Magnetic fields seen through Faraday rotation

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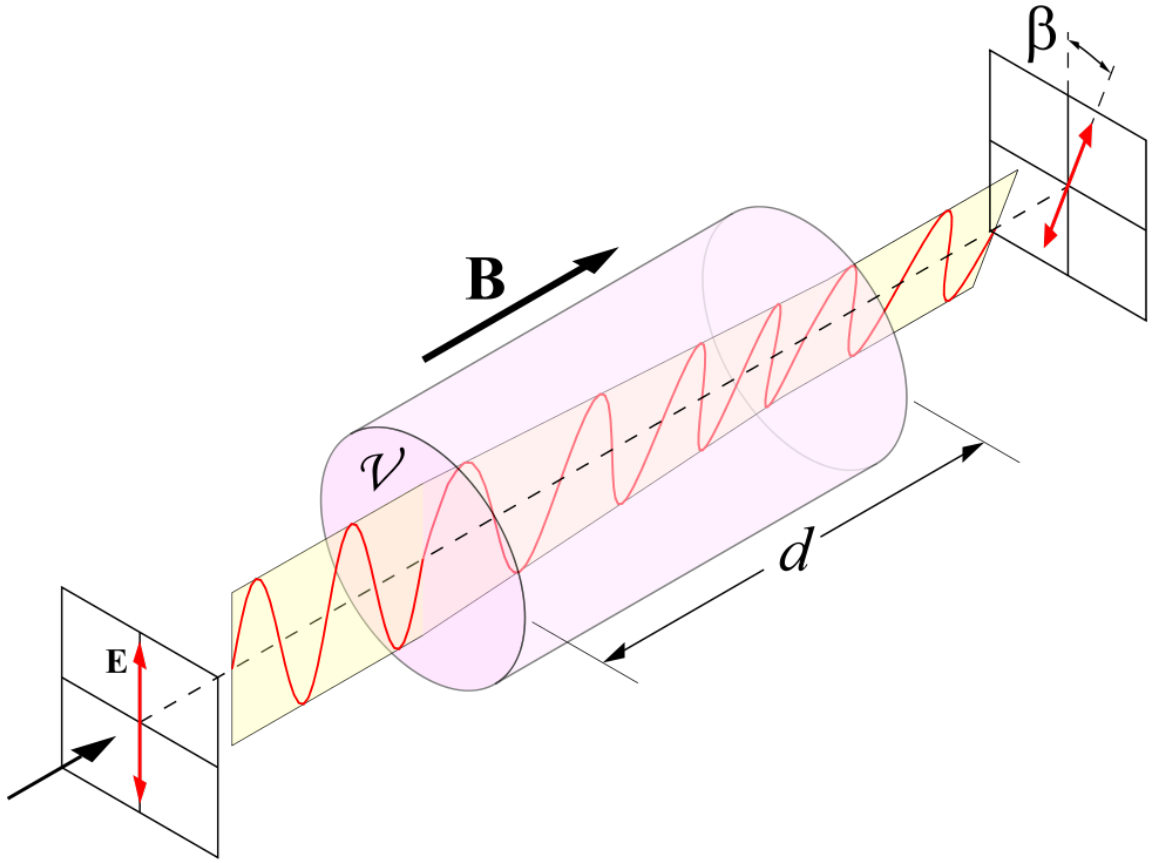
from the Milky Way to cosmic scales

Niels Oppermann

in collaboration with:
B. Gaensler (Dunlap, Toronto)
J. Stil, J.-A. Brown (UofC, Calgary)
V. Vacca, T. Enßlin (MPA, Munich)
H. Junklewitz, D. Schnitzeler (MPIfR, Bonn)
...

