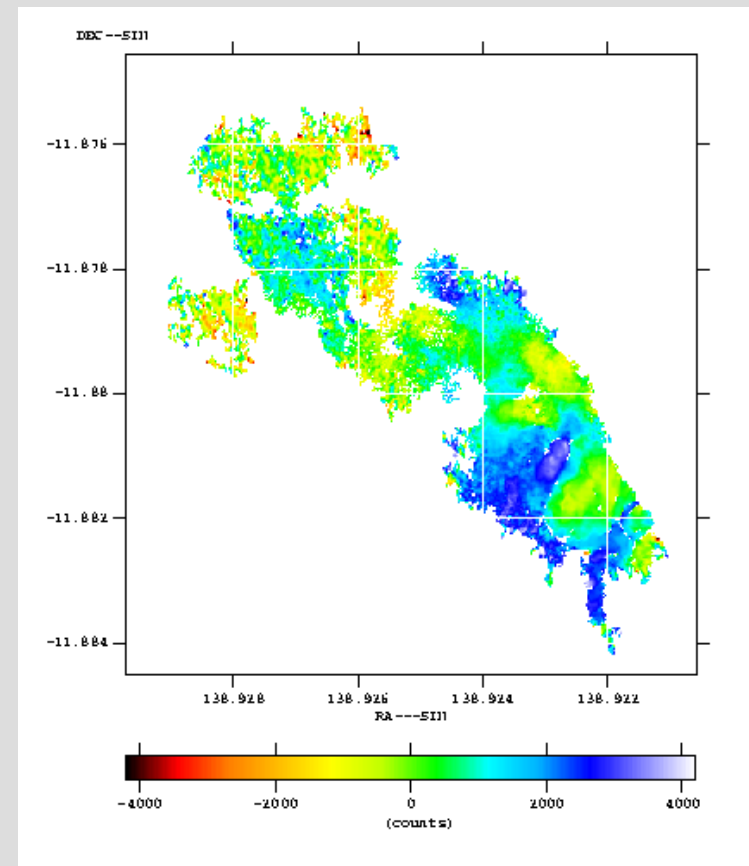
Faraday rotation measure (RM):

$$RM = a_0 \int dz n_e(\vec{x}) B_z(\vec{x})$$

# Example: The cool core of Hydra A

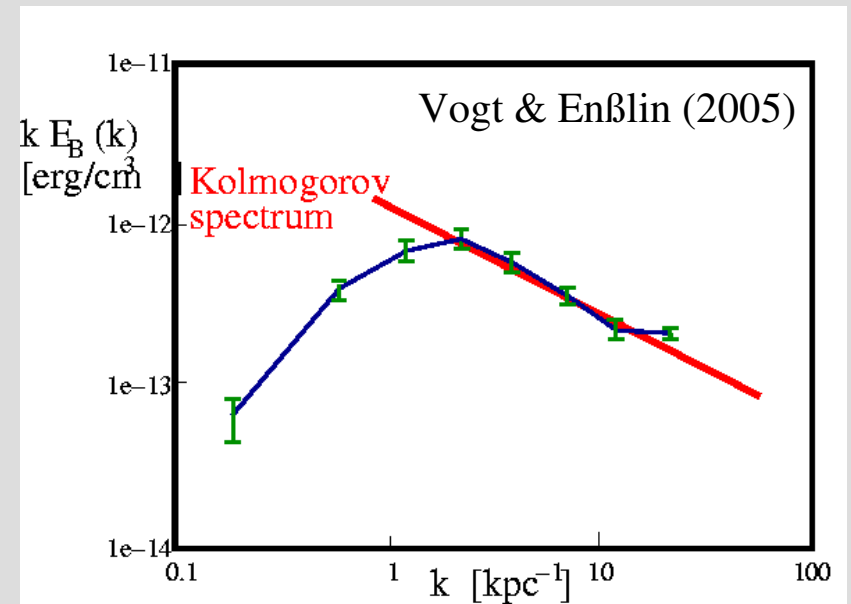
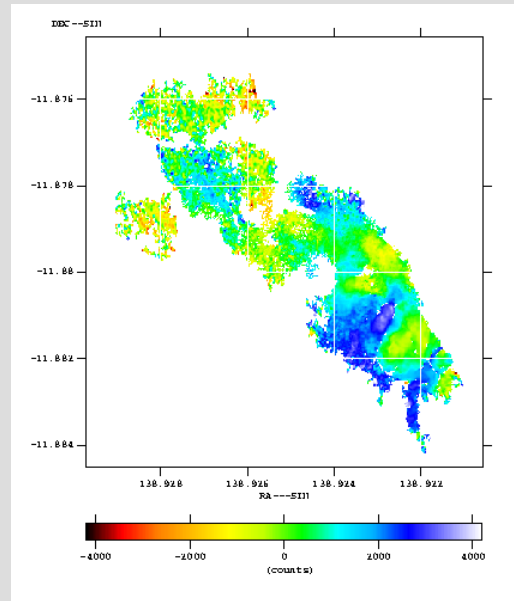


