Galactic magnetic field reconstruction form the Faraday rotation measures

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with

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DFG-RFBR project:
"*Magnetized ISM probed by radio emission: a quantitative analysis of interstellar turbulence* "

Tomography: reconstruction form integral projections

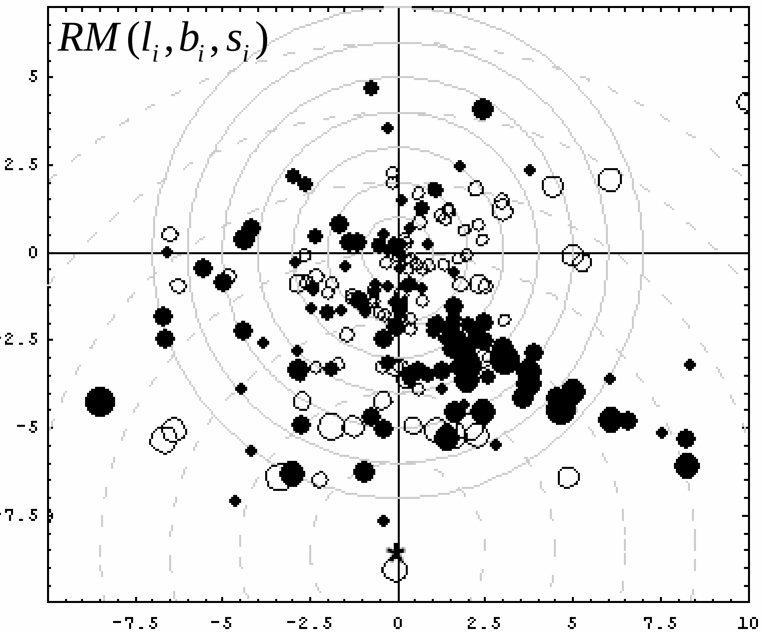
• Faraday rotation measure (an integral estimator)

$$RM(l,b,s) = K\int_0^s (n_e \overline{B})(l,b,s')\cdot \overline{ds'}$$

$$(n_e B_\parallel)(l,b,s) = \frac{\partial RM(l,b,s)}{\partial s}$$

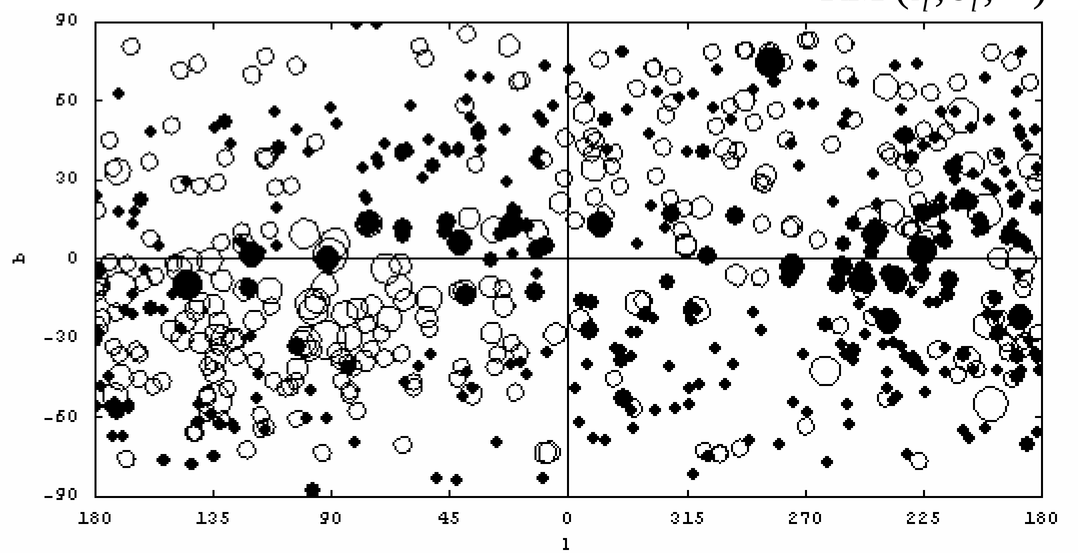
• Inhomogeneous coverage of the Galaxy

Pulsars, in the Galactic plane
(**343** sources, ATNF)



Extragalactic sources
(**663** sources mostly from Simard-Normandin et al. (1981) and Broten et al. (1988))

$RM(l_i,b_i,\infty)$



• Any acceptable model of *B* must satisfy (statistically) all the data

How to combine pulsars and EGRS?