CASCA Annual Meeting, Hamilton, 2015-05-27

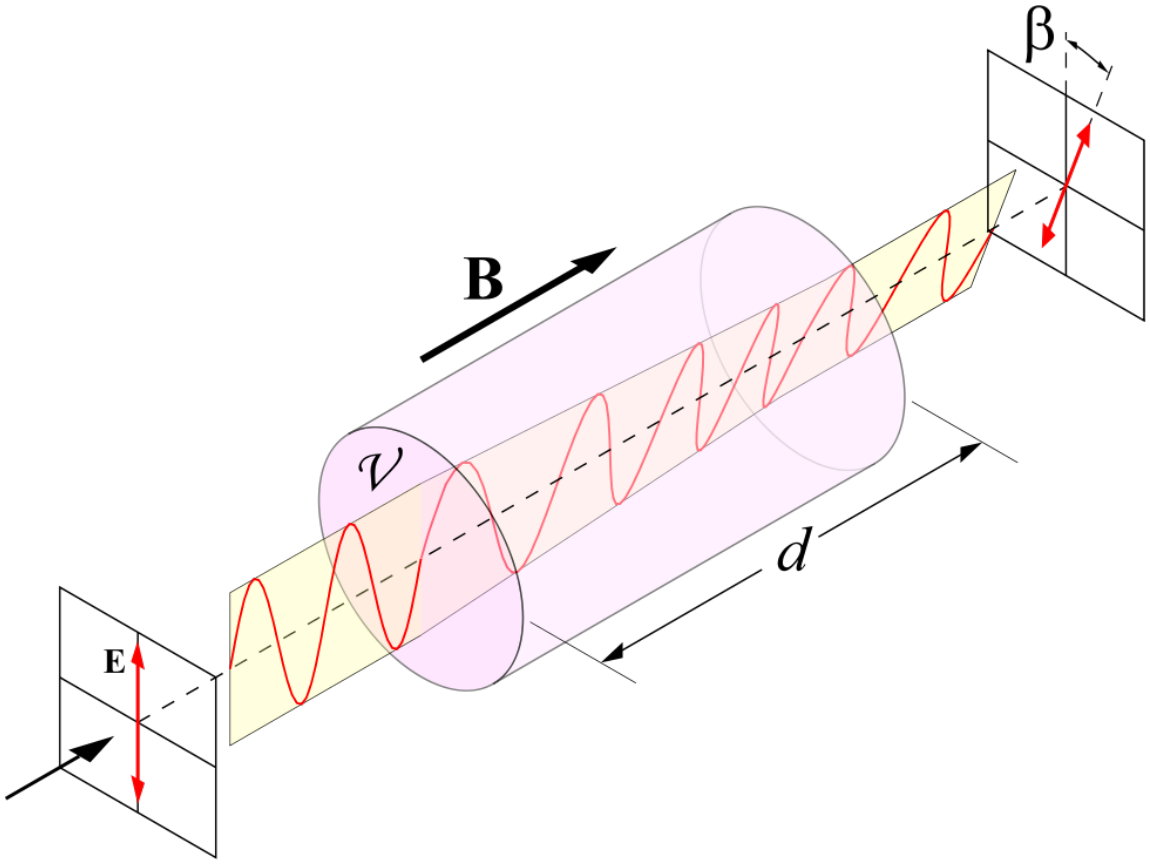
Faraday rotation



$$\mathrm{d}\beta \propto \lambda^2 n_\mathrm{e} B_r \,\mathrm{d}r$$

$$\Rightarrow \quad \beta \propto \lambda^2 \int_{r_\mathrm{source}}^{0} (1+z)^{-2}\; n_\mathrm{e} B_r \,\mathrm{d}r$$

