Modelling of depolarization effects in the ISM

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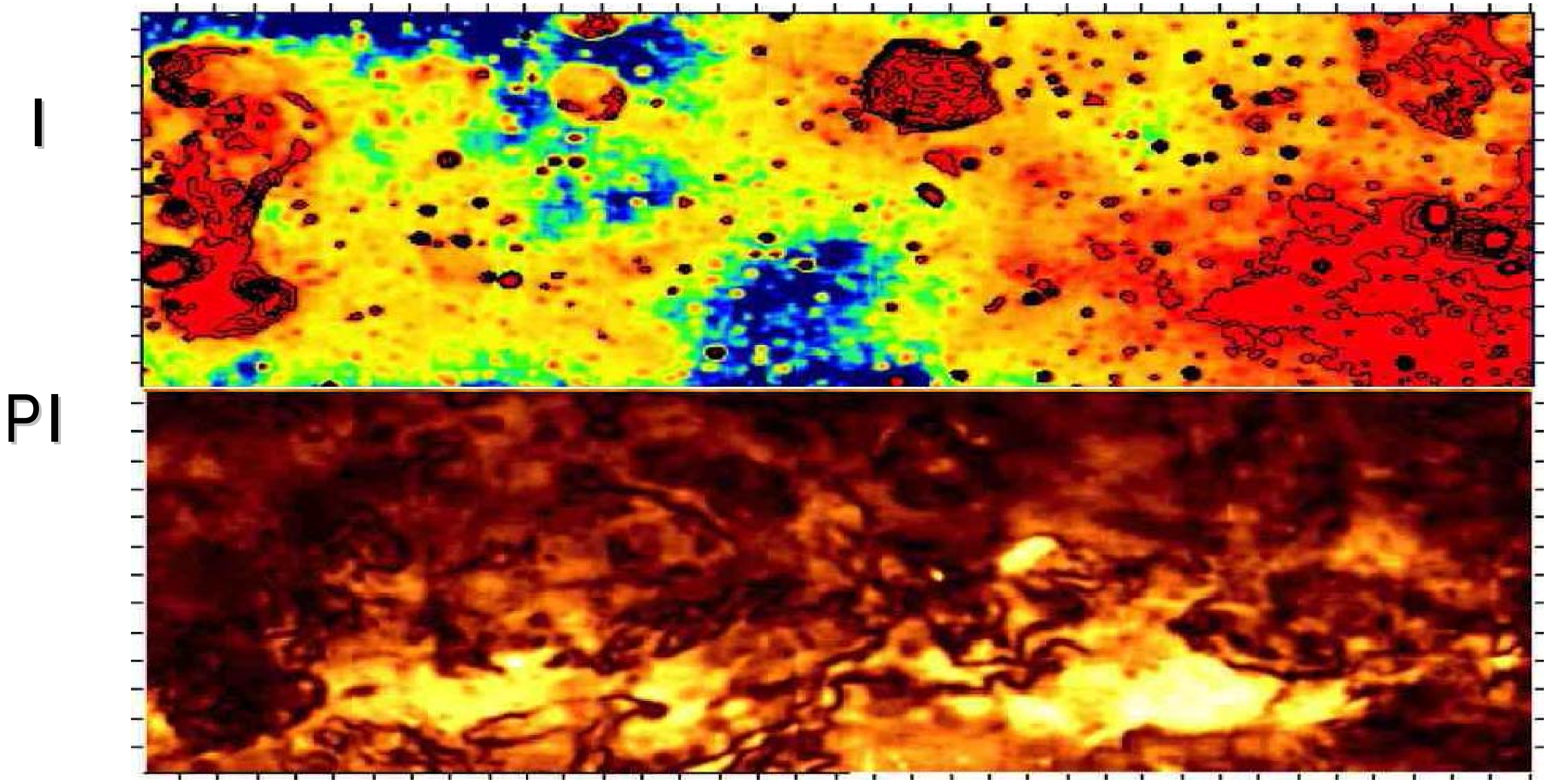
How to interpret the results of radioastronomical observations?



