

ASTRON



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Cosmic Magnetism with LOFAR

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Cosmic Magnetism research is at a turning point

FROM:

“ As usual in astrophysics, the way out of a difficulty is to invoke the poorly understood magnetic field. One tends to ignore the field so long as one can get away with it.”

Cox (1990)

TO:

Key Science projects

LOFAR: *Studying Cosmic Magnetism in the Nearby Universe with LOFAR*

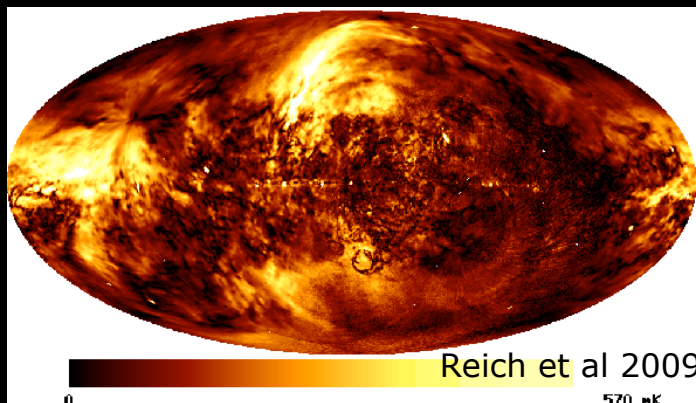
SKA: *The Origin and Evolution of Cosmic Magnetism*

New developments give an impulse to cosmic magnetic field studies



Low frequencies (LOFAR, MWA etc):
sensitive to low rotation measures = weak
magnetic fields in the Galactic halo

Focal plane arrays (APERTIF, ASKAP etc):
do large-area surveys in a finite time



Radio spectro-polarimetry (GMIMS etc):
broad multi-channel frequency bands for
rotation measure synthesis

LOFAR Cosmic Magnetism observations:

The Methods:

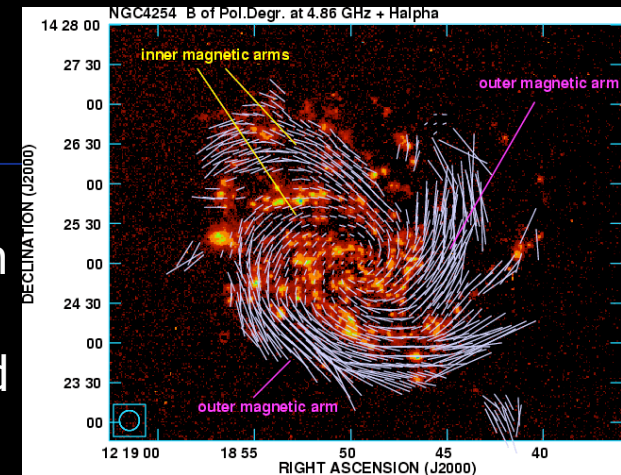
- The Rotation Measure (RM) Grid
- Diffuse polarization: RM Synthesis

The Goals:

- characterize magnetic fields in (the halo of) the Milky Way and external galaxies
- explore the role of magnetism in perturbed galaxies
- detect and characterize intergalactic magnetic fields
- explore the origin and evolution of cosmic magnetism: test dynamo theories
- find the magnetic structure of stellar and AGN jets

measuring cosmic magnetism: radio polarimetry

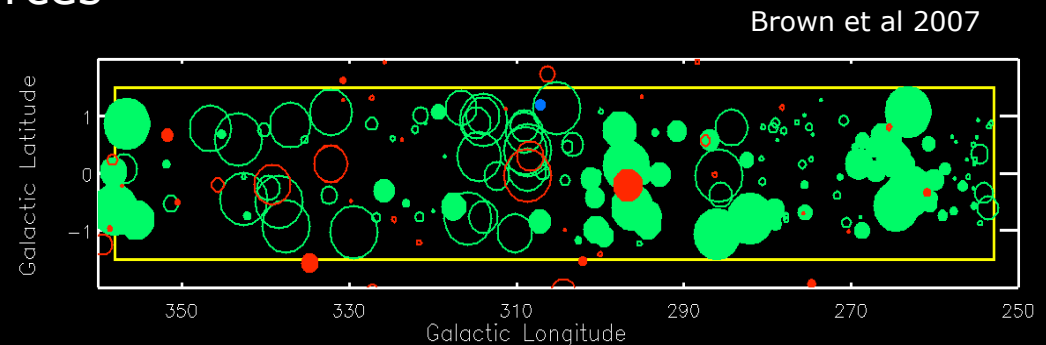
1. (De)polarization of diffuse synchrotron emission
 - total intensity probes total magnetic field
 - polarized intensity probes regular magnetic field