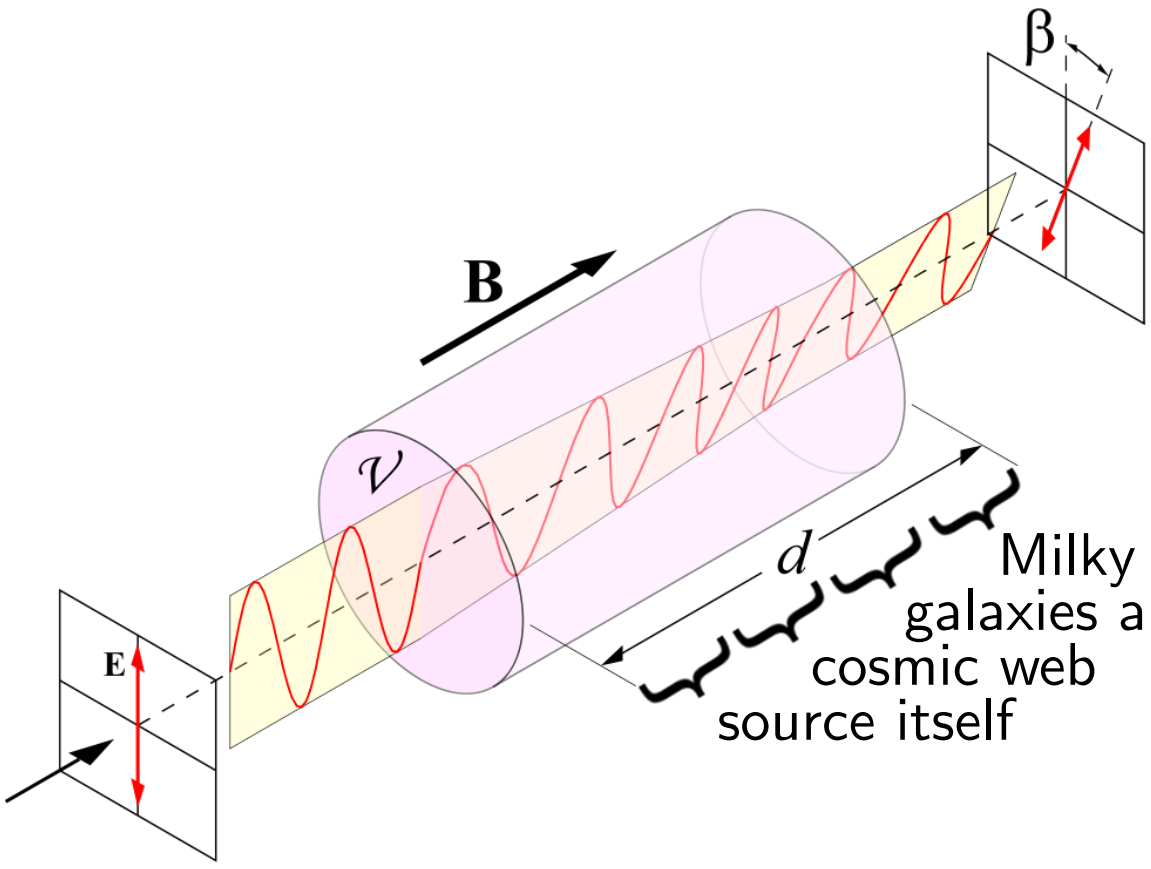
Faraday rotation

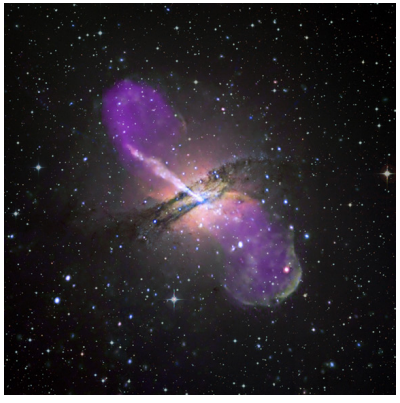


Faraday depth: $\phi \propto \int_{r_{\rm source}}^{0} (1+z)^{-2}\, n_{\rm e}\, B_r\, {\rm d}r$

$$\beta = \phi\lambda^2$$

Faraday rotation





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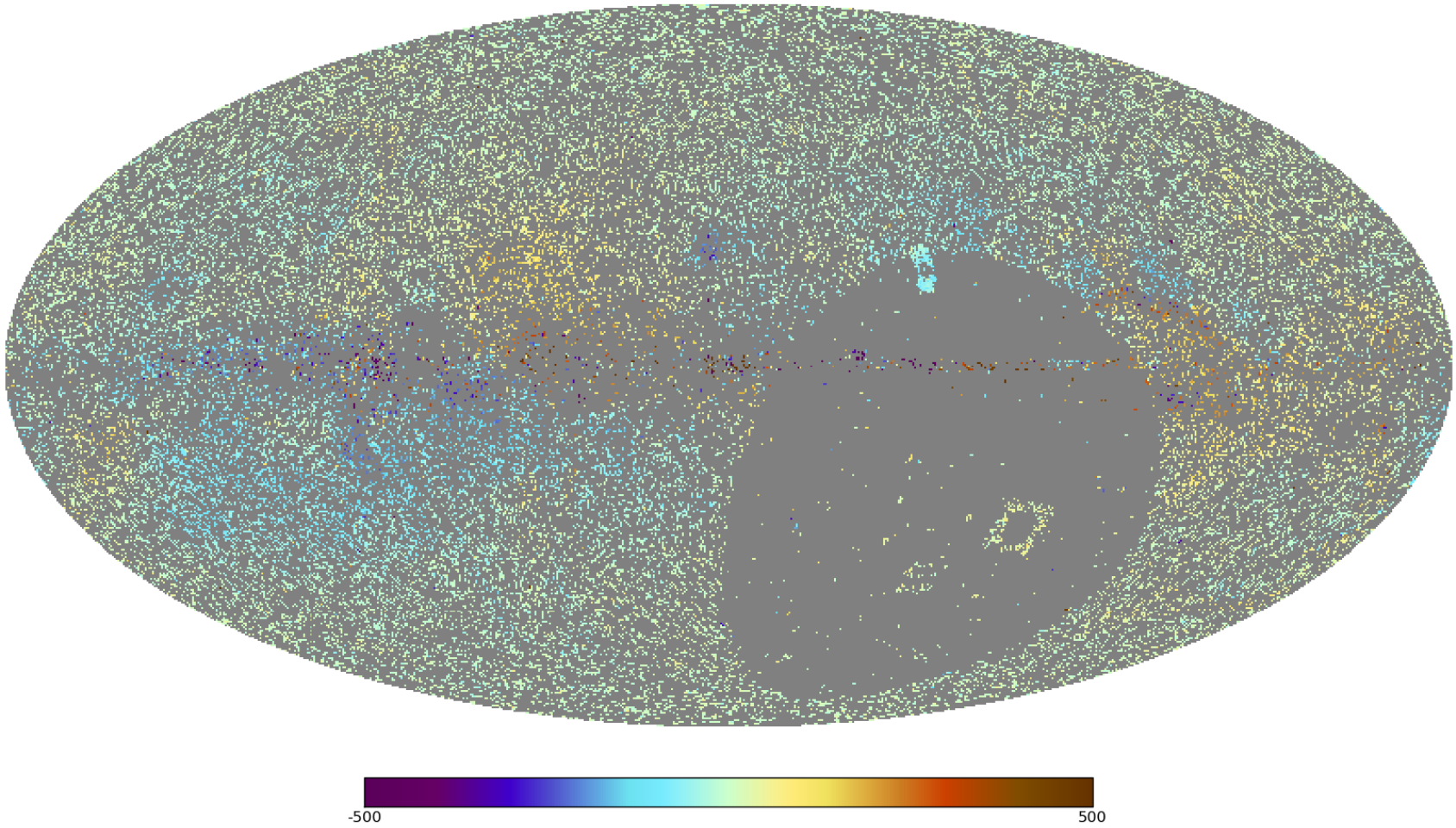
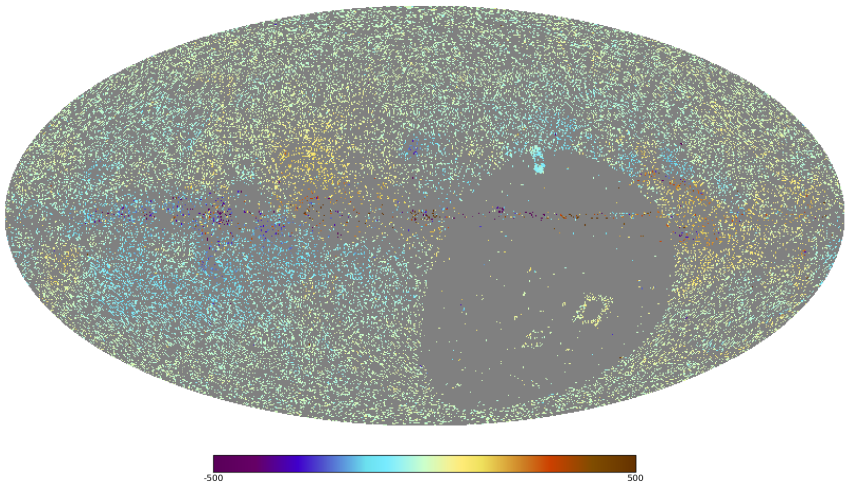
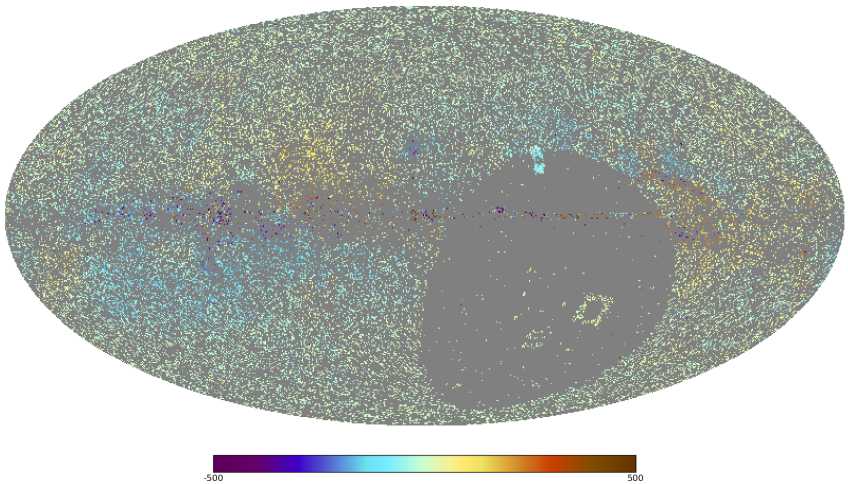