- New variable: distance $\rightarrow$ "optical depth" (normalized DM)

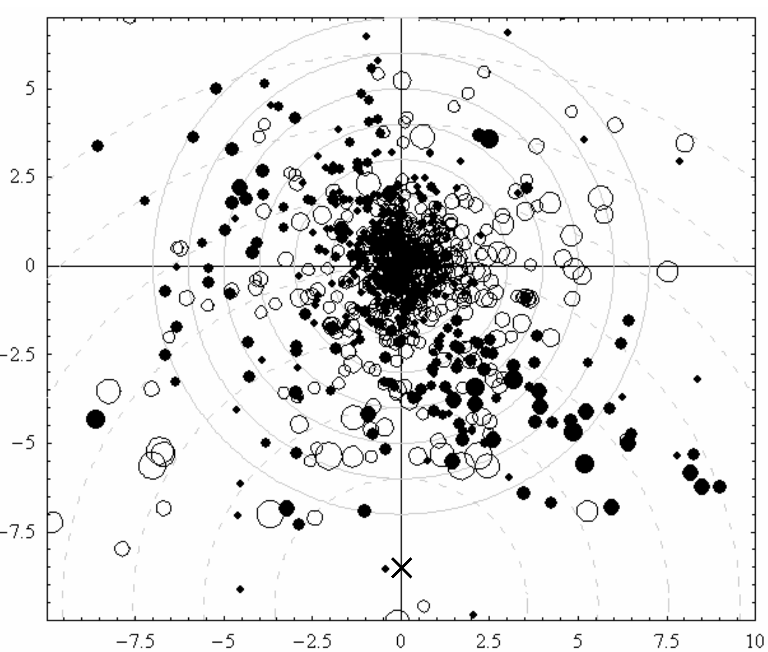
$$q(l,b,s) = \int_0^s g(l,b,s')ds'$$

$$RM(l,b,s) \rightarrow RM(l,b,q)$$

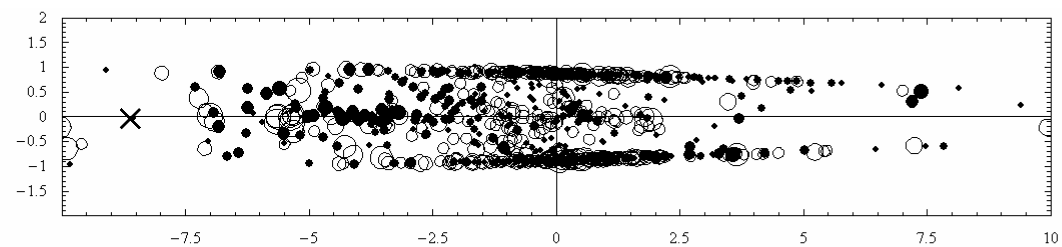
$$g(x,y,z) = \mathrm{sech}(z/h)^2 \frac{\mathrm{sech}(\sqrt{x^2+y^2}/A)^2}{\mathrm{sech}(S_\odot/A)^2}$$

- Distribution of pulsars & EGRS in coordinates (q_x, q_y, q_z)

view from top



view from side



How to improve the result?

