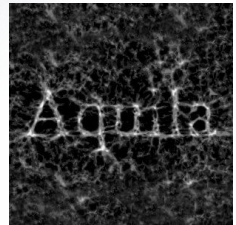


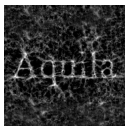
IMPERIAL

Advancements in large-scale structure reconstructions in light of cosmological tensions

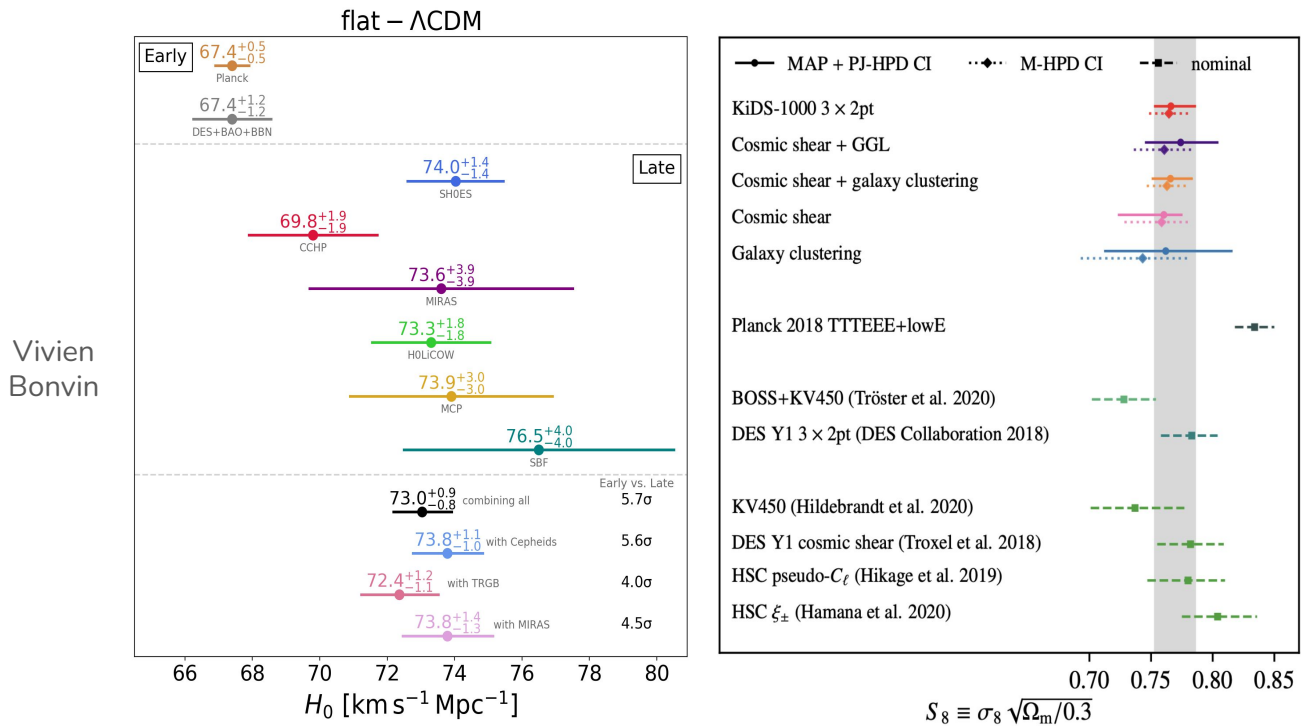
Eleni Tsaprazi
Imperial College London

Standard cosmology at the threshold of change?, Thessaloniki, July 2024





Persisting tensions in Λ CDM

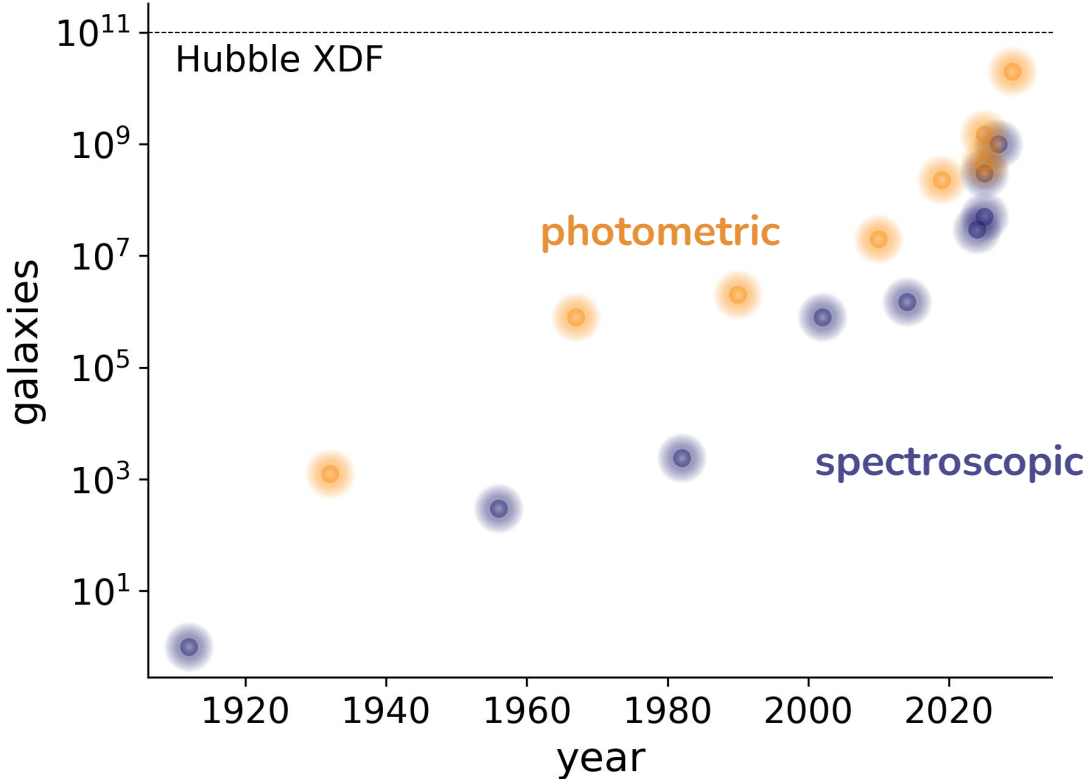


Vivien Bonvin

Eleonora Di Valentino

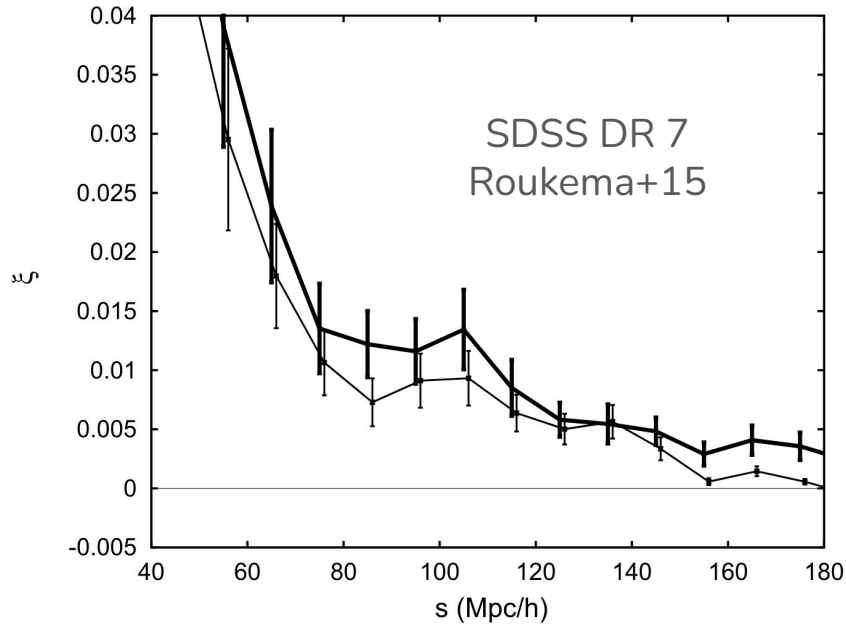


Reaching an observational limit: how to optimally extract information?

