Probing Magnetic Helicity

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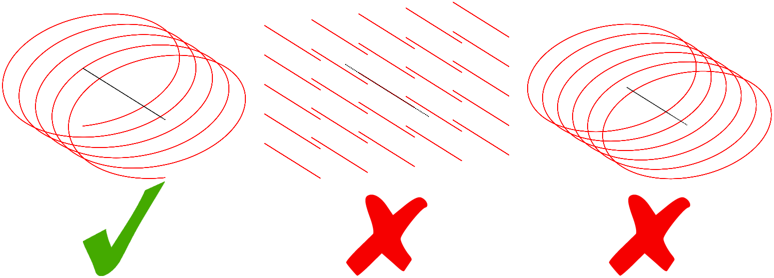
H. Junklewitz, G. Robbers, T. Enßlin
arXiv:1008.1246

November 23, 2010

Local
Inference
Test for
Magnetic fields,
which **U**ncovers
helice**S**

Junklewitz & Enßlin (2010), arXiv:1008.1243

$$H = \int A \cdot B \, \mathrm{d}V$$

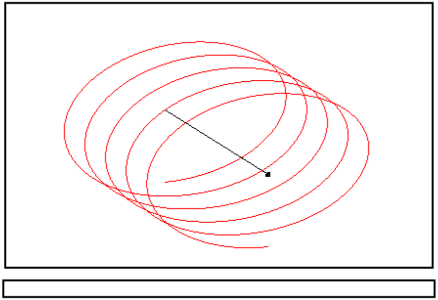


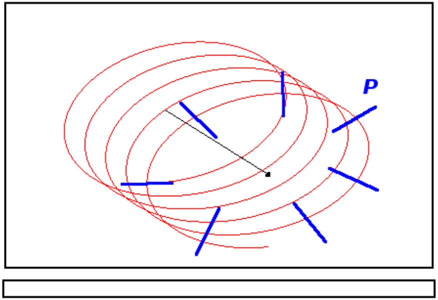
Synchrotron Emission

- magnetic field + charged particles
- $\vec{B}$-component $\perp$ LoS
- polarized $\perp$ $\vec{B}_\perp$

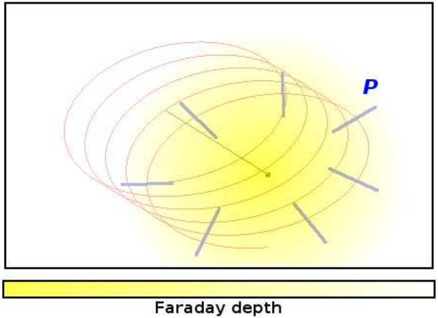
Faraday Rotation

- magnetic field + polarized background source
- $\vec{B}$-component $\parallel$ LoS
- rotation of polarization plane $\propto \lambda^2$
- $\rightarrow$ Faraday depth $\phi = \int n_\mathrm{e} \vec{B} \cdot \mathrm{d}\vec{l}$

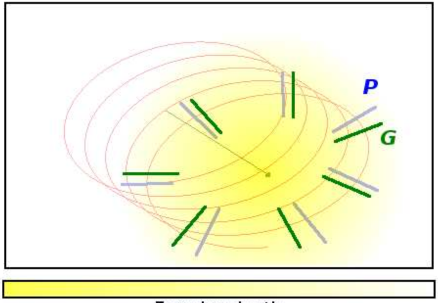




$$P = |P|\, e^{2i\alpha}$$



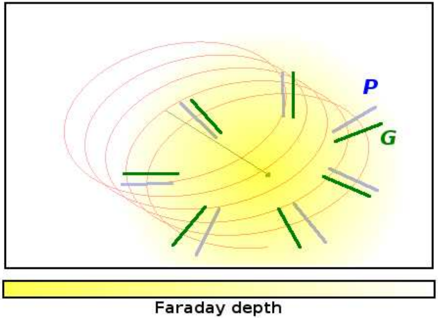
$$P = |P|\, e^{2i\alpha}$$



$$P = |P| \, e^{2i\alpha}$$

$$G = T_2(\nabla\phi) = (\partial_x\phi + i\partial_y\phi)^2 = |G| \, e^{2i\gamma}$$

