

The Faraday sky

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in collaboration with:

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B.M. Gaensler (Dunlap, Toronto)

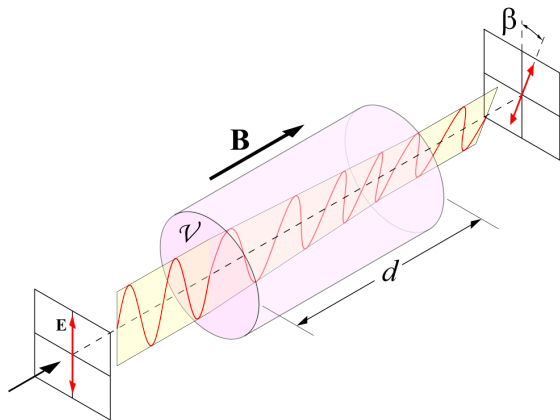
J. Stil, J.-A. Brown (UofC, Calgary)

H. Junklewitz, S.A. Mao, D. Schnitzeler (AlfA/MPIfR, Bonn)

E. Carretti (INAF, Cagliari)

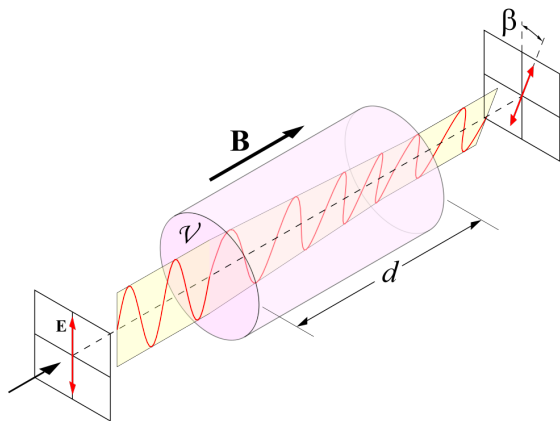
and others

Faraday rotation



$$d\beta \propto \lambda^2 n_e B_r dr$$
$$\Rightarrow \beta \propto \lambda^2 \int_{r_{\text{source}}}^0 (1+z)^{-2} n_e B_r dr$$

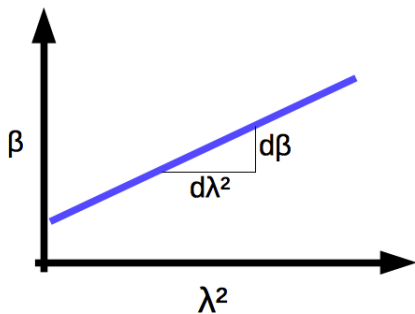
Faraday rotation



$$\text{Faraday depth: } \phi \propto \int_{r_{\text{source}}}^0 (1+z)^{-2} n_e B_r dr$$
$$\beta = \phi \lambda^2$$

Faraday rotation

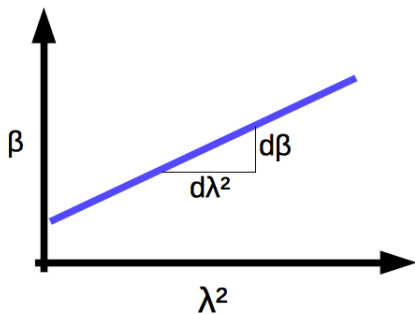
if B-fields in front of emission:



$$\phi = \text{RM} = \frac{d\beta}{d\lambda^2}$$

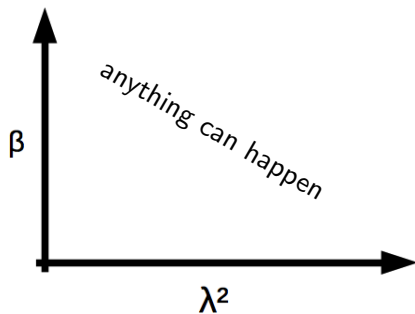
Faraday rotation

if B-fields in front of emission:



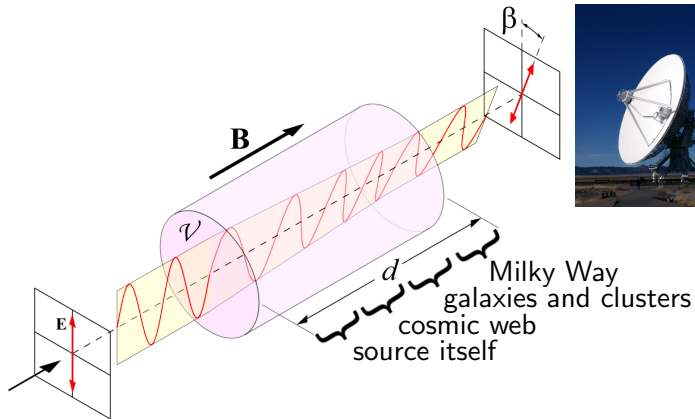
$$\phi = \text{RM} = \frac{d\beta}{d\lambda^2}$$

if B-fields and emission mixed:



Use $Q(\lambda)$, $U(\lambda)$, $I(\lambda)$,
RM synthesis, ...