Use wavelets to perform a reconstruction

- noise filtering
- differentiation of the signal **(with minimum damage, Stepanov et al., A&A,2002)**
- spiral pattern recognition **(**applied for spiral arms im M51, **Patrikeev et al., A&A,2006 (accepted))**

Mathematics

The 2D wavelet differentiation technique A&A 2002

Wavelet transform is the convolution product analyzed function with wavelets.

$$w(\bar{r}_0, a) = a^{-2} \int n_e B_{\|}(\bar{r}) \Psi_{\bar{r}_0, a}(\bar{r}) d^3 r = a^{-2} \int A[RM(\bar{r})] \Psi_{\bar{r}_0, a}(\bar{r}) d^3 r$$

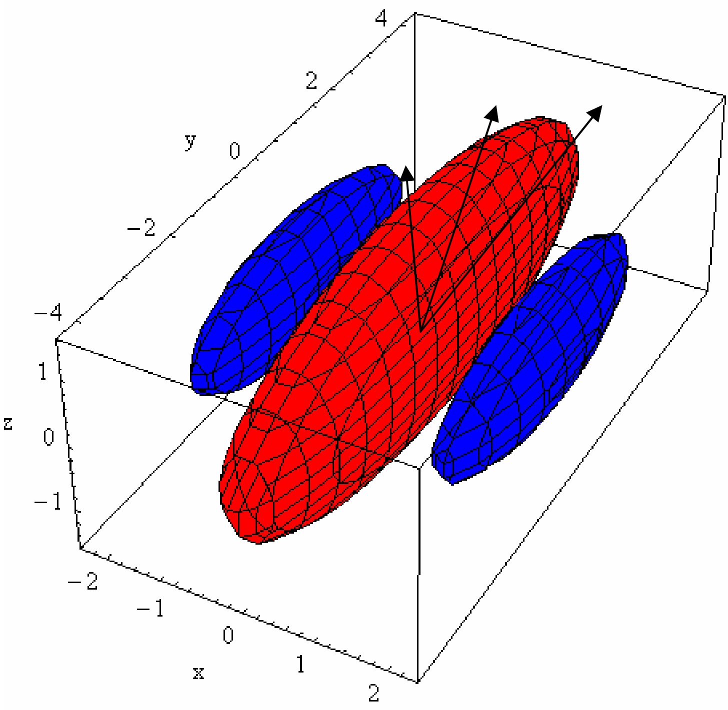
$A[.]$ - differential operator along line-of-sight

$$w(\bar{r}_0, a) = a^{-2} \int RM(\bar{r}) F[\Psi_{\bar{r}_0, a}(\bar{r})] d^3 r = a^{-2} \int RM(\bar{r}) \tilde{\Psi}_{\bar{r}_0, a}(\bar{r}) d^3 r$$

$\tilde{\Psi}_{\bar{r}_0, a}(\bar{r}) \equiv F[\Psi_{\bar{r}_0, a}(\bar{r})]$ - new family of wavelets

Anisotropic wavelet

$$\Psi(\bar{r} = \{x, y, z\}, h) = (1 - x^2) e^{-\frac{1}{2}\left(x^2 + \left(\frac{y}{h}\right)^2 + z^2\right)}$$