$$T_2 : \mathbb{R}^2 \rightarrow \mathbb{C}$$



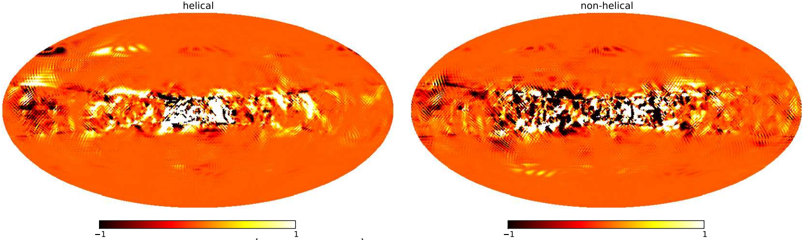
Helicity

$$\mathrm{Re}\left(GP^{*}\right) > 0$$

$$P = |P|\, e^{2i\alpha}$$

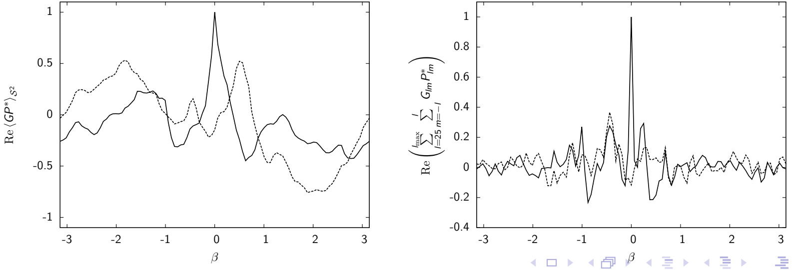
$$G = T_2\left(\nabla\phi\right) = \left(\partial_x\phi + i\partial_y\phi\right)^2 = |G|\, e^{2i\gamma}$$

$$T_2 : \ \mathbb{R}^2 \rightarrow \mathbb{C}$$



with helicity: $\left\langle \mathrm{Re}\left\langle GP^* \right\rangle_{\mathcal{S}^2} \right\rangle_{\mathrm{samples}} = 1.0, \quad \sigma_{\mathrm{Re}\langle GP^* \rangle_{\square}} = 0.57$

without helicity: $\left\langle \mathrm{Re}\left\langle GP^* \right\rangle_{\mathcal{S}^2} \right\rangle_{\mathrm{samples}} = -0.43, \quad \sigma_{\mathrm{Re}\langle GP^* \rangle_{\square}} = 0.74$



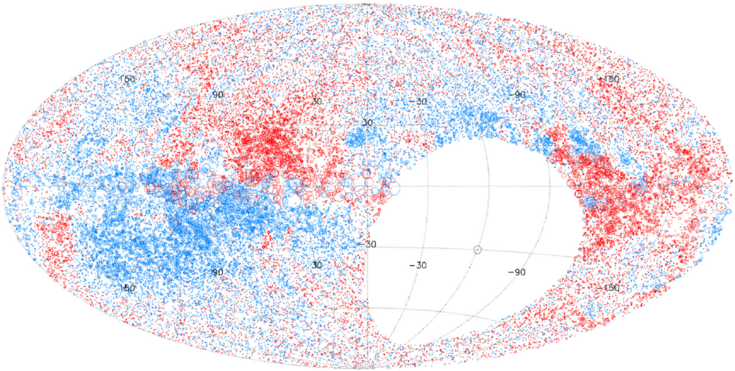


Figure 3. Plot of 37,543 RM values over the sky north of $\delta = -40°$. Red circles are positive rotation measure and blue circles are negative. The size of the circle scales linearly with magnitude of rotation measure.