Credit: X-Ray (purple): NASA/CXC/SAO;  
Radio (green): Greg Taylor (NRAO)



PACERMAN Faraday Rotation map of northern radio lobe  
credit: Radio: Taylor & Perley (VLA); Klaus Dolag

# From RM to magnetic turbulence



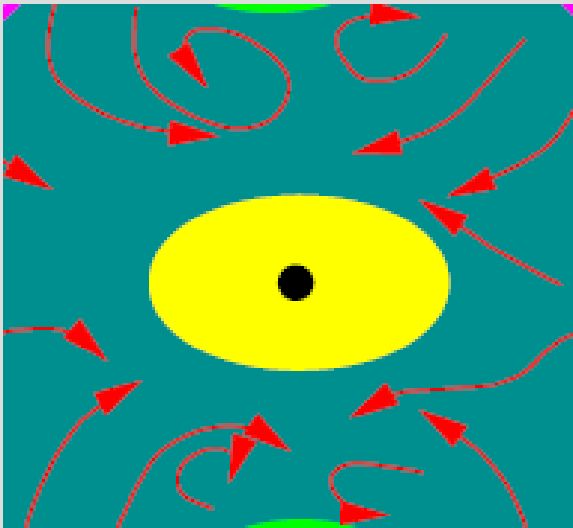
Vogt & Enßlin's (2005) analysis is based on:

- homogeneous, isotropic and divergence free magnetic turbulence
- known cluster geometry (window function)
- Bayes theorem connecting probabilities model spectra & observed RM fluctuations

# What could it be?

## A small scale dynamo at work?

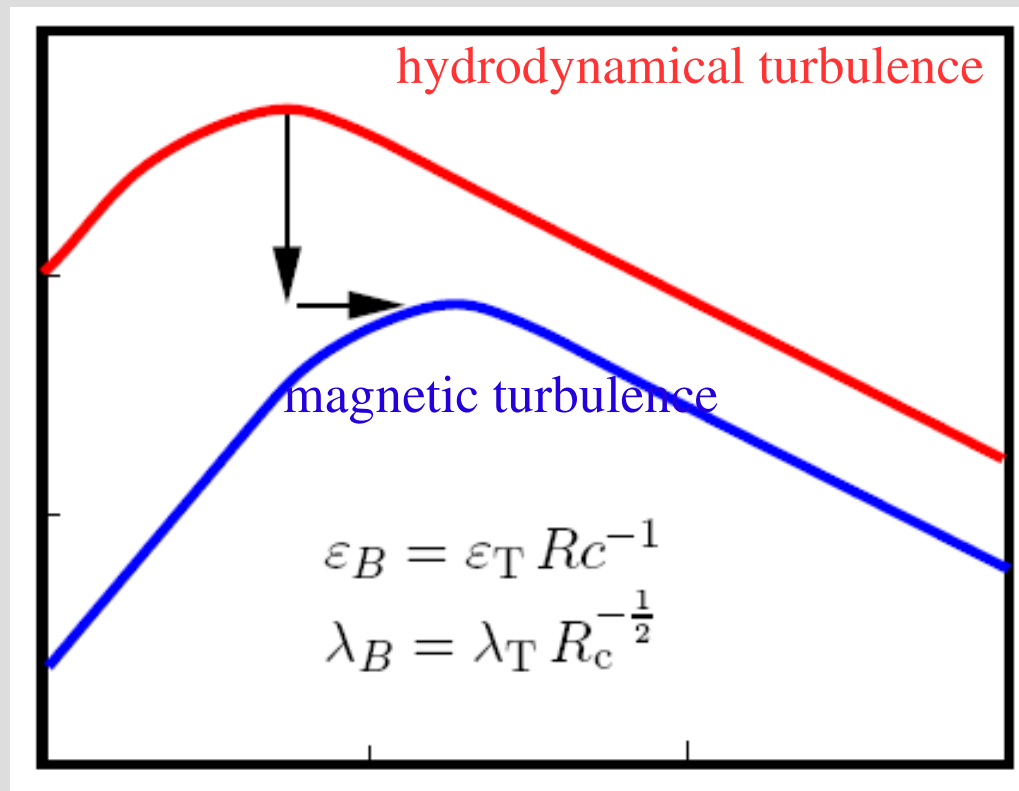
random motion stretches and twists initial magnetic fields:



- + magnetic field is amplified until magnetic fields become dynamically important
- + saturation is reached
- + critical Reynold's number ( $R_c$ )

# Magnetic turbulence in cool cores

magnetic turbulence traces hydrodynamical turbulence on a bit smaller scales (e.g. Subramanian et al. 2005)

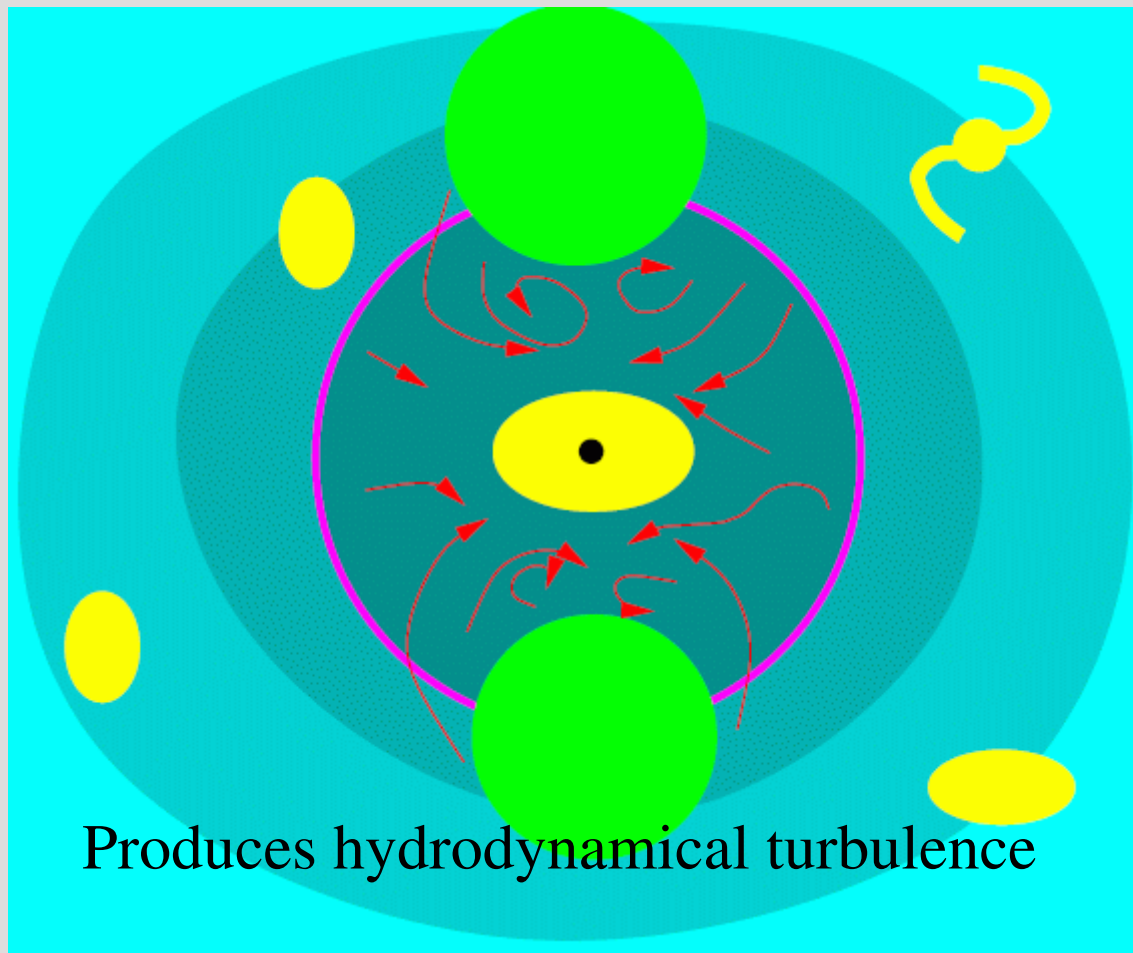


# Hydrodynamical turbulence in a cool core?

Central Radio galaxy feedback heating a cool core (self regulating)  
developed by Churazov et al. (2001)