Chyzy et al 2008

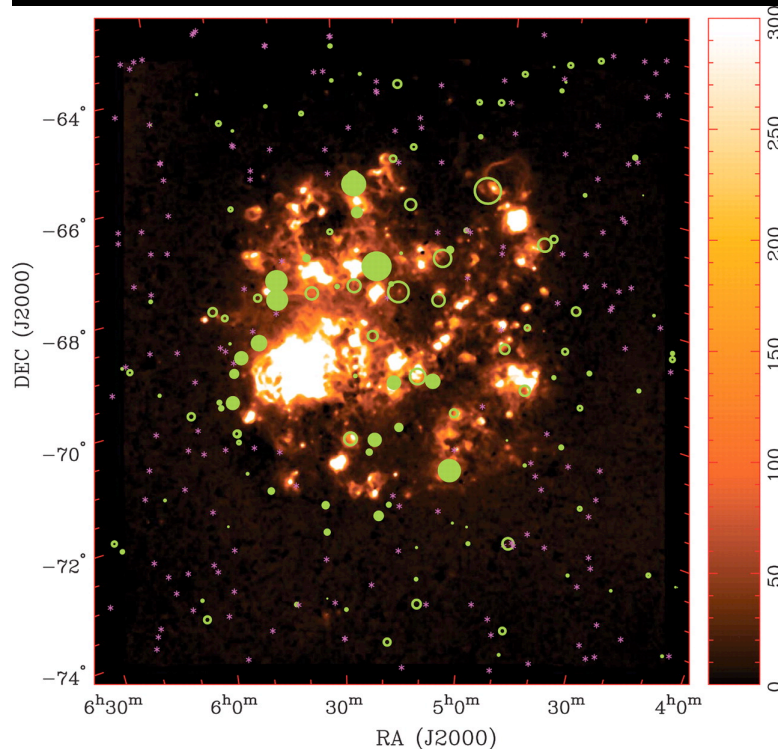
2. Rotation measures of point sources
(extragalactic and/or pulsars)

$$\text{polarization angle } \theta = \text{RM } \lambda^2$$
$$\text{RM} \propto \int n_e \mathbf{B} \cdot d\mathbf{l}$$



3. Rotation measures of diffuse synchrotron emission
RM synthesis / Faraday tomography
(Burn 1966, Brentjens & de Bruyn 2005)

