The Unique ‘Message’ of Radiopolarimetry

at Low Frequencies

with the WSRT

Radio emission polarization → magnetic fields

Information on (components of) magnetic field from

Equipartition argument → B_{tot}

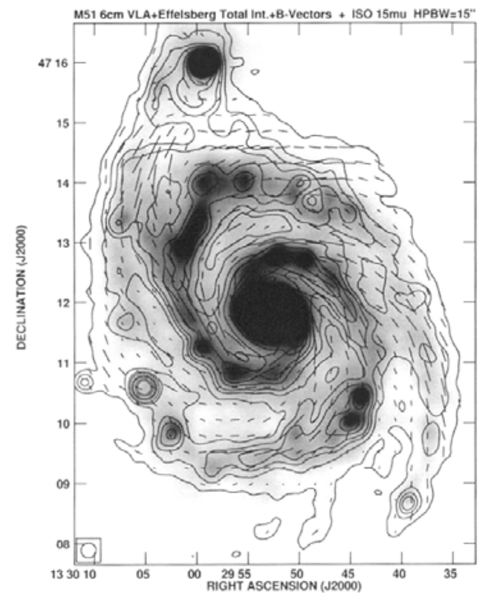
Faraday rotation → $B_{//}$ Faraday tomography

(synchrotron) intensity → $B_{\perp}$

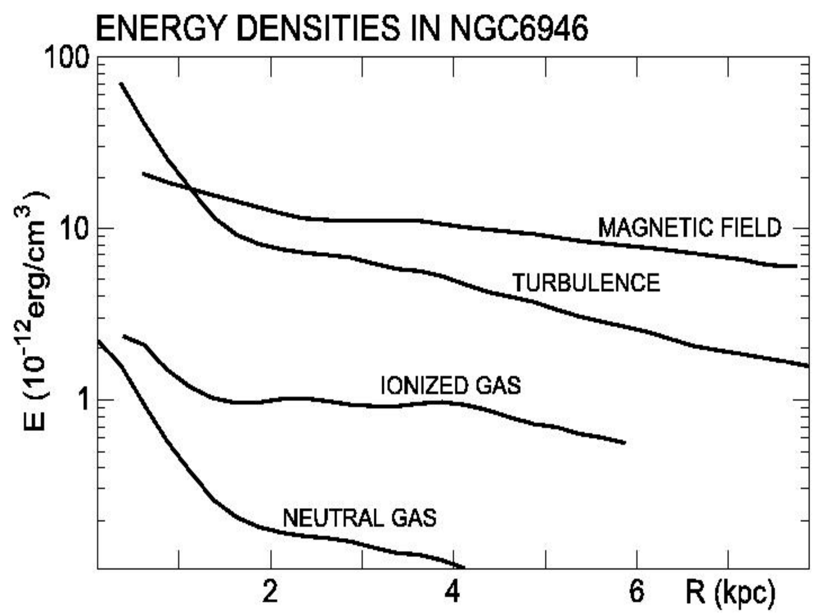
The importance of magnetic fields

- link with galactic (gas) dynamics

M51
I_{tot} $\lambda = 6$ cm
B-vectors
15 μ



- magnetic pressure often comparable to gas pressure



- coupling with many components of ISM

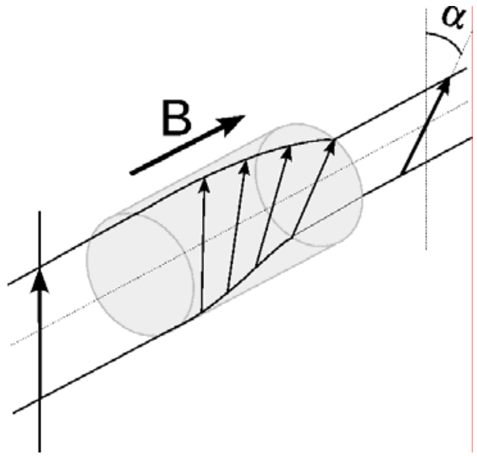
The importance of magnetic fields

- link with galactic (gas) dynamics e.g. M51
- magnetic pressure often comparable to gas pressure
- coupling with many components of ISM

Some questions

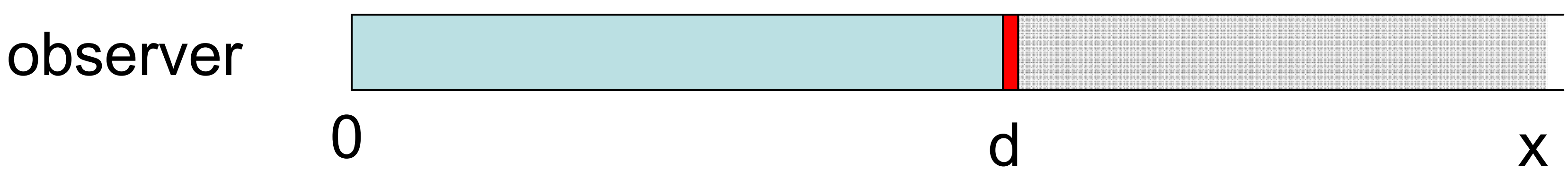
- topology / strength of large-scale field (reversals ?!)
- small-scale vs. large-scale field
- role of magnetic field in turbulence of ISM
- origin and amplification (seed fields – dynamo ?)

