Università degli Studi di Milano

VIPERS: Unbiased Growth Rate Estimate at z=0.85 in VIPERS-PDR2 Galaxy Sample

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erc DARK LIGHT

Osservatorio Astronomico di Brera

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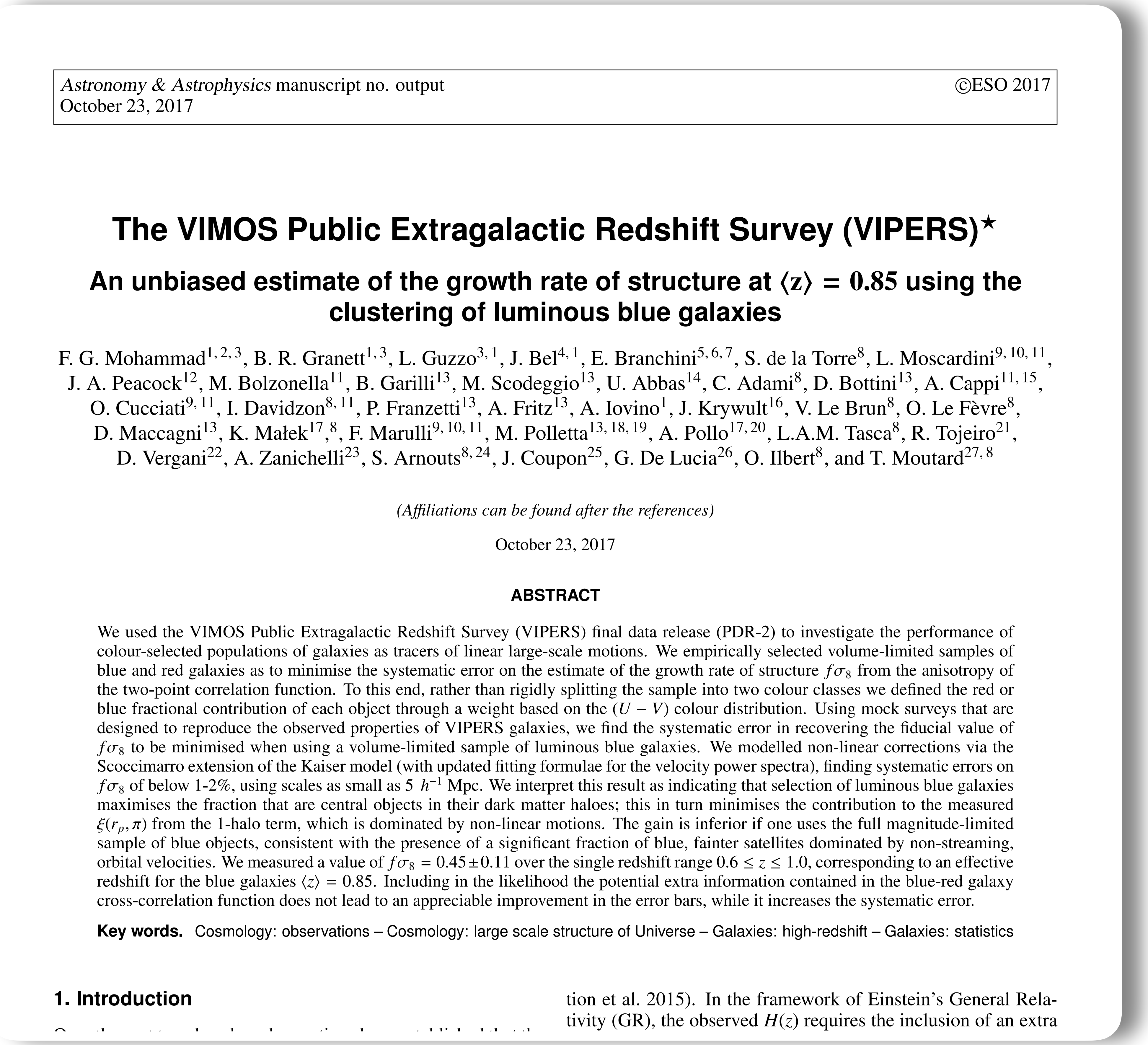
UNBIASED GROWTH RATE ESTIMATES USING LUMINOUS BLUE GALAXIES



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October 23, 2017

The VIMOS Public Extragalactic Redshift Survey (VIPERS)⋆

An unbiased estimate of the growth rate of structure at $\langle z \rangle = 0.85$ using the clustering of luminous blue galaxies

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(Affiliations can be found after the references)

October 23, 2017

ABSTRACT

We used the VIMOS Public Extragalactic Redshift Survey (VIPERS) final data release (PDR-2) to investigate the performance of colour-selected populations of galaxies as tracers of linear large-scale motions. We empirically selected volume-limited samples of blue and red galaxies as to minimise the systematic error on the estimate of the growth rate of structure $f\sigma_8$ from the anisotropy of the two-point correlation function. To this end, rather than rigidly splitting the sample into two colour classes we defined the red or blue fractional contribution of each object through a weight based on the $(U - V)$ colour distribution. Using mock surveys that are designed to reproduce the observed properties of VIPERS galaxies, we find the systematic error in recovering the fiducial value of $f\sigma_8$ to be minimised when using a volume-limited sample of luminous blue galaxies. We modelled non-linear corrections via the Scoccimarro extension of the Kaiser model (with updated fitting formulae for the velocity power spectra), finding systematic errors on $f\sigma_8$ of below 1-2%, using scales as small as 5 h^{-1} Mpc. We interpret this result as indicating that selection of luminous blue galaxies maximises the fraction that are central objects in their dark matter haloes; this in turn minimises the contribution to the measured $\xi(r_p, \pi)$ from the 1-halo term, which is dominated by non-linear motions. The gain is inferior if one uses the full magnitude-limited sample of blue objects, consistent with the presence of a significant fraction of blue, fainter satellites dominated by non-streaming, orbital velocities. We measured a value of $f\sigma_8 = 0.45 \pm 0.11$ over the single redshift range $0.6 \leq z \leq 1.0$, corresponding to an effective redshift for the blue galaxies $\langle z \rangle = 0.85$. Including in the likelihood the potential extra information contained in the blue-red galaxy cross-correlation function does not lead to an appreciable improvement in the error bars, while it increases the systematic error.