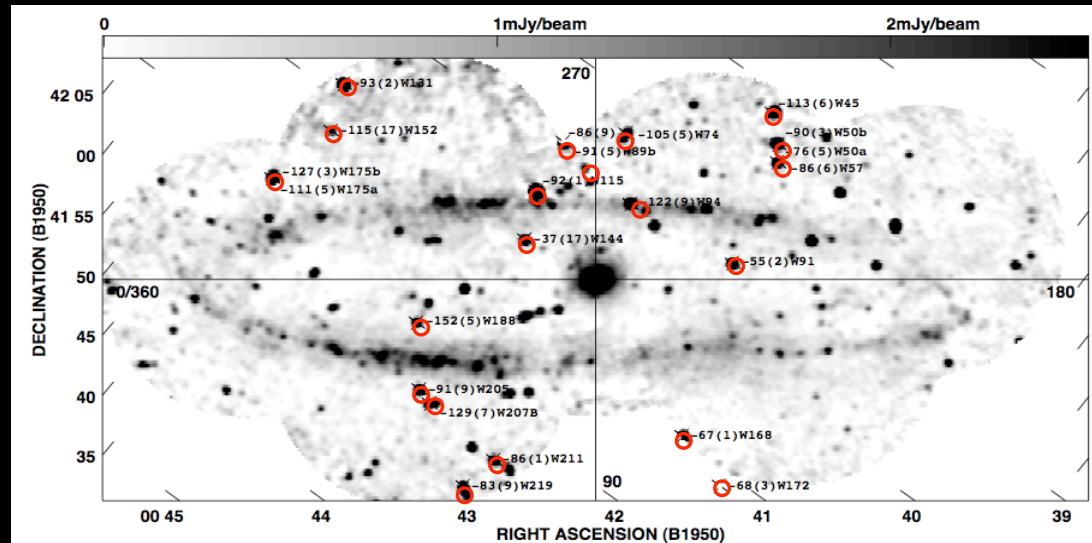
The RM grid



Gaensler, Haverkorn et al 2005

Large Magellanic Cloud:
~100 background sources reveal a large-scale azimuthal magnetic field

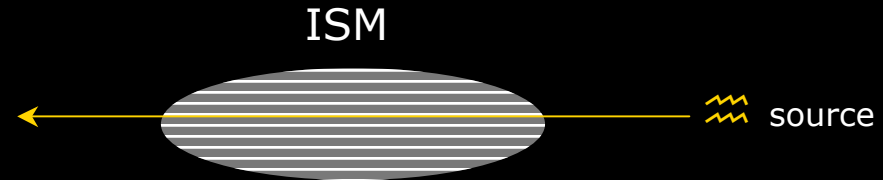
M31:
(only) 21 sources hint at axisymmetric field structure, detect field far out



Han et al 1998

Rotation Measure synthesis

Faraday rotation:

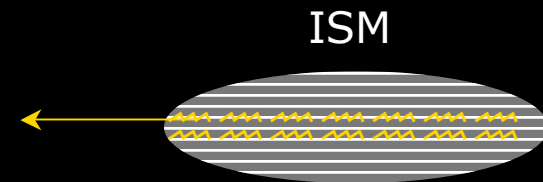


Polarization angle rotates with observing wavelength λ : $\theta \propto \text{RM} \lambda^2$

where rotation measure

$$\text{RM} \propto \int n_e \mathbf{B} \cdot d\mathbf{l}$$

Rotation measure synthesis:



$$P(\lambda^2) = W(\lambda^2) \int F(\phi) e^{2i\phi\lambda} d\phi$$

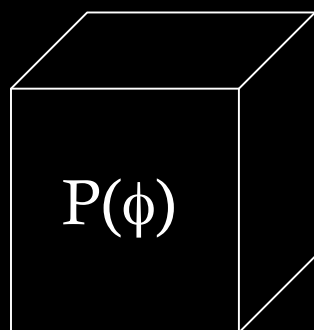
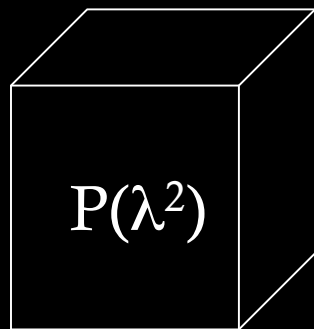
$$F(\phi) * R(\phi) = \int P(\lambda^2) e^{-2i\phi\lambda} d\lambda^2$$