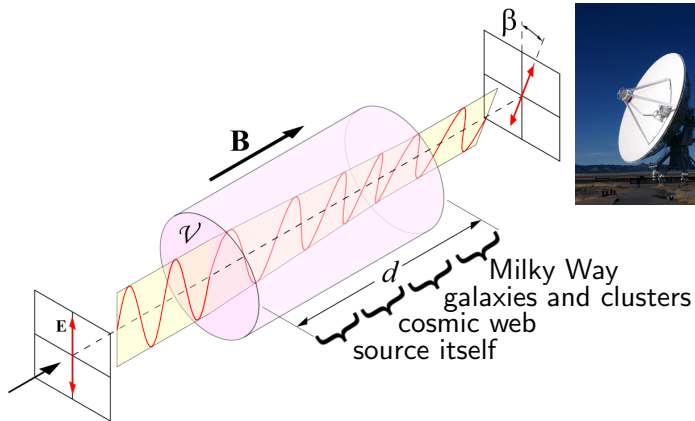
Faraday rotation



A photograph of a galaxy cluster, showing a central bright core surrounded by a diffuse, purple and blue glow, with several individual galaxies visible.

$$\text{Faraday depth: } \phi \propto \int_{r_{\text{source}}}^0 (1+z)^{-2} n_e B_r dr$$
$$\beta = \phi \lambda^2$$

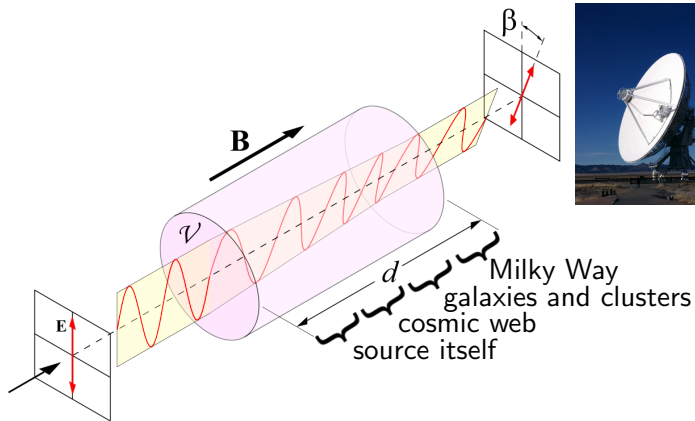
Faraday rotation



$$\text{Faraday depth: } \phi \propto \int_{r_{\text{source}}}^0 (1+z)^{-2} n_e B_r dr$$

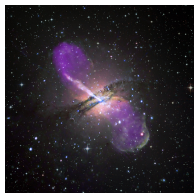
$$\phi = \phi_{\text{MW}} + \phi_{\text{other galaxies}} + \phi_{\text{clusters}} + \phi_{\text{filaments}} + \phi_{\text{sheets}} + \phi_{\text{voids}} + \phi_{\text{source}}$$