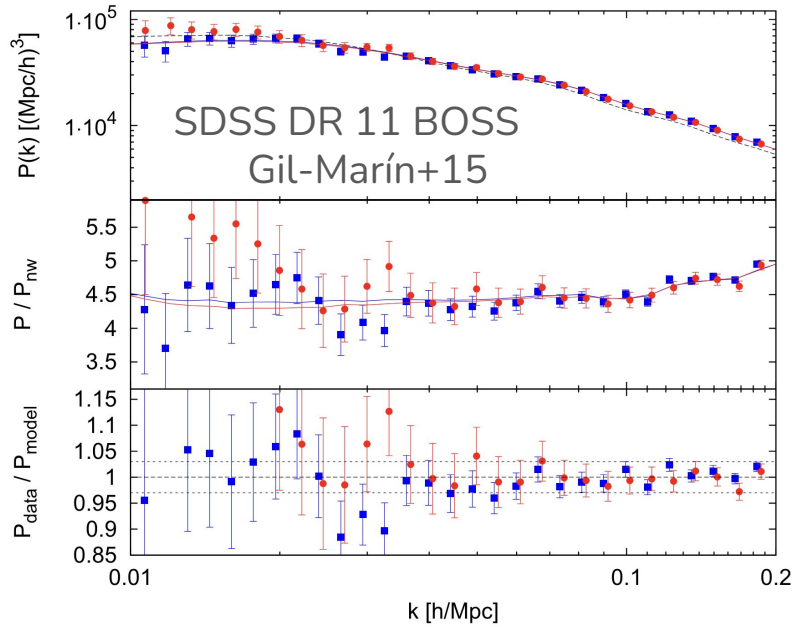




2-point statistics of galaxy clustering

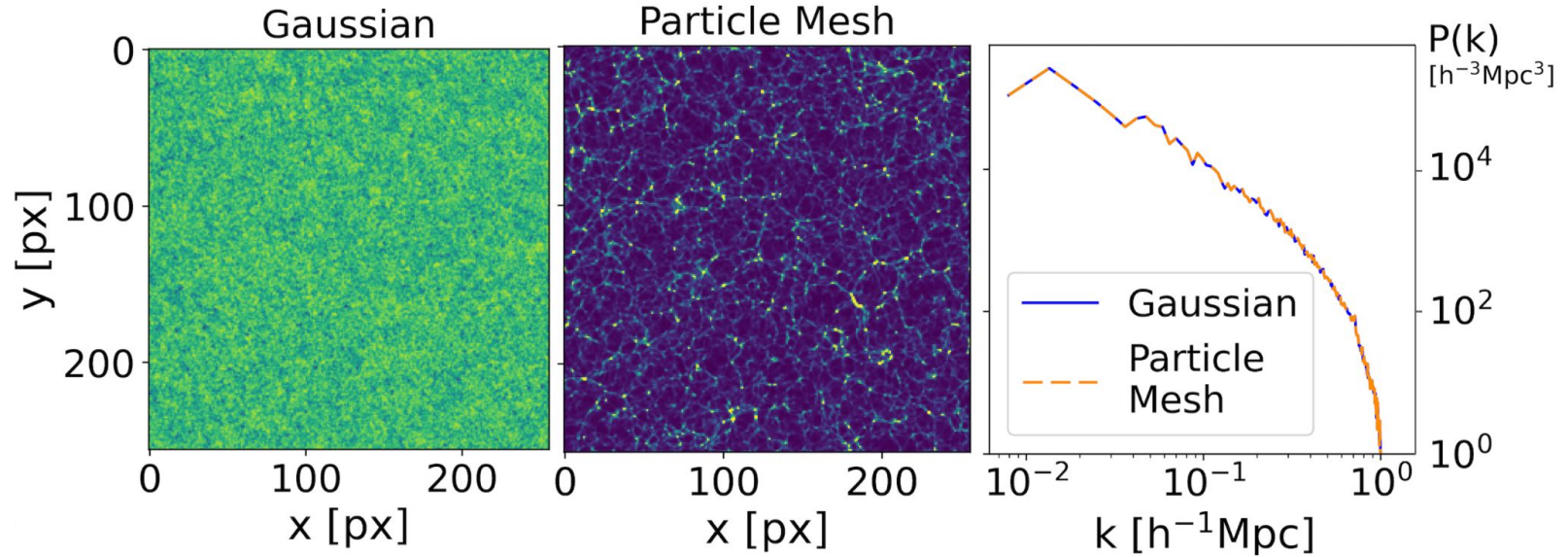


excess probability of observation



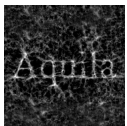
$P(k) \propto k^3$

Beyond 2-point statistics

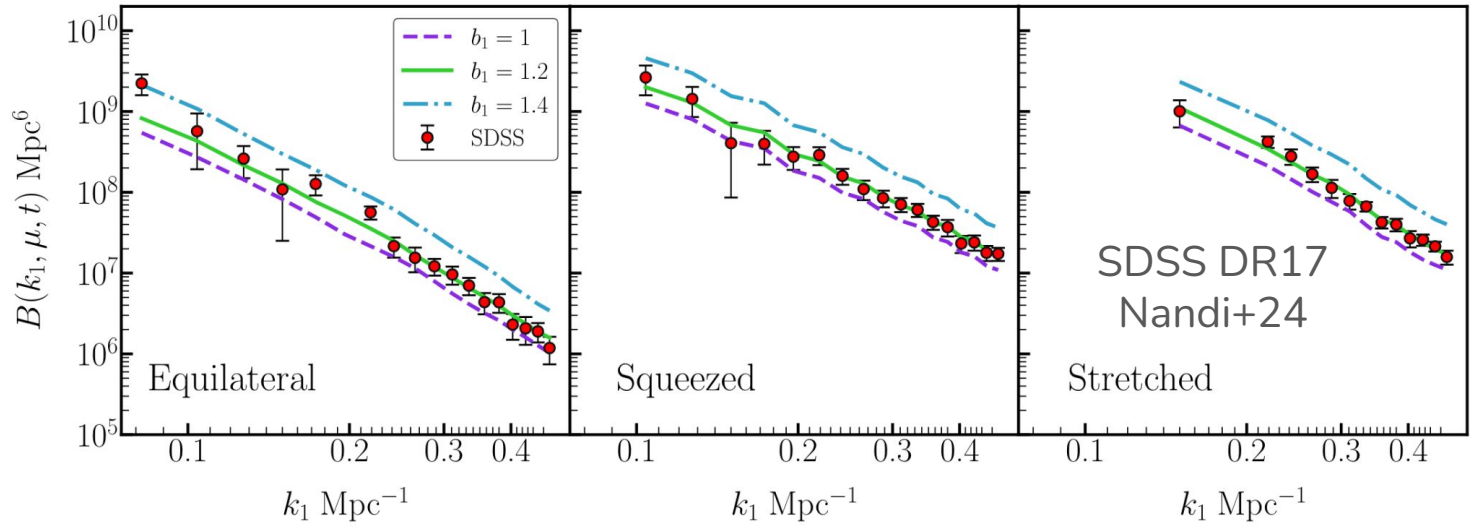


Tsaprazi 23

How can we go beyond?