Key words. Cosmology: observations – Cosmology: large scale structure of Universe – Galaxies: high-redshift – Galaxies: statistics

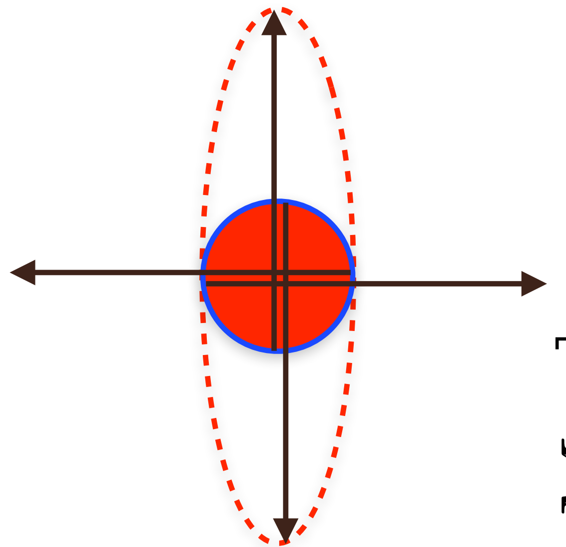
1. Introduction

tion et al. 2015). In the framework of Einstein's General Relativity (GR), the observed $H(z)$ requires the inclusion of an extra

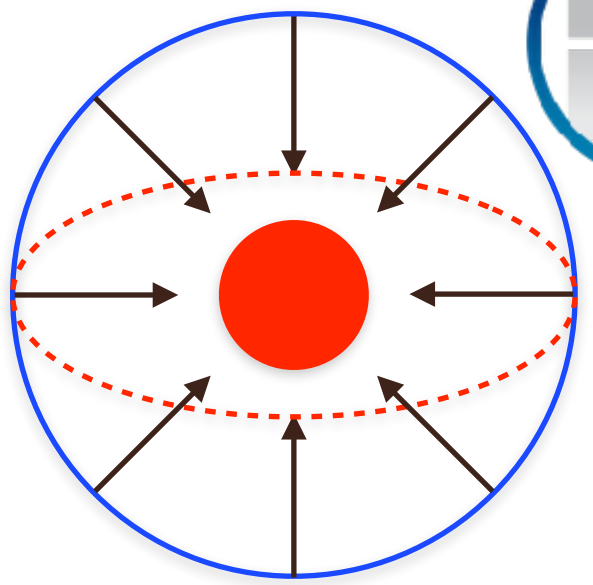
Mohammad et al 2017
(A&A 610.A59, arXiv 1708.00026)

