MAGNETIC FIELDS MEASUREMENTS IN THE LARGE SCALE STRUCTURE OF THE UNIVERSE

VALENTINA VACCA

Collaborators:

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Leiden, The Netherlands, 23-27 October 2017

OUTLINE

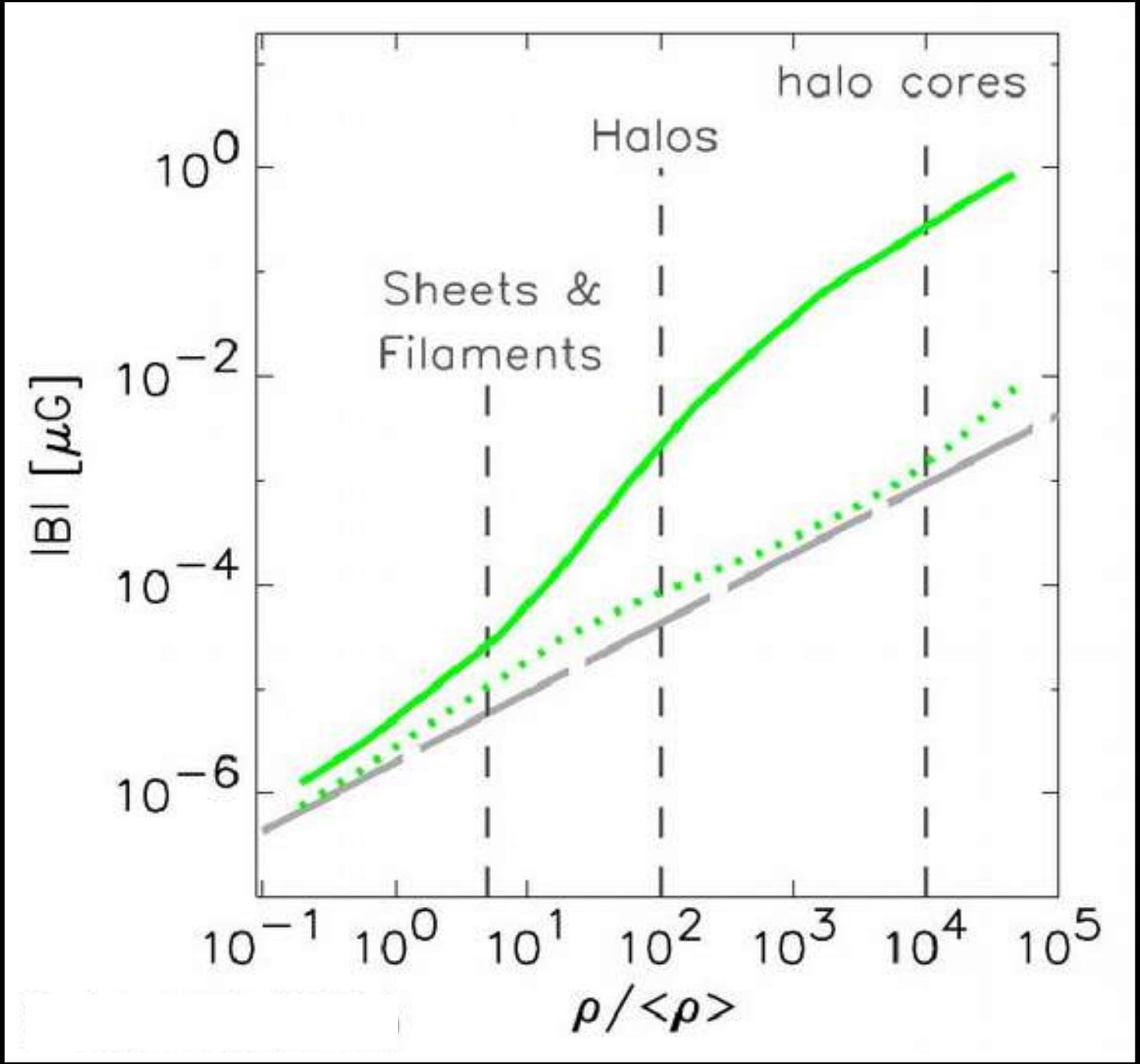
Context

Decomposition algorithms (1), (2), (3)

Magnetic Fields in the Large Scale Structure

Summary

CONTEXT


halo cores
Halos
Sheets &
Filaments
10^0
10^{-2}
10^{-4}
10^{-6}
|B| [μG]
10^{-1} 10^0 10^1 10^2 10^3 10^4 10^5
$\rho/\langle\rho\rangle$

CONTEXT

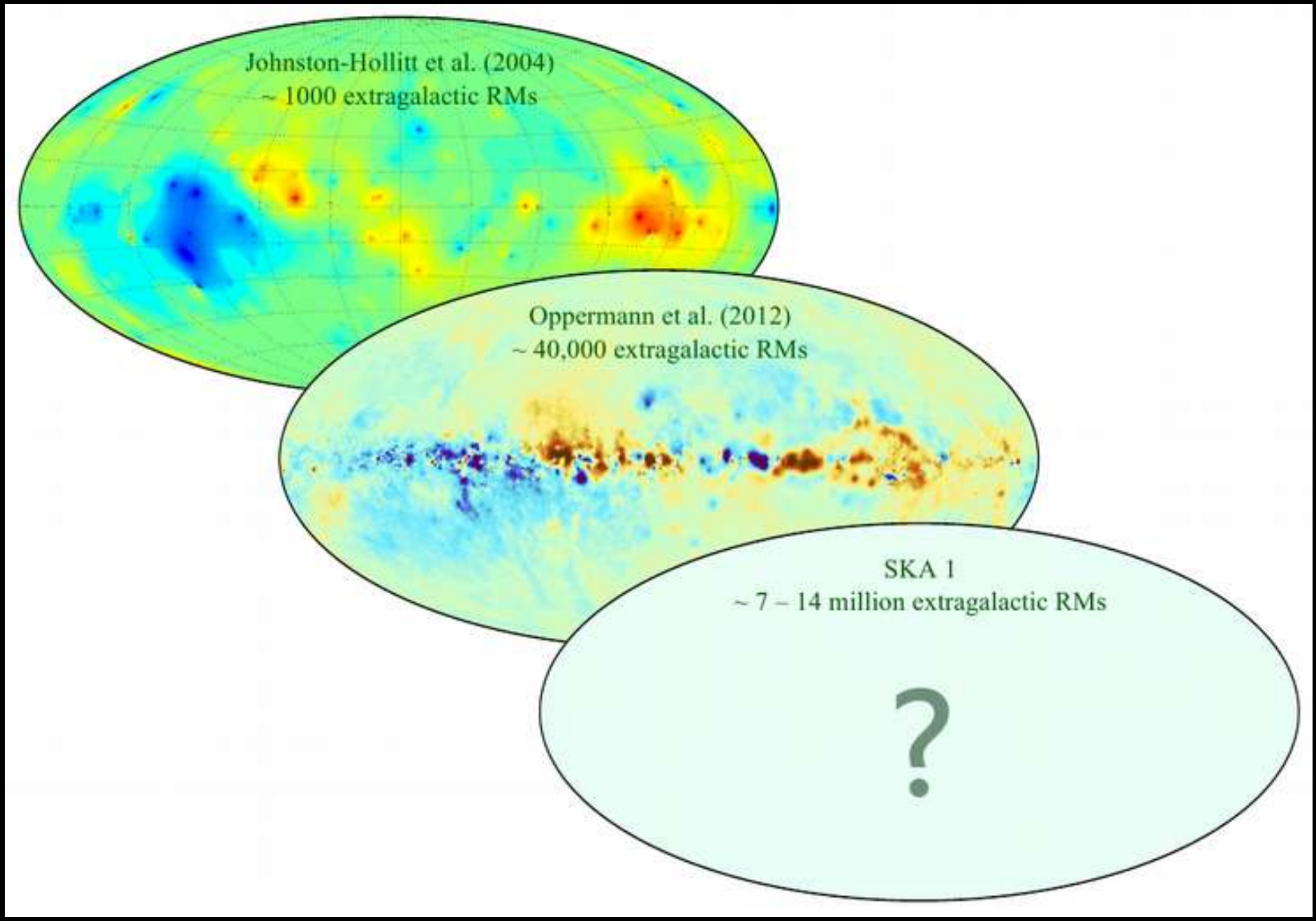
VOIDS

FILAMENTS

CLUSTERS

CREDITS: Franco Vazza

CONTEXT


Johnston-Hollitt et al. (2004)
~ 1000 extragalactic RMs
Oppermann et al. (2012)
~ 40,000 extragalactic RMs
SKA 1
~ 7 – 14 million extragalactic RMs
?