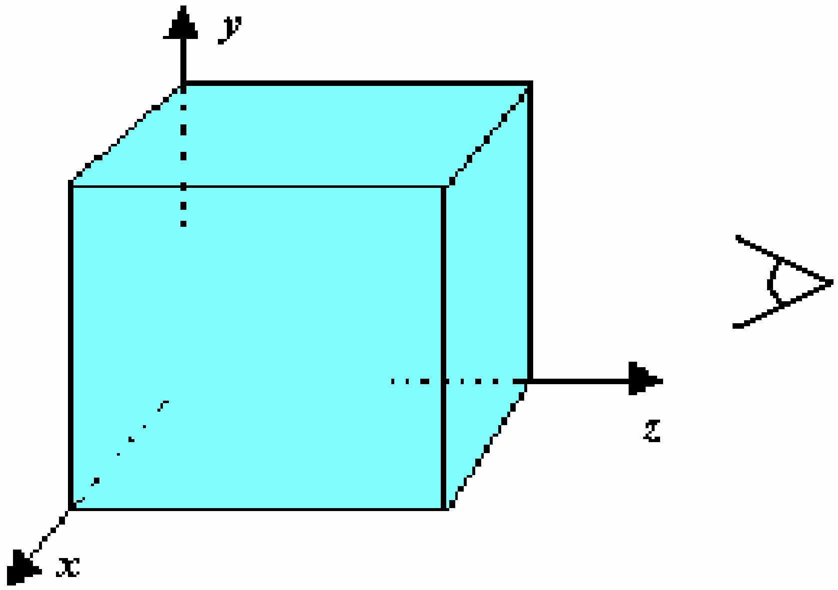
(Andrew Fletcher & Anvar Shukurov, 2006)

What is relationship between spectral properties of interstellar magnetic fields and spectral characteristics of radio polarization maps?

Parameters adopted in the simulation

The area of calculations is a cub (side L = 0.5 kpc) with periodic conditions.

Grid size 256^3 pixels Cell size 1 pixel = 1/512 kpc



Various input data of ISM components: magnetic field B in μG, the thermal and relativistic electron density ne and nc in cm^{-3} correspond with different modelling examples.

3-Dimensional magnetic field model

- We adopted a power-law energy spectra

$$E(k) \propto \left|\vec{k}\right|^{\alpha}, \quad E(k) = \int_{\left|\vec{k}\right|} B^2(\vec{k})\,d\vec{k}, \quad \vec{k} = \{k_x, k_y, k_z\}$$ - wave vector

- Condition div(B)=0

$$\hat{B}\left(\vec{k}\right) \cdot \vec{k} = 0,$$

- The magnetic field: $\hat{B}\left(\vec{k}\right) = \frac{\vec{k} \times \vec{a}}{\left|\vec{k} \times \vec{a}\right|} \cdot \left|\vec{k}\right|^{\frac{\alpha-2}{2}},$ $\vec{a} = \{a_x, a_y, a_z\}$ where

$\vec{a}$ - random vector with uniform distribution all along sphere;

is then transformed back into the real space using a three-dimensional Fast Fourier Transform

Mathematics

- total intensity of synchrotron emission $$I(x,y) = \int_0^h n_c B_{x,y}{}^2 dz$$

h in kpc is depth, B in μG, the thermal and relativistic electron density ne and nc in cm^{-3}

- intrinsic polarization angle and Faraday rotation measure

$$\psi_0(x,y,z) = arctg\left(\frac{B_y}{B_x}\right) + \frac{\pi}{2} \quad RM(x,y,z) = 812\int_0^z n_e B_z dz' \quad \text{rad m}^{-2}$$

- observed polarization angle

$$\psi(x,y,z) = \psi_0(x,y,z) + RM(x,y,z)\cdot\lambda^2, \quad \text{wavelength } \lambda \text{ in m}$$

- Stokes parameters Q, U

$$Q(x,y) = \int_0^h n_c B_{x,y}{}^2 \cos(2\psi)dz \quad U(x,y) = \int_0^h n_c B_{x,y}{}^2 \sin(2\psi)dz$$

- polarized intensity $$PI(x,y) = \sqrt{Q^2 + U^2}$$

Modelling examples

- Superposition waves with various ψ_0 along the line-of-sight
  input data Bz=0, Bx,By by blue Eq.