Taylor et al. (2009)

Wiener Filter

$$m = \int \mathcal{D}s \; s \; \mathcal{P}(s|d)$$

$$d = Rs + n$$

$$m = Dj, \;\text{ where } \quad \begin{array}{l} j = R^\dagger N^{-1} d \\ D = \left(S^{-1} + R^\dagger N^{-1} R\right)^{-1} \end{array}$$

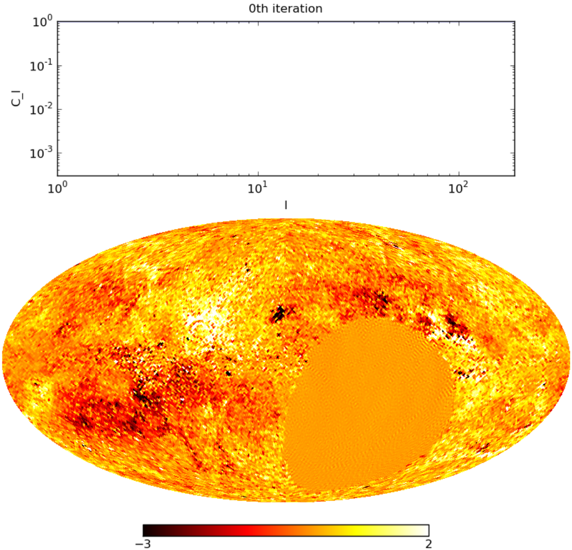
Critical Filter

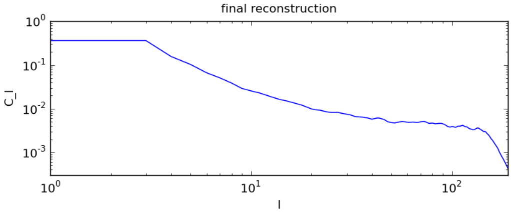
$$m = Dj$$

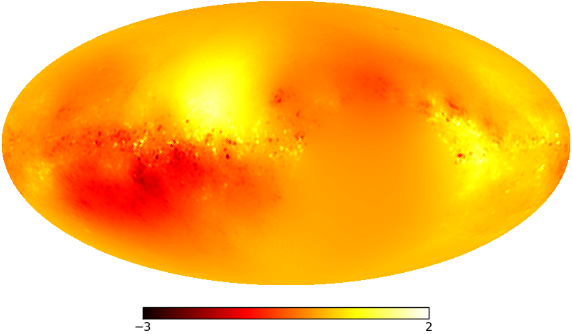
$$C_\ell = \frac{1}{2\ell + 1} \mathrm{tr}\left(\left(mm^\dagger + D\right) P_\ell\right)$$

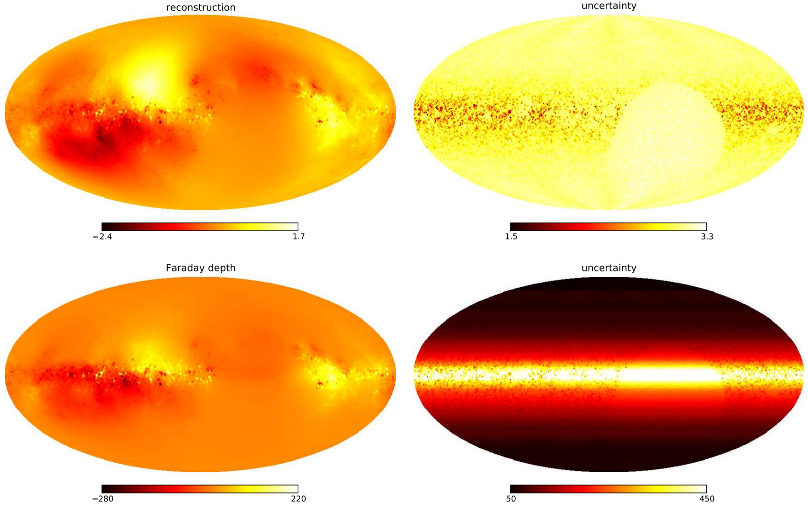
Enßlin & Frommert (2010), arXiv:1002.2928