DECOMPOSITION ALGORITHMS (1)

$$\phi \propto \int B_{los} n_e \, dl$$

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

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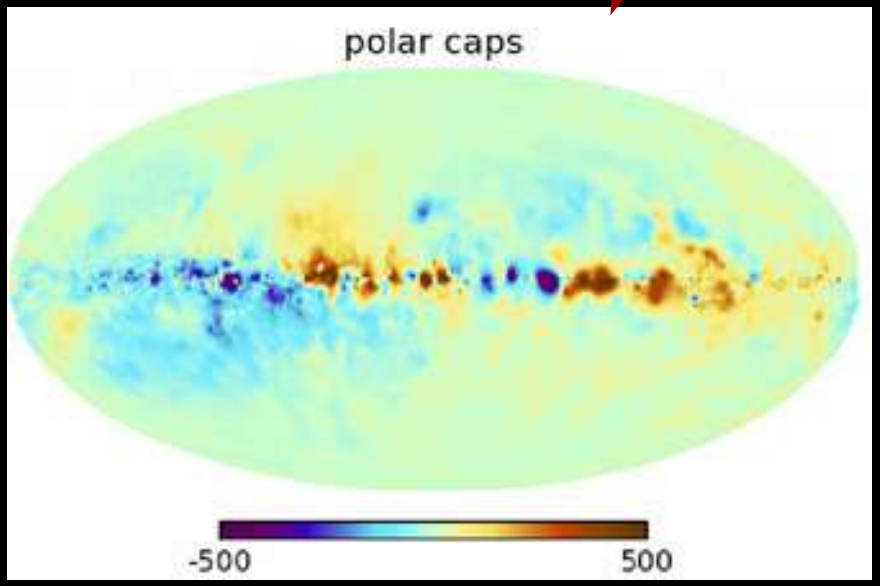
GALACTIC



Oppermann et al. (2015)

DECOMPOSITION ALGORITHMS (1)

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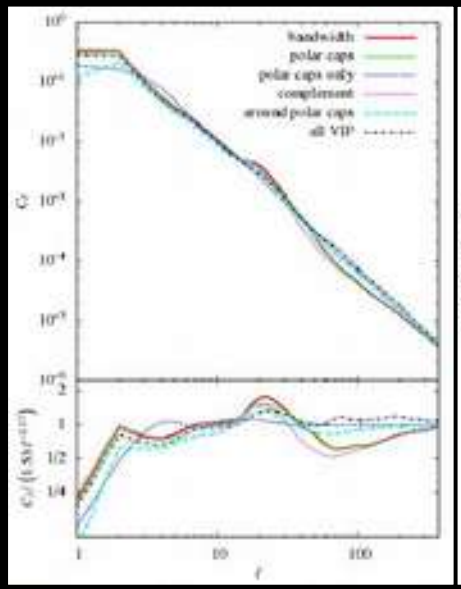
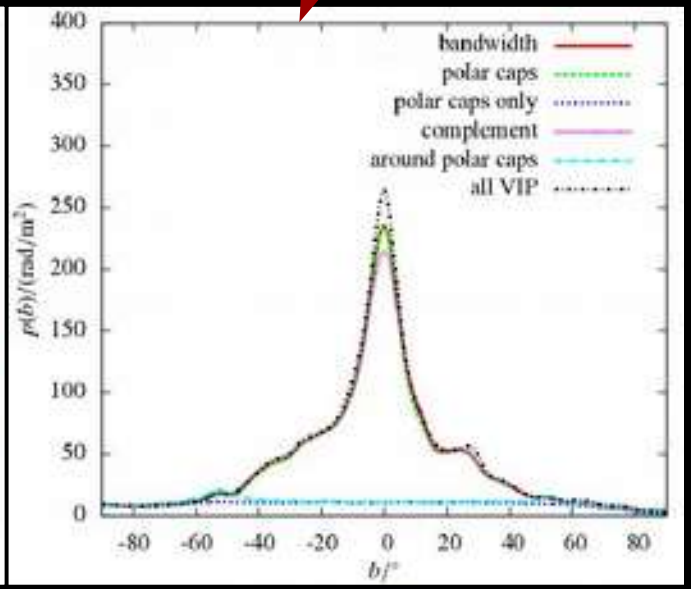
GALACTIC





Oppermann et al. (2015)

DECOMPOSITION ALGORITHMS (1)

$$\phi \propto \int B_{los}\, n_e\, dl$$

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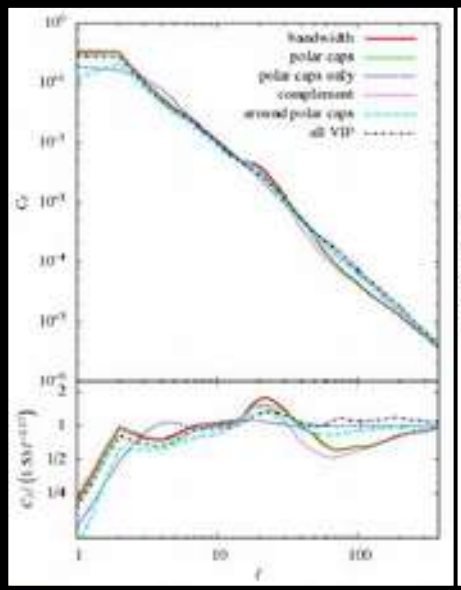
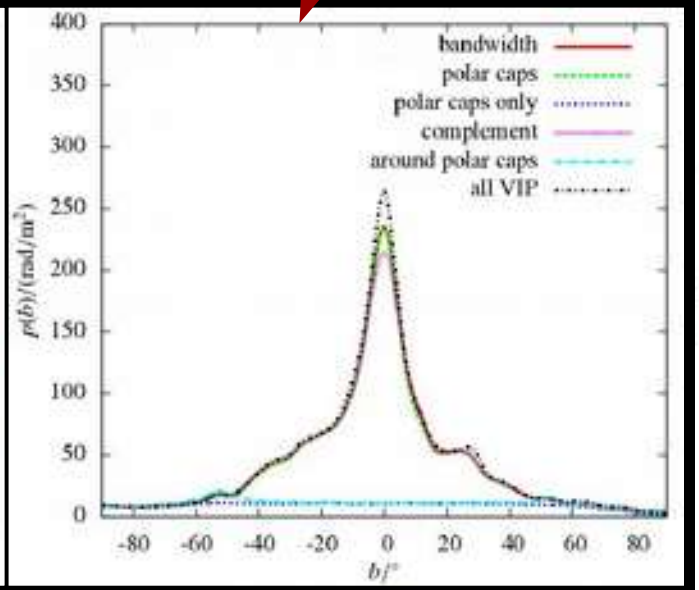
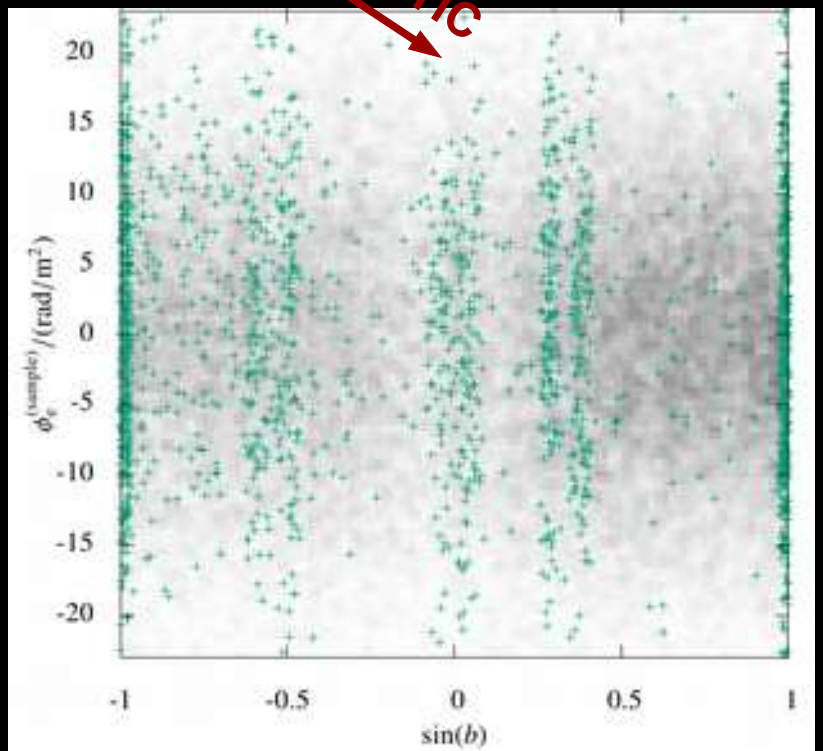
GALACTIC

EXTRAGALACTIC

σ_e~7rad/m^2







Oppermann et al. (2015)

DECOMPOSITION ALGORITHMS (2)

$$\phi \propto \int B_{los}\, n_e\, dl$$

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

EXTRAGALACTIC

$$\langle \phi^2_{e,i} \rangle = \sigma^2_{int,i} + \sigma^2_{env,i}$$

Other contributions (magnesium absorbers, ionosphere, etc.) can be easily included.