Faraday tomography



- disentangling (polarized) emission and Faraday rotation
- undoing line-of-sight (depth-) depolarization

Faraday depth $\mathcal{R}(d) = 0.81 \int B_{//}(x)\, n_e(x)\, dx \quad [d \rightarrow 0]$



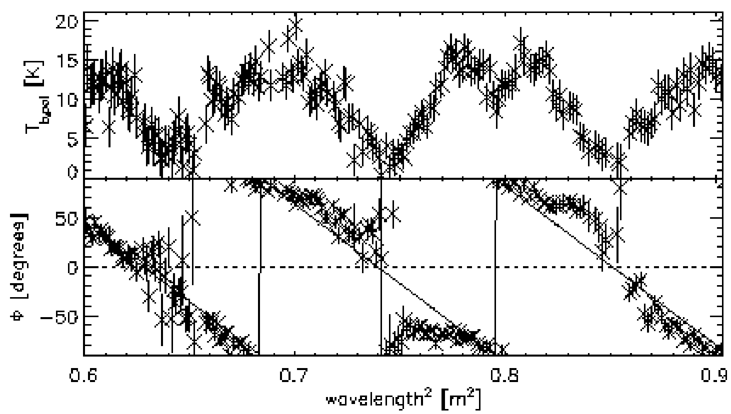
polarized emission originating at distance d has its plane of polarization rotated by an angle $\theta(d) = \mathcal{R}(d)\, \lambda^2$

Observed polarization vector $P_{obs}(\lambda)$ is vector sum (integral) of all infinitesimal polarization vectors $P_{em}(d,\lambda)$ each rotated by their respective $\theta(d)$

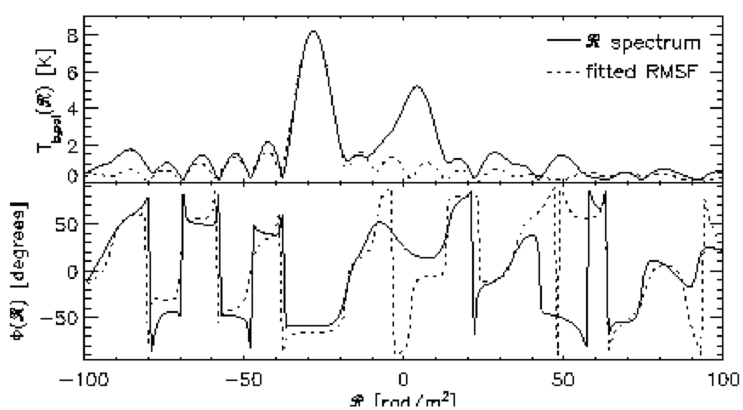
With $P_{obs}(\lambda)$ available over wide, well-sampled λ-interval $P_{em}(\mathcal{R})$ (spectrum of Faraday depth) can be recovered

$$P_{em}(\mathcal{R}) \approx \text{FT}\{P_{obs}(\lambda^2)\}$$

Faraday-depth spectrum

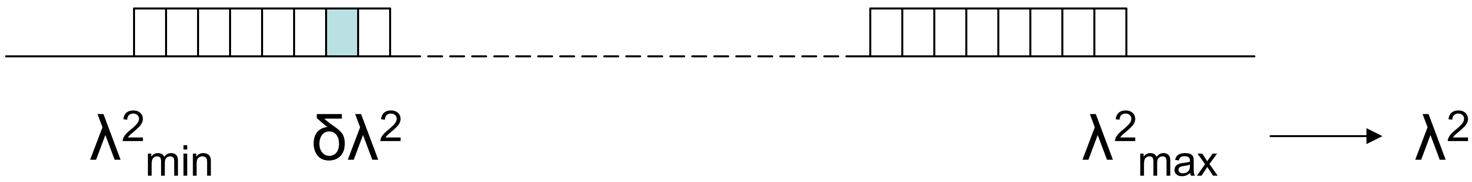


N.B.