$$\text{Faraday depth } \phi \propto \int n_e \mathbf{B} \cdot d\mathbf{l}$$

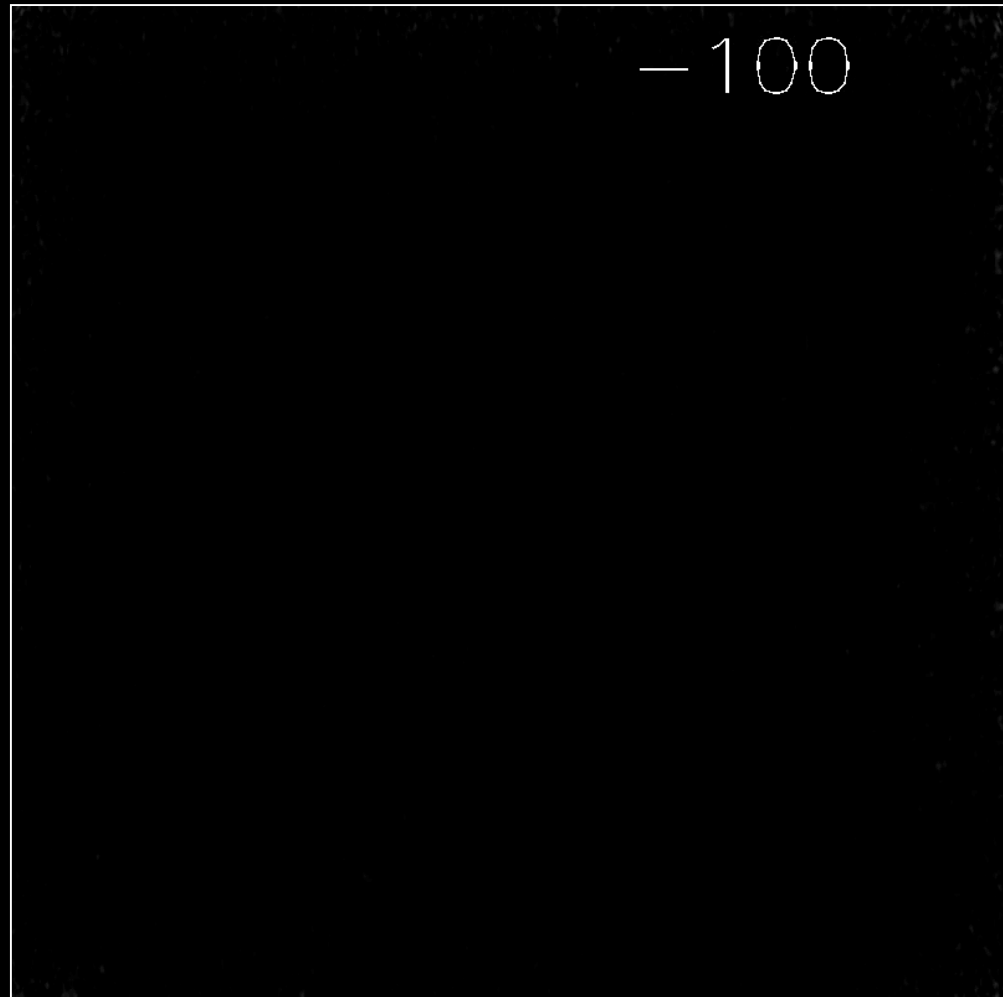
(Burn 1966, Brentjens & de Bruyn 2005)

Rotation Measure Synthesis

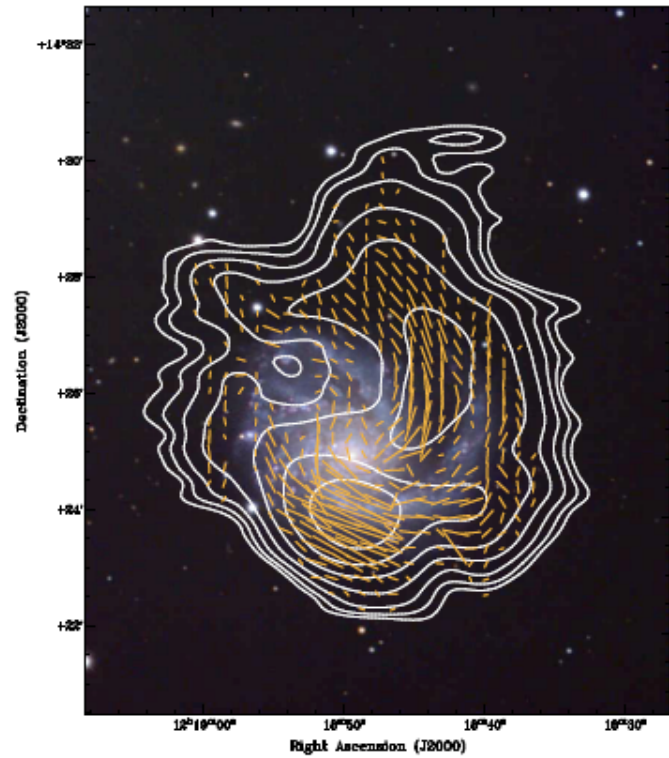
(Burn 1966, Killeen et al 1996, de Bruyn 1996, Brentjens & de Bruyn 2005)