Vacca et al. (2016)

DECOMPOSITION ALGORITHMS (2)

$$\phi \propto \int B_{los}\, n_e\, dl$$

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INTRINSIC

$$\left(\frac{L_i}{L_0}\right)^{\chi_{lum}} \frac{\sigma^2_{int,0}}{(1+z_i)^4}$$

Vacca et al. (2016)

DECOMPOSITION ALGORITHMS (2)

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INTRINSIC

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LLS

$$\frac{D(z_i, \chi_{\mathrm{red}})}{D_0} \sigma^2_{\mathrm{env},0}$$

Vacca et al. (2016)

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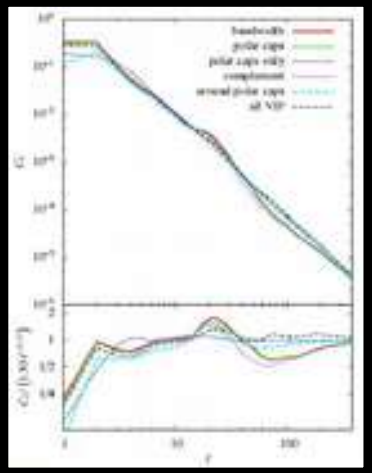
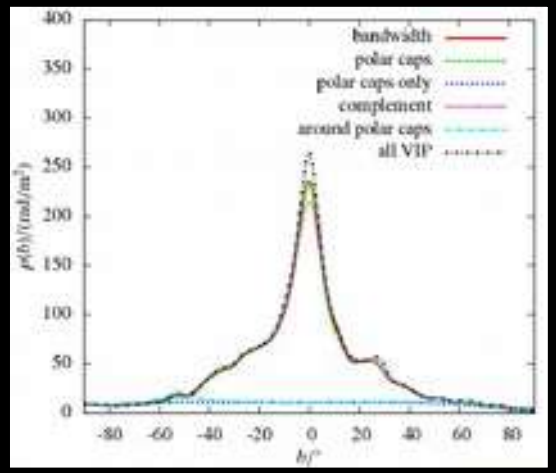
$$\frac{D(z_i, \chi_{red})}{D_0} \sigma^2_{env,0}$$

Vacca et al. (2016)

DECOMPOSITION ALGORITHMS (2)

Faraday depth, redshift, and luminosity catalogs





+

$\phi_{e,i}$

Metropolis-Hasting sampling

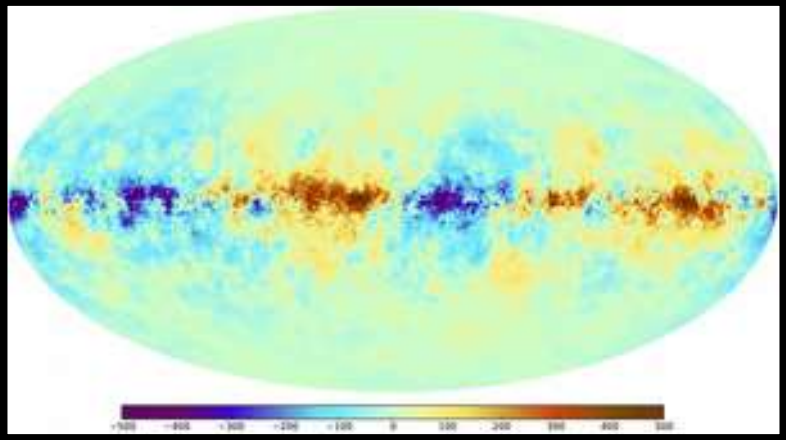
$\sigma_{\mathrm{int},0}$, $\sigma_{\mathrm{env},0}$, χ_{lum}, χ_{red}

new prior $\sigma_e(z_i, L_i, \sigma_k, \chi_j)$

Vacca et al. (2016)

DECOMPOSITION ALGORITHMS (2)

Faraday depth, redshift, and luminosity catalogs



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Vacca et al. (2016)

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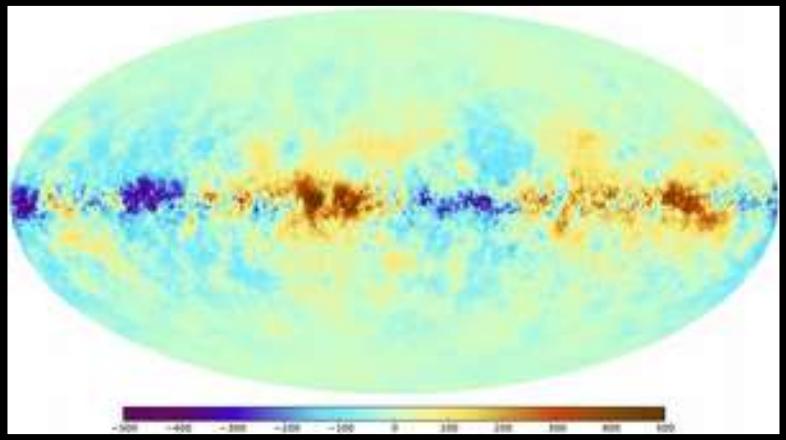

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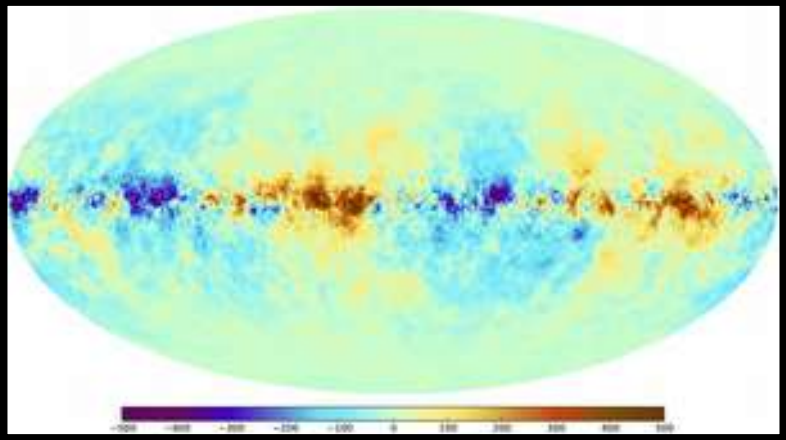

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Vacca et al. (2016)

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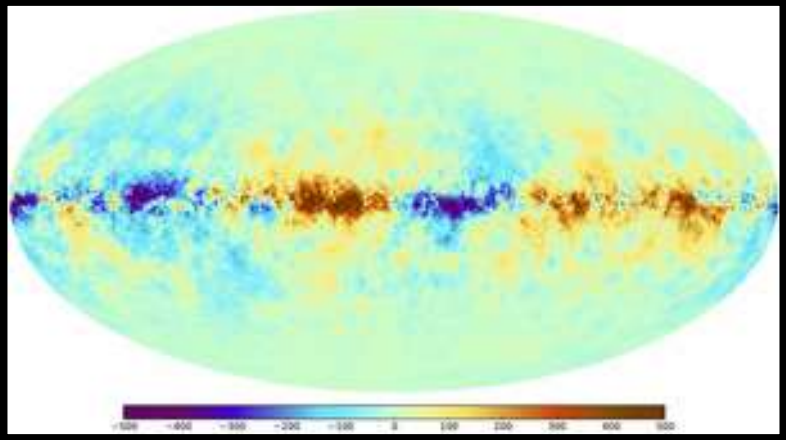