$\gtrsim$ 40 000 data points



Challenges

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



Challenges

- Regions without data
- Galactic/extragalactic split unknown
- Uncertain uncertainties
  - $n\,\pi$ ambiguity
  - multiple components along a LOS
  - ionosphere
  - ...

$$d = \phi_{\mathrm{g}} + \phi_{\mathrm{e}} + n$$

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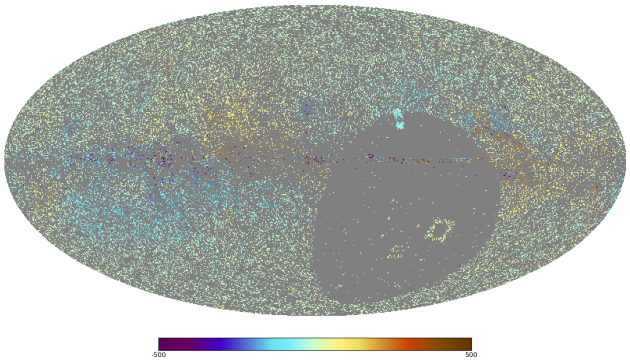
data



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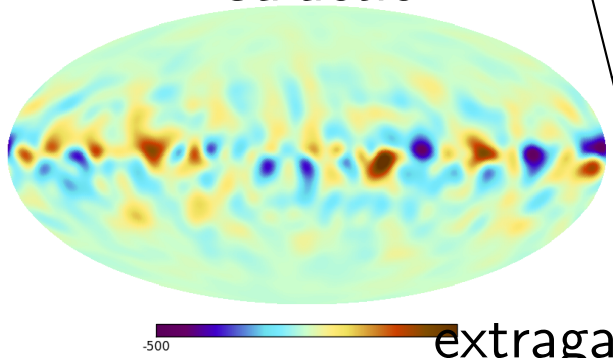
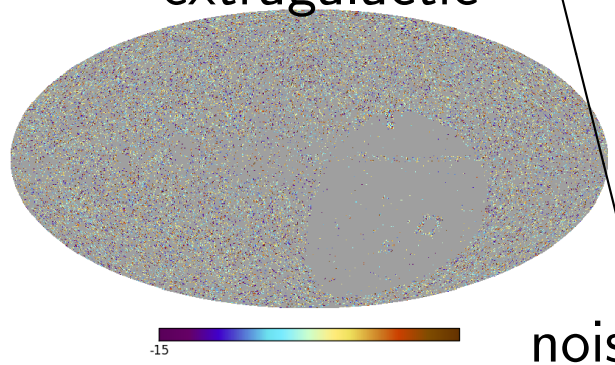
Galactic