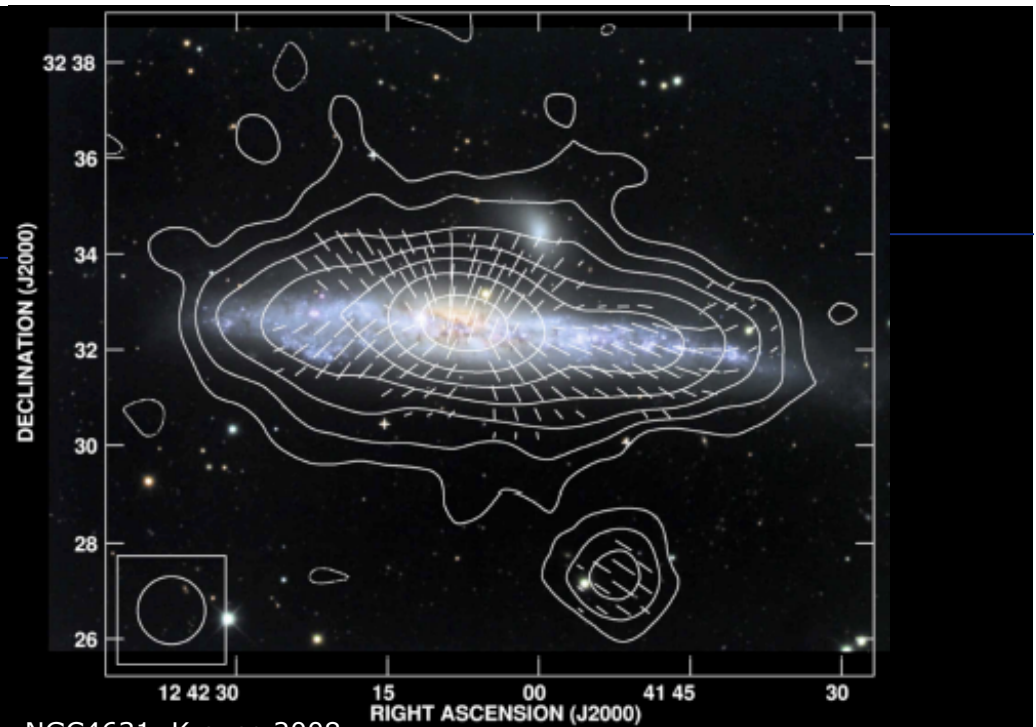
$$\begin{aligned}\phi &= \text{Faraday depth} \\ &= 0.81 \int n_e \mathbf{B} \cdot d\mathbf{l}\end{aligned}$$