Faraday rotation

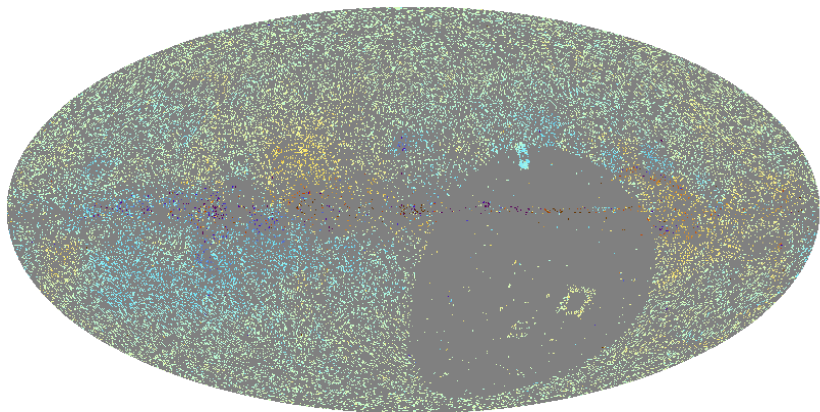


Faraday depth:
$$\phi \propto \int_{r_{\text{source}}}^0 (1+z)^{-2} n_e B_r dr$$

$$\phi = \phi_{\text{MW}} + \phi_{\text{extragalactic}}$$



$$d = \phi_{\text{MW}} + \phi_{\text{extragalactic}} + n$$

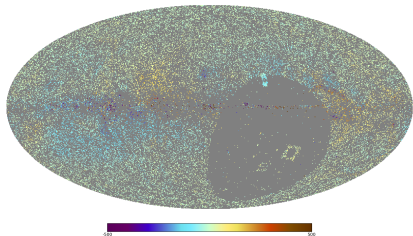


\approx 40 000 data points

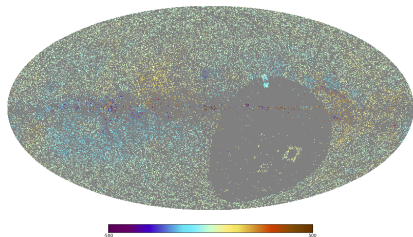
$$d = \phi_{\text{MW}} + \phi_{\text{extragalactic}} + n$$

Challenges

- ▶ Regions without data
- ▶ Galactic/extragalactic split unknown
- ▶ Uncertain uncertainties



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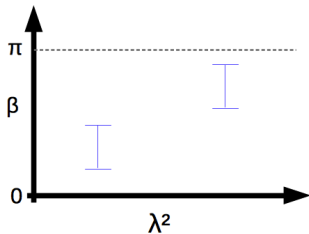
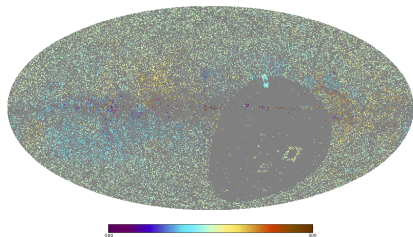
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- ▶ Regions without data
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 - ▶ $n\pi$ ambiguity
 - ▶ multiple components along a LOS
 - ▶ ionosphere
 - ▶ ...

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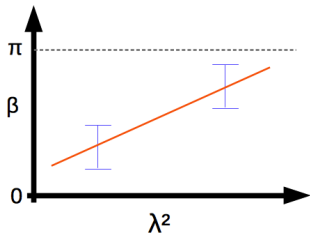
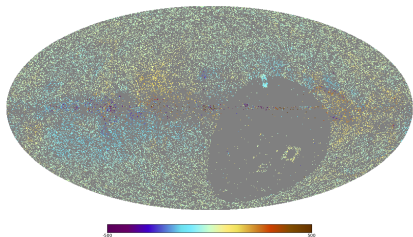
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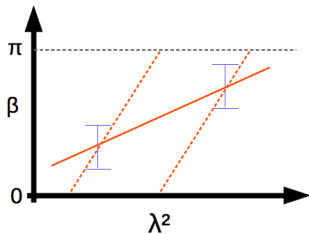
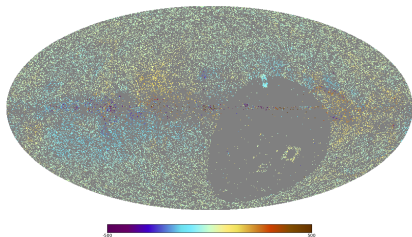
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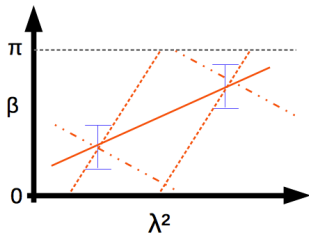
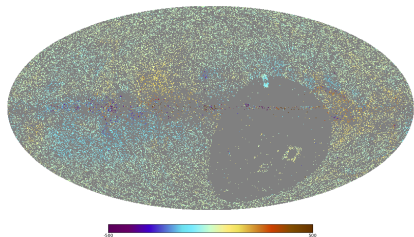
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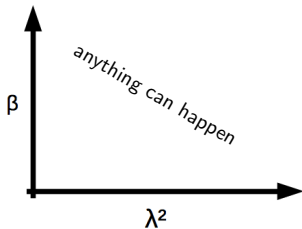
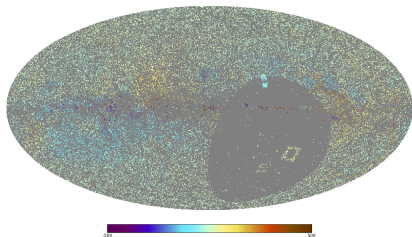
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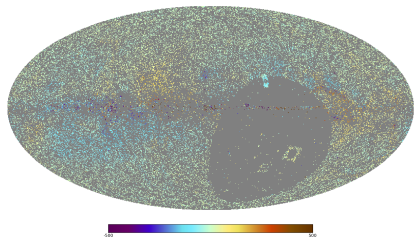
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$$d = \phi_{\text{MW}} + \phi_{\text{extragalactic}} + n$$