extragalactic

+



noise

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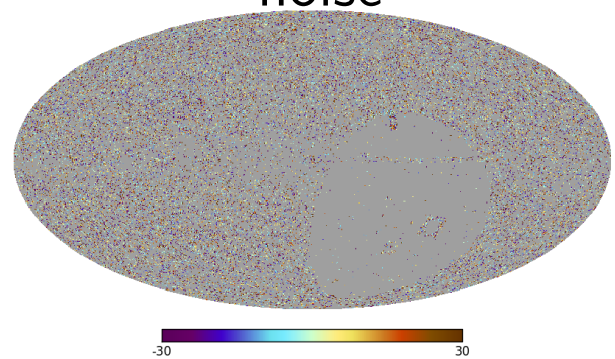
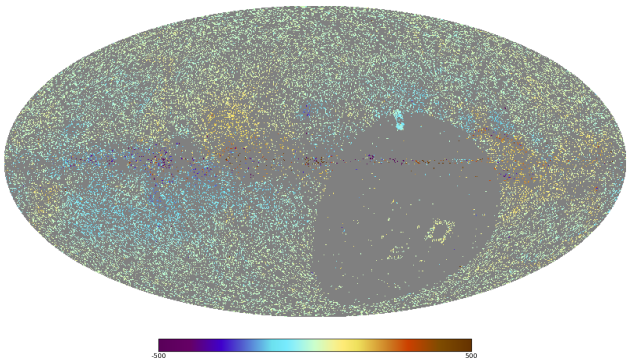


$$d = \phi_{\mathrm{g}} + \phi_{\mathrm{e}} + n$$

data



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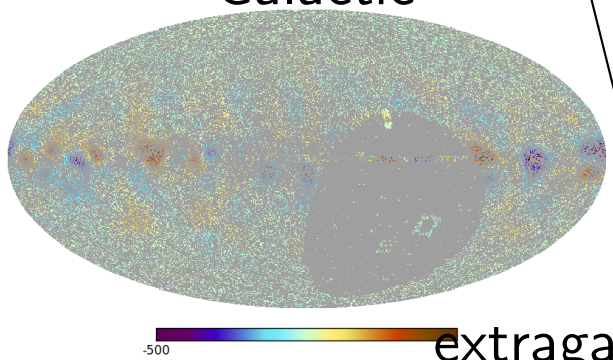
Galactic



extragalactic

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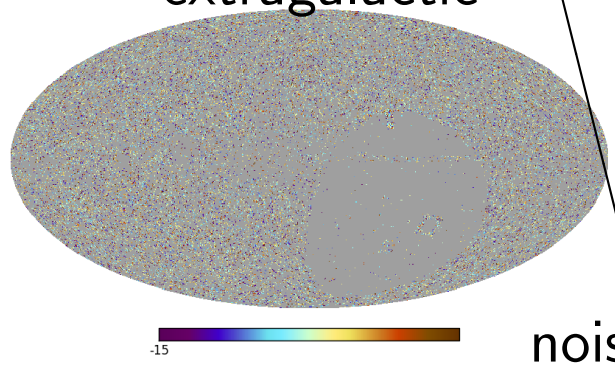

noise

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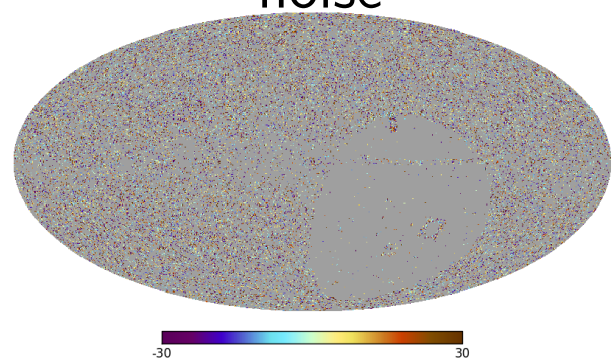

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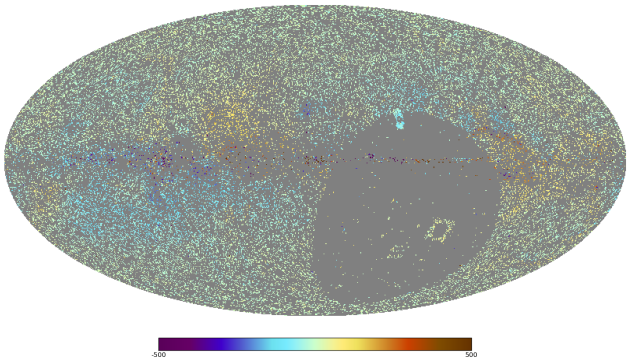

