Max-Planck-Institute
for Astrophysics

Statistical methods for the analysis of rotation measure grids in large scale structures

Valentina Vacca

Main collaborators:

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Other people involved:

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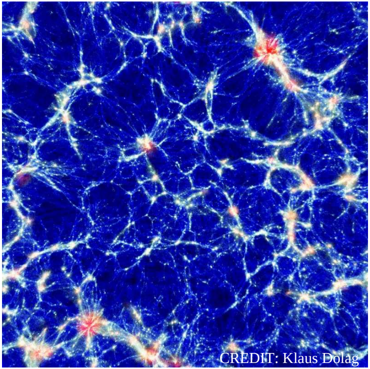
OUTLINE

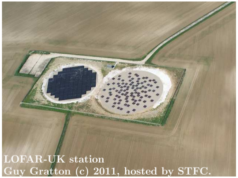
1. Context and general description
2. Bayesian approach
3. Test of the code and results
4. Future developements
5. Summary and conclusion

CONTEXT

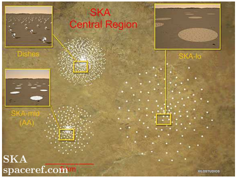
GOAL: Study the origin and evolution of cosmic magnetism



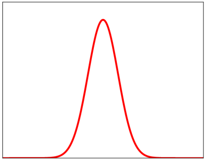
CREDIT: Klaus Dolag



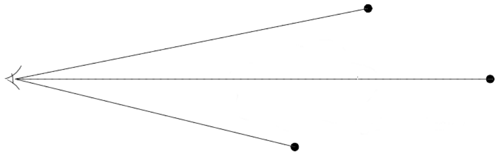
LOFAR-UK station
Guy Gratton (c) 2011, hosted by STFC.



SKA
spaceref.com



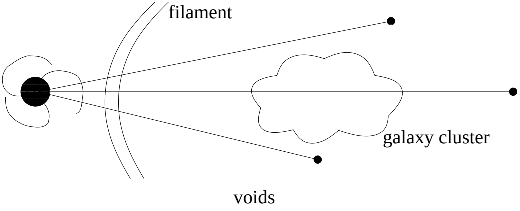
FARADAY DEPTH



$$\phi_i = a_0 \int_0^{x_i} dx \frac{n_\mathrm{e} B_\mathrm{x}}{(1+z)^2}$$

$$\langle \phi_i^2 \rangle \sim \int_0^{x_i} \frac{\mathrm{d}x}{(1+z)^4} a_0^2 n_\mathrm{e}^2 \langle B_x^2 \rangle \lambda_x$$

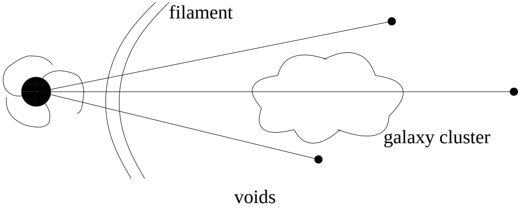
FARADAY DEPTH



$$\phi_i = a_0 \int_0^{x_\mathrm{l}} dx \frac{n_\mathrm{e} B_\mathrm{x}}{(1+z)^2}$$

$$\langle \phi_i^2 \rangle \sim \int_0^{x_i} \frac{\mathrm{d}x}{(1+z)^4} a_0^2 n_\mathrm{e}^2 \langle B_x^2 \rangle \lambda_x$$