Higher-order / non-Gaussian statistics

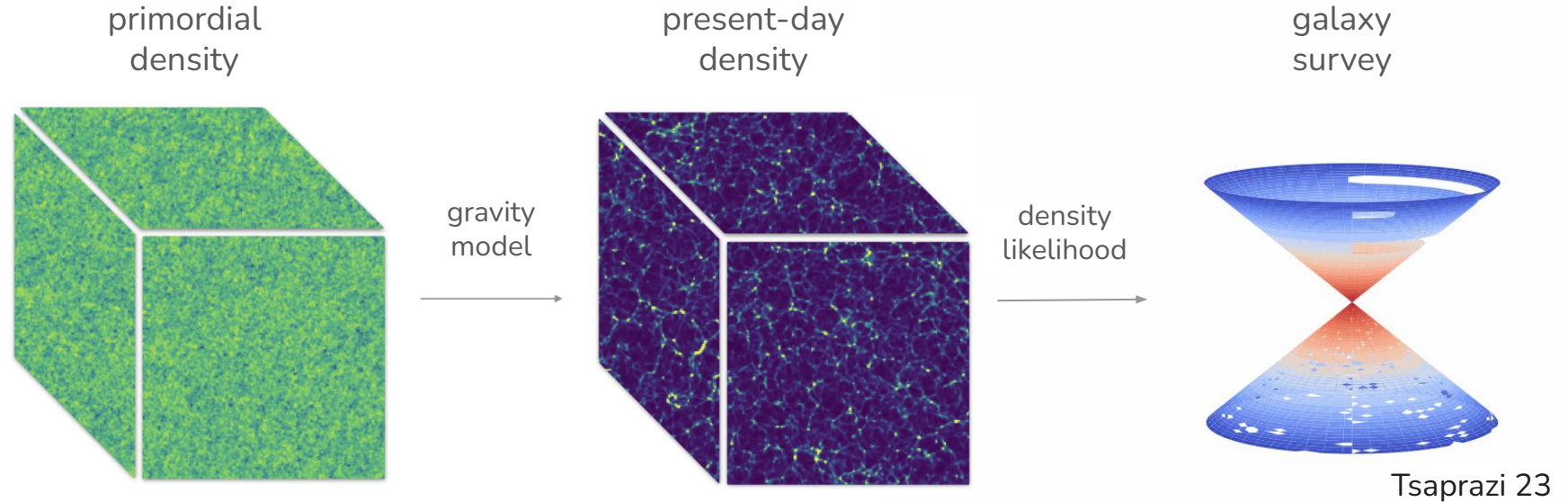


- wavelet-based peak statistics
- Minkowski functionals
- Betti numbers
-
-
-

SDSS DR17
Nandi+24

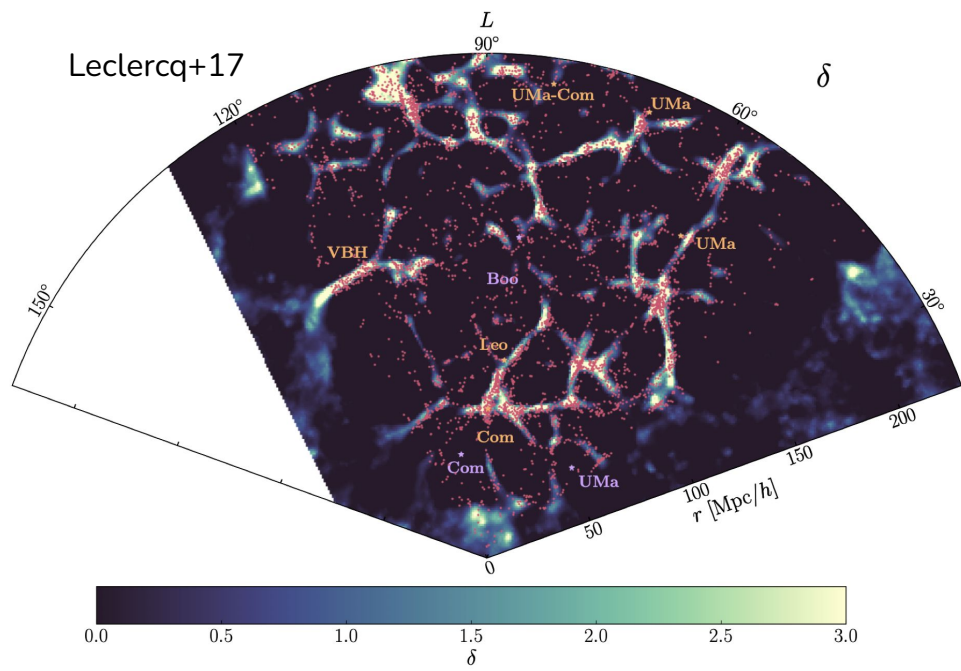
How can we extract information of the full field?

Extracting the full-field statistics with BORG

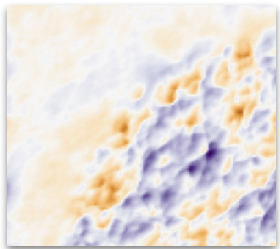


3D large-scale structure constrained with galaxy clustering accounting for survey geometry

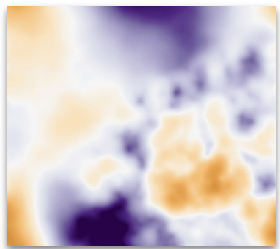
BORG has been successfully applied to real data