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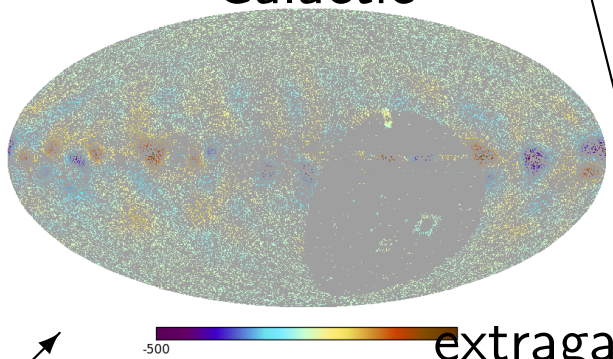
Galactic



correlated

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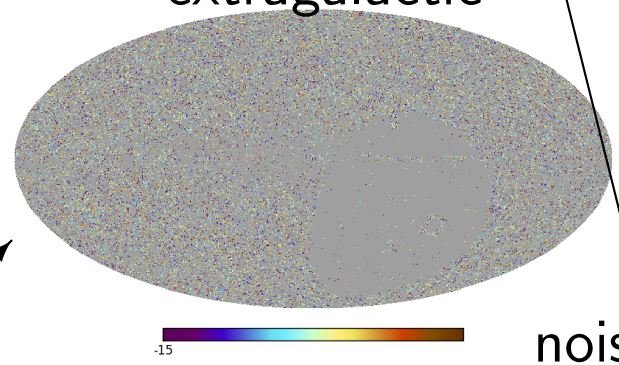
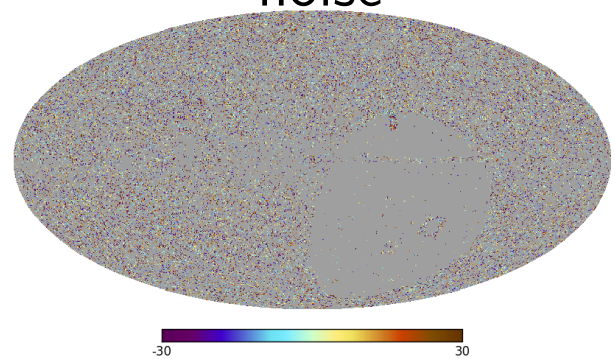
extragalactic