- $\mathcal{R} \neq$ RM in general
- $\mathcal{R} \xrightarrow{?} n_e(d)$ & $B_{//}(d)$

Some ‘facts-of-life’ in Faraday tomography



- Resolution in $\mathcal{R}$ $\Delta\mathcal{R}_{min} = 3.8 / [\lambda^2_{max} - \lambda^2_{min}]$ rad/m^2
- Bias from missing $\lambda = 0$ $\Delta\mathcal{R}_{max} \sim \pi / \lambda^2_{min}$
- ‘Field of view’ $\mathcal{R}_{max} \sim 1.9 / \delta\lambda^2$ (λ in meters)

→ low frequency, wide-band, high-resolution polarimetry

$\Delta\mathcal{R}_{min} <<$ for $\lambda^2_{max} [1 - \lambda^2_{min} / \lambda^2_{max}] >>$

or $\lambda^2_{max} >>$ and $\lambda^2_{min} / \lambda^2_{max} <<$

$\mathcal{R}_{max} >>$ for $\delta\lambda^2 <<$

Low frequency, wide-band, high-resolution polarimetry

With the WSRT

- well-behaved instrumental poln.
- excellent wide-field mapping

Some examples

1. $\lambda \sim 2$ m ‘Ring’ $\Delta\mathcal{R}_{min} \sim$ 3 rad/m^2

$\lambda \sim$ 2-m movie

Low frequency, wide-band, high-resolution polarimetry

With the WSRT

- well-behaved instrumental poln.
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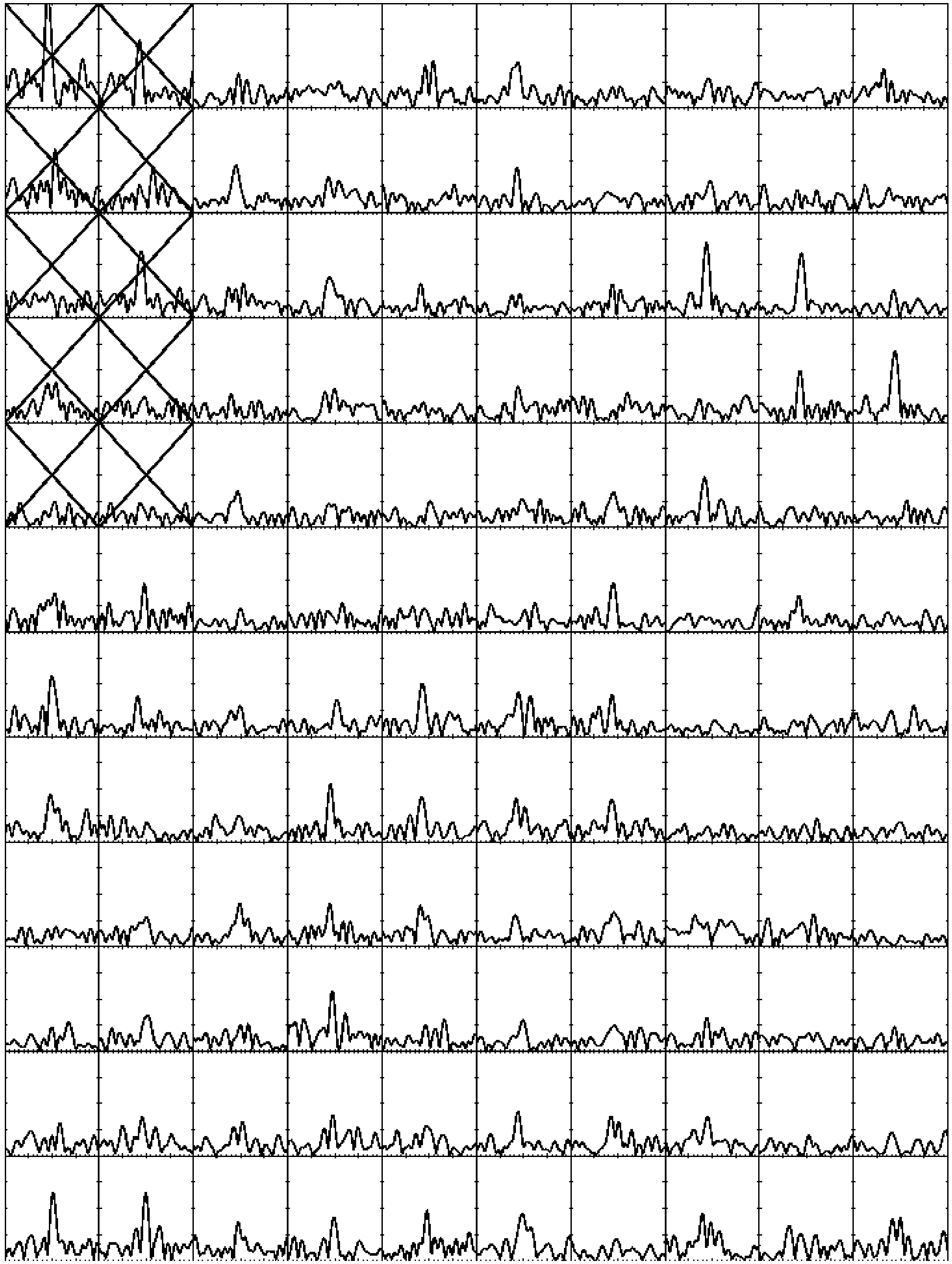
Some examples