Vector form

$$\overline{\Psi}(\bar{r}, h, b) = \{0, Cos(b), Sin(b)\}\Psi(\bar{r}, h)$$

Contour surfaces for

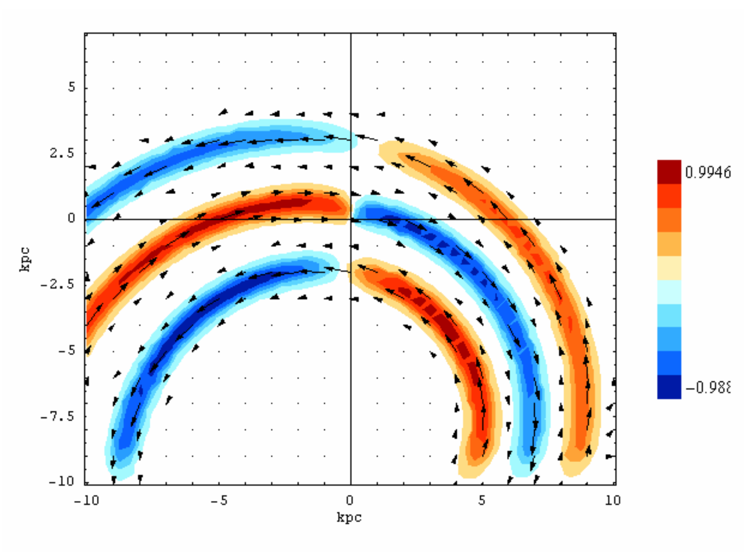
$\Psi = 0.3$ - red

$\Psi = -0.3$ - blue

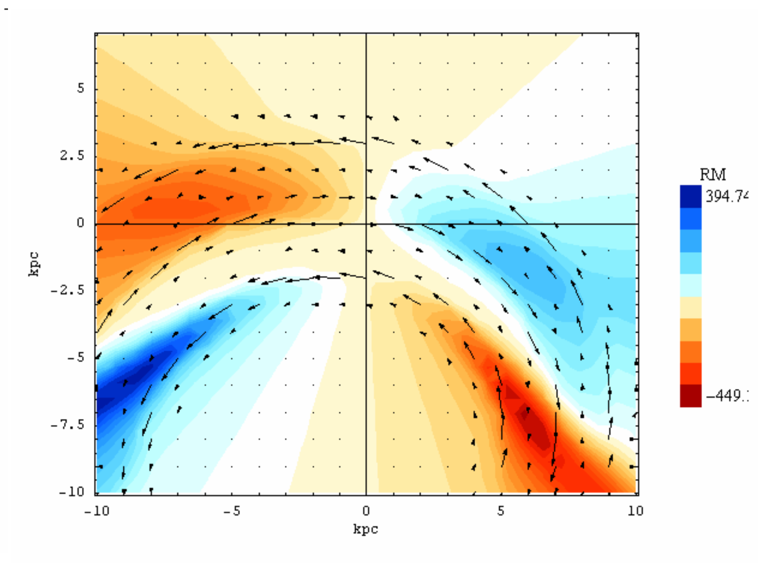
$$w(\bar{r}_0, a, \varphi, b, h) = a^{-2} \int n_e B_{\|}(\bar{r}) \quad T_{r_0} D_a R_\varphi \overline{\Psi}(\bar{r}, h, b) \cdot d^3 \bar{r}$$

Model for (B ne)