FARADAY DEPTH



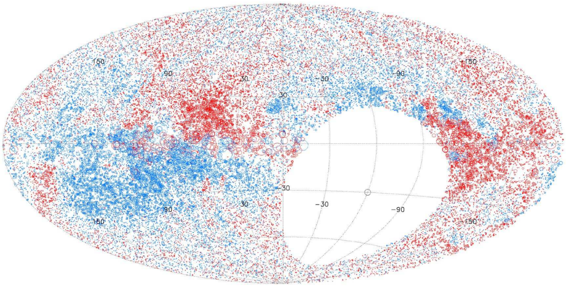
$$\langle \phi_i^2 \rangle \sim \sigma_{i,\mathrm{gal}}^2 + \sigma_{i,\mathrm{int}}^2 + \sigma_{i,\mathrm{env}}^2$$

$$\approx \sigma_{i,\mathrm{gal}}^2 + \frac{e^{\chi_0}}{(1+z_i)^{4+\chi_2}} + \frac{L(z_i,\chi_3)}{L_0} e^{\chi_1}$$

$$L(z_i,\chi_3) = \int_0^{z_i} \frac{c(1+z_i)^{4+\chi_3}}{H_0 \sqrt{W_\mathrm{m}(1+z_i)^3 + W_\mathrm{c}(1+z_i)^2 + W_\mathrm{l}}} \mathrm{d}z$$

AVAILABLE INFORMATION

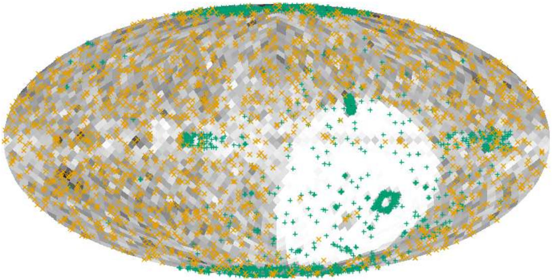
FARADAY ROTATION CATALOG FOR 37543 SOURCES FROM NVSS



Taylor et al. (2009)

AVAILABLE INFORMATION

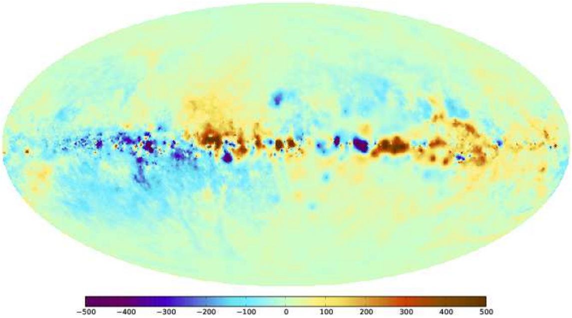
SIP AND VIP POINTS



Oppermann et al. (2014)

AVAILABLE INFORMATION

GALACTIC AND EXTRAGALACTIC CONTRIBUTION

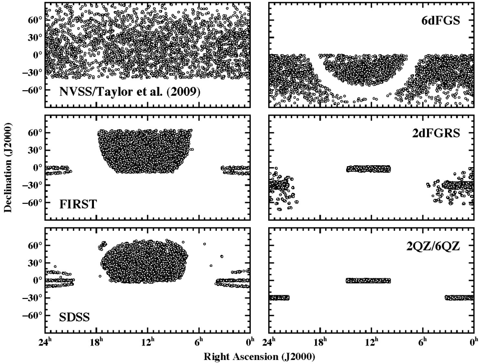


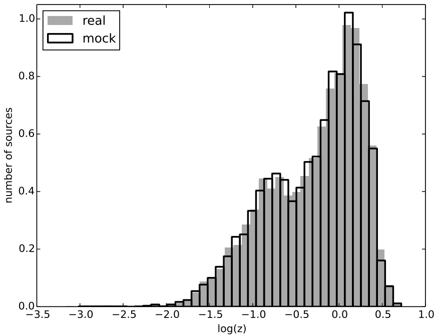
$$d_i = \phi_{\mathrm{g},i} + \phi_{\mathrm{e},i} + n_i$$

Oppermann et al. (2012, 2014)

AVAILABLE INFORMATION

REDSHIFT CATALOG

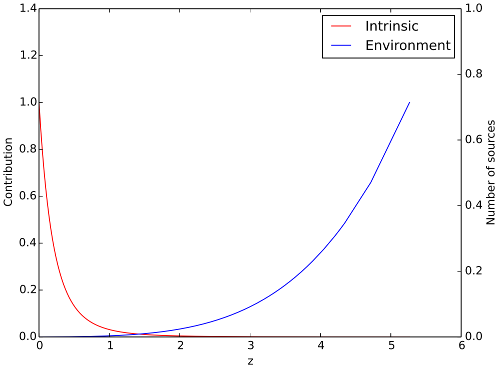




Hammond et al. (2012)