1. $\lambda \sim 2$ m ‘Ring’ $\Delta\mathcal{R}_{min} \sim 3$ rad/m^2
2. $\lambda \sim 1$ m 4 mosaics in 2nd gal. quadrant $\Delta\mathcal{R}_{min} \sim 12$ rad/m^2



P($\mathcal{R}$)-spectra

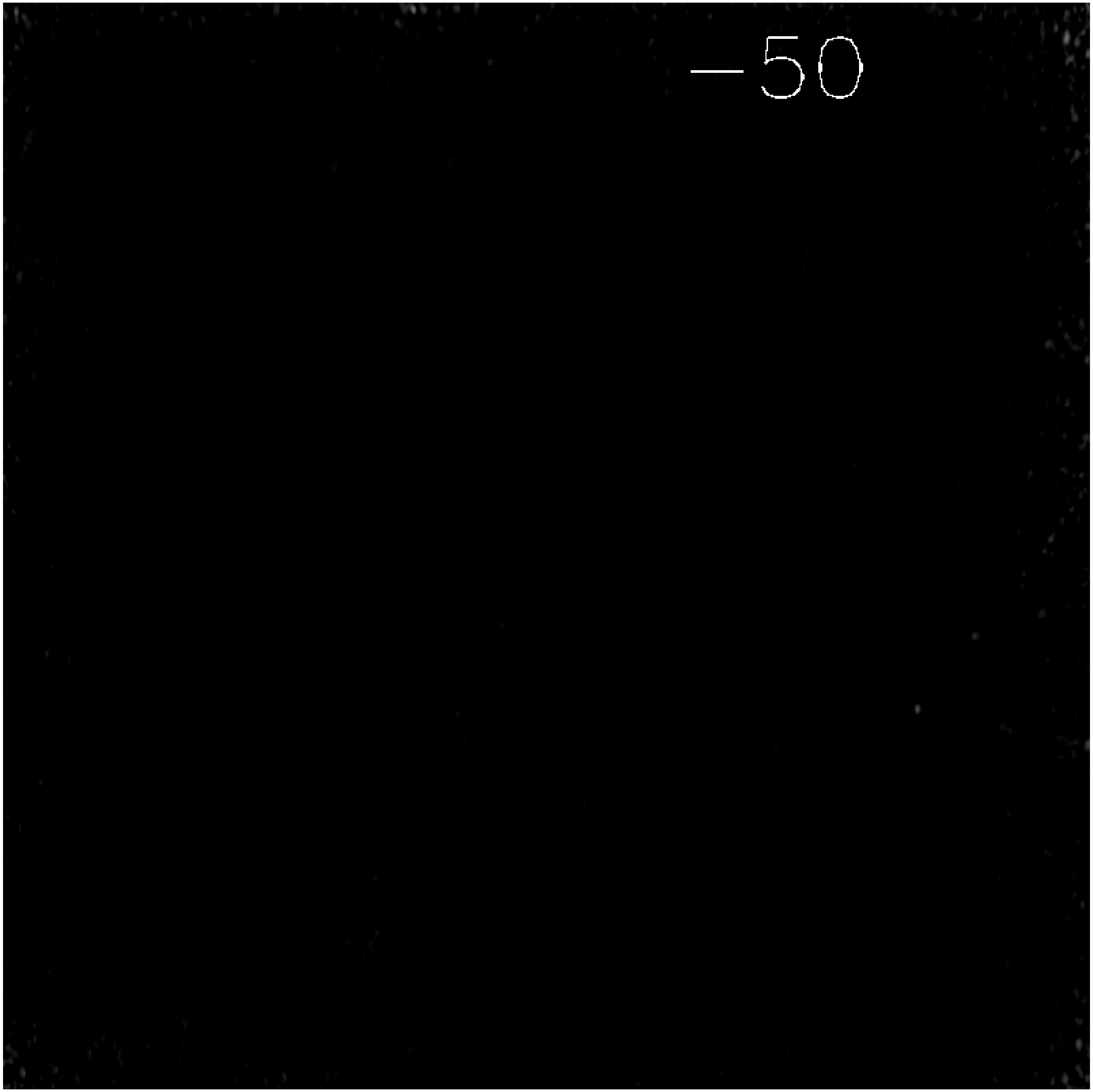
Cepheus

$\mathcal{R}$: [-100, 100]