Line-of-sight component



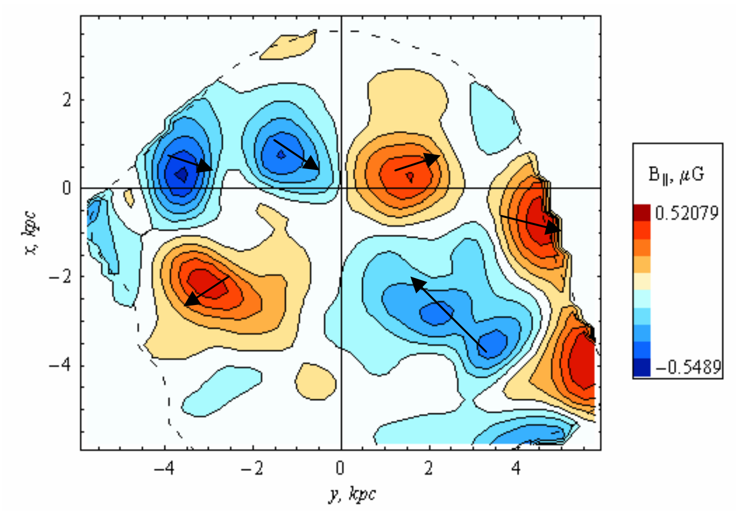
RM from model



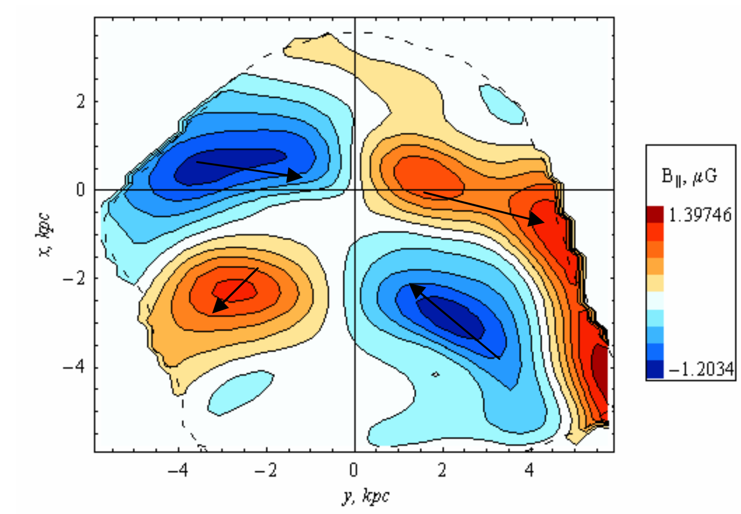
Wavelet decomposition of model RM

but calculated only in source position

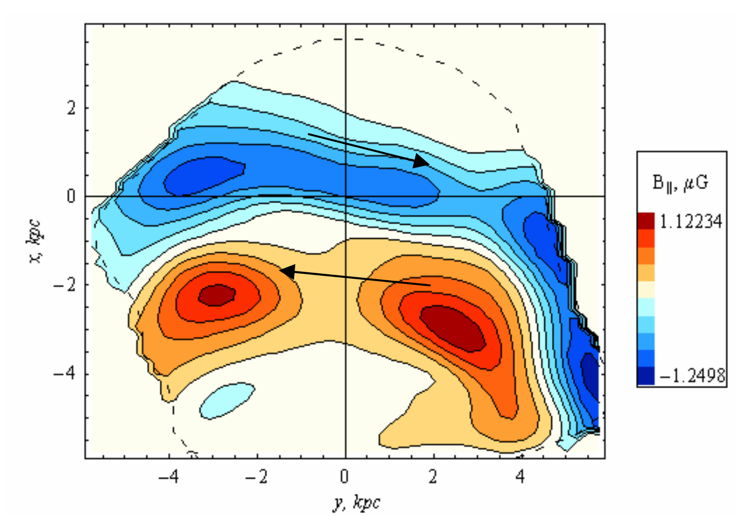
with isotropic wavelet



with anisotropic wavelet



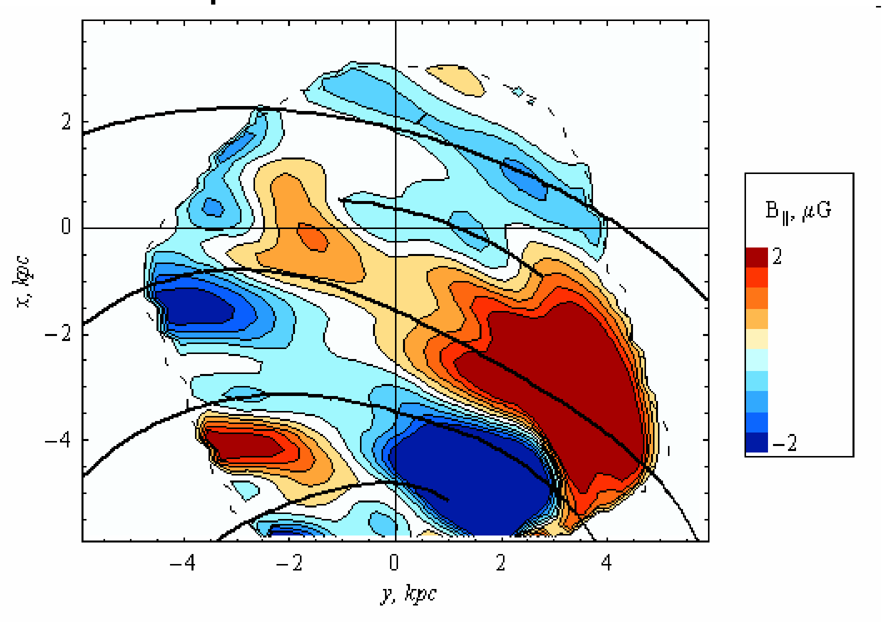
with anisotropic wavelet in vector form



What are the results from wavelet analysis?