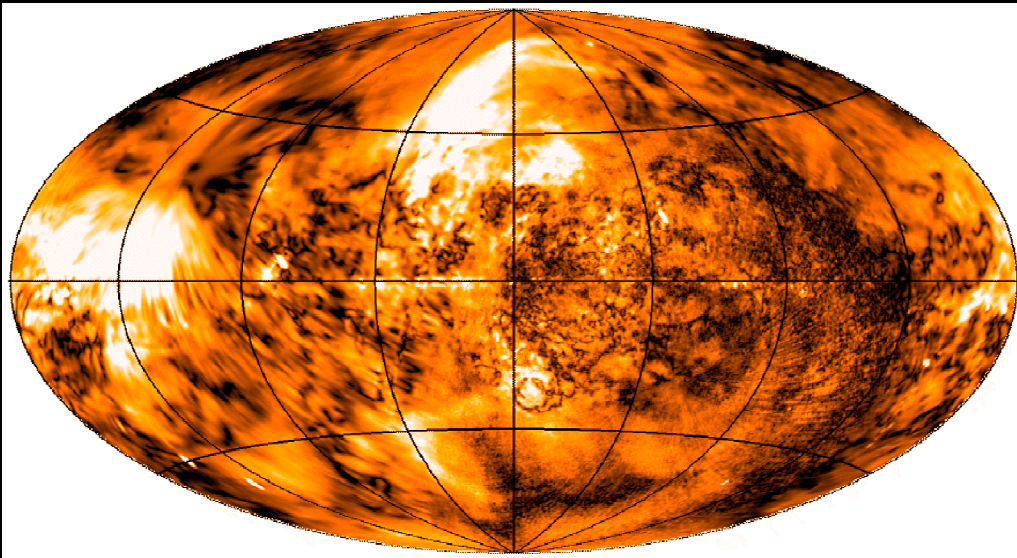
$7^\circ \times 7^\circ$ field around $(l,b) = (181^\circ, 20^\circ)$
Schnitzeler et al 2008



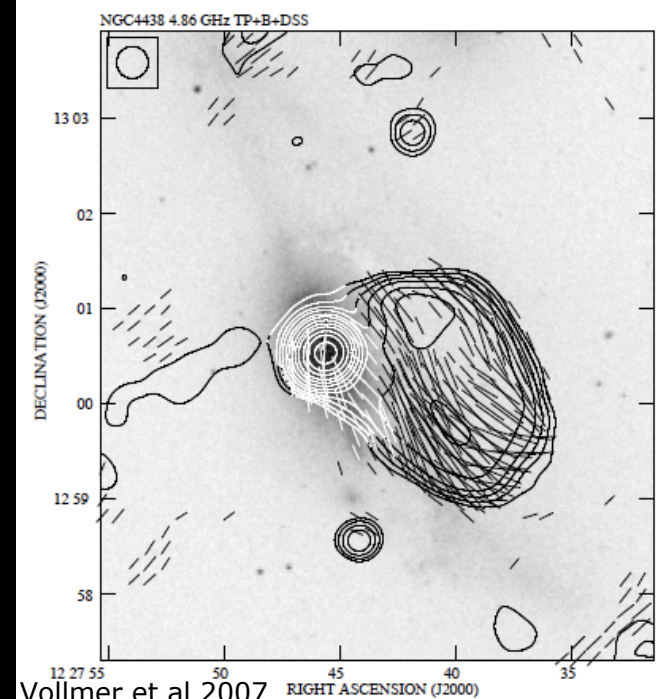
NGC4254, Heald et al 2009, optical courtesy Robert Gendler