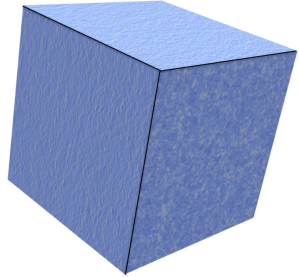
peculiar velocities



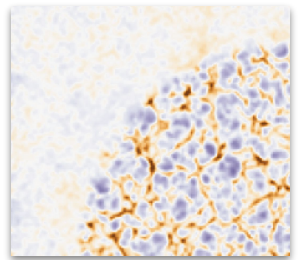
gravitational potential



tidal shear

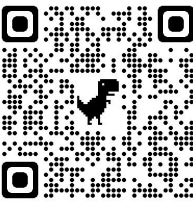


divergence



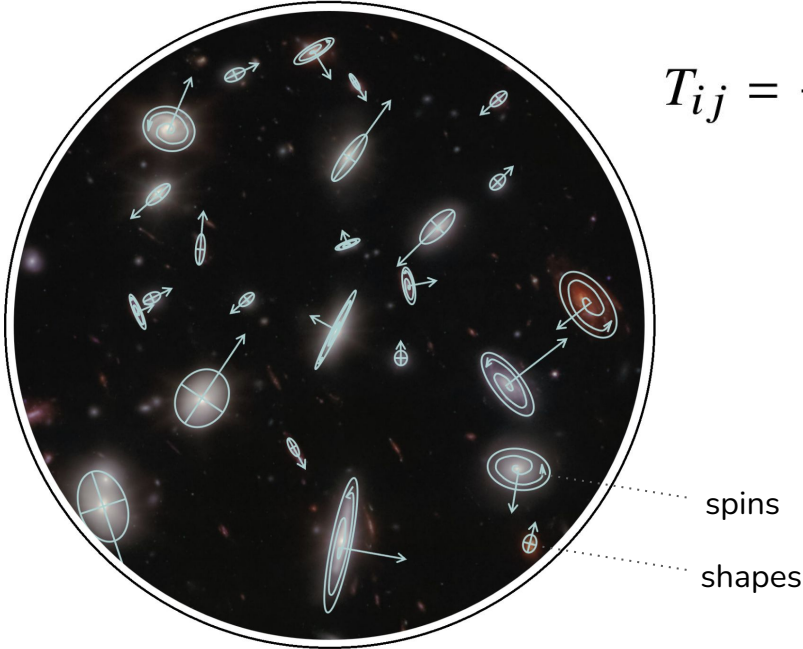
Tsaprazi+23

How can we prepare for next-generation data?
Full inference and / or cross-correlations



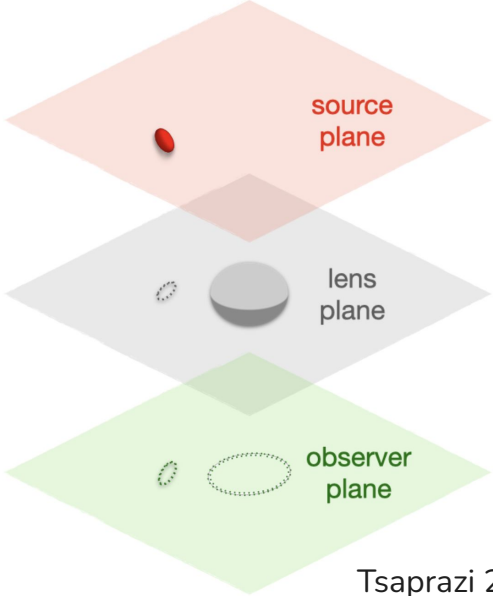
Tsaprazi+22

Field-level inference of galaxy intrinsic alignment



Lamman, Tsaprazi, Shi + 24

$$T_{ij} = \frac{\partial^2 \Phi}{\partial x_i \partial x_j}$$



Tsaprazi 23

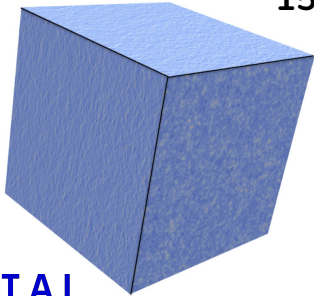
So far constrained at 2- / 3- point statistics

Field-level inference of galaxy intrinsic alignment

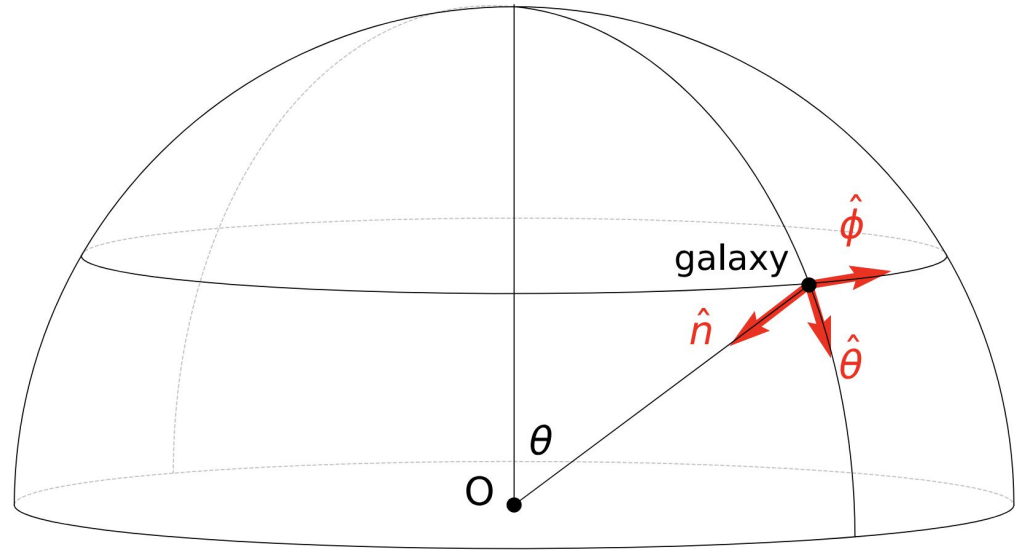
70,000 SDSS-III BOSS LRGs



3D tidal fields from SDSS-III BOSS
15.6 Mpc/h



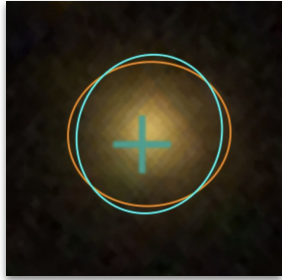
North Celestial Pole



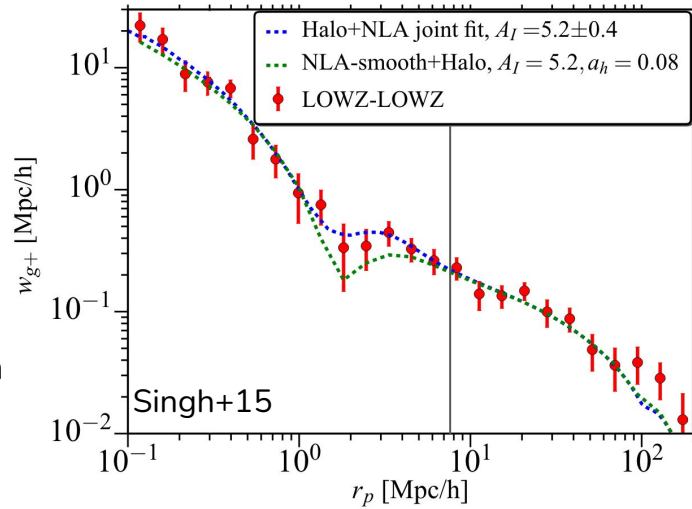
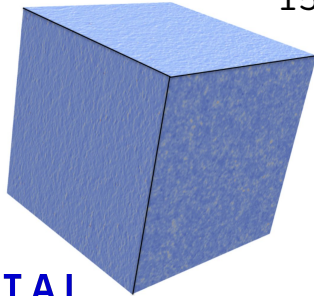
Tsaprazi 23

The non-linear alignment model

70,000 SDSS-III BOSS LRGs



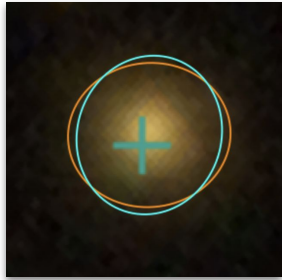
3D tidal fields from SDSS-III BOSS
15.6 Mpc/h