Reconstruction with wavelets: scale 0.5 kpc and pitch angle 20°

from pulsars and EGRS RM

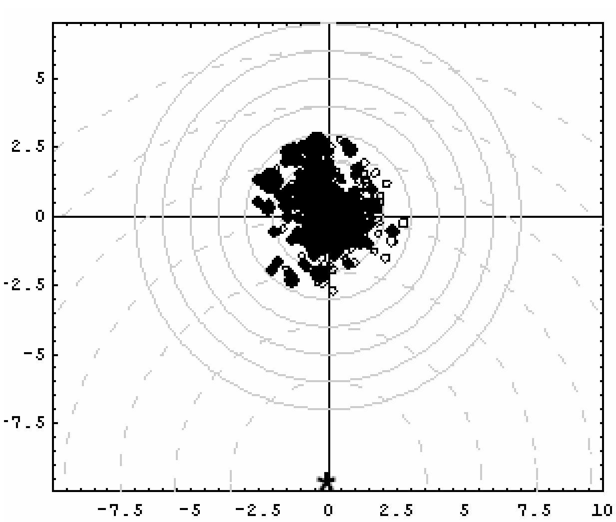


Remarks

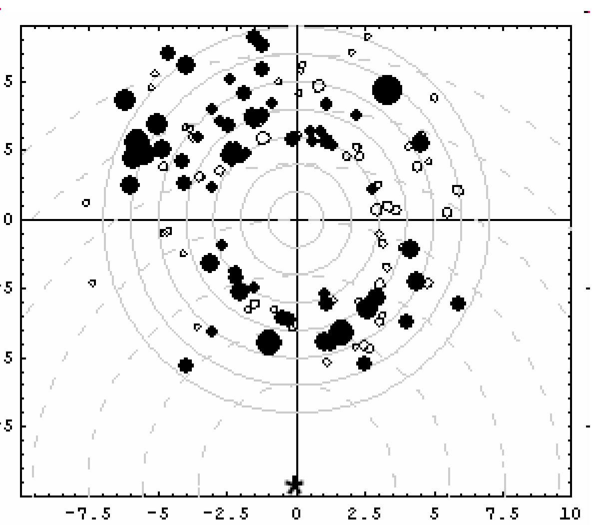
- More sources are necessary for better statistics

- Low latitude EGRS's are more important to measure RM

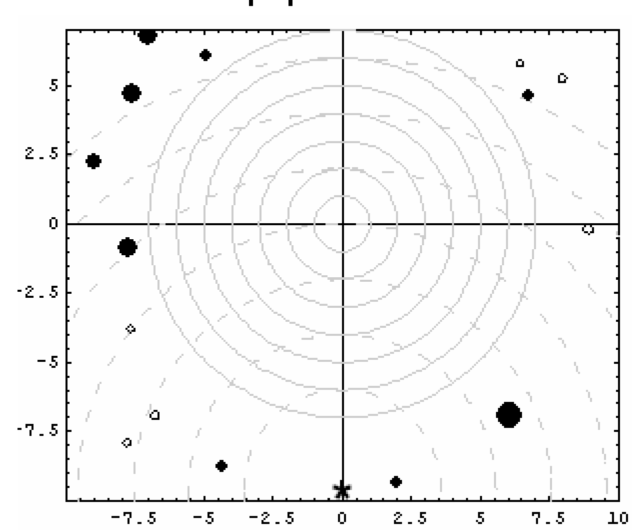
$|b|>20^{o}$



$7^{o}<|b|<20^{o}$



$|b|<7^{o}$



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