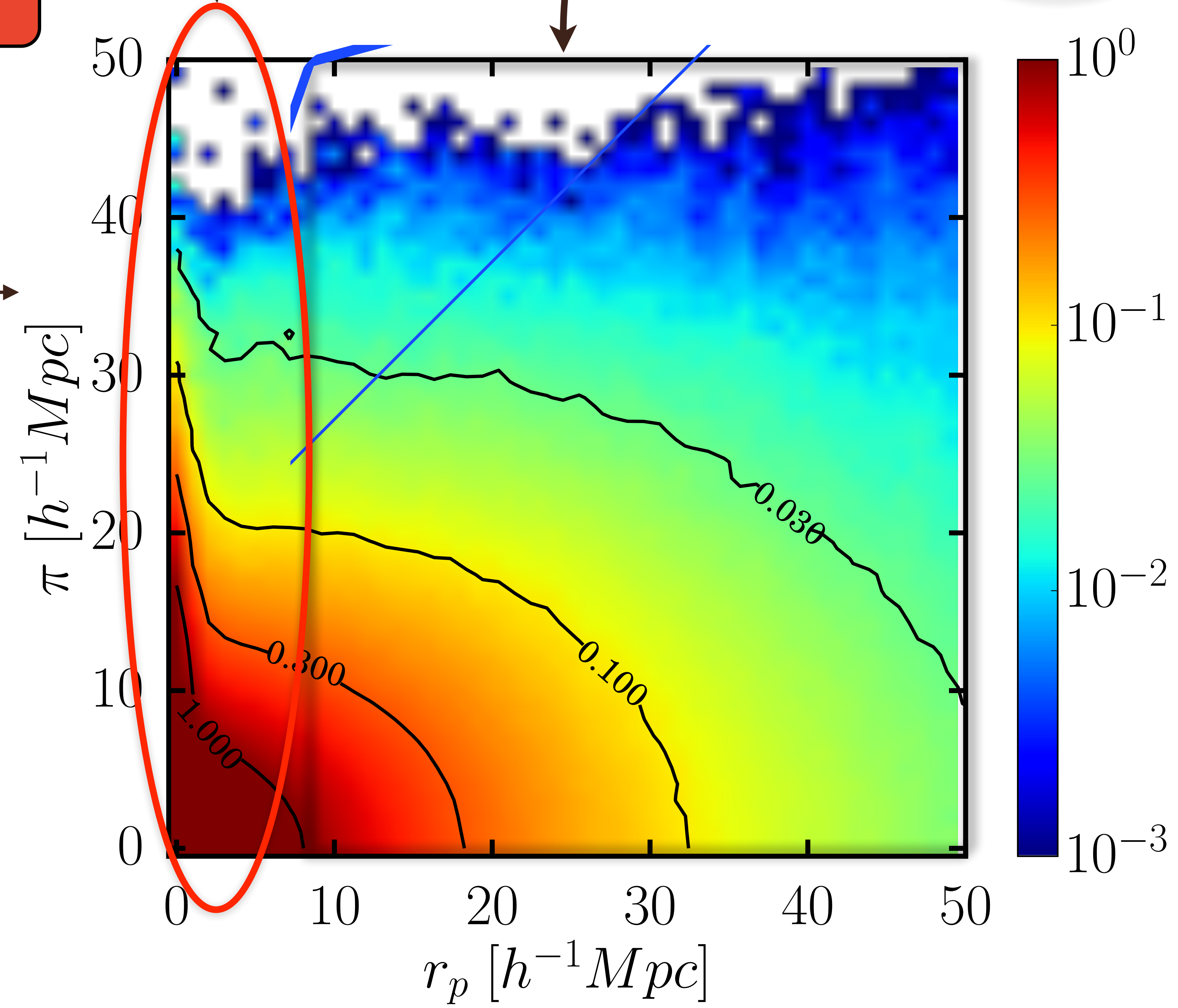
RSD: CHALLENGES AND POSSIBLE SOLUTIONS

Virialized motions



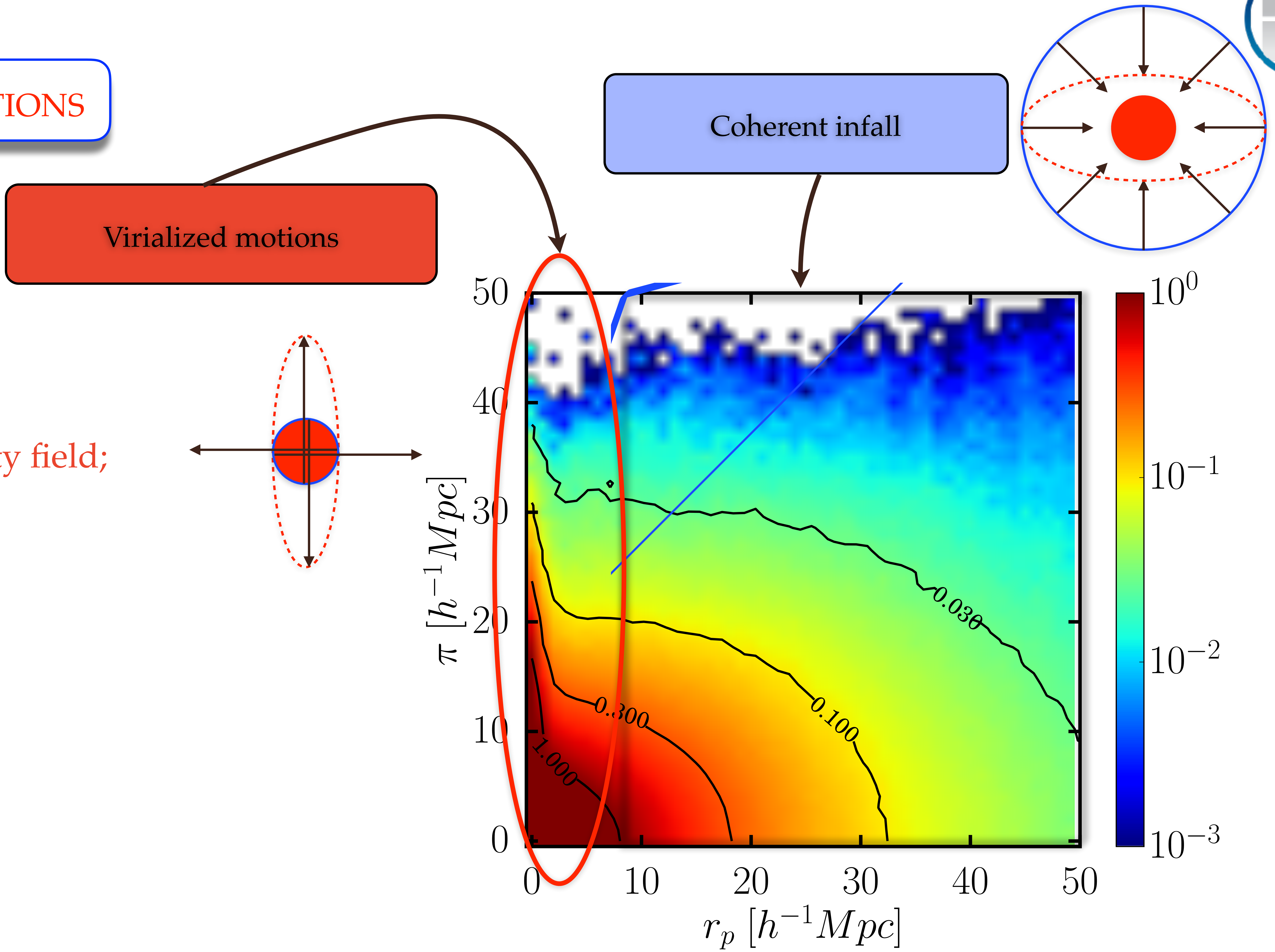
Coherent infall





RSD: CHALLENGES AND POSSIBLE SOLUTIONS

- Non-linear evolution of density and velocity field;