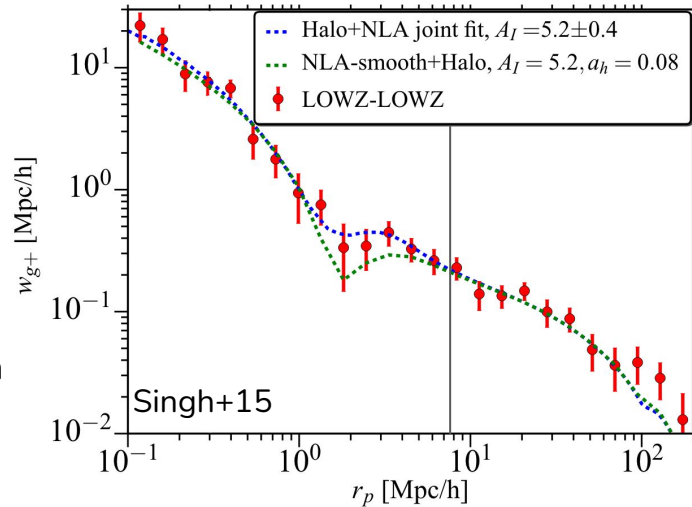
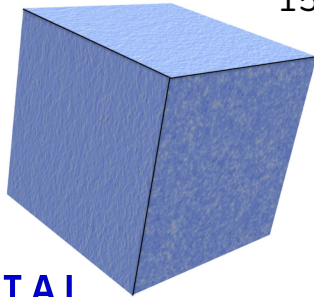
$$e_1^I \pm \iota e_2^I = -\frac{C}{4\pi G} T_{\pm}$$

The non-linear alignment likelihood

70,000 SDSS-III BOSS LRGs



3D tidal fields from SDSS-III BOSS
15.6 Mpc/h

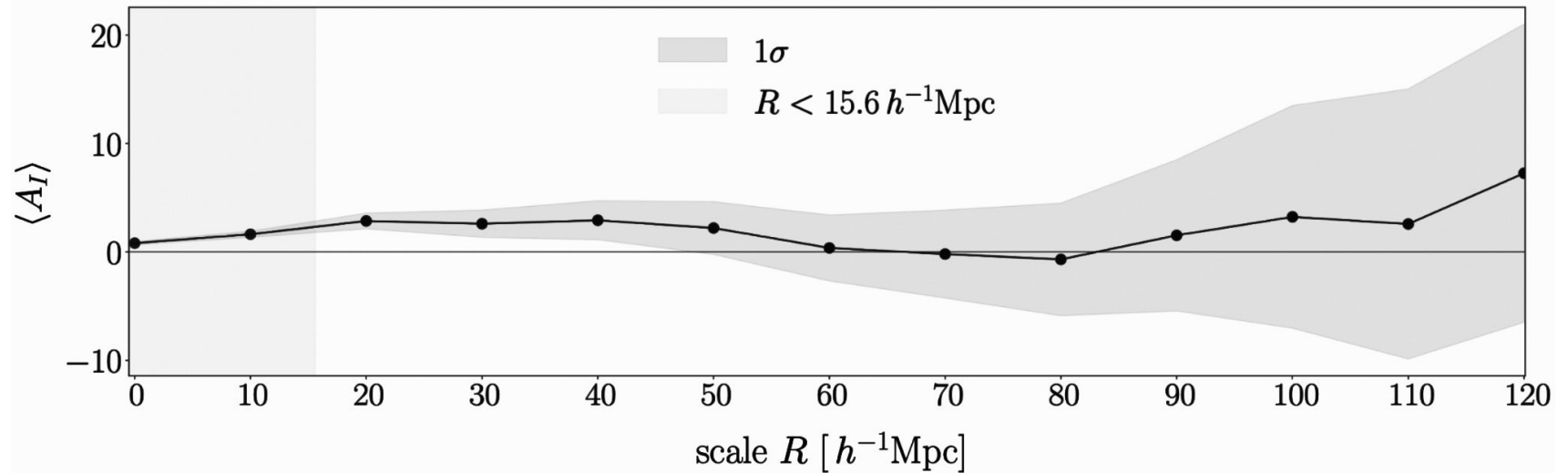


$$e_1^I \pm \iota e_2^I = -\frac{C}{4\pi G} T_{\pm}$$

$$P(e|C, T_s, \sigma^2) = \prod_{g=1}^{2N_g} \frac{1}{\sqrt{2\pi\sigma^2}} \exp \left[-\frac{(e_g - CT_{g,s})^2}{2\sigma^2} \right]$$



4 σ detection at 20 Mpc/h



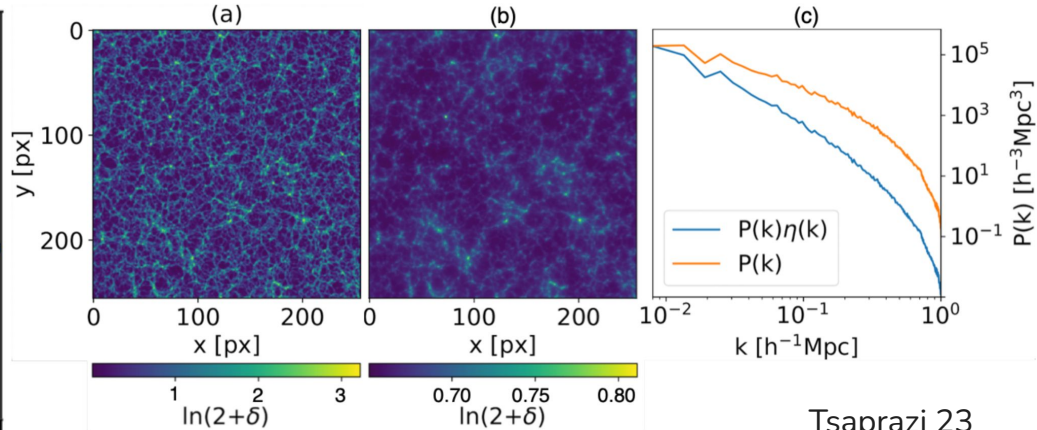
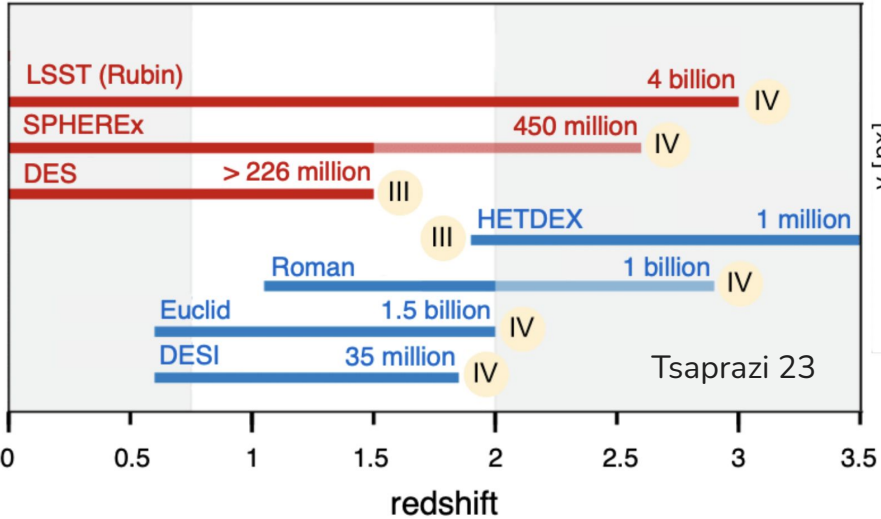
Constant with luminosity, color and redshift