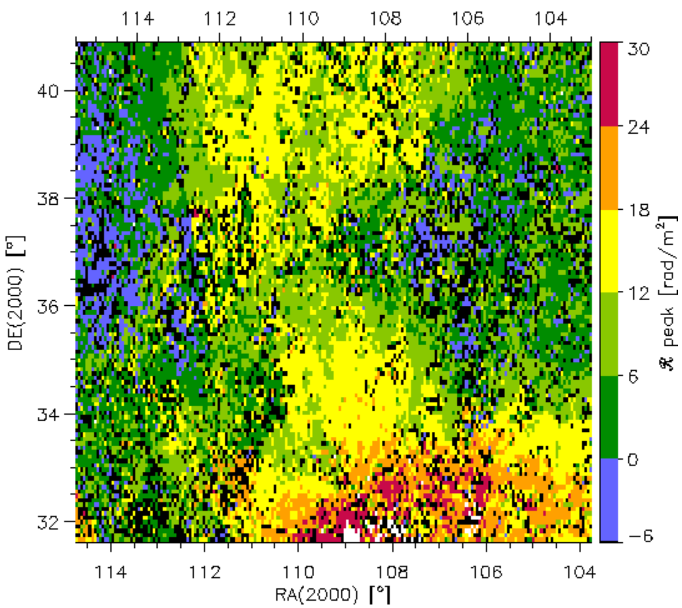
P($\mathcal{R}$): 0 – 4 K

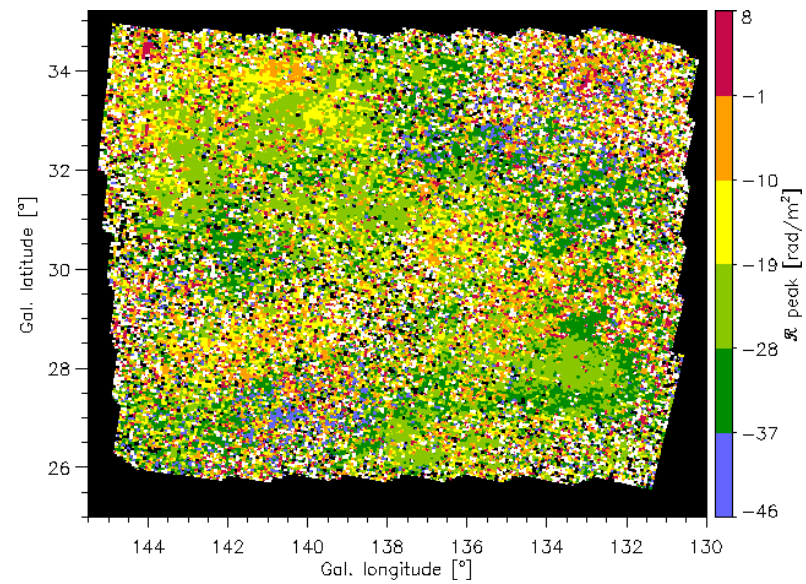
movie of
Gemini mosaic

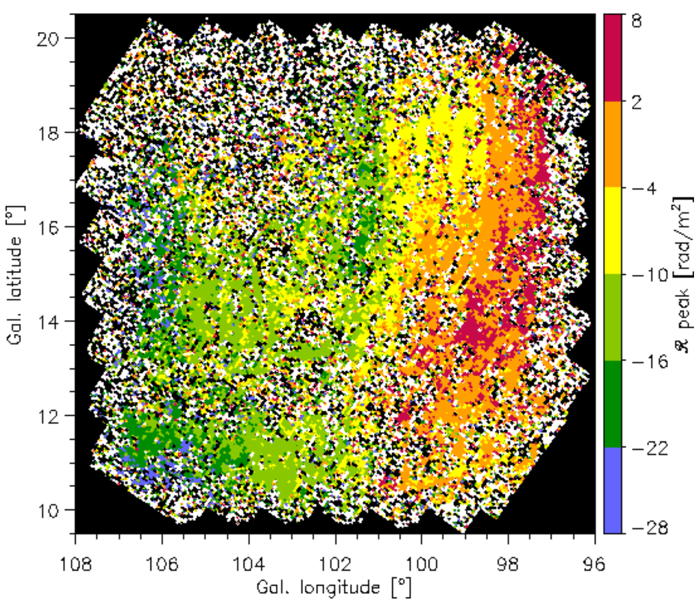
l = 185, b = 20

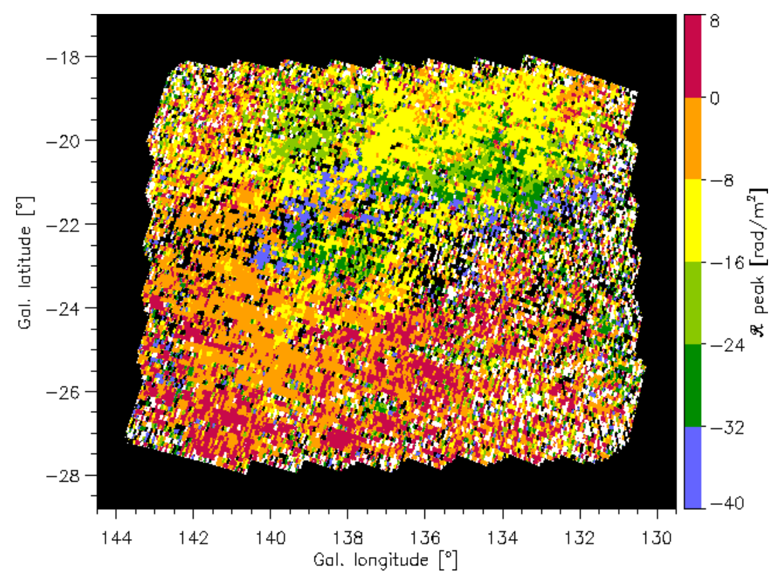


Summary of movies: $\mathcal{R}(P_{max})$ as function of position









Low frequency, wide-band, high-resolution polarimetry

With the WSRT

- well-behaved instrumental poln.
- excellent wide-field mapping