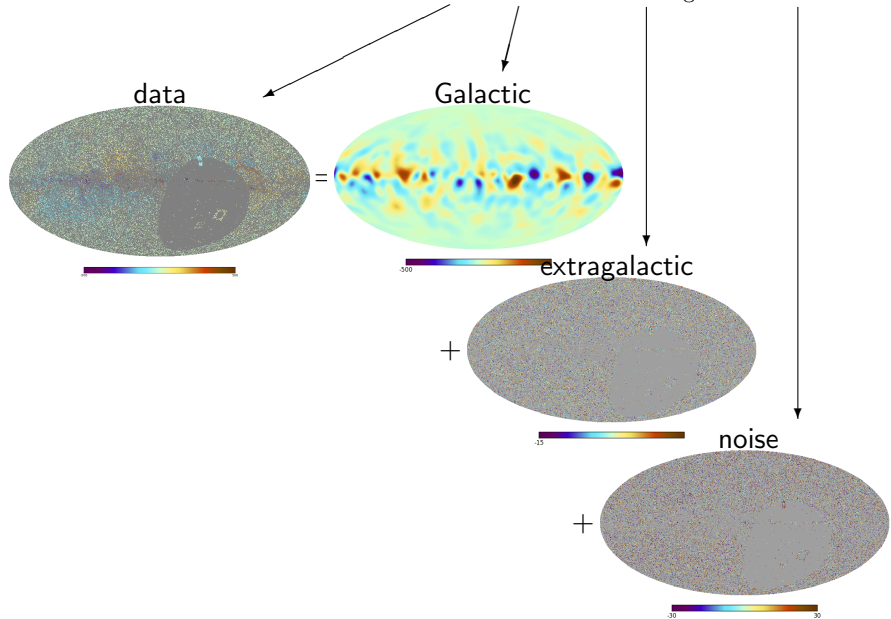
Challenges

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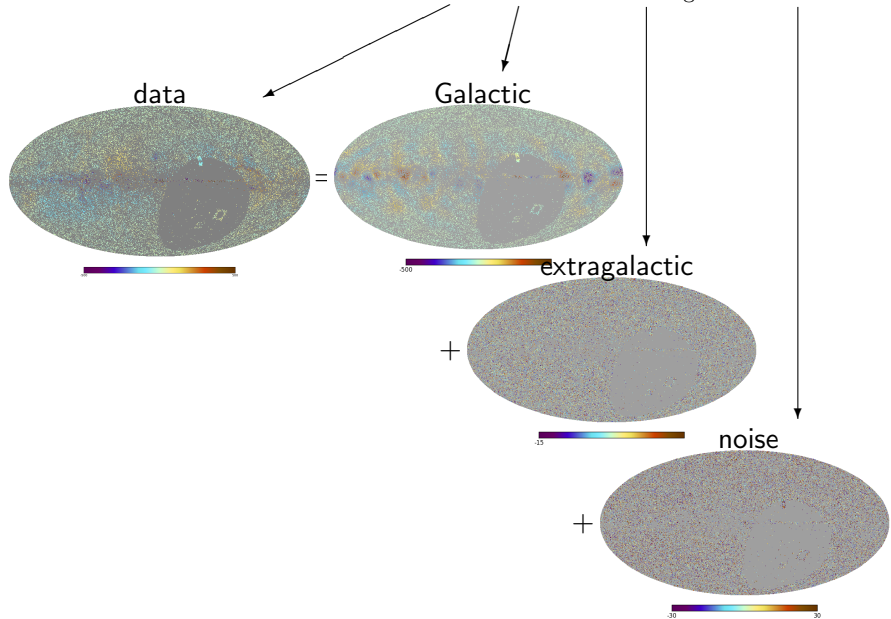
$$d = \phi_{\text{MW}} + \phi_{\text{extragalactic}} + \phi_{\text{ionosphere}}(t) + n$$