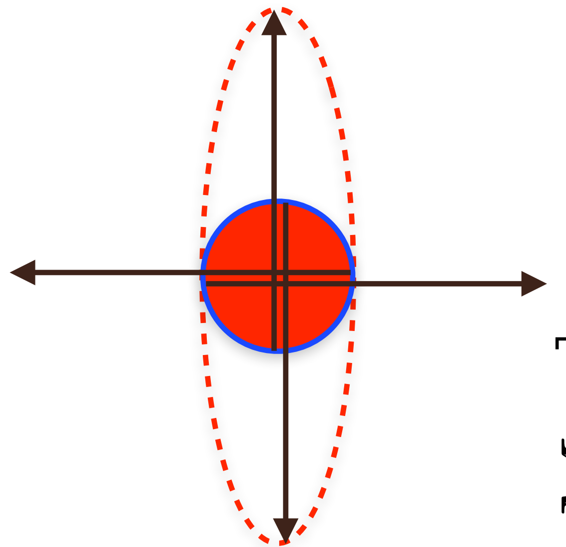


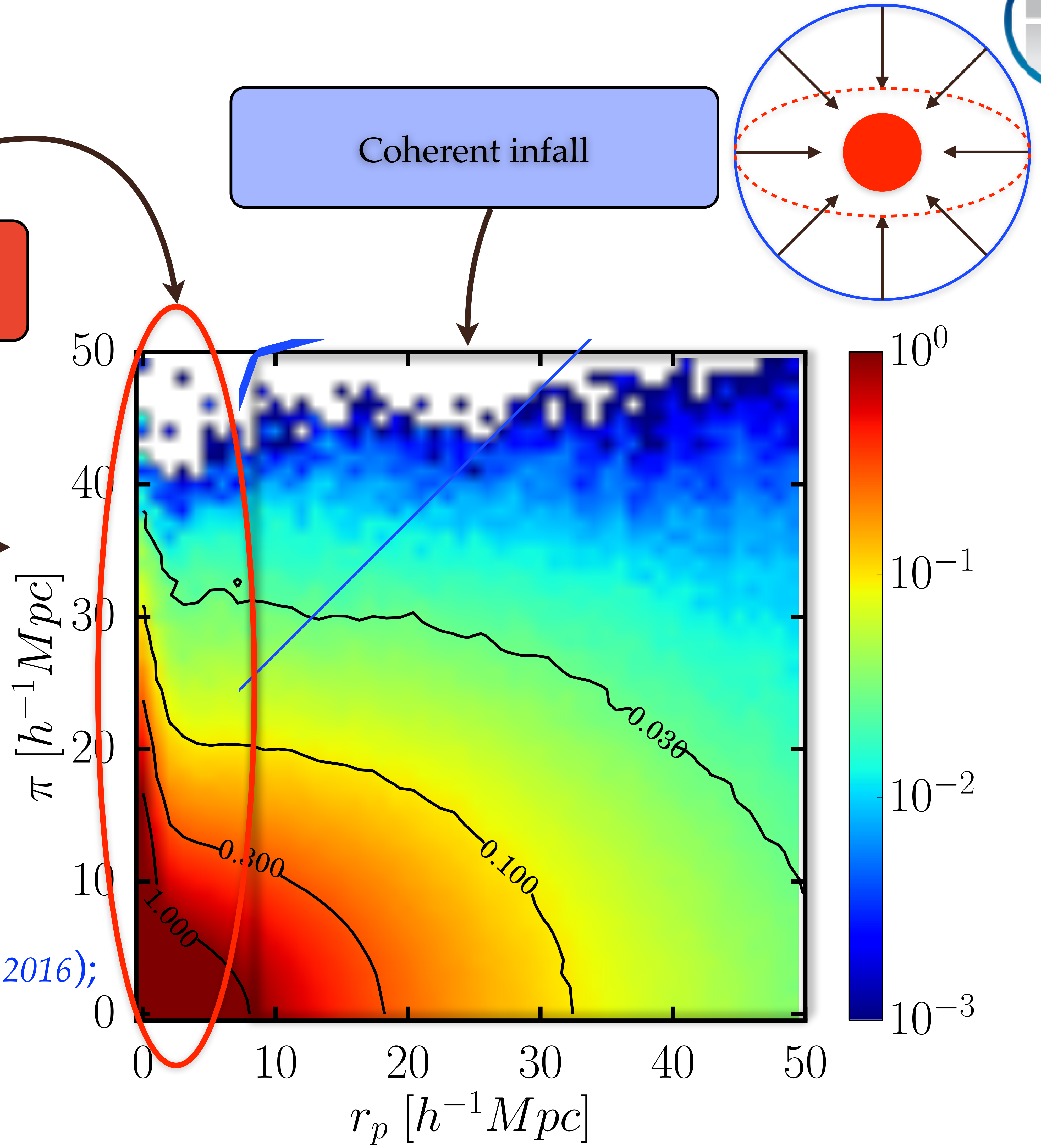
Virialized motions

Coherent infall

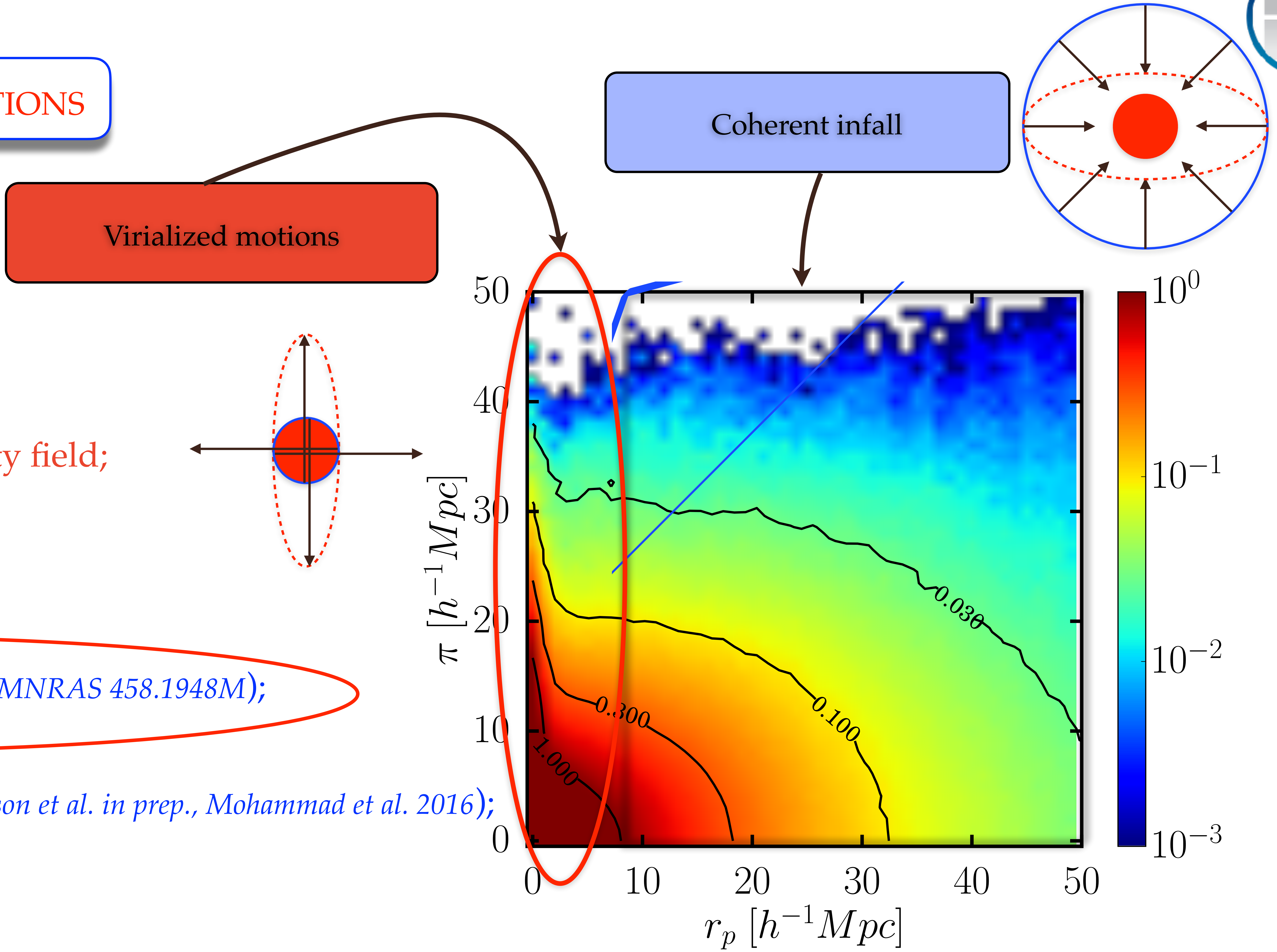
RSD: Challenges and Possible Solutions

- Non-linear evolution of density and velocity field;
- Sophisticated theoretical models;
- Appropriate tracers (e.g. *Mohammad et al. 2016, MNRAS 458.1948M*);
- Improved statistics (e.g. *Simpson et al. 2016, Wilson et al. in prep., Mohammad et al. 2016*);