Some examples

1. $\lambda \sim 2$ m	'Ring'	$\Delta\mathcal{R}_{min}$	$\sim$ 3 rad/m^2
2. $\lambda \sim 1$ m	4 mosaics in 2nd gal. quadrant	$\Delta\mathcal{R}_{min}$	$\sim$ 12 rad/m^2

Main conclusions

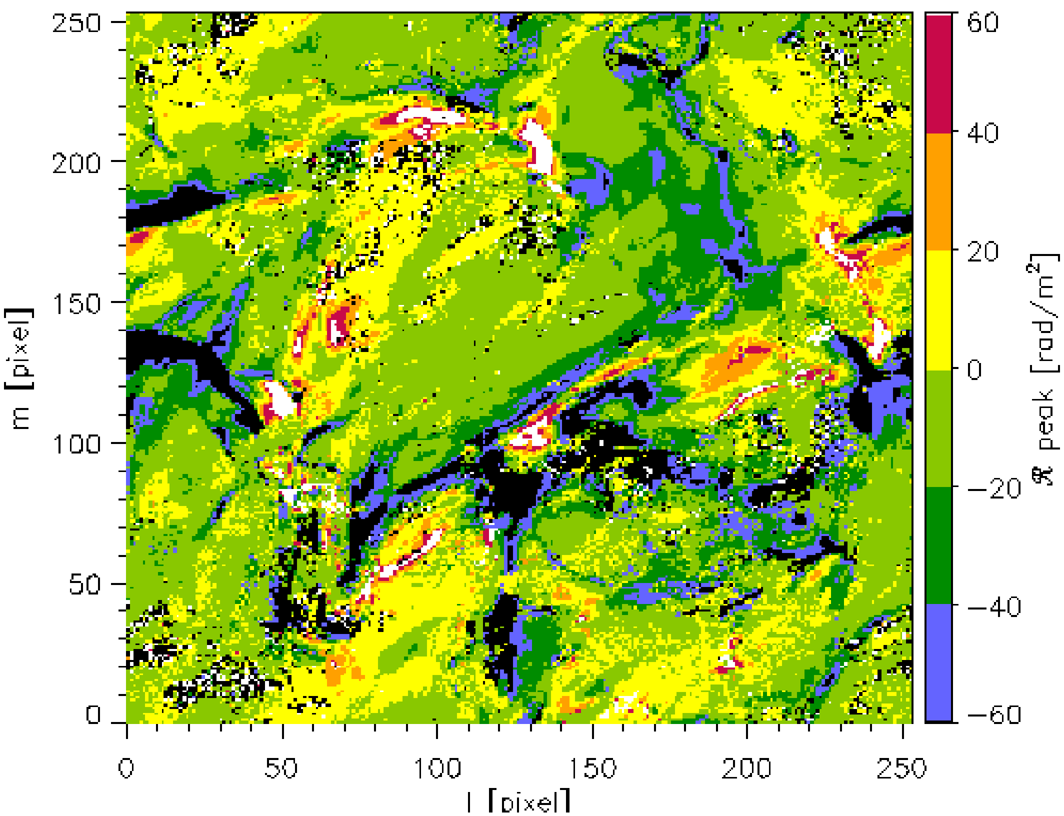
- abundant structure in $P(\mathcal{R})$ spectra ⟶ ISM
- $P(\mathcal{R})$ spectra extragalactic point sources and diffuse galactic emission are different ⟶ large-scale B-field