$$d = \phi_{\text{MW}} + \phi_{\text{extragalactic}} + n$$

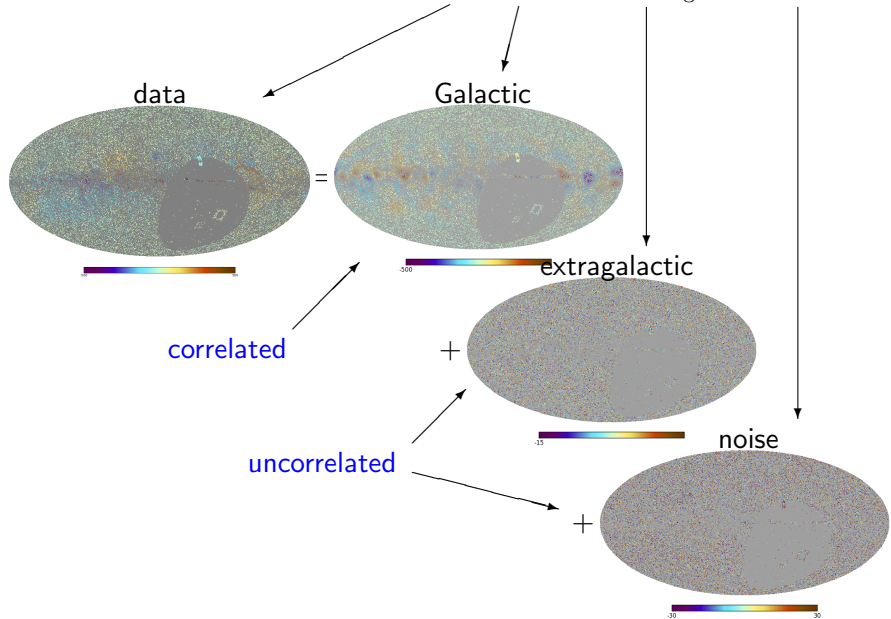
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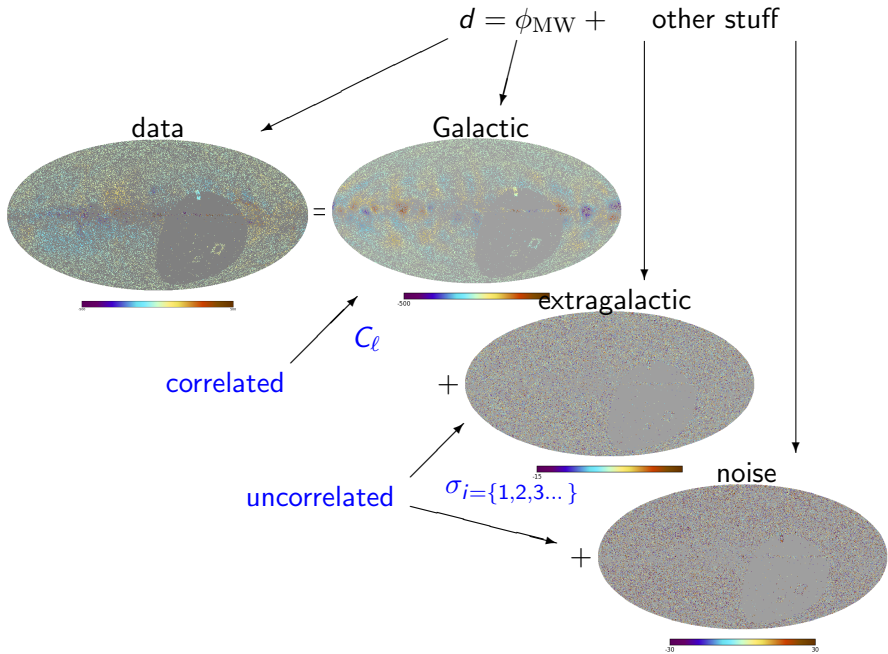


$$d = \phi_{\text{MW}} + \phi_{\text{extragalactic}} + n$$

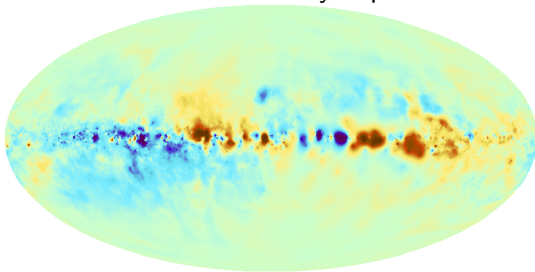


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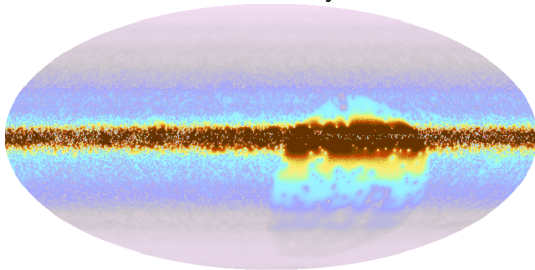