+

$\phi_{e,i}$

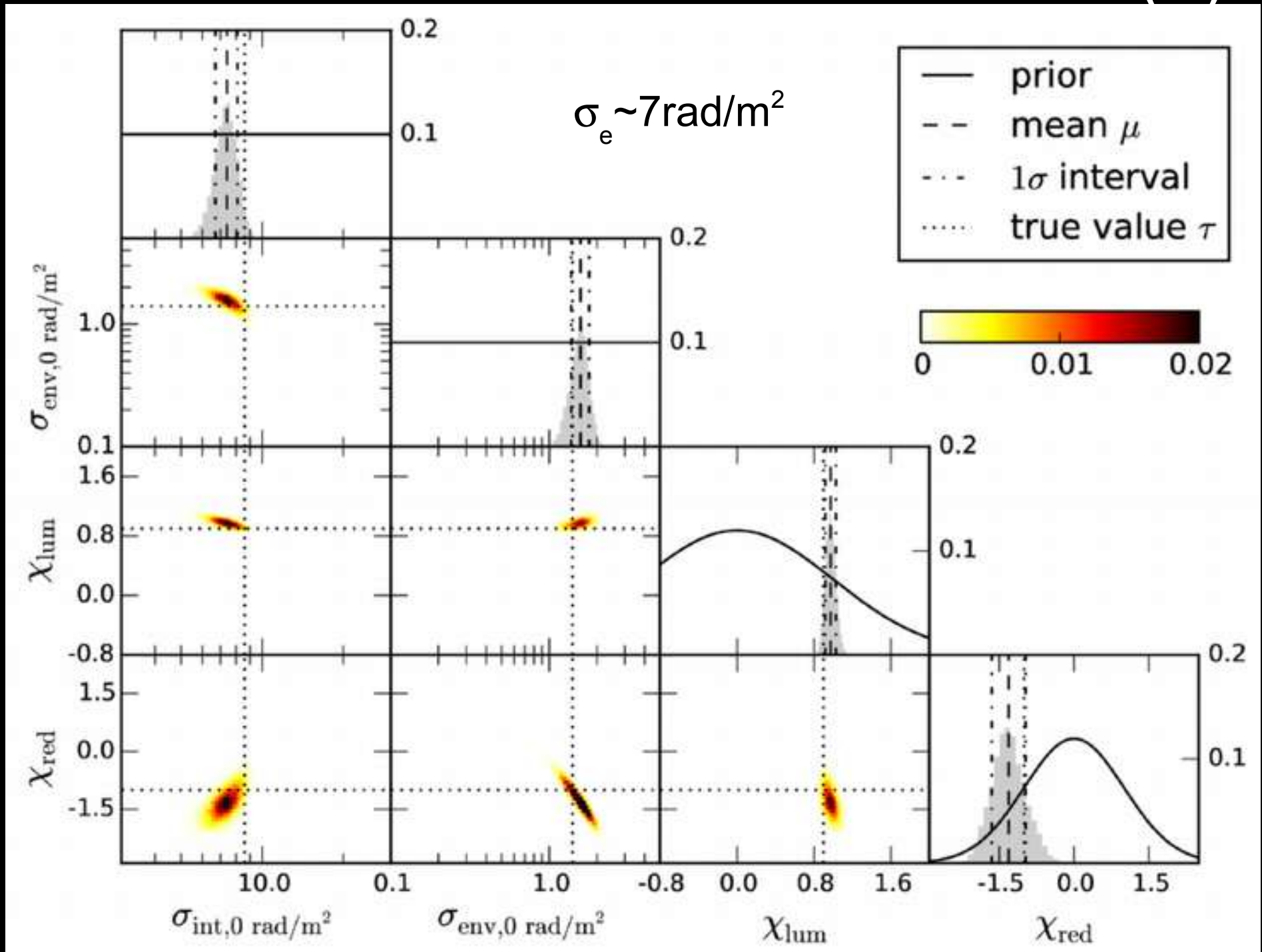
Metropolis-Hasting sampling

$\sigma_{int,0}$, $\sigma_{env,0}$, χ_{lum}, χ_{red}

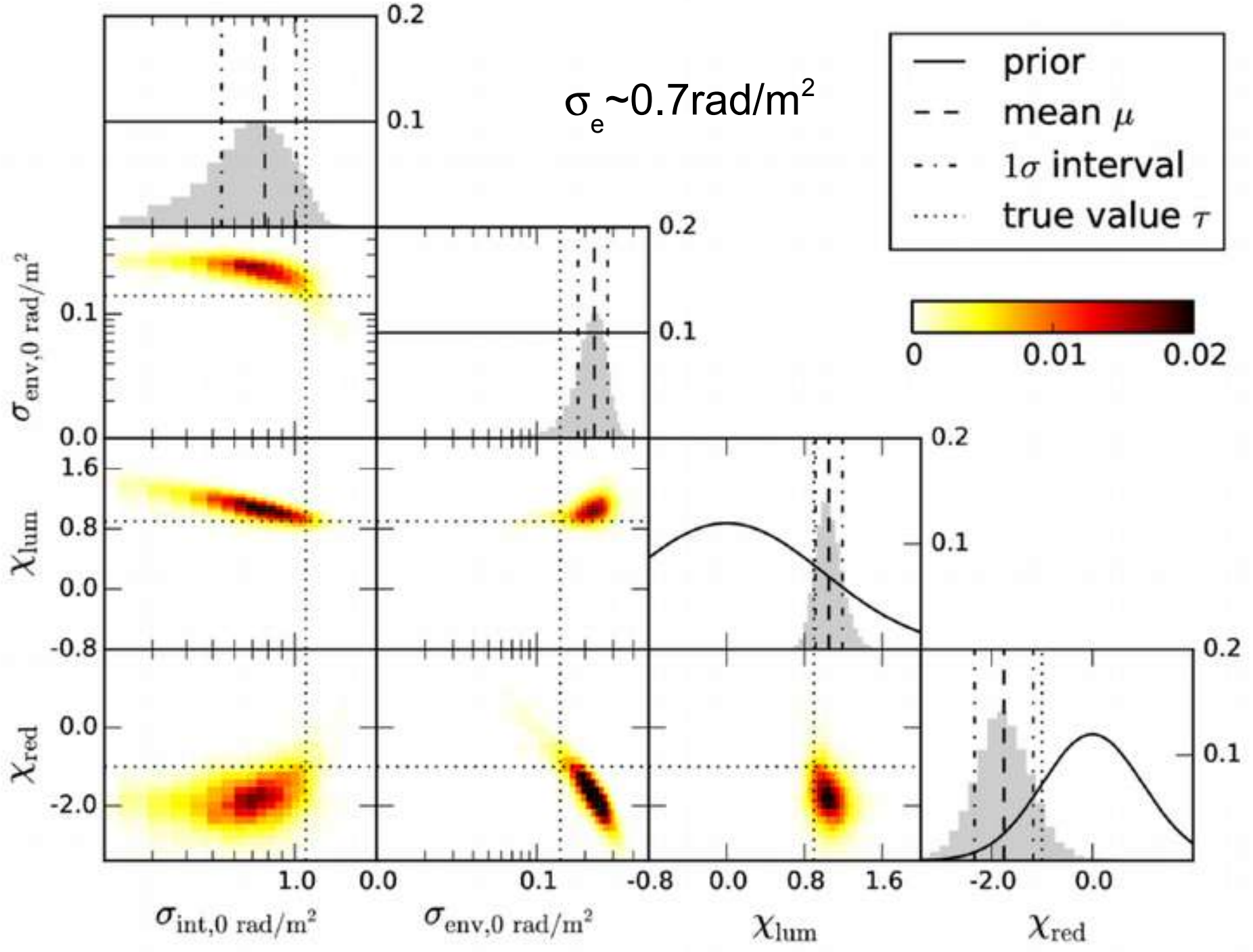
new prior $\sigma_e(z_i, L_i, \sigma_k, \chi_j)$

Vacca et al. (2016)

DECOMPOSITION ALGORITHMS (2)



DECOMPOSITION ALGORITHMS (2)



DECOMPOSITION ALGORITHMS (2)

$\sigma_e \sim 7\,\mathrm{rad/m^2}$

- Radio emitting source (L size of the source)

$$\frac{\sqrt{\langle B_{ox}^2 \rangle}}{\mu\mathrm{G}} \sim 0.5 \div 1 \left(\frac{n_0}{10^{-3}\,\mathrm{cm^{-3}}}\right)^{-1} \left(\frac{\Lambda_{0x}}{5\,\mathrm{kpc}}\right)^{-1} \left(\frac{L}{100\,\mathrm{kpc}}\right)^{-1}$$

- Large scale structure

$$\frac{\sqrt{\langle B_{ox}^2 \rangle}}{\mathrm{nG}} \sim 2 \left(\frac{n_0}{10^{-5}\,\mathrm{cm^{-3}}}\right)^{-1} \left(\frac{\Lambda_{0x}}{5\,\mathrm{Mpc}}\right)^{-1}$$

$\sigma_e \sim 0.7\,\mathrm{rad/m^2}$

- Radio emitting source (L size of the source)

$$\frac{\sqrt{\langle B_{ox}^2 \rangle}}{\mu\mathrm{G}} \sim 0.05 \div 0.1 \left(\frac{n_0}{10^{-3}\,\mathrm{cm^{-3}}}\right)^{-1} \left(\frac{\Lambda_{0x}}{5\,\mathrm{kpc}}\right)^{-1} \left(\frac{L}{100\,\mathrm{kpc}}\right)^{-1}$$

- Large scale structure

$$\frac{\sqrt{\langle B_{ox}^2 \rangle}}{\mathrm{nG}} \sim 0.2 \left(\frac{n_0}{10^{-5}\,\mathrm{cm^{-3}}}\right)^{-1} \left(\frac{\Lambda_{0x}}{5\,\mathrm{Mpc}}\right)^{-1}$$

Already with
~1000 LOS LOFAR (120-160 MHz)
~3500 LOS SKA MID Band 2 (950-1670 MHz) at least for σ_e~7rad/m^2

Vacca et al. (2016)

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$$\langle \phi^2_{e,i} \rangle = \sigma^2_{int,i} + \sigma^2_{env,i}$$

LLS

$$\sigma^2_{fil,i} + \sigma^2_{gc,i} + \sigma^2_{voids,i} + \sigma^2_{sheets,i}$$

Vacca et al. (2015, 2016)

DECOMPOSITION ALGORITHMS (3)

$$\phi \propto \int B_{los}\, n_e\, dl$$

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LLS

$$\sum_{j=1}^{N_{env}} l_{ij} \sigma^2_j$$

Vacca et al. (2015, 2016)

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INTRINSIC

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LLS

$$\sum_{j=1}^{N_{env}} l_{ij}\sigma^2_j$$

Vacca et al. (2015, 2016)