- Differential Faraday rotation
  input data Bx,By,Bz by blue Eq.

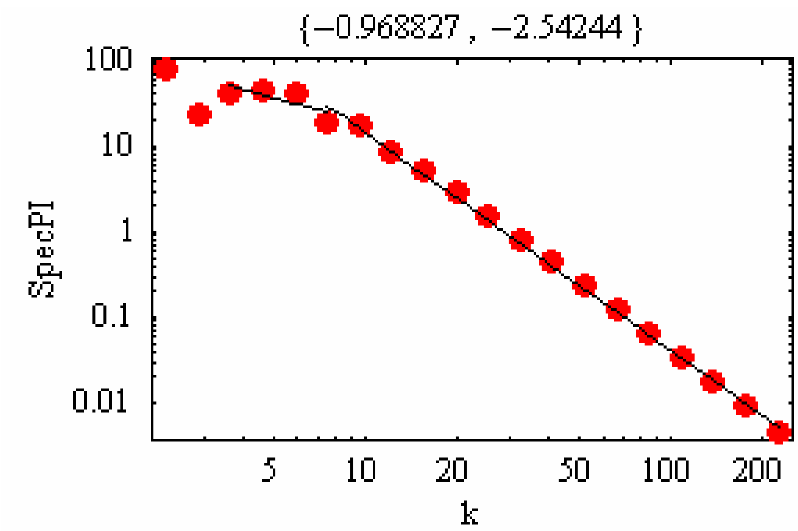
- Faraday depolarization
  input data Bx=By, Bz   by blue Eq.

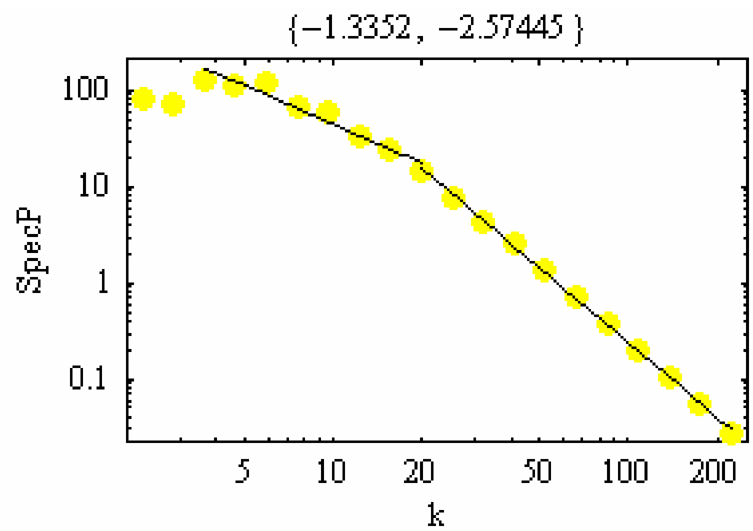
here: ne=1 cm^{-3}, nc=1 cm^{-3} , B in μG,