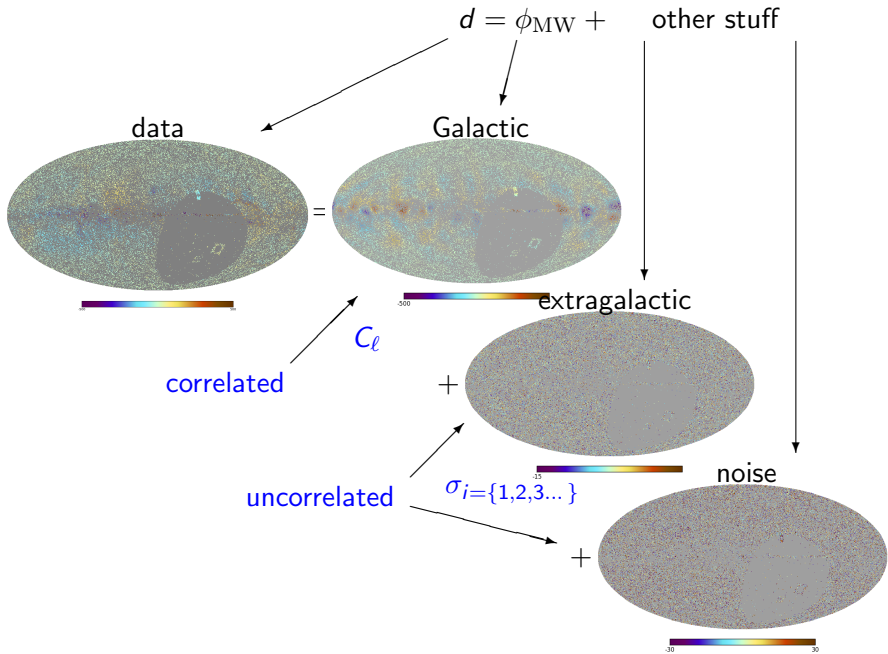


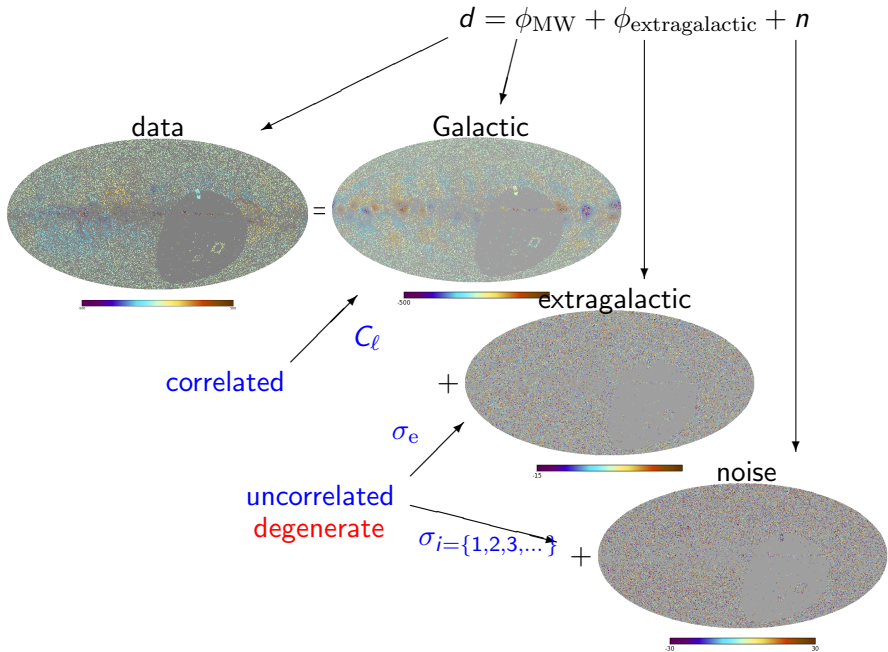
Galactic Faraday depth

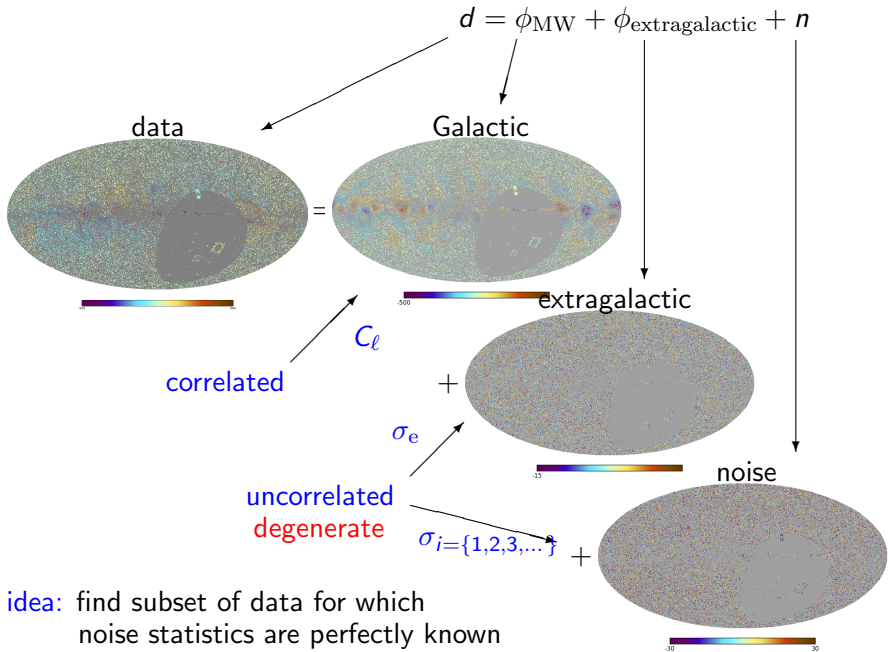


uncertainty









Results:

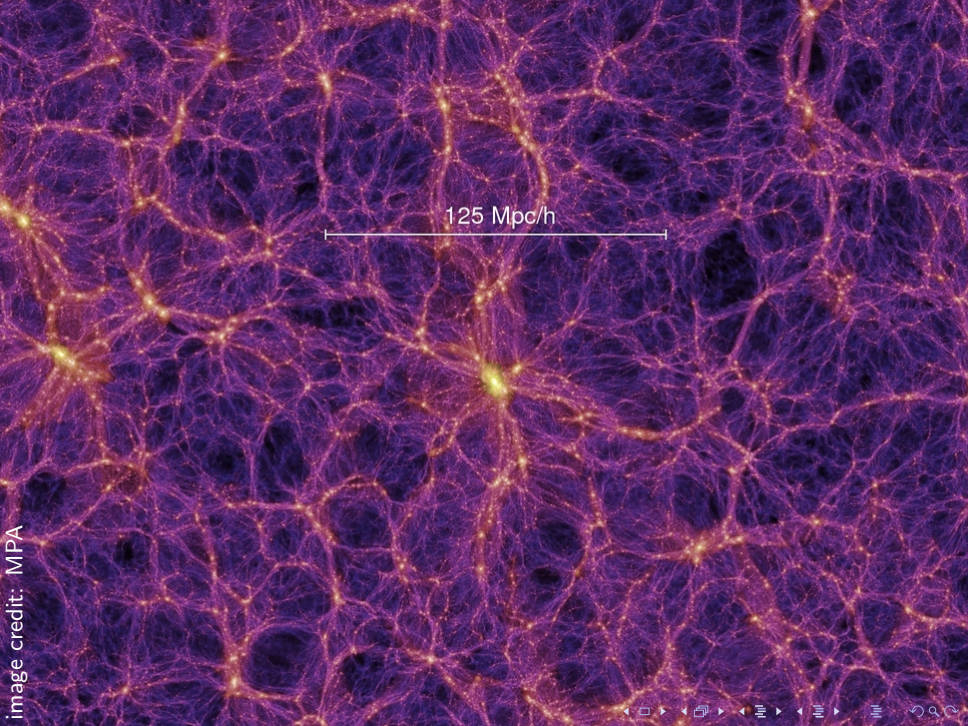
- ▶ $\sigma_e \lesssim 7 \text{ rad/m}^2$
- ▶ constraints on extragalactic contributions for individual sources very weak

What magnetic fields is this due to?