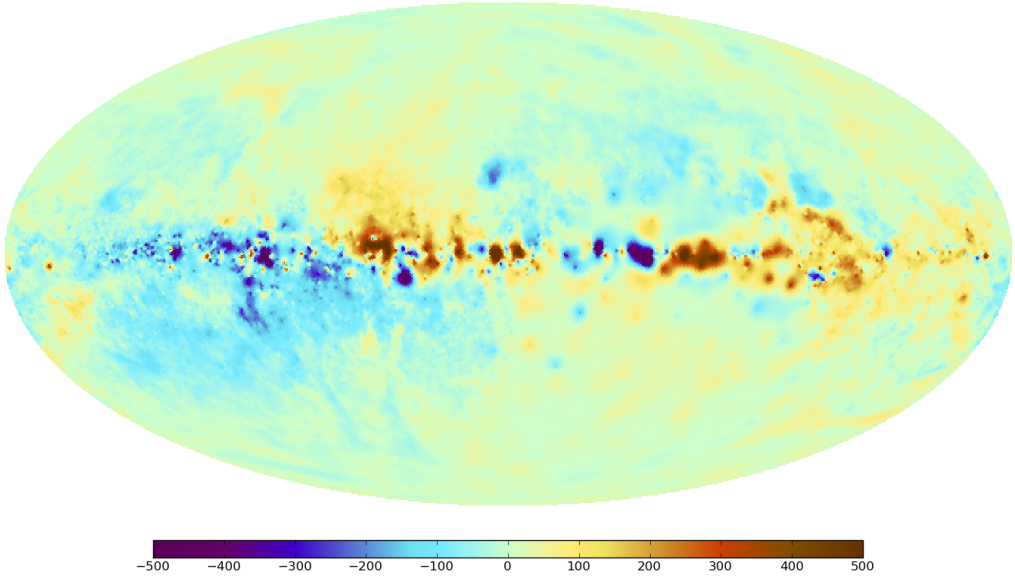
uncorrelated

+

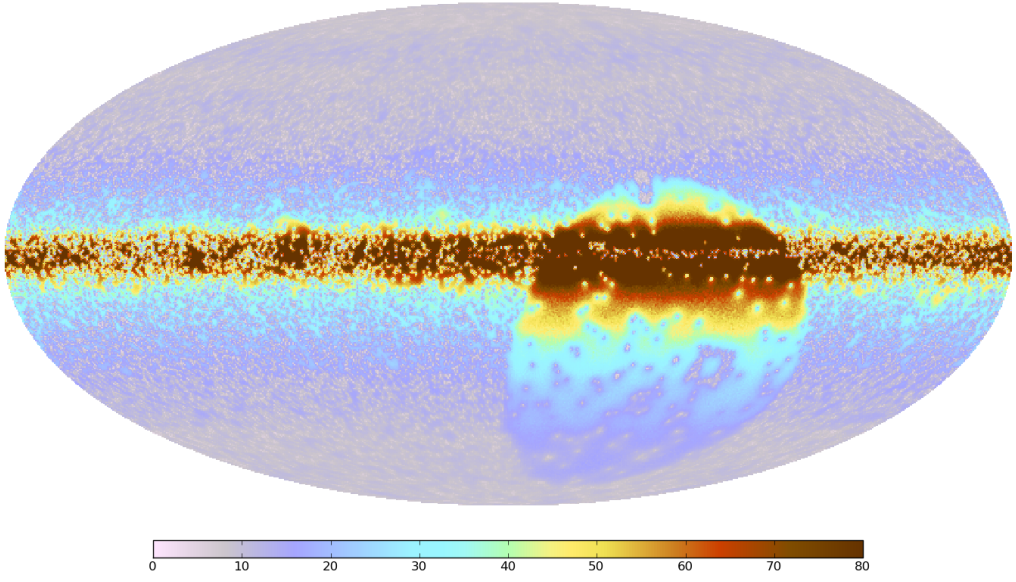
noise



Galactic Faraday depth



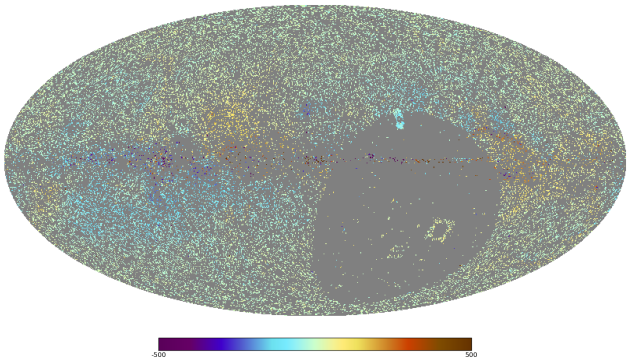
uncertainty



Oppermann et al. (2012/2015)

$$d = \phi_{\mathrm{g}} + \phi_{\mathrm{e}} + n$$

data



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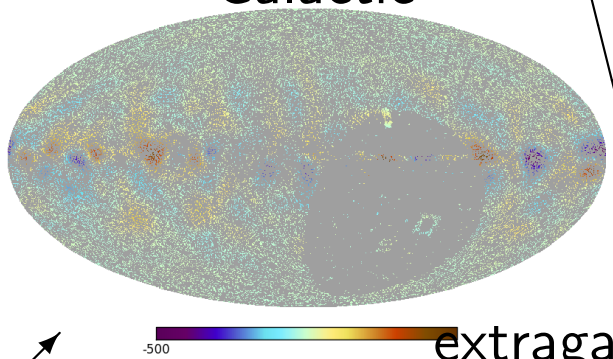

correlated

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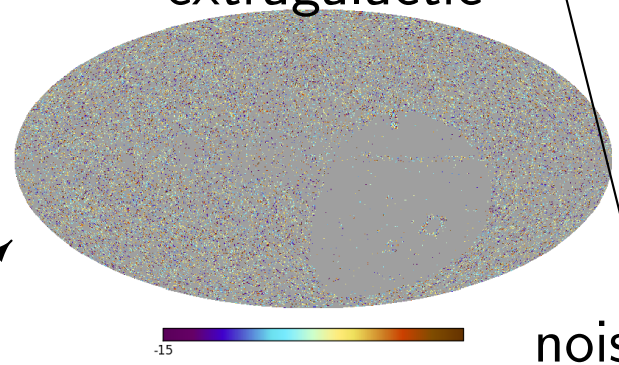
extragalactic



uncorrelated

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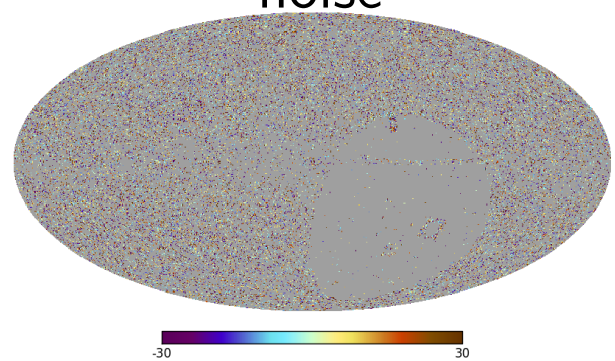
noise



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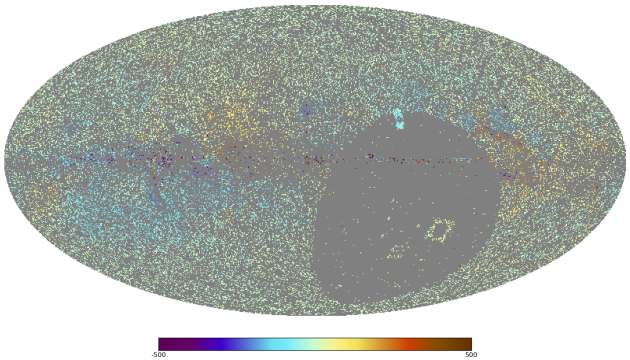

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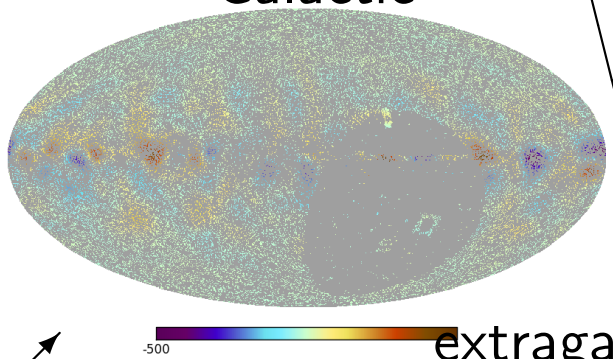