Structure of ISM

remember: $\mathcal{R} \xrightarrow{?} n_e(d)$ & $B_{//}(d)$

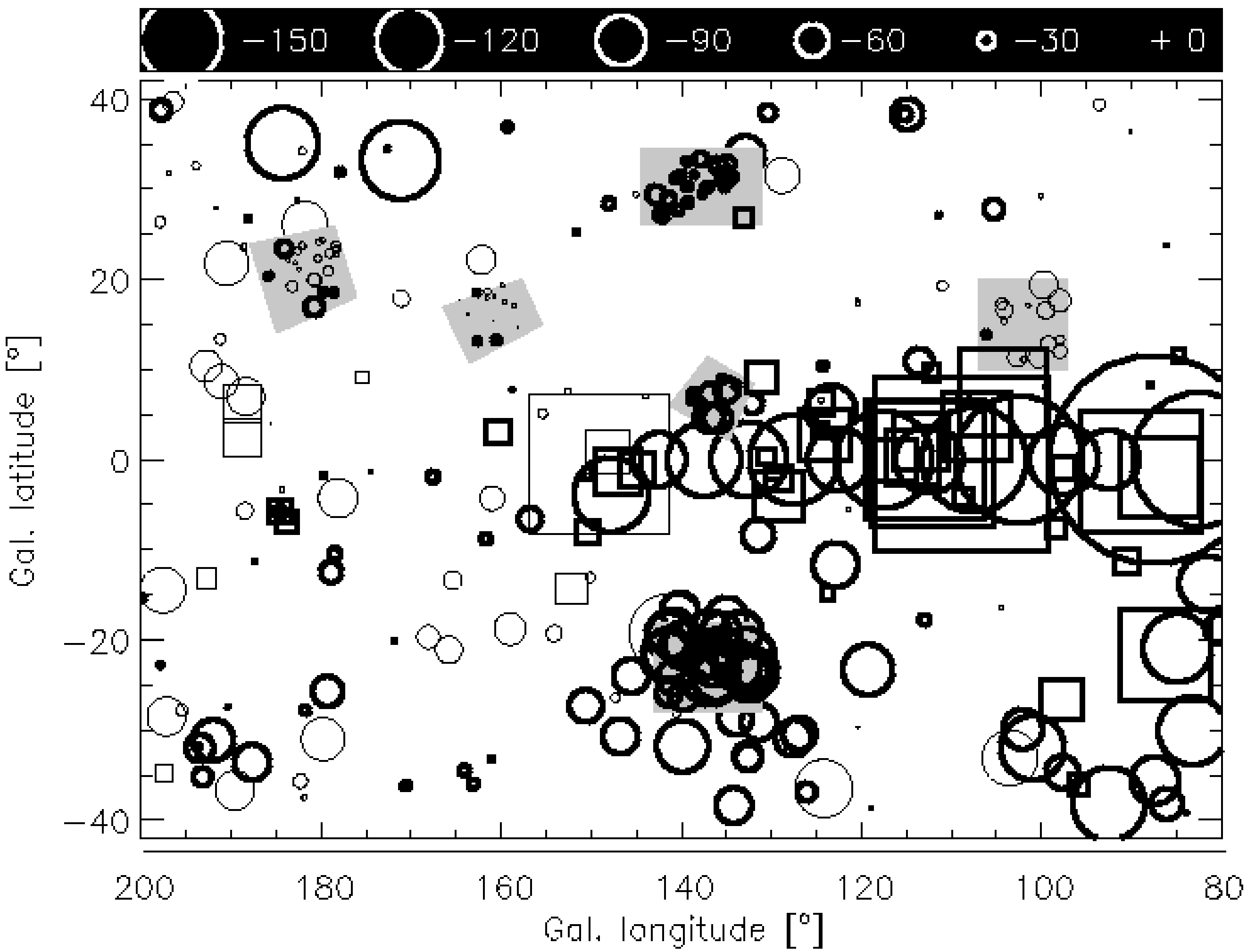
Use 3-d MHD-simulations to understand $P(\mathcal{R})$ spectra

3-d information can then be used to study the build-up of Faraday-depth in (simulated) ISM



← 'observed' MHD cube

Large-scale magnetic-field structure of the Galaxy in 2nd galactic quadrant (combining 4 mosaics with data from literature, like BS)