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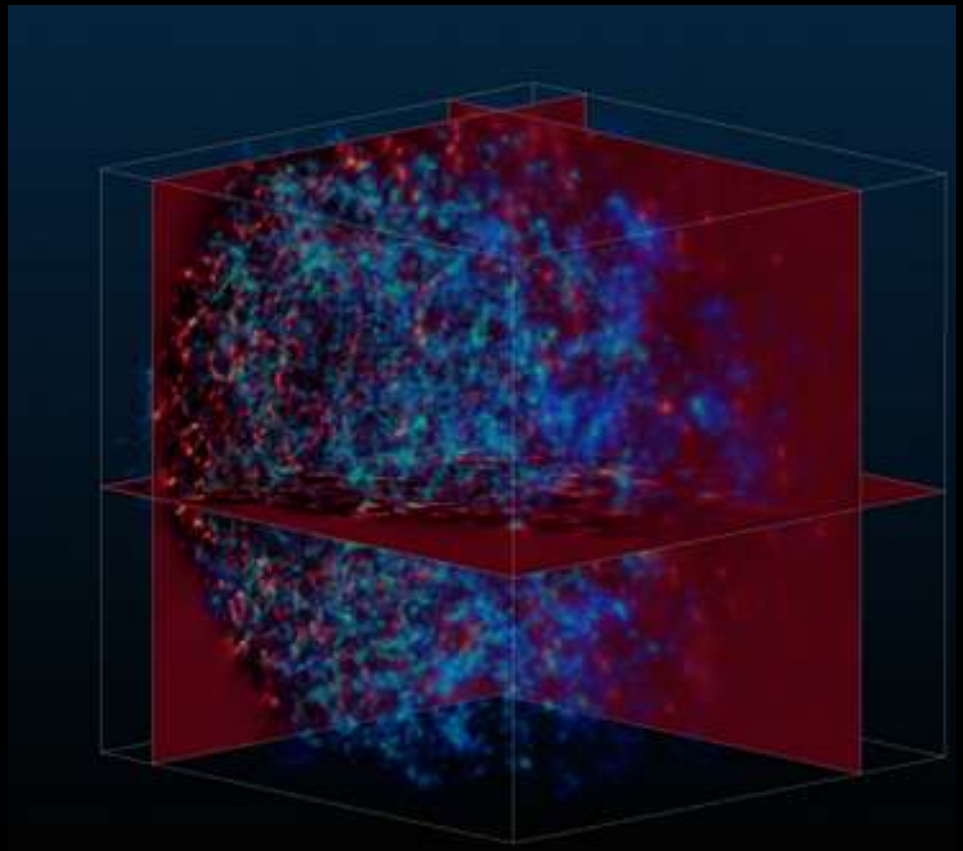
$$\left(\frac{L_i}{L_0}\right)^{\chi_{\mathrm{lum}}} \frac{\sigma^2_{\mathrm{int},0}}{(1+z_i)^4}$$

$$\sum_{j=1}^{N_{\mathrm{env}}} I_{ij} \sigma^2_j$$

Vacca et al. (2015, 2016)

COSMIC WEB STRUCTURE

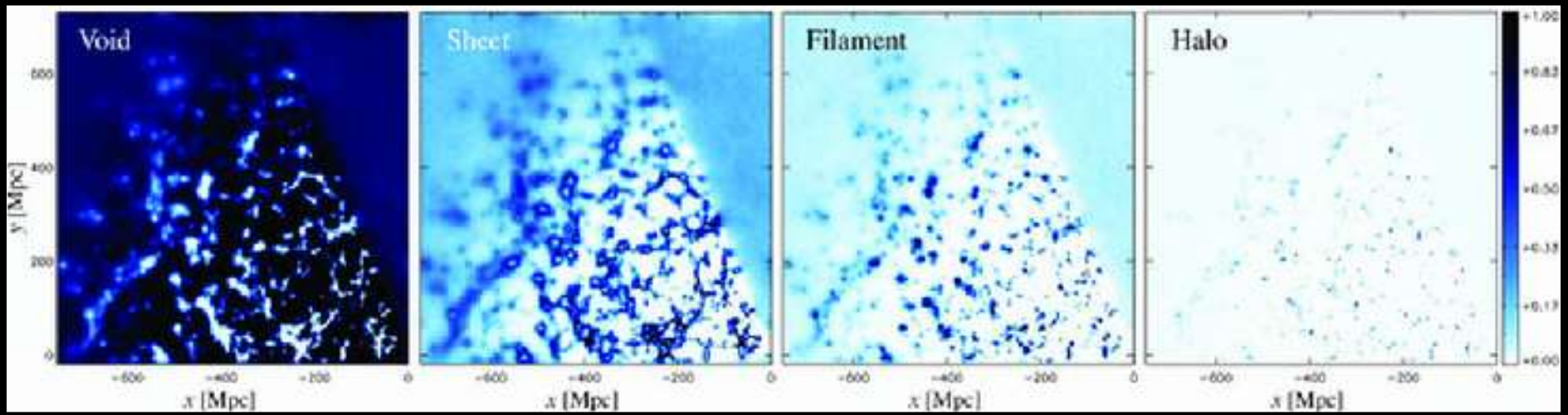


Jasche et al. (2010)

From SDSS galaxy counts

z<0.2

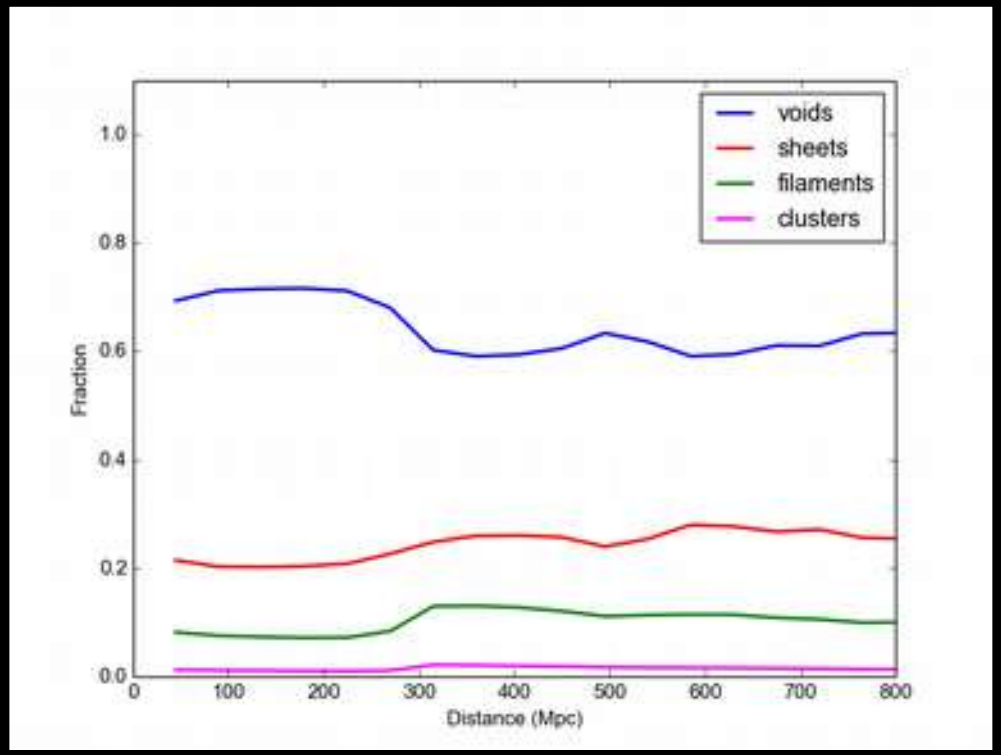
Curvature of the vector potential



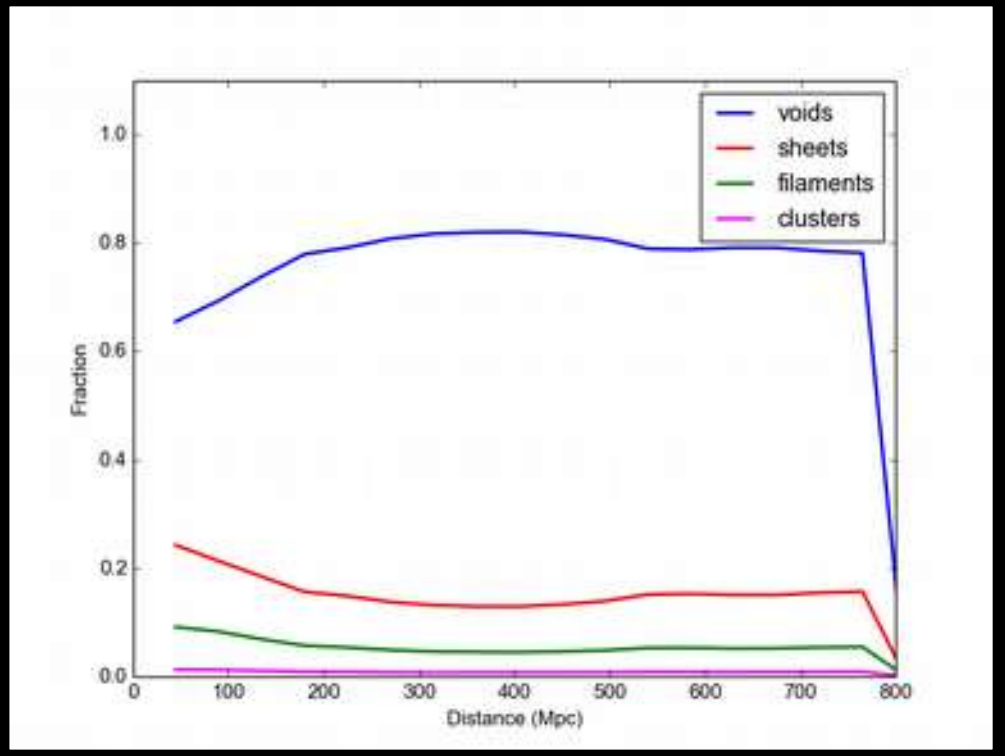
DECOMPOSITION ALGORITHMS (3)