extragalactic

correlated

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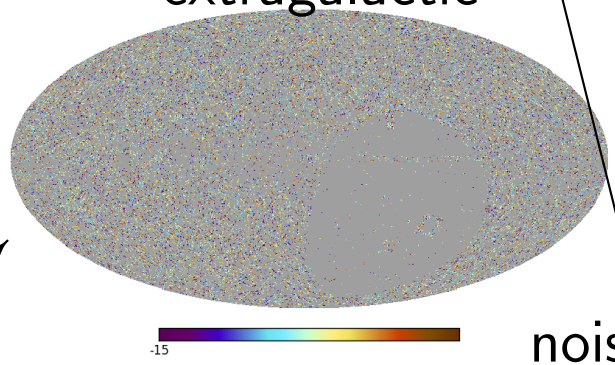
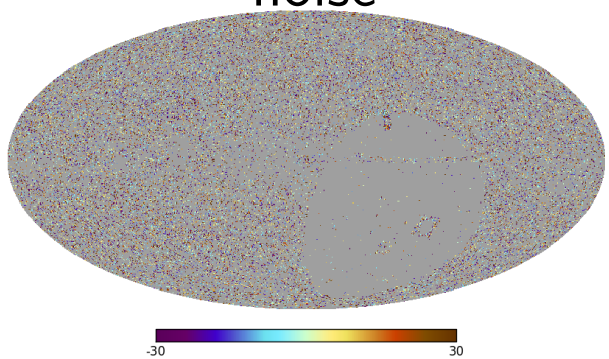


uncorrelated
degenerate

noise

+



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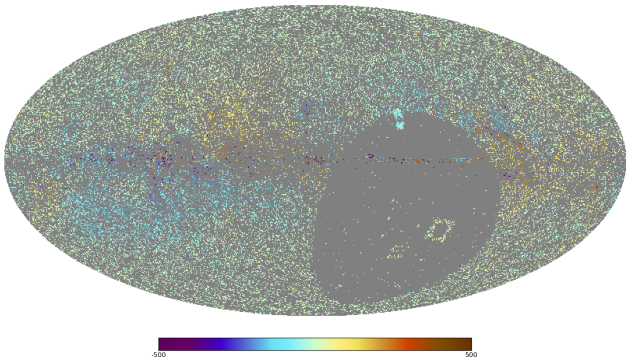

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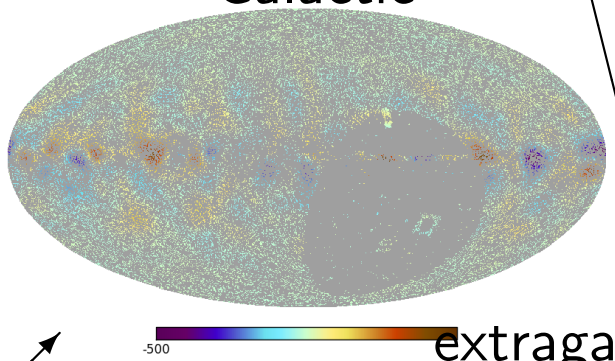
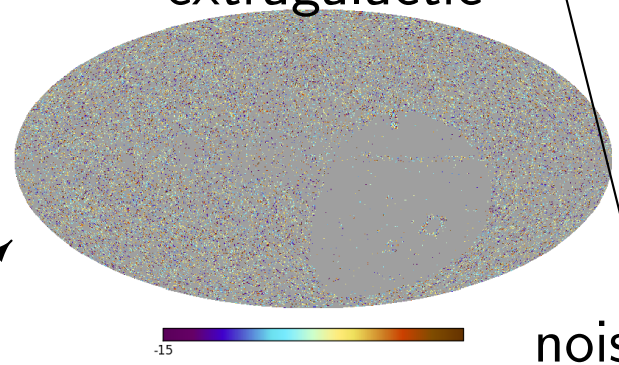
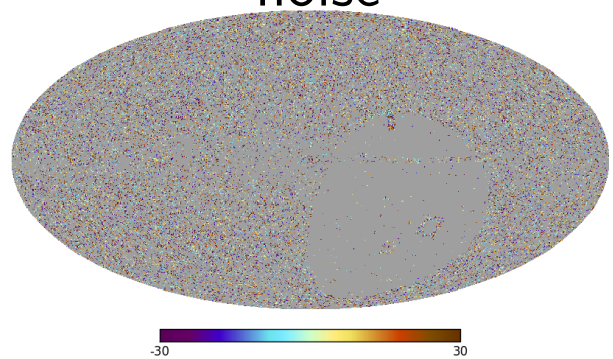
Galactic



extragalactic



noise



correlated

uncorrelated

degenerate

idea: find subset of data for which noise statistics are perfectly known

Results:

- $\sigma_{\mathrm{e}} \lesssim 7\,\mathrm{rad/m^2}$
- constraints on extragalactic contributions for individual sources very weak

What magnetic fields is this due to?

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Next step:

- $\sigma_{\mathrm{e}} = \sigma_{\mathrm{e}}$(objects on the line of sight, source properties, etc.)

Summary

- Galactic contribution (correlated) can be separated from rest (uncorrelated)
- Rest can be separated statistically into extragalactic and noise
- Uncertainties are large and should not be ignored
- Extragalactic contributions may hold the key to finding cosmological magnetic fields

All results at
http://www.mpa-garching.mpg.de/ift/faraday/