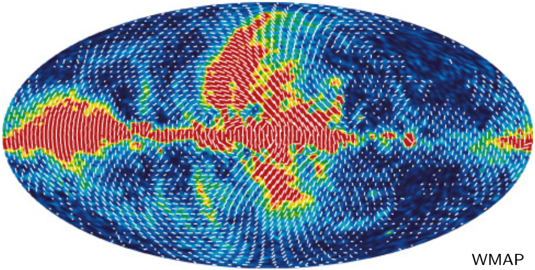
Enßlin & Weig (2010), arXiv:1004.2868


0th iteration
10^0
10^{-1}
10^{-2}
10^{-3}
C_l
10^0
10^1
10^2
l
−3
2

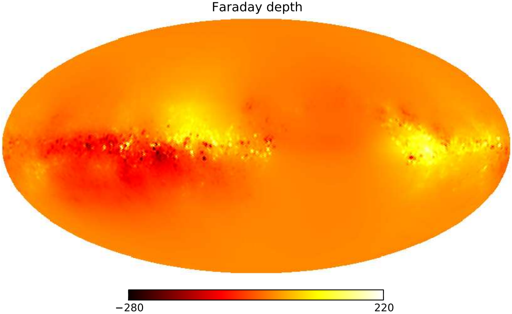

final reconstruction
10^0
10^{-1}
10^{-2}
10^{-3}
C_l
10^0
10^1
10^2
l

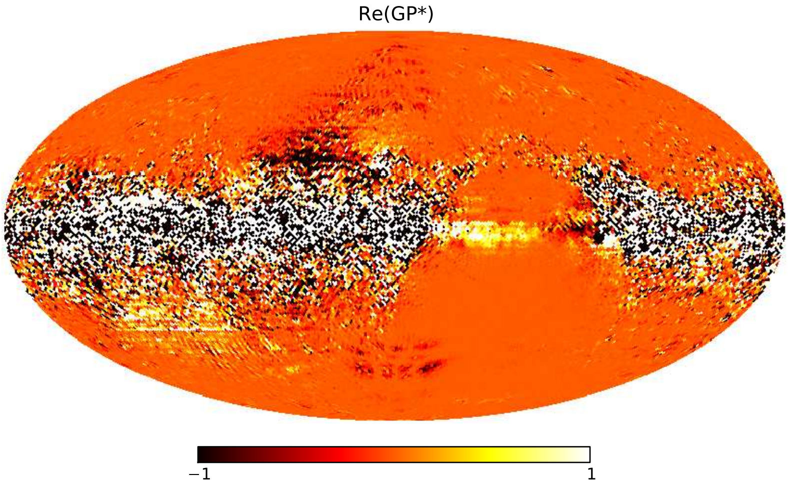

−3
2


reconstruction
−2.4
1.7
uncertainty
1.5
3.3
Faraday depth
−280
220
uncertainty
50
450

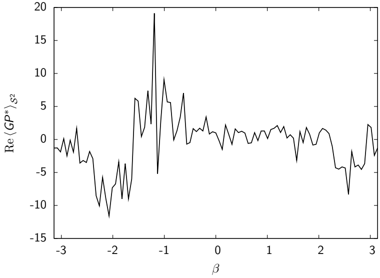


WMAP

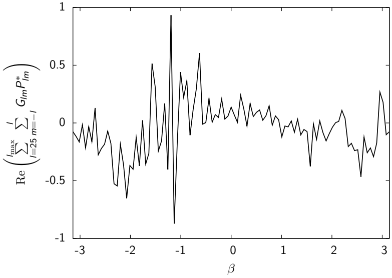



Re(GP*)
−1
1

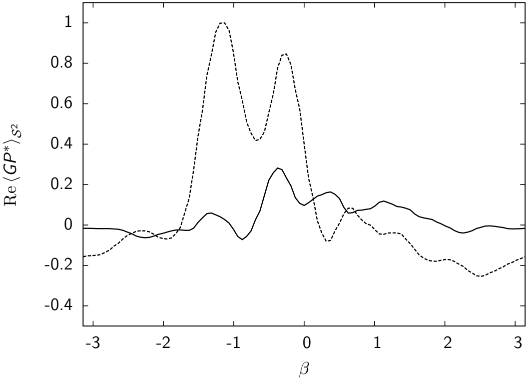
contributions of all scales



small-scale contributions



Test case with non-trivial electron densities:



Conclusions

- *Critical Filter* works.
- *LITMUS* test works, provided the electron densities don't vary too much.
- $\Rightarrow$ *LITMUS* test does **not** work on galactic scales.

Outlook

- Use $\langle T_2 (\nabla\phi)\rangle$ instead of $T_2 (\langle\nabla\phi\rangle)$.
- Incorporate several datasets.
- Include reconstruction of the measurement errors.
- Increase resolution in order to detect helicity on small scales.