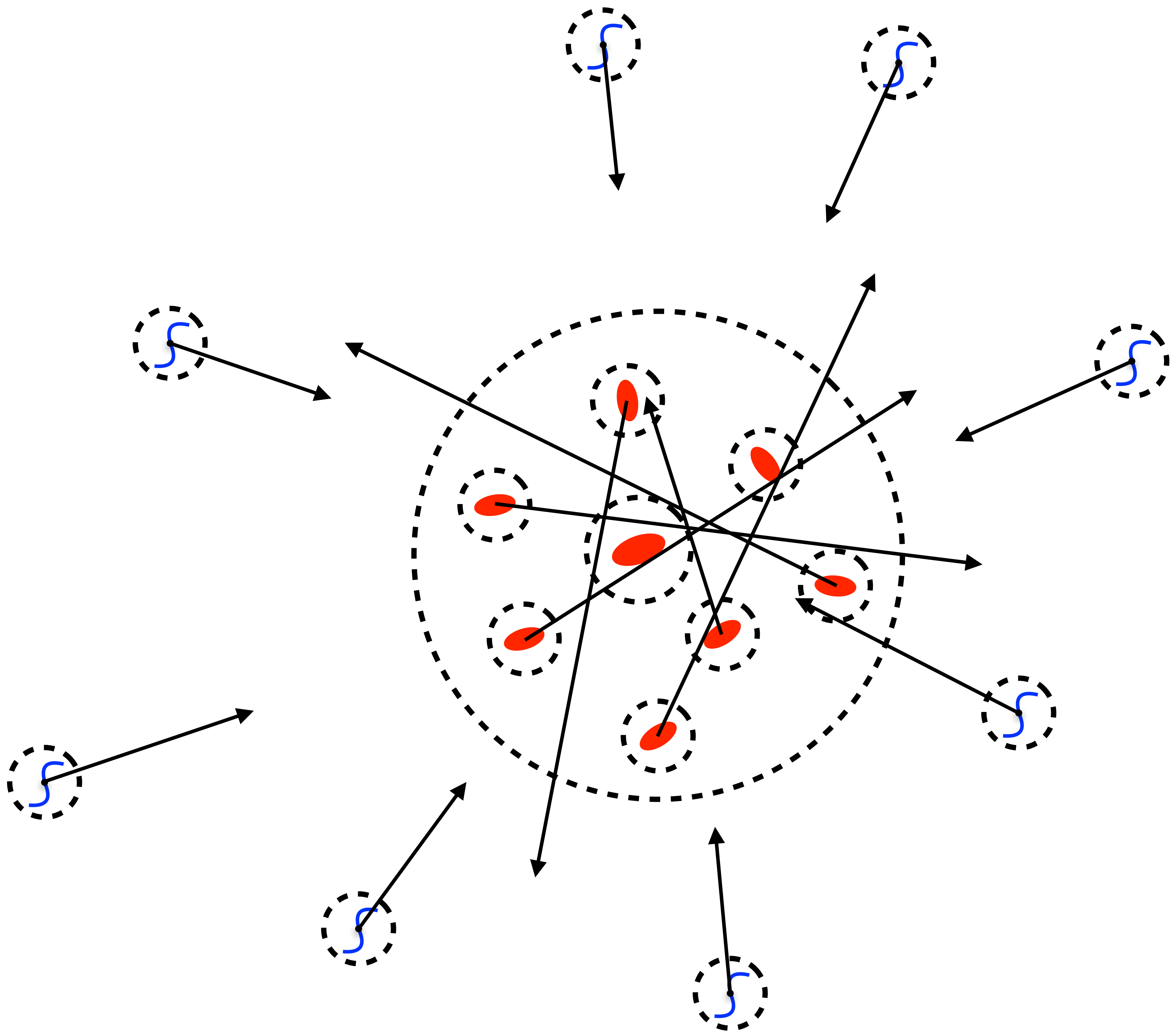
RSD: CHALLENGES AND POSSIBLE SOLUTIONS



- Non-linear evolution of density and velocity field;
- Sophisticated theoretical models;
- Appropriate tracers (e.g. *Mohammad et al. 2016, MNRAS 458.1948M*);
- Improved statistics (e.g. *Simpson et al. 2016, Wilson et al. in prep., Mohammad et al. 2016*);

VIPERS: APPROPRIATE TRACERS

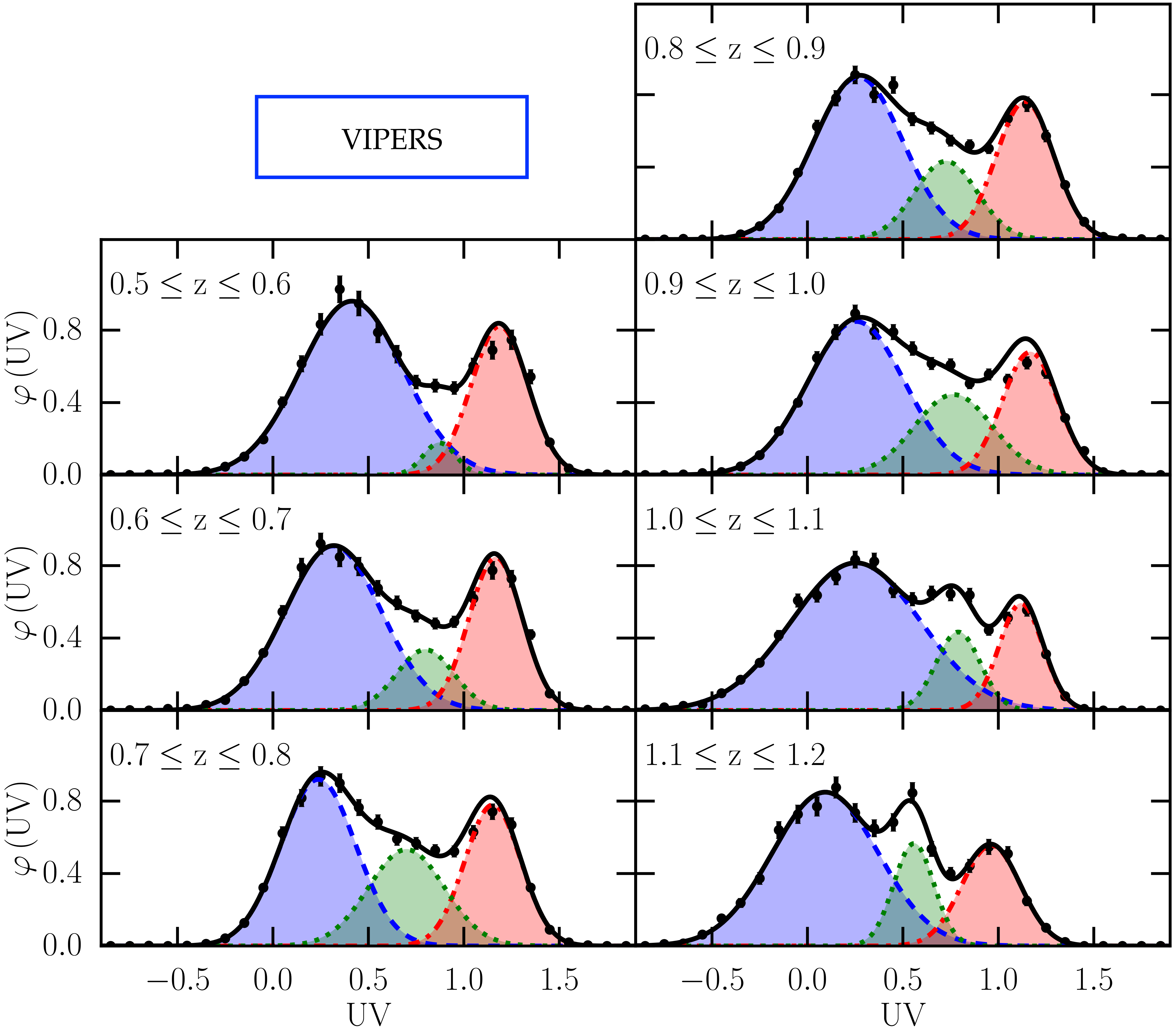
- Morphological segregation (*e.g. Dressler 1980*);
- Red (satellites) inside massive virialised structures;
- Blue (centrals) inhabit the *"field"*;