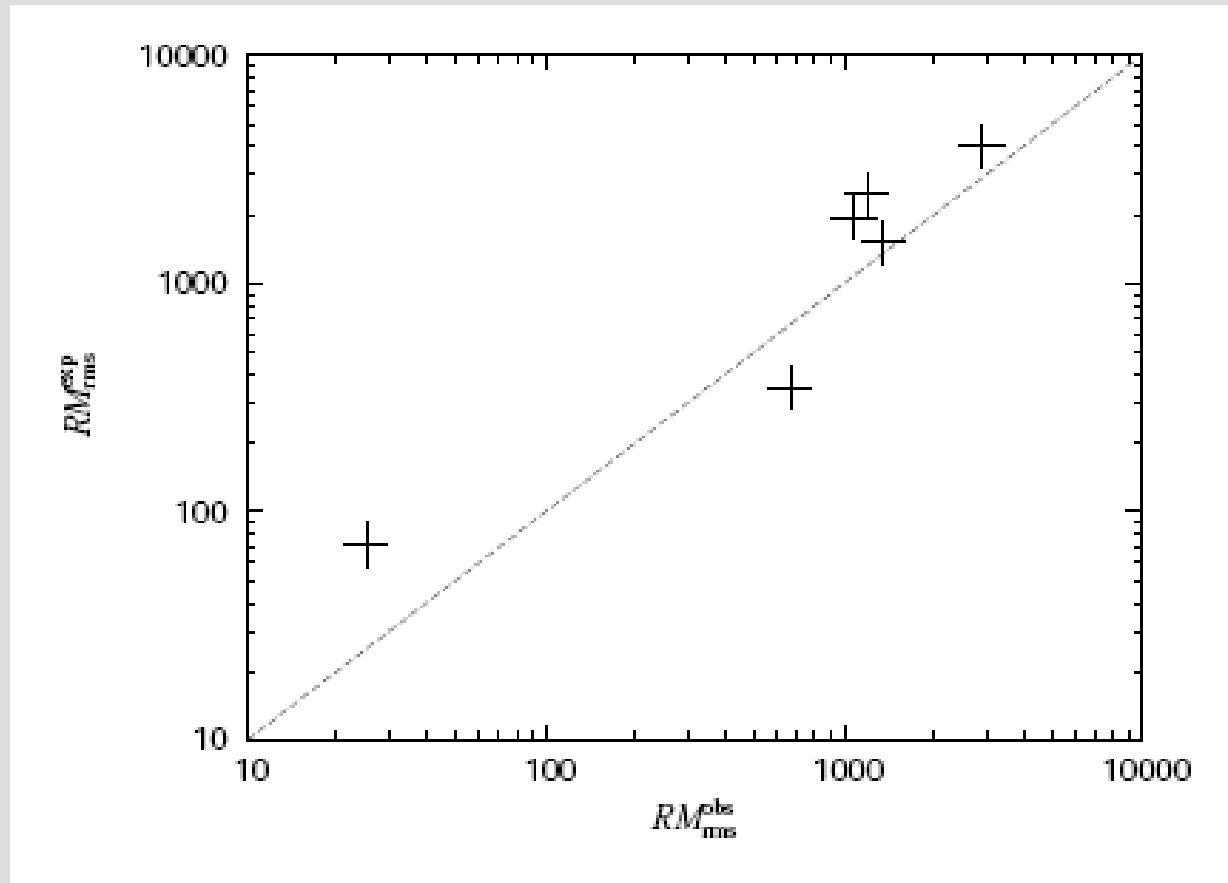
# Hydrodynamical turbulence in a cool core?