2pt: 9 σ at 6 Mpc/h, smaller scales — higher redshifts: need photometry



Tsaprazi+23

Field-level inference from spectroscopic and photometric redshifts

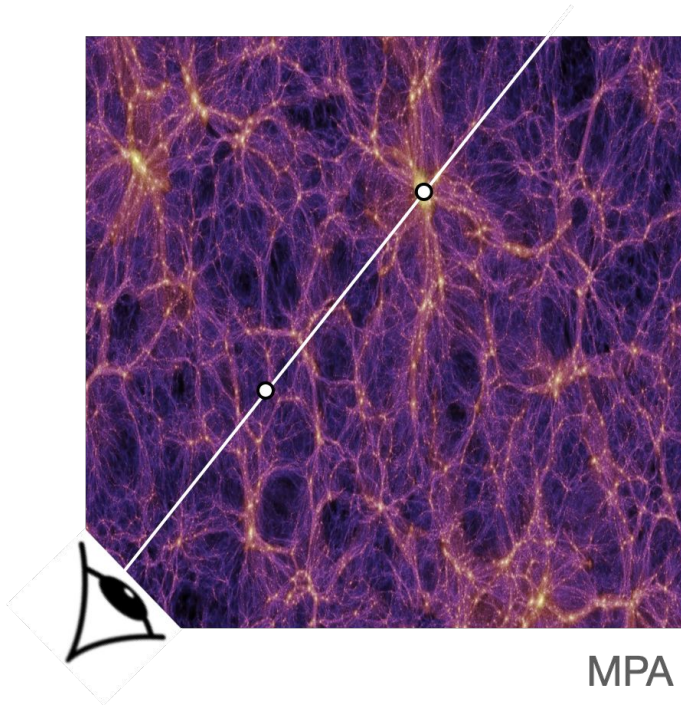


Tsaprazi 23

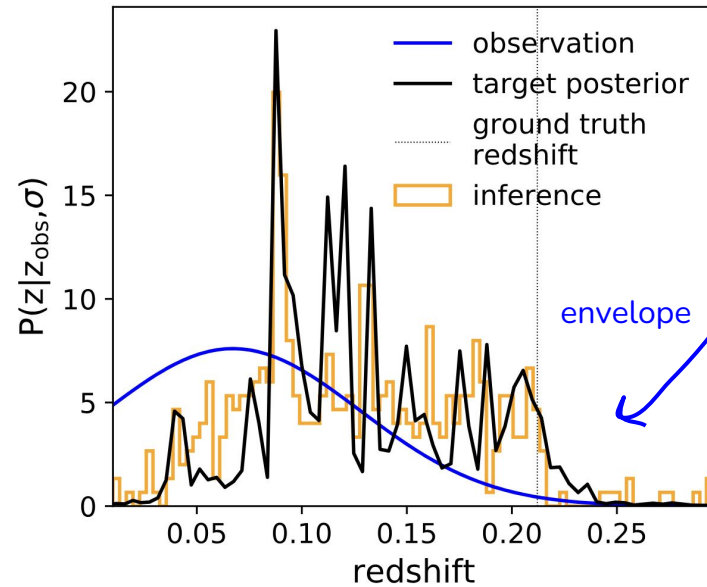
- Depth / magnitude vs accuracy
- Photo-z uncertainties can bias cosmological analyses

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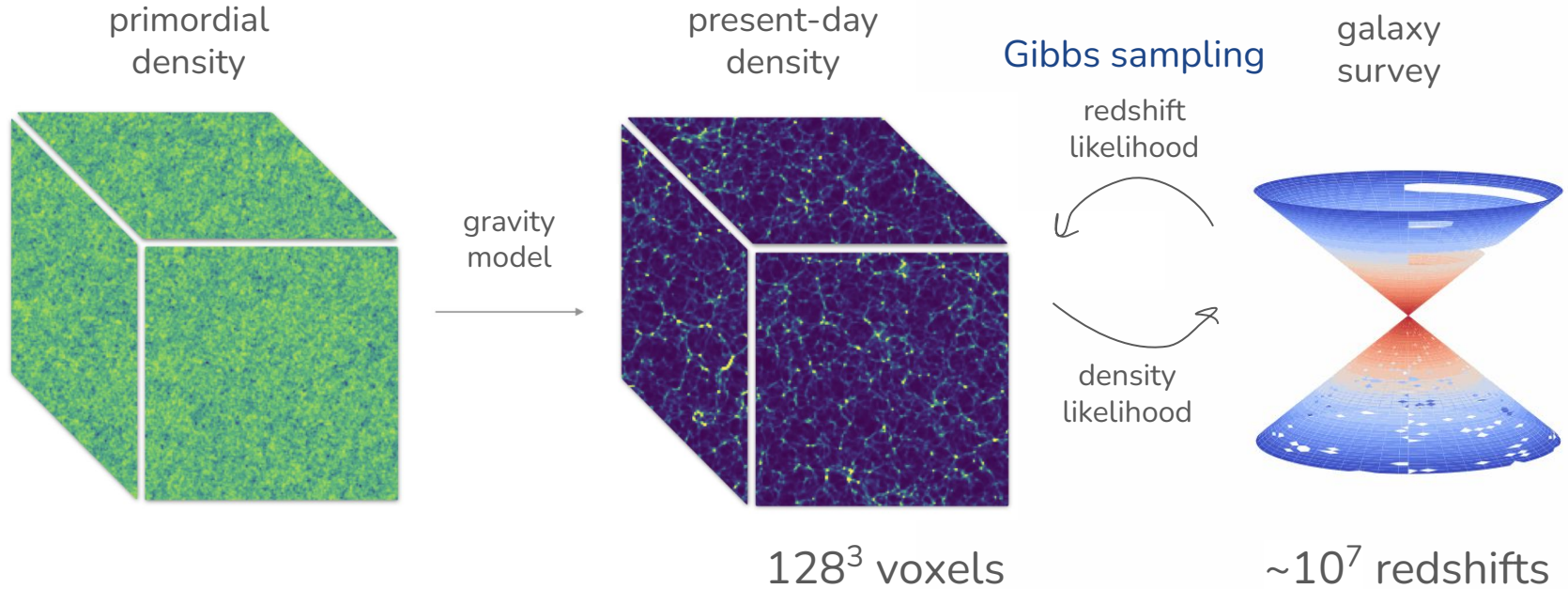
3D dark matter density can constrain galaxy locations



$$\mathcal{P}(z_i | z_{\text{obs}i}, \delta) \propto \mathcal{P}(\delta | z_i) \mathcal{P}(z_i | z_{\text{obs}i})$$