spectral index α = -3/3 , -5/3 , -7/3

Bz=0, superposition waves with various ψ_0 along the line-of-sight

energy spectra of PI and P $\quad \alpha = -5/3$



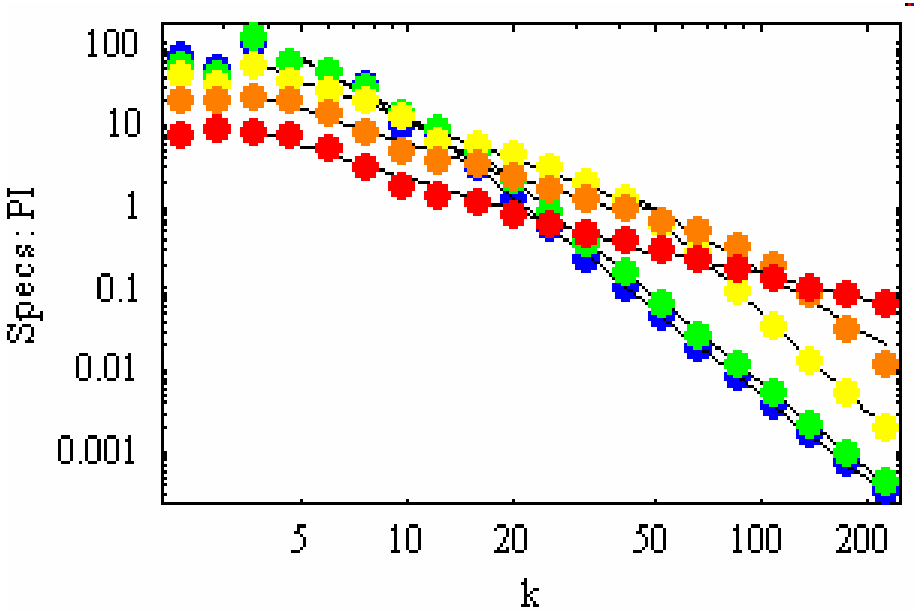


α	Spec I	Spec PI	Spec P
-3/3	-1.62534	-1.06146 -1.61193	-0.72462 -1.46605
-5/3	-2.54772	-0.96882 -2.54244	-1.33520 -2.57445
-7/3	-3.30891	-1.42527 -3.38714	-1.68656 -3.50907

Differential Faraday rotation

α = -5/3

energy spectra of PI



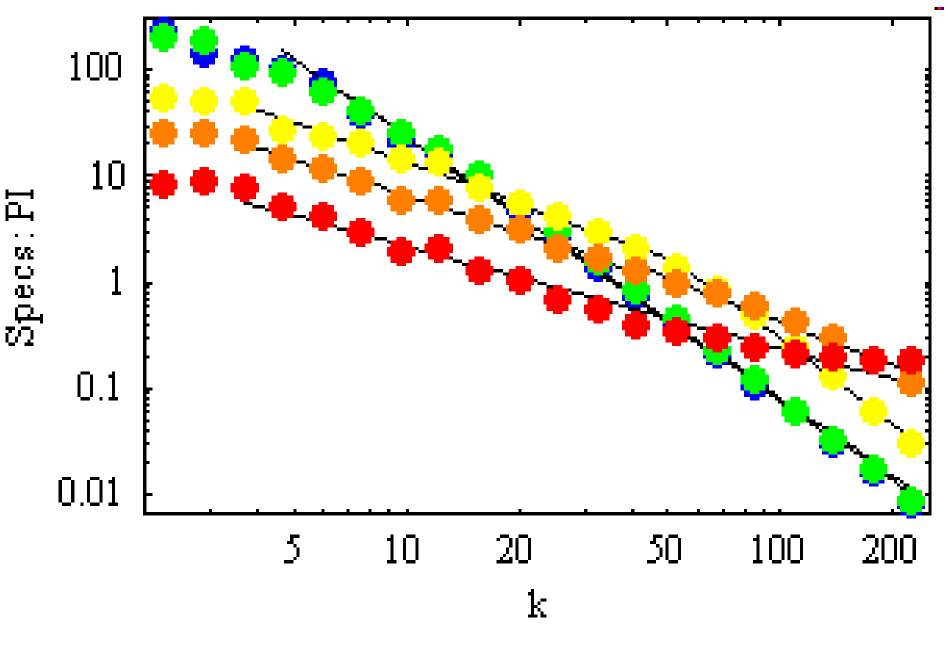
λ (cm) scale : **5** **10** **20** **30** **50**

α	Spec I	Spec PI / Spec P				
-5/3	-2.54553	-1.66217 -2.62766 -1.28729 -2.50803	-1.80743 -2.62766 -1.40553 -2.50803	-1.16452 -2.61019 -0.651715 -2.57716	-1.1119 -1.25287 -0.604273 -1.20733	-1.18258 -0.269594 -0.786703 -0.198728
λ cm		5	10	20	30	50

Faraday depolarization

α = -5/3

energy spectra of PI



λ (cm) scale : **5 10 20 30 50**

α	Spec I	Spec PI / Spec P				
-5/3	-2.47741	-2.47477	-2.45111	-1.28428 -2.65949	-1.14727 -1.37875	-0.957736
		-2.50036	-2.3895	-0.893354 -2.62577	-0.781678 -1.25355	-0.731107
λ cm		5	10	20	30	50