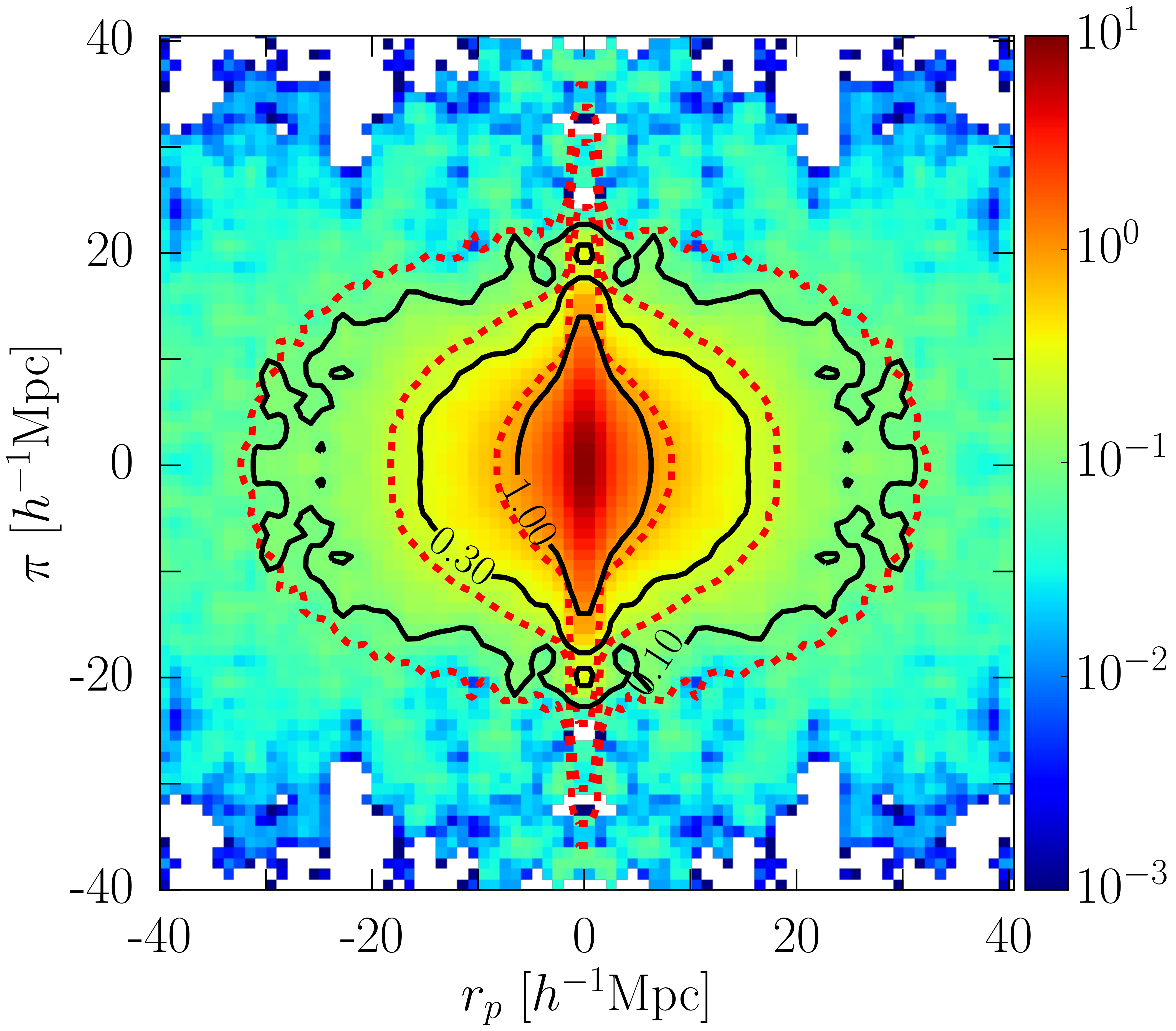
VIPERS: COLOUR CLASSIFICATION

- Rest-frame UV colour bimodality;
- Evolution with redshift;
- Three Gaussian model;
- Colour weights;