Line of sight characterization

Composition towards a filament peak

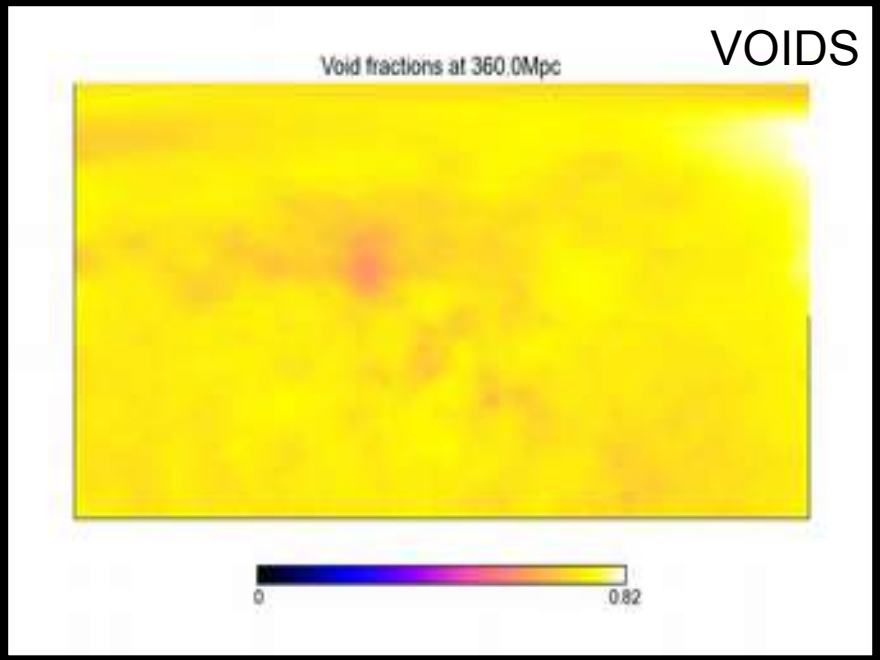


Composition towards a void peak

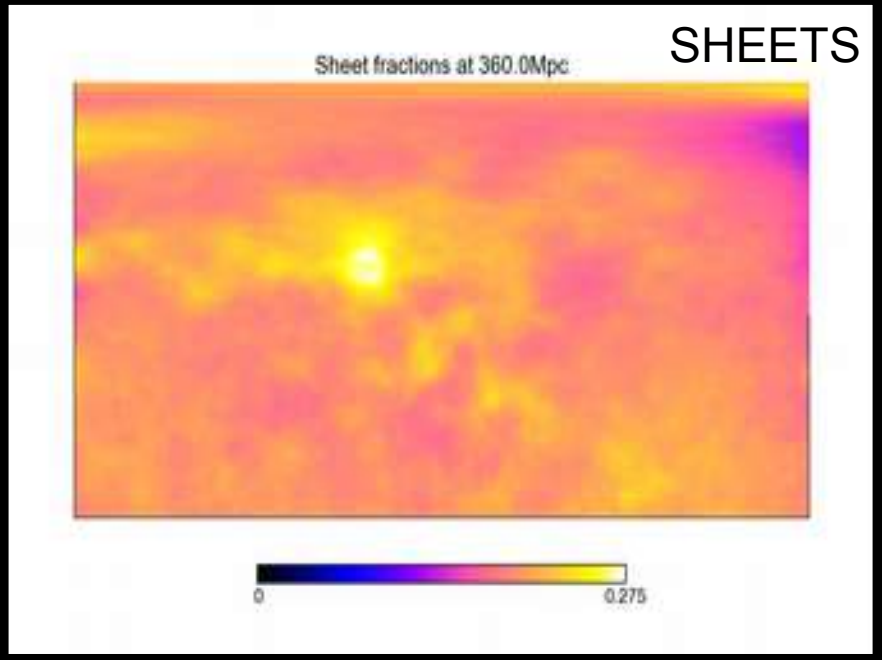


DECOMPOSITION ALGORITHMS (3)

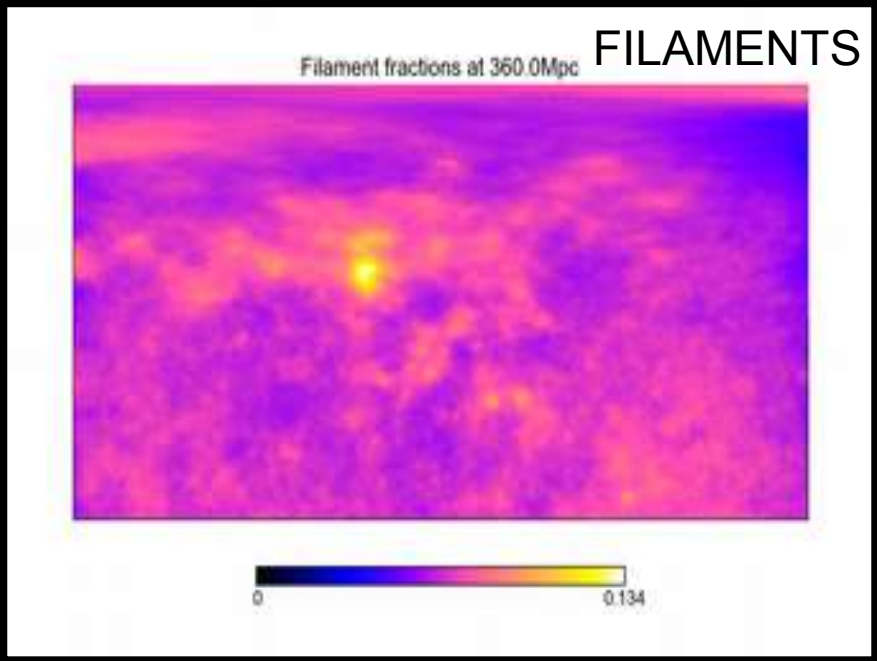
VOIDS



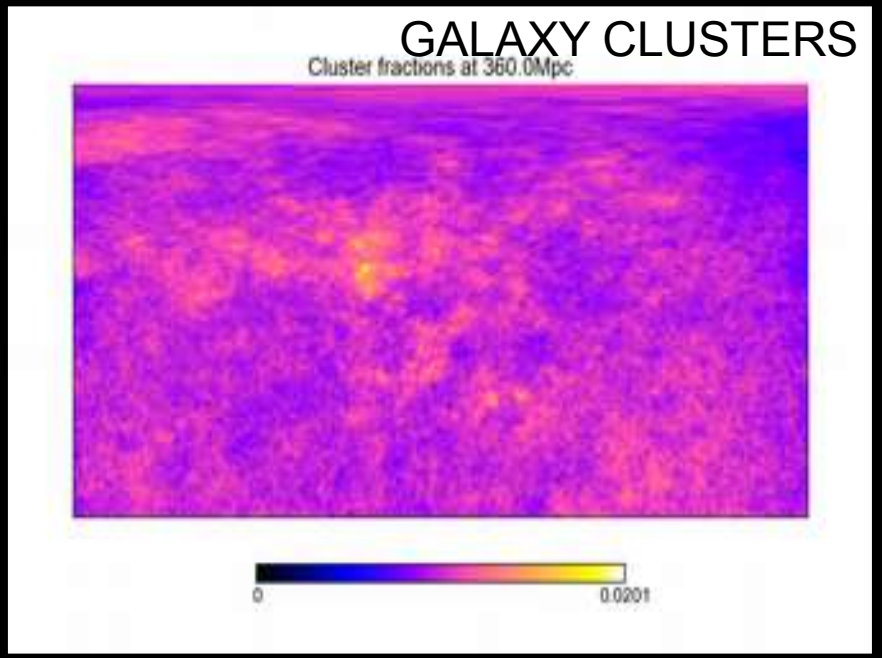
SHEETS



FILAMENTS



GALAXY CLUSTERS



DECOMPOSITION ALGORITHMS (3)

RM catalog: 37543 sources (Taylor et al. 2009)

RM versus redshift catalog: 4003 (Hammond et al. 2012)

DECOMPOSITION ALGORITHMS (3)