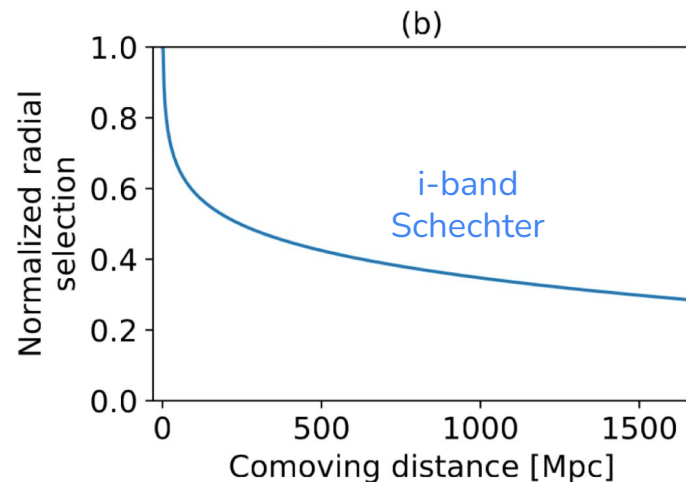
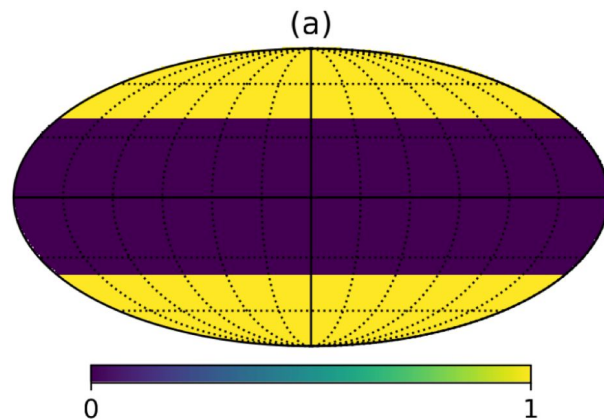
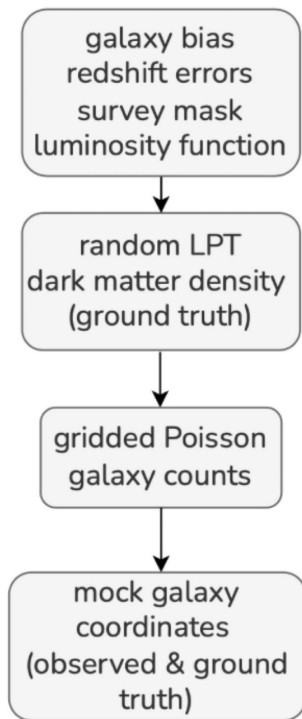


Constraining galaxy locations with clustering



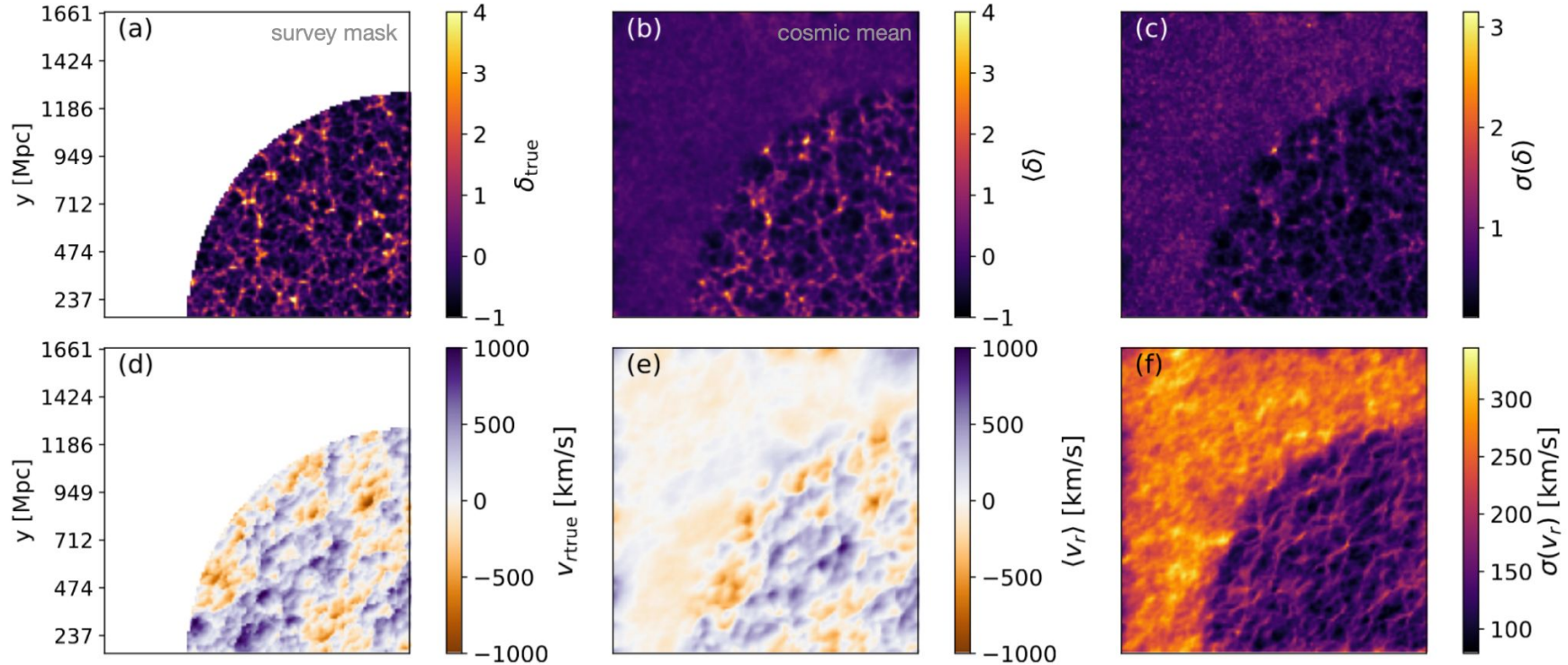


Validation on self-consistent mock data

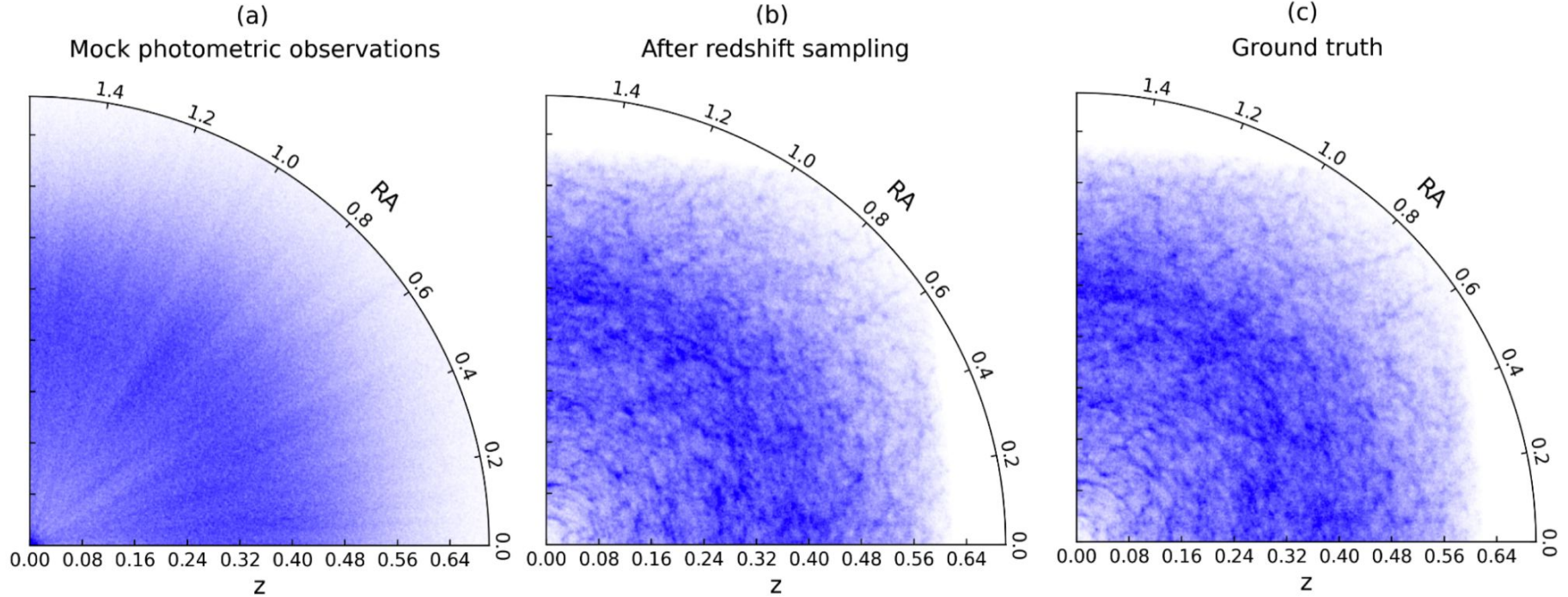


- Worst-case redshift uncertainties for upcoming surveys (300 Mpc)
- $2e7$ photometric and 1% spectroscopic redshifts
- Power-law galaxy bias (linear), resolution 13 Mpc
- $z = 0.7$