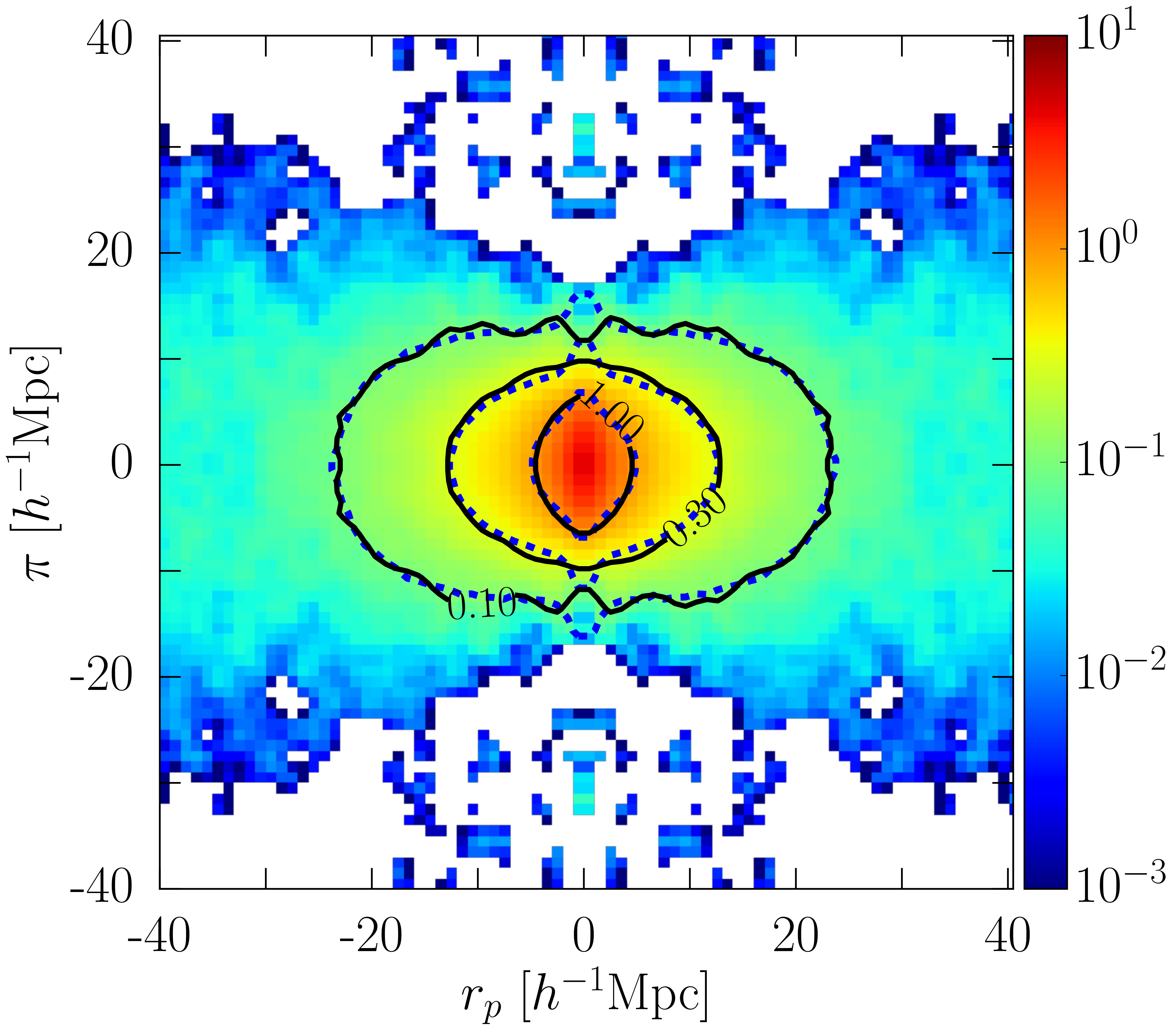
Type	N^{W1+W4}	z_{eff}
Blue	~32 666	0.66
Red	~16 188	0.69



VIPERS: ANISOTROPIC CLUSTERING



Red



Blue

RSD MODELS

- Kaiser model;

$$P^s(k,\nu) = \left[(b\sigma_8) + (f\sigma_8)\nu^2\right]^2 P_{\delta\delta}(k)$$

- Scoccimarro model;

$$P^s(k,\nu) = (b\sigma_8)^2 P_{\delta\delta}(k) + 2(f\sigma_8)(b\sigma_8)\nu^2 P_{\delta\theta}(k) + \nu^4 (f\sigma_8)^2 P_{\theta\theta}(k)$$

- Lorentzian damping;

$$D(k\nu\sigma_{12}) = \frac{1}{1 + (k\nu\sigma_{12})^2}$$

- Fit multipole moments of the 2PCF;

$$\xi^{(\ell)}(s) = \frac{2\ell+1}{2}\int_{-1}^{+1} \xi(s,\mu)\mathcal{L}(\mu)d\mu$$

RSD MODELS

- Improved fitting func. for $P_{\delta\theta}$,$P_{\theta\theta}$ (*Bel et al. in preparation*);

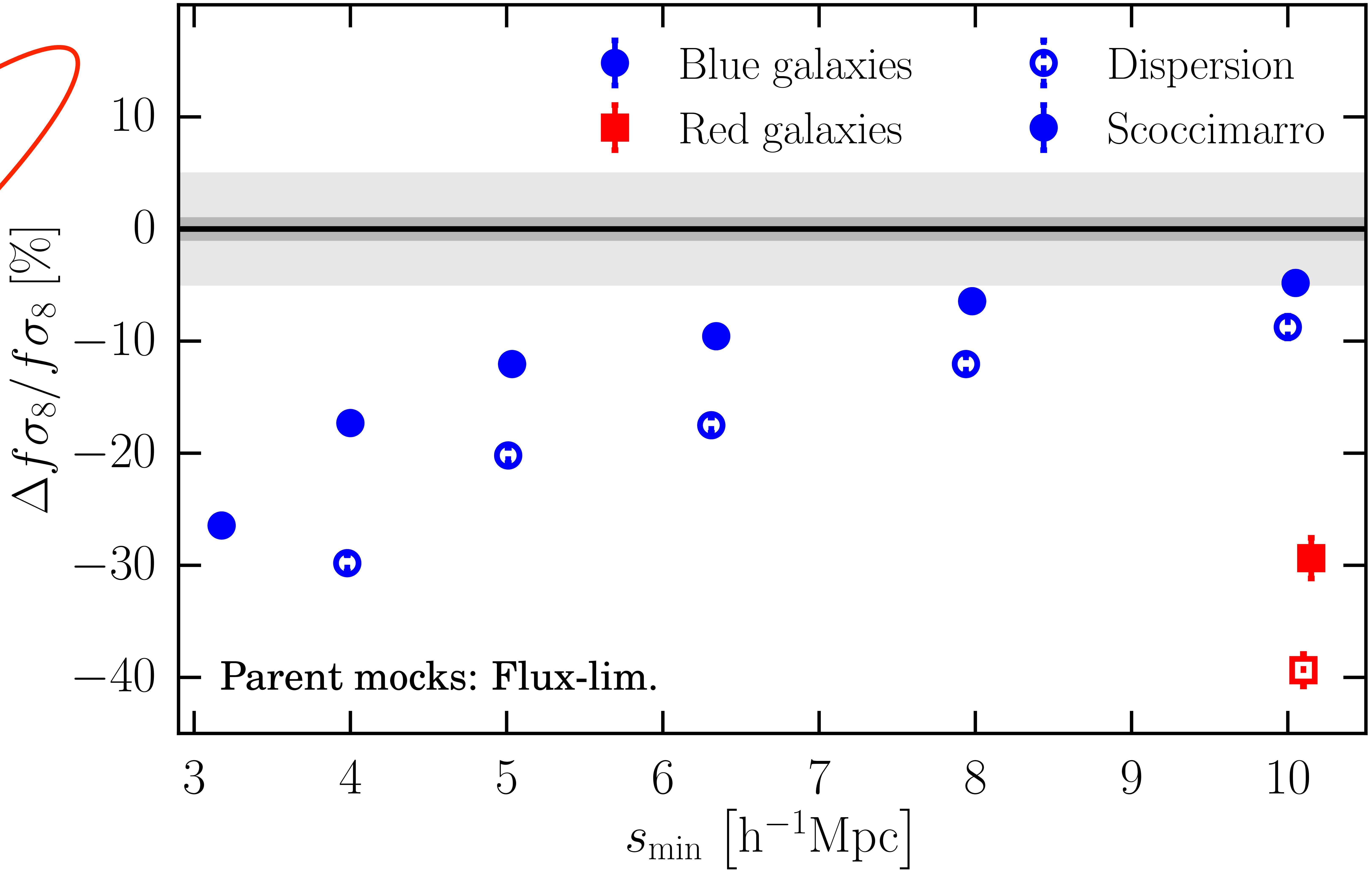
$$\boxed{P_{\theta\theta} = P^{\mathrm{lin}}_{\delta\delta}(k)e^{-k/k^*_{\theta\theta}}}$$