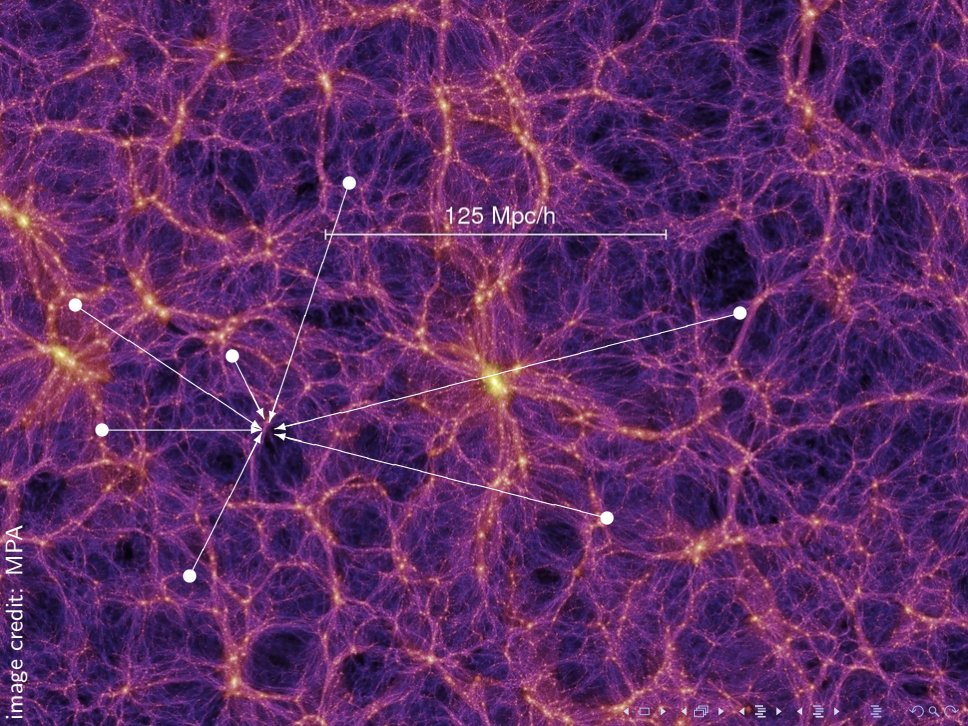
Results:

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image credit: MPA



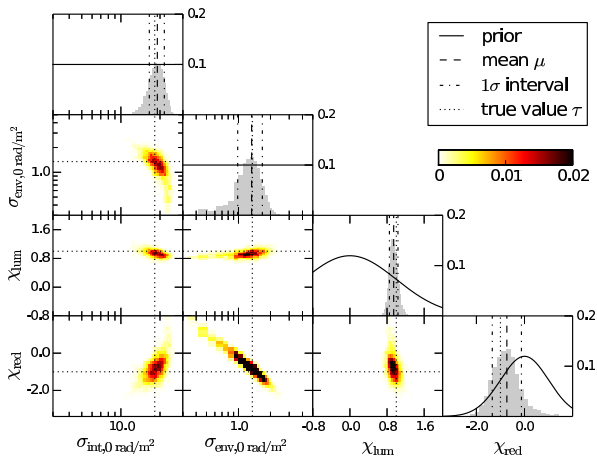
125 Mpc/h



125 Mpc/h

$$\sigma_{e,i}^2 \propto \left(\frac{L}{L_0} \right)^{\chi_{\text{lum}}} \frac{\sigma_{\text{int}}^2}{(1+z_i)^4} + \frac{D_i}{D_0} \sigma_{\text{env}}^2$$

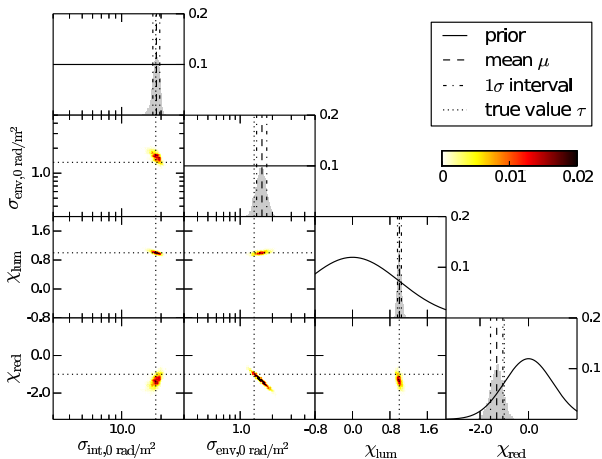
$$D_i = \int_0^{z_i} \frac{c}{H(z)} (1+z)^{4+\chi_{\text{red}}} dz$$



4003 lines of sight

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$$D_i = \int_0^{z_i} \frac{c}{H(z)} (1+z)^{4+\chi_{\text{red}}} dz$$



41632 lines of sight

Summary

- ▶ Galactic contribution (correlated) can be separated from rest (uncorrelated)
- ▶ Rest can be separated statistically into extragalactic and noise
- ▶ Extragalactic contributions contain information on B -fields on cosmic scales
- ▶ Uncertainties are large and need to be understood

All results at

<http://www.mpa-garching.mpg.de/ift/faraday/>