Central Radio galaxy feedback heating a cool core (self regulating)  
developed by Churazov et al. (2001)



- ★ gas cools down
- ★ condensing onto the core
- ★ triggers galaxy activity
- ★ radio bubbles are inflated
- ★ buoyant motion of bubbles

# Magnetic turbulence in cool cores



expected vs. observed RM dispersion

# Another Approach - Stokes-correlation & Lorentz forces

Faraday-free polarisation maps (also provided by PLANCK):

*Are physical meaningful signals encoded?*

Scheckochihin, Walkens & Enßlin: took a closer look at the  
Lorentz Force:

$$\frac{1}{c}(\vec{J} \times \vec{B}) = -\nabla \left( \frac{B^2}{8\pi} \right) + \frac{1}{4\pi} [(\vec{B} \nabla) \vec{B}]$$

The magnetic tension force

- + interesting for distinguishing between MHD scenarios
- + study its statistical properties

# Another Approach - Stokes-correlation & Lorentz forces

Faraday-free polarisation maps (also provided by PLANCK):

Are physical meaningful signals encoded?

**Observables:** I, Q, U and their six correlation functions (e.g.  $\Sigma_{II}, \dots$ )

The tension force power spectrum:

$$\hat{\Phi}_{ii}(k_{\text{perp},0}^{\rightarrow}) = \frac{1}{4} k^2 [\hat{\Sigma}_{II}(k_{\text{perp}}^{\rightarrow}) + \hat{\Sigma}_{QI}(k_{\text{perp}}^{\rightarrow}) + \hat{\Sigma}_{IQ}(k_{\text{perp}}^{\rightarrow}) + \hat{\Sigma}_{QQ}(k_{\text{perp}}^{\rightarrow}) + 8 \hat{\Sigma}_{UU}(k_{\text{perp}}^{\rightarrow})]$$

# Prospects to LOFAR



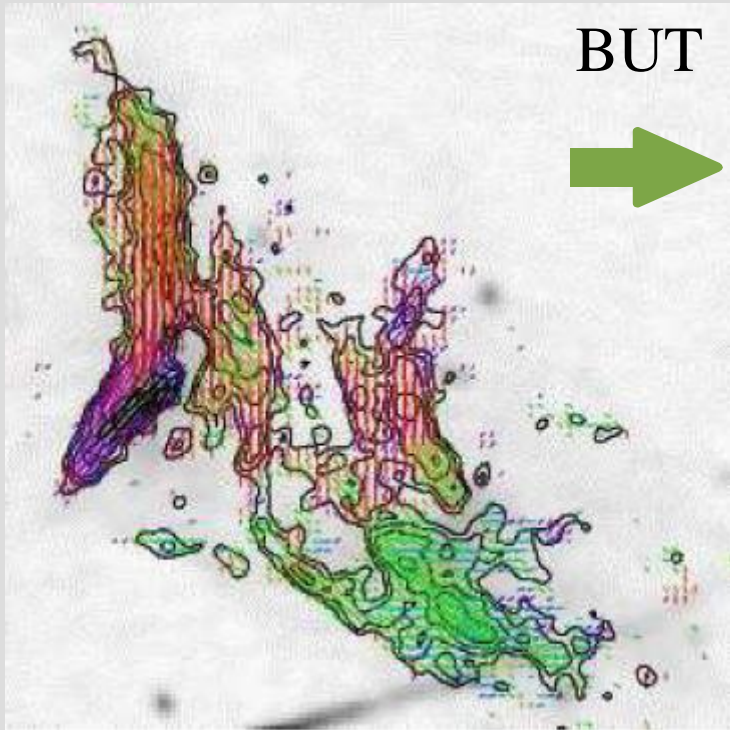
RM point source studies – no problem

BUT



analysis of diffuse emission at low frequencies

- lots of diffuse emission will be detected!
- polarisation, RM at low frequencies?



Clarke & Enßlin

# Prospects to LOFAR



Two things working against us:



Faraday depth:

- nothing we can do about this except looking at the right sources



Beam depolarisation -

Depolarisation if RM gradient across the beam  $\sim$  a few radians:

- again looking at the right sources
- smaller beams = push for higher resolution
- long LOFAR baselines

# Conclusion



**Tools** to study magnetic turbulence:

- ★ RM as a magnetic power spectrum estimator
  - ★ successfully applied to cool core of Hydra A
  - ★ magnetic turbulence (Kolmogorov-like) detected!
- ★ Stokes-correlations possibly as a Lorentz force power spectra estimator



We will be able (with a long baseline) LOFAR to apply these tools to RM/polarisation maps to study the properties of magnetic fields further.



Thank You!