$$\boxed{P_{\delta\theta} = \left[P_{\delta\delta}(k)P^{\mathrm{lin}}_{\delta\delta}(k)e^{-k/k^*_{\delta\theta}}\right]^{1/2}}$$

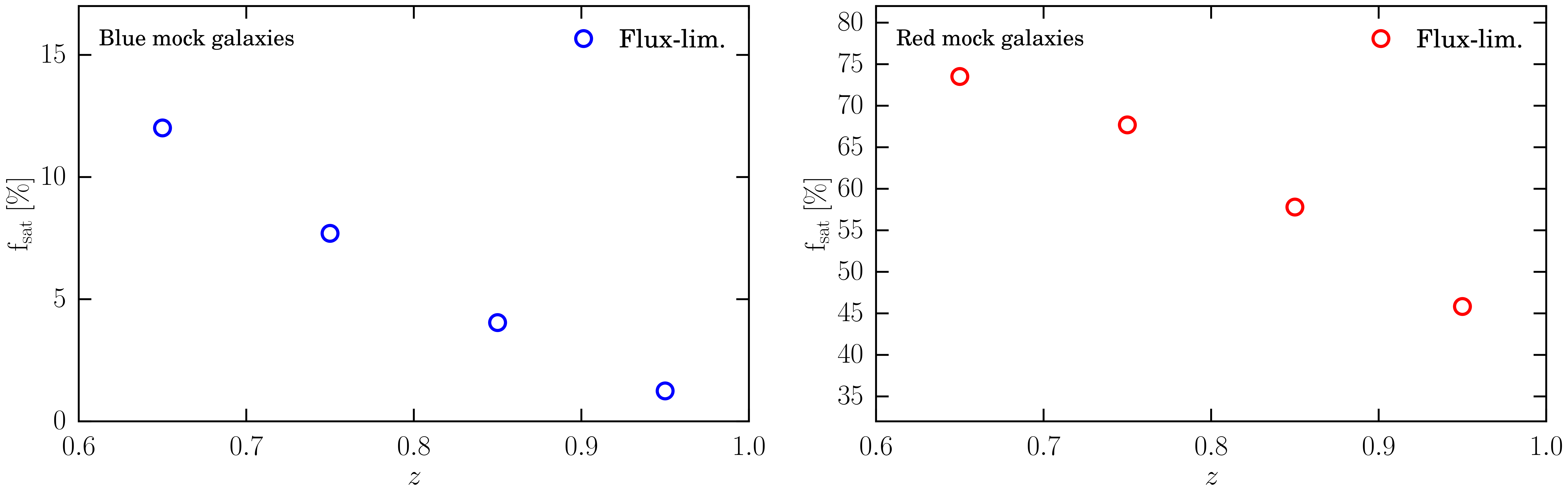
$$\boxed{\frac{1}{k^*_{xy}} = p_1\sigma_8^{p_2}}$$

MODELLING SYSTEMATICS

No Ang. Selection!



MODELLING SYSTEMATICS



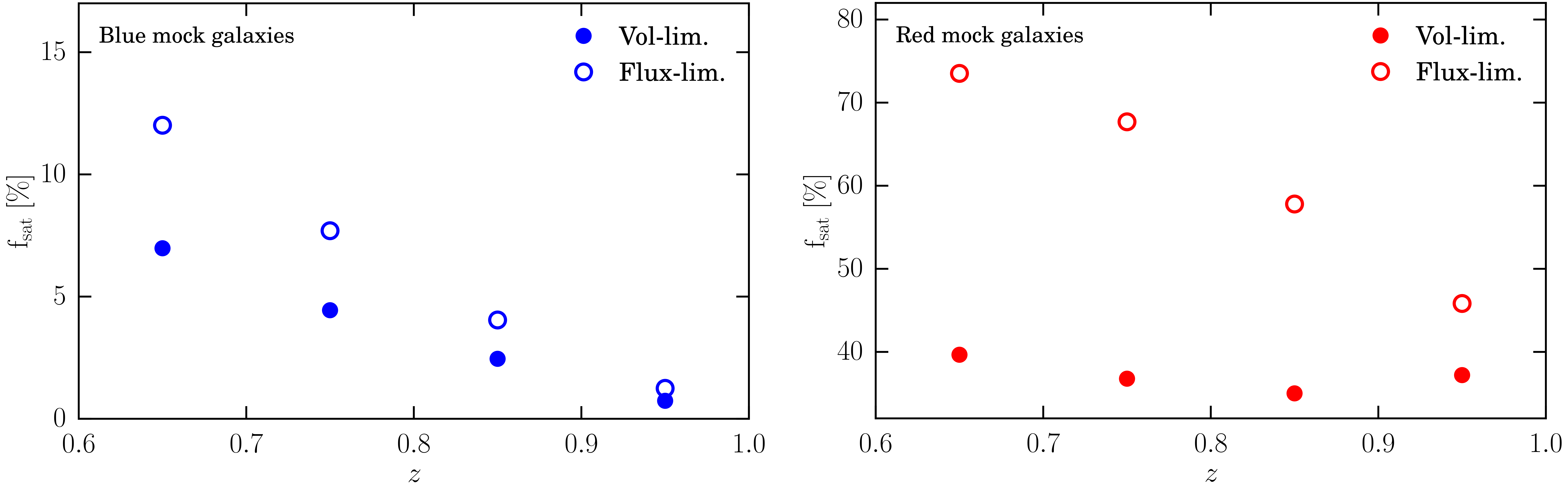
VOLUME-LIMITED SAMPLES

- Passive luminosity evolution;
- Rare mergers;
- Neglect galaxy quenching;
- Constant n(z) => estimate $M_B^{th}(z)$;

$$M_B^{th}(z) = M_0 + M_1 z$$

MODELLING SYSTEMATICS