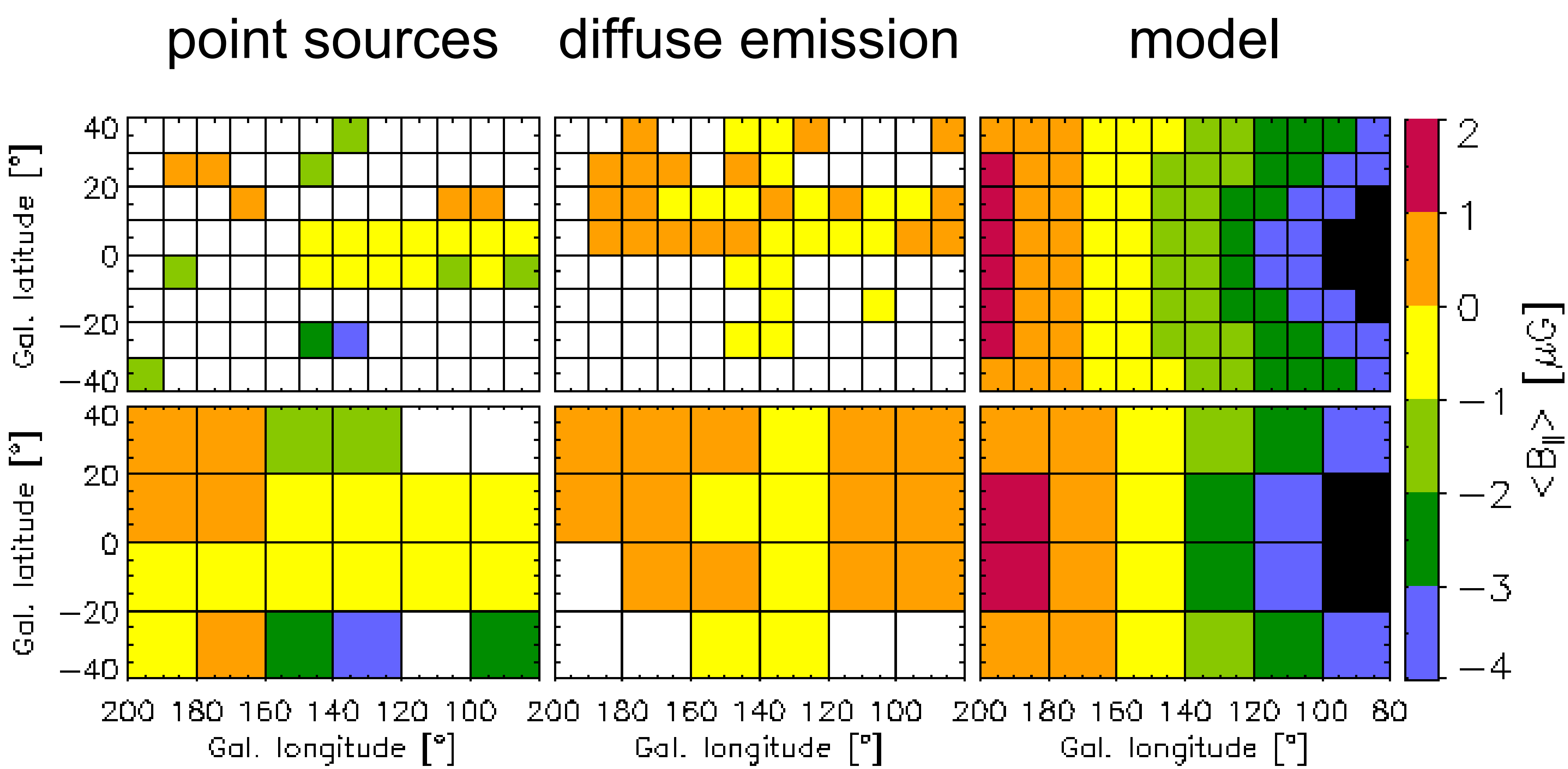
Faraday-
Rotation
depths
Measures

diffuse
and Faraday
emission
depths

point sources

Large-scale magnetic-field structure of the Galaxy in 2nd galactic quadrant (combining 4 mosaics with data from literature, like BS)

$< B_{//} > = \mathcal{R}(P_{max}) / [0.81\ DM]$ DM from CL & WHAM



Proposal for systematic low-frequency polarization survey of 2nd galactic quadrant

Previous 4 mosaics at λ ~ 1m of 7*7 pointings took about 30 half days

New survey of ~ 100 mosaics of 3*3 pointings (15 * 7) at ~ half the integration time requires 40 – 60 half days

Optimum specs to be derived from the previous mosaic data

Not centered on 12h & 12-hr runs can be split