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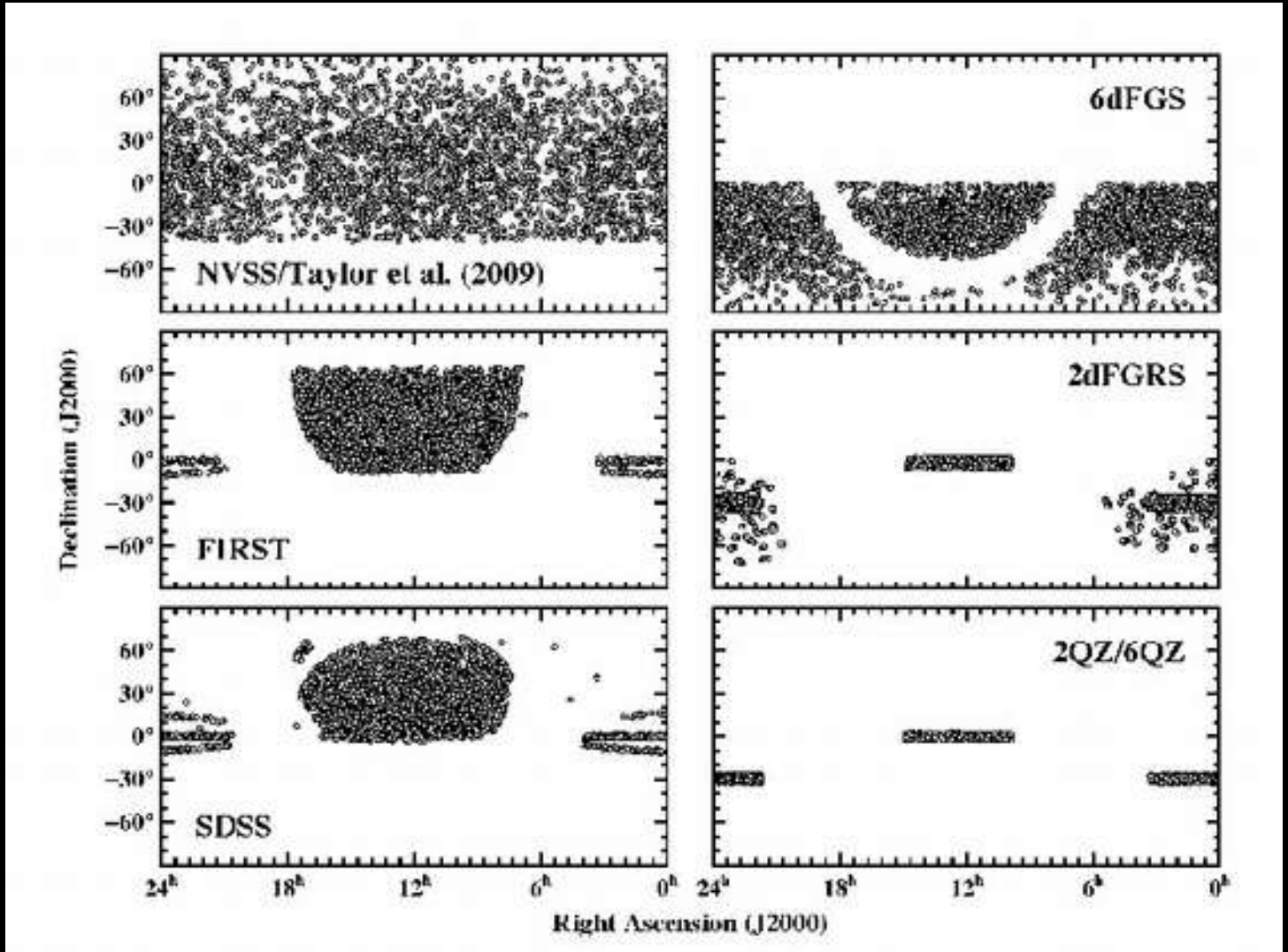


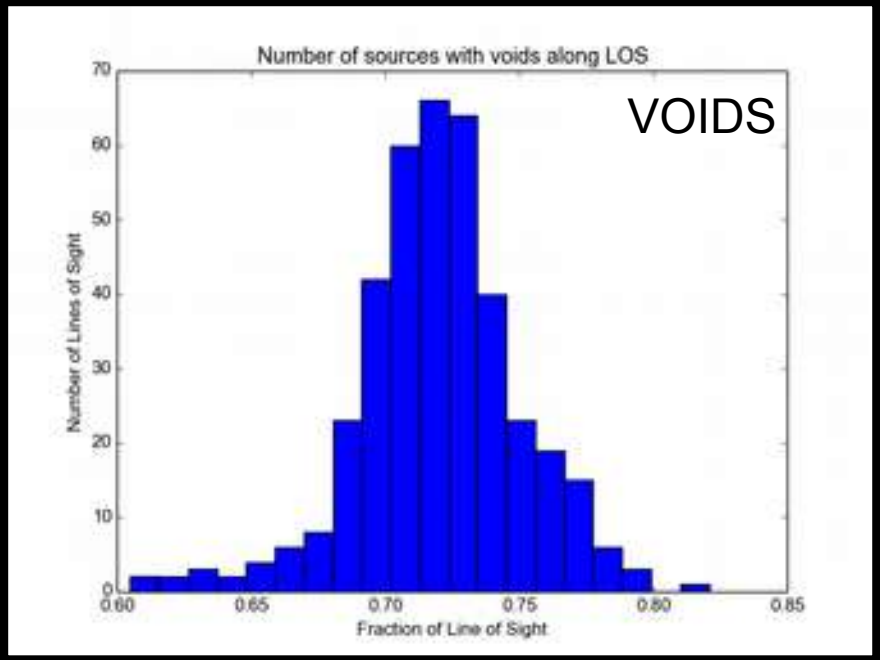
DECOMPOSITION ALGORITHMS (3)

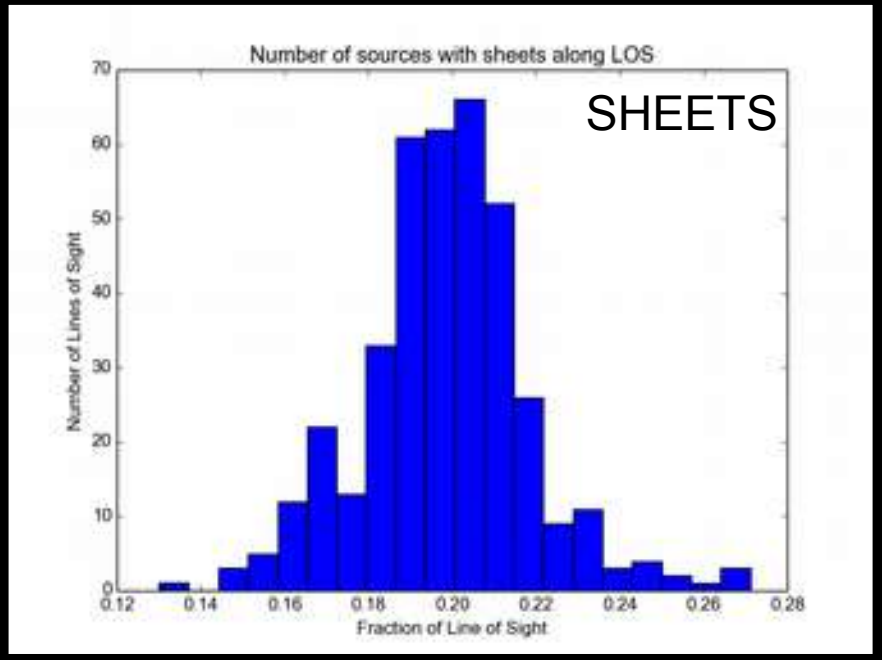
RM catalog: 37543 sources (Taylor et al. 2009)

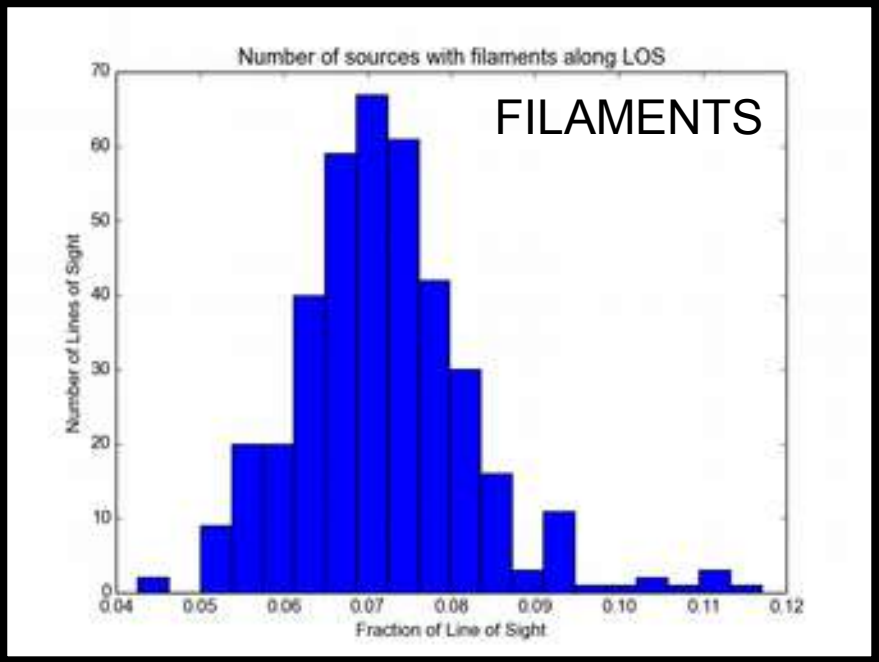
RM versus redshift catalog: 4003 (Hammond et al. 2012)