Constrained dark matter density and peculiar velocity

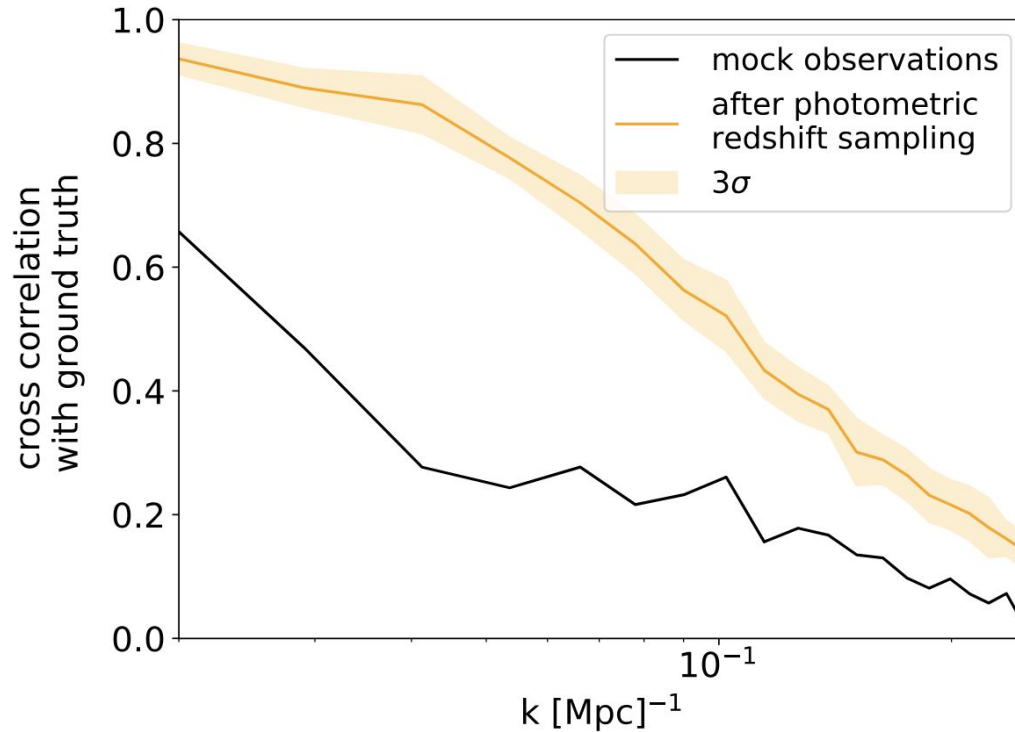


Filamentary structure thanks to the gravity model

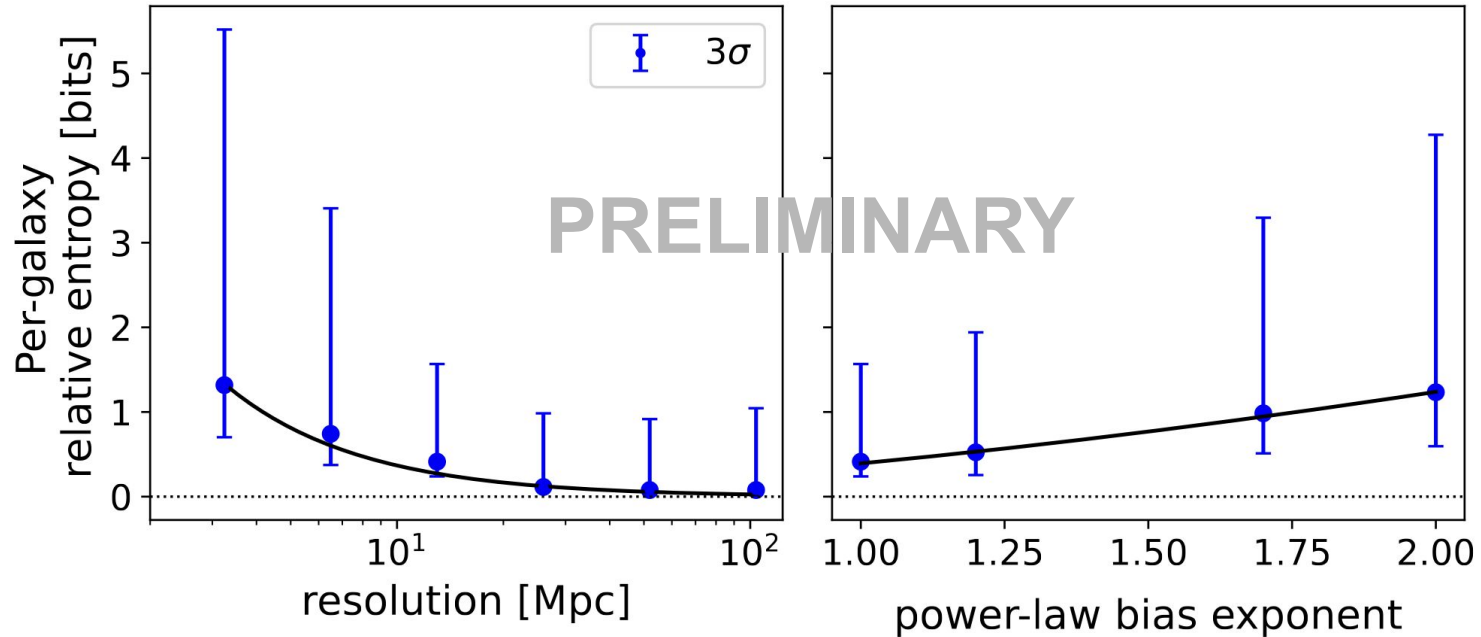




Increase in the galaxy count cross-correlation



Information gain vs resolution / galaxy bias

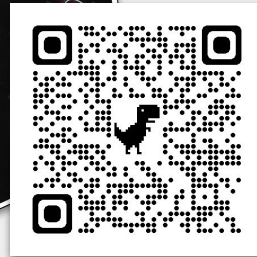


Summary

- Existing 2-point estimators miss information
- Need all high-order statistics
- Galaxy intrinsic alignment
- Photometric galaxy clustering



Lamman+24



Outlook

- We're reaching the limit of observable galaxies
- Focus on
 - fully exploiting information in the data
 - self-consistently propagating uncertainties
 - demonstrating the power of high-order statistics