AVAILABLE INFORMATION

REDSHIFT CATALOG



$$\sigma^2_{\rm int} \propto \frac{e^{\chi_0}}{(1+z_i)^{4+\chi_2}}$$

$$\sigma^2_{\rm env} \propto e^{\chi_1} \frac{L(z_i,\chi_3)}{L_0}$$

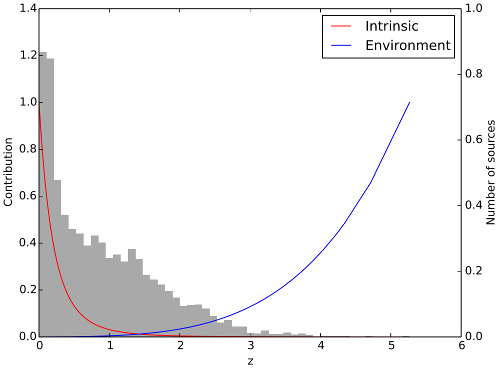
$$\chi_0 = 0.$$
$$\chi_1 = -6.$$
$$\chi_2 = 1.$$
$$\chi_3 = 1.$$

z≤3: 3947 sources

z>3: 56 sources

AVAILABLE INFORMATION

REDSHIFT CATALOG



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$$\chi_0 = 0.$$
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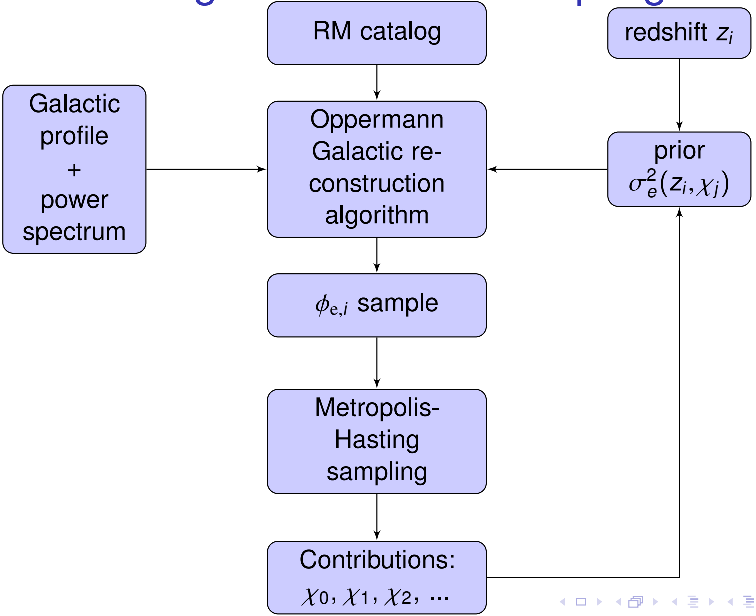
$z \leq 3$: 3947 sources

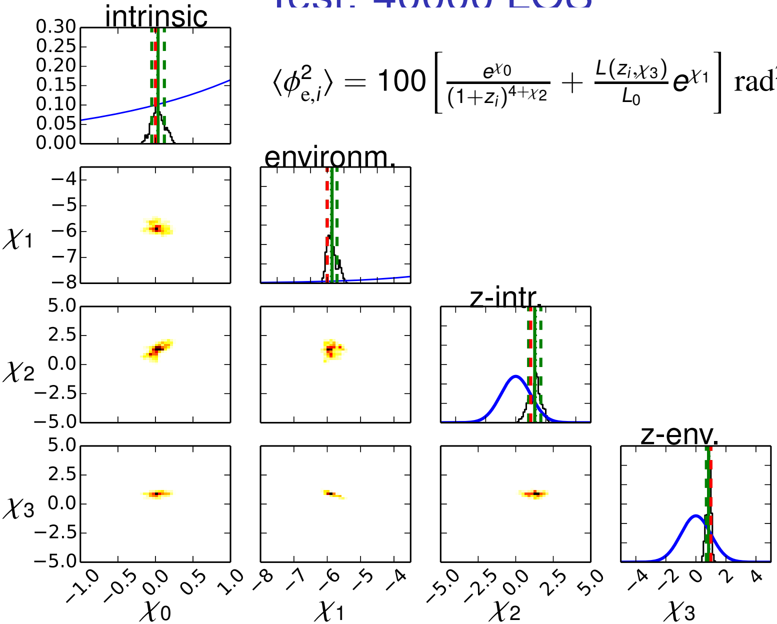
$z > 3$: 56 sources

Algorithm: Gibbs sampling

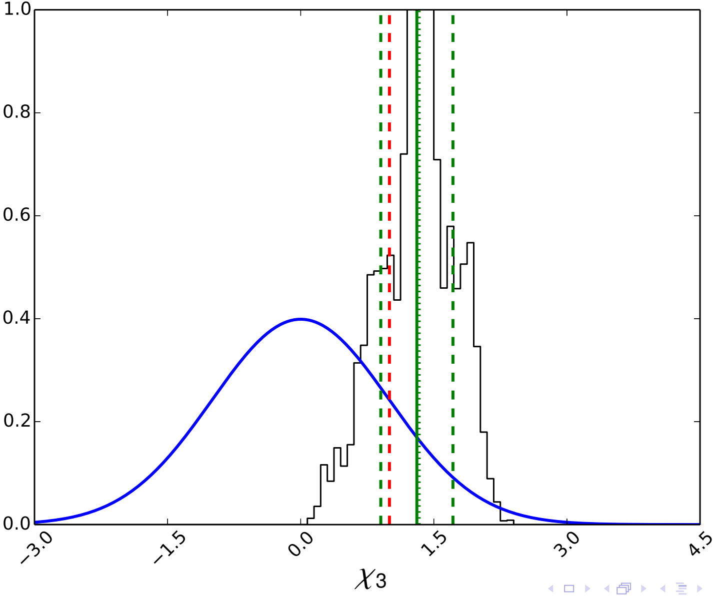


Test: 40000 LOS

$$\langle \phi^2_{\mathrm{e},i} \rangle = 100 \left[\frac{e^{\chi_0}}{(1+z_i)^{4+\chi_2}} + \frac{L(z_i,\chi_3)}{L_0} e^{\chi_1} \right] \mathrm{rad}^2/\mathrm{m}^4$$

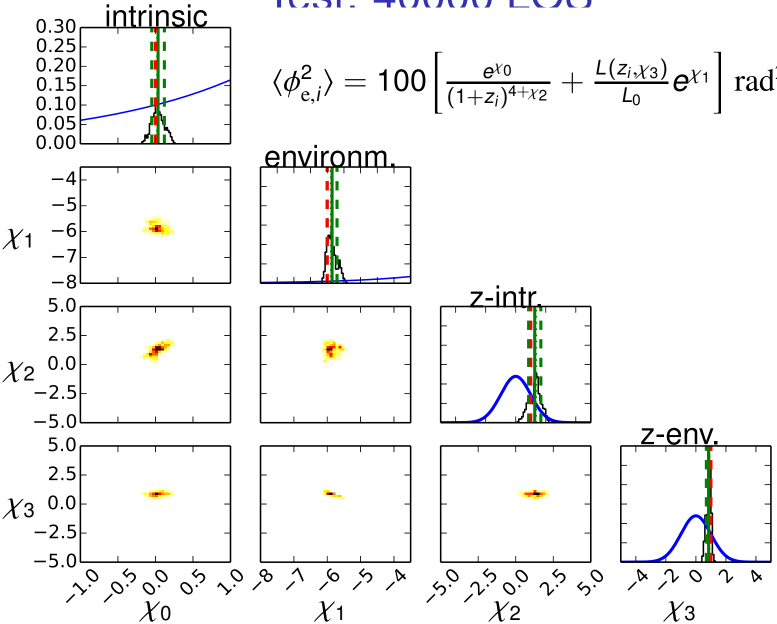


Test: 40000 LOS



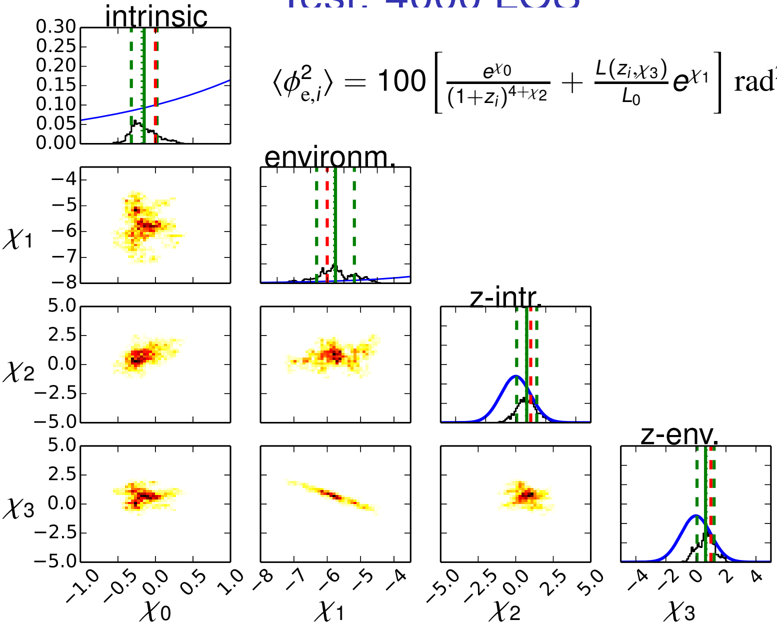
Test: 40000 LOS

$$\langle \phi^2_{\mathrm{e},i} \rangle = 100 \left[\frac{e^{\chi_0}}{(1+z_i)^{4+\chi_2}} + \frac{L(z_i,\chi_3)}{L_0} e^{\chi_1} \right] \mathrm{rad}^2/\mathrm{m}^4$$



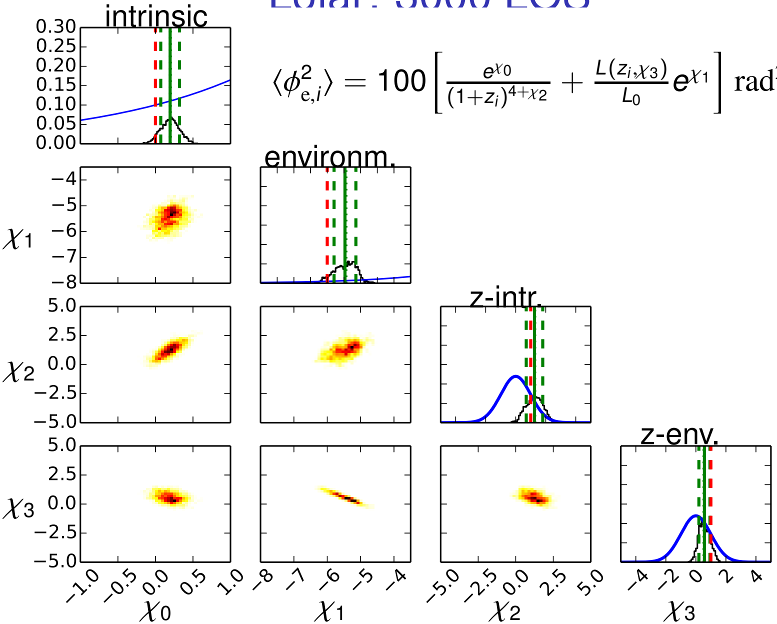
Test: 4000 LOS

$$\langle \phi_{e,i}^2 \rangle = 100 \left[\frac{e^{\chi_0}}{(1+z_i)^{4+\chi_2}} + \frac{L(z_i,\chi_3)}{L_0} e^{\chi_1} \right] \mathrm{rad}^2/\mathrm{m}^4$$



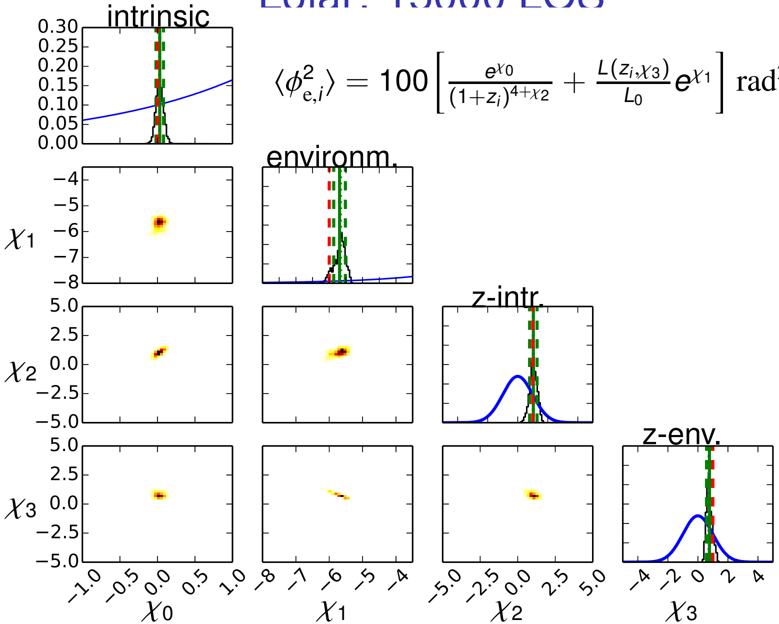
Lofar: 3000 LOS

$$\langle \phi_{\mathrm{e},i}^2 \rangle = 100 \left[\frac{e^{\chi_0}}{(1+z_i)^{4+\chi_2}} + \frac{L(z_i,\chi_3)}{L_0} e^{\chi_1} \right] \mathrm{rad}^2/\mathrm{m}^4$$



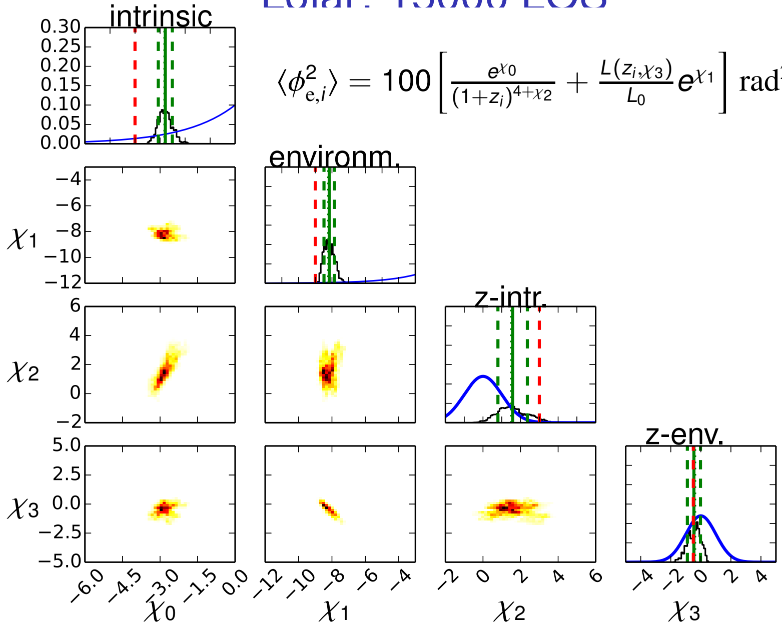
Lofar: 15000 LOS

$$\langle \phi^2_{e,i} \rangle = 100 \left[\frac{e^{\chi_0}}{(1+z_i)^{4+\chi_2}} + \frac{L(z_i,\chi_3)}{L_0} e^{\chi_1} \right] \mathrm{rad}^2/\mathrm{m}^4$$

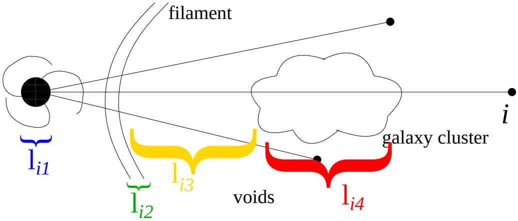


Lofar: 15000 LOS

$$\langle \phi^2_{\mathrm{e},i} \rangle = 100 \left[\frac{e^{\chi_0}}{(1+z_i)^{4+\chi_2}} + \frac{L(z_i,\chi_3)}{L_0} e^{\chi_1} \right] \mathrm{rad}^2/\mathrm{m}^4$$



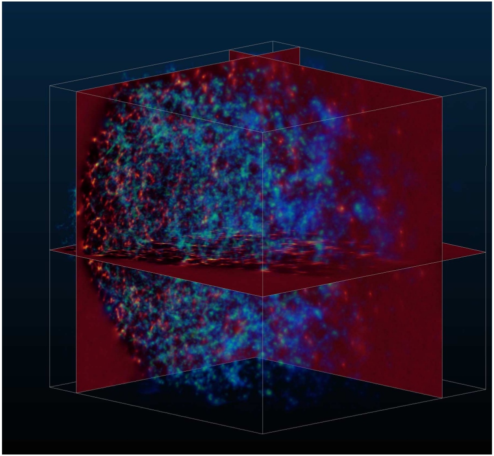
Second step



$$\langle \phi_i^2 \rangle \sim \sigma_{i,\mathrm{int}}^2 + \underbrace{\int_0^{x_i} \frac{dx}{(1+z)^4}}_{l_{ij}} \underbrace{a_0^2 n_\mathrm{e}^2 \langle B_x^2 \rangle \lambda_x}_{\chi_j} ,$$

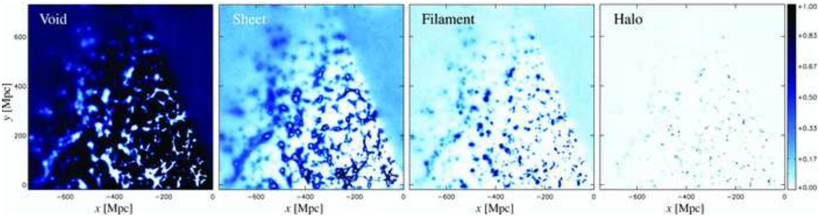
$$\approx e^{\chi_{i0}} + l_{i1} e^{\chi_1} + l_{i2} e^{\chi_2} + l_{i3} e^{\chi_3} + l_{i4} e^{\chi_4} + l_{i5} e^{\chi_5}$$

ADDITIONAL AVAILABLE INFORMATION



Jasche et al. (2010), Leclercq et al. (2015)

ADDITIONAL AVAILABLE INFORMATION



$$\langle \phi_{e,i}^2 \rangle \sim exp(\chi_0) + \Sigma_{j=1}^{N} l_{ij} exp(\chi_j)$$

Cosmic web structure, redshift catalog → length matrix l_{ij}

Jasche et al. (2010), Leclercq et al. (2015)

Conclusions

- To infer the intrinsic and environment contribution a good knowledge of the observational noise and the redshift information are necessary;
- Lofar is in principle able to infer information for B$\sim$nG, for weaker fields SKA will be necessary;
- Proper reconstruction of the large scale structure up to high redshift as well as a proper modeling of the magnetic Universe is needed to test the algorithm for investigating magnetic fields in the different environments and make predictions.

THANK YOU!