NGC4631, Krause 2008

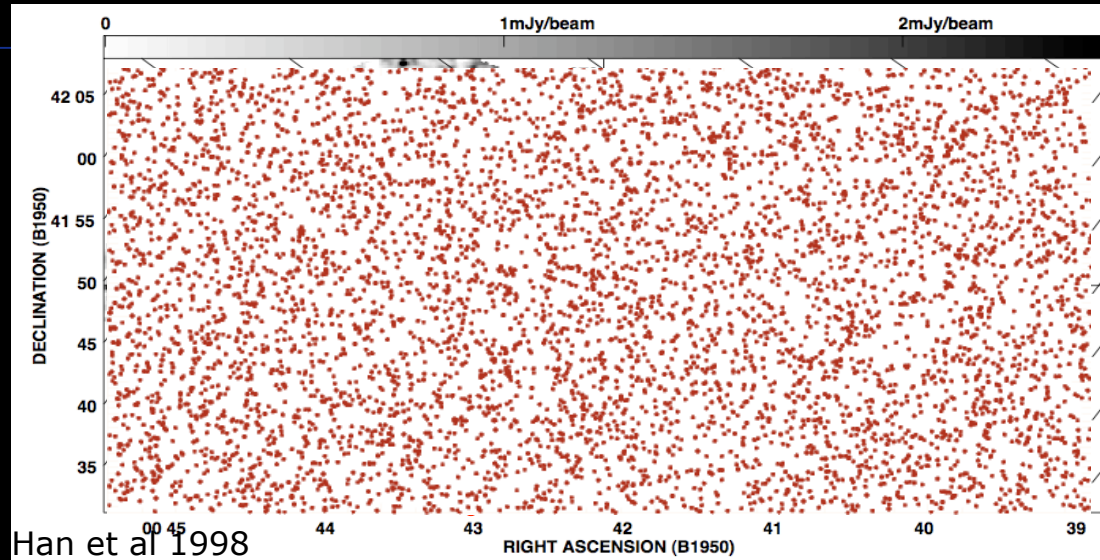


1.4 GHz Polarized intensity, Reich et al 2009

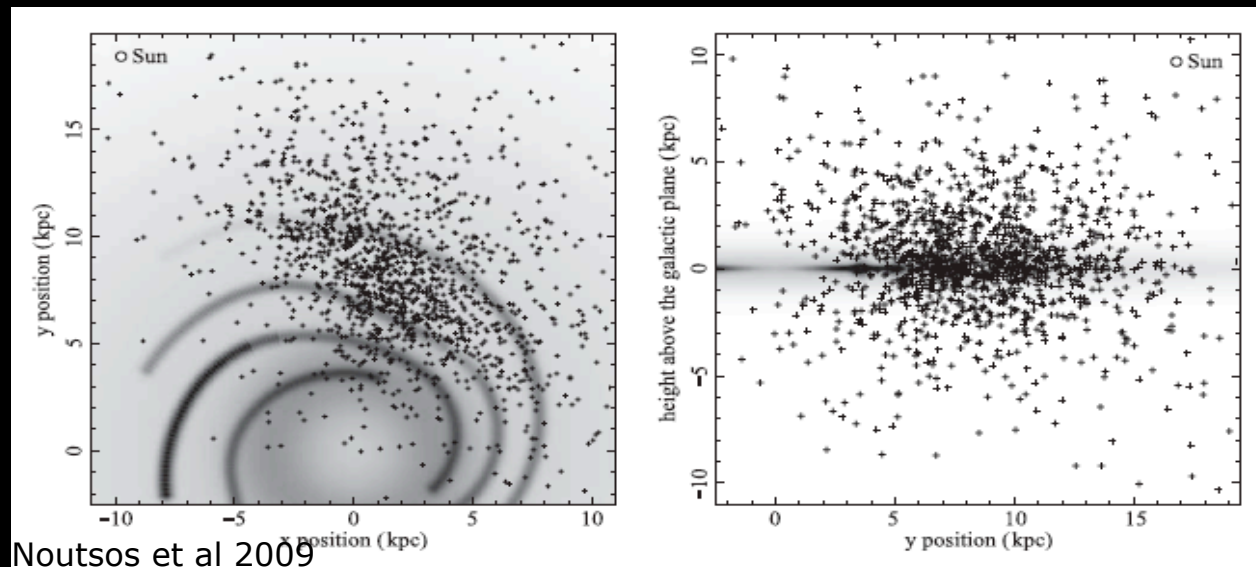


Vollmer et al 2007

The LOFAR RM grid



>2500 sources behind M31



1000+ pulsars in
the Milky Way

Conclusions

Magnetic fields play a large role in the ecosystems of galaxies and galaxy groups/clusters, but big questions are still open:

- what is the origin and evolution of Galactic magnetism?
- what is its interaction with other galaxy components?
- what is its role in disk-halo interaction?

LOFAR is uniquely sensitive to weak magnetic fields: ideal for study of Galactic halos and the outskirts of galaxies

--> The RM Grid and RM Synthesis of diffuse polarization

Want to help?

Small MKSP commissioning teams work on various data sets, get together in biweekly telecons and regular Busy Weeks.

Want to join? Let us know!