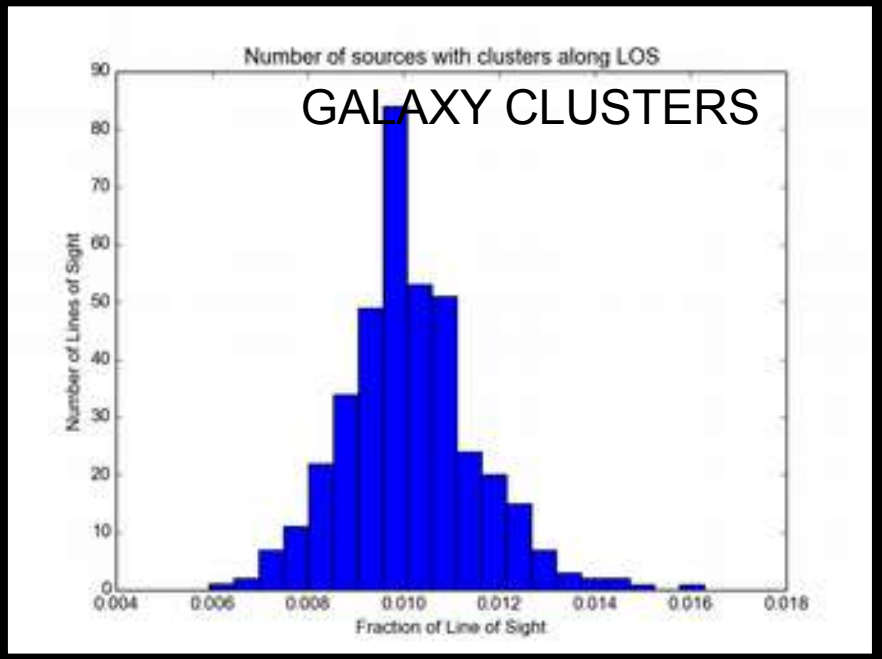
Cosmic web reconstruction (Jasche et al. 2010) for $z < 0.2$: 390 sources

DECOMPOSITION ALGORITHMS (3)









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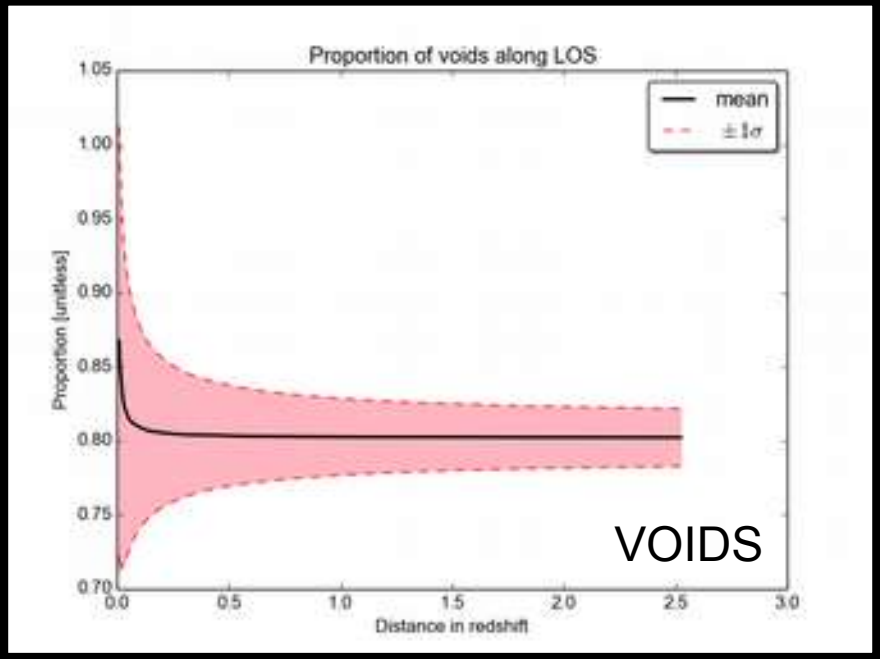

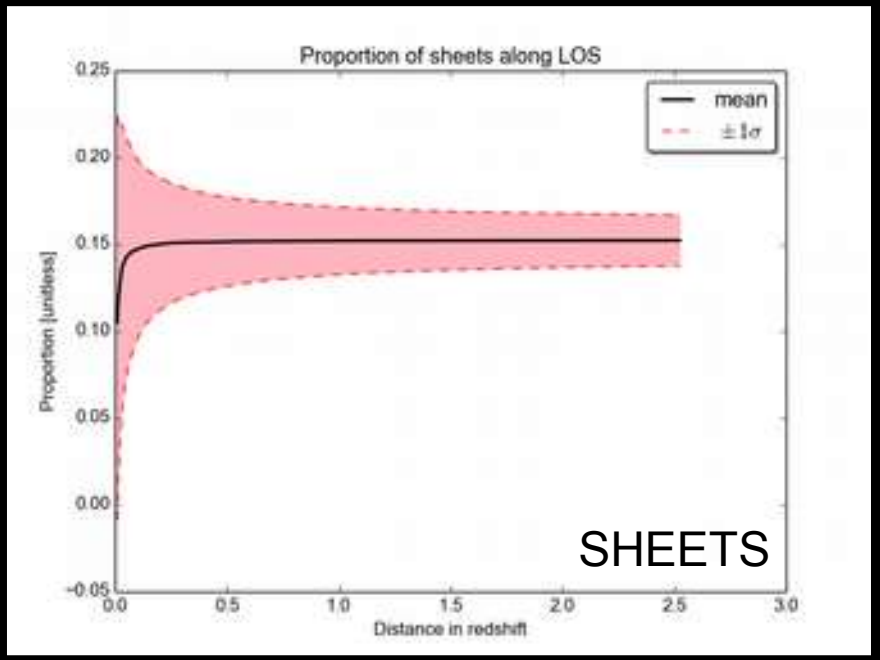

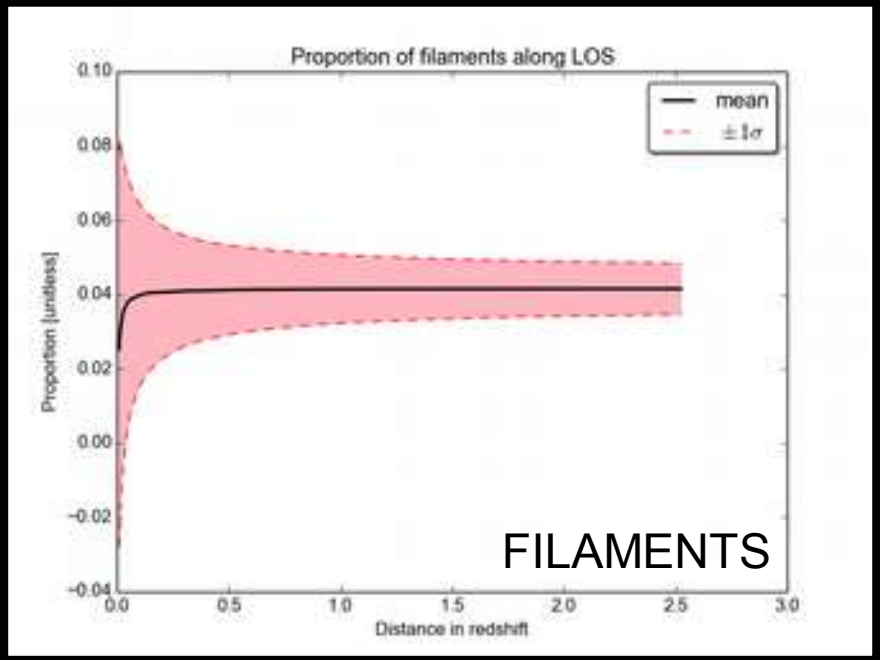

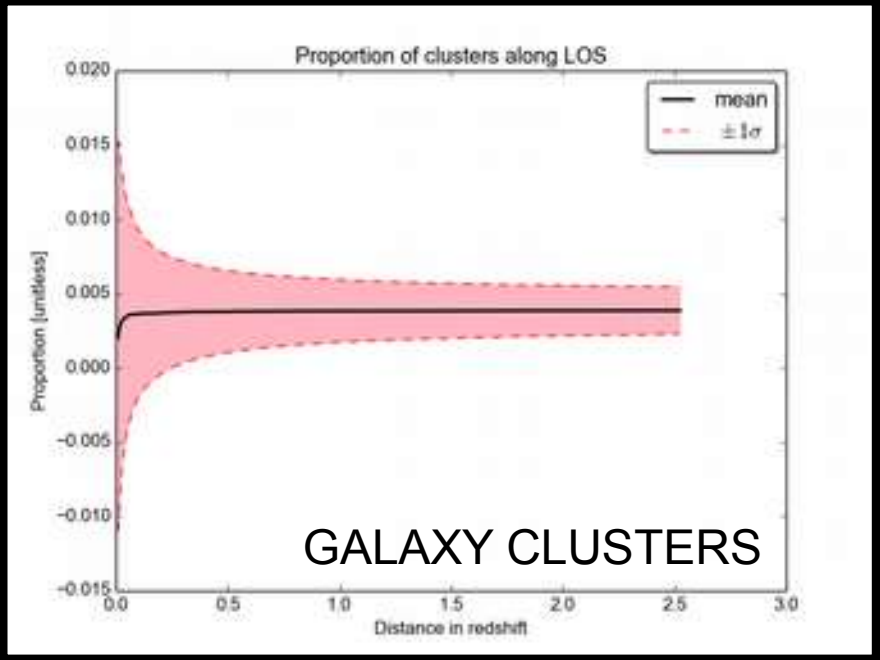

SUMMARY

The new generation of radio interferometers will produce large and reliable Faraday depth catalogs.

Advanced statistical approaches are necessary to uncover the weak contribution from the large scale structure.

Knowledge of redshift and of the cosmic web is crucial to disentangle the contributions due to different environments.

Sources in the local Universe are particularly suitable to this aim.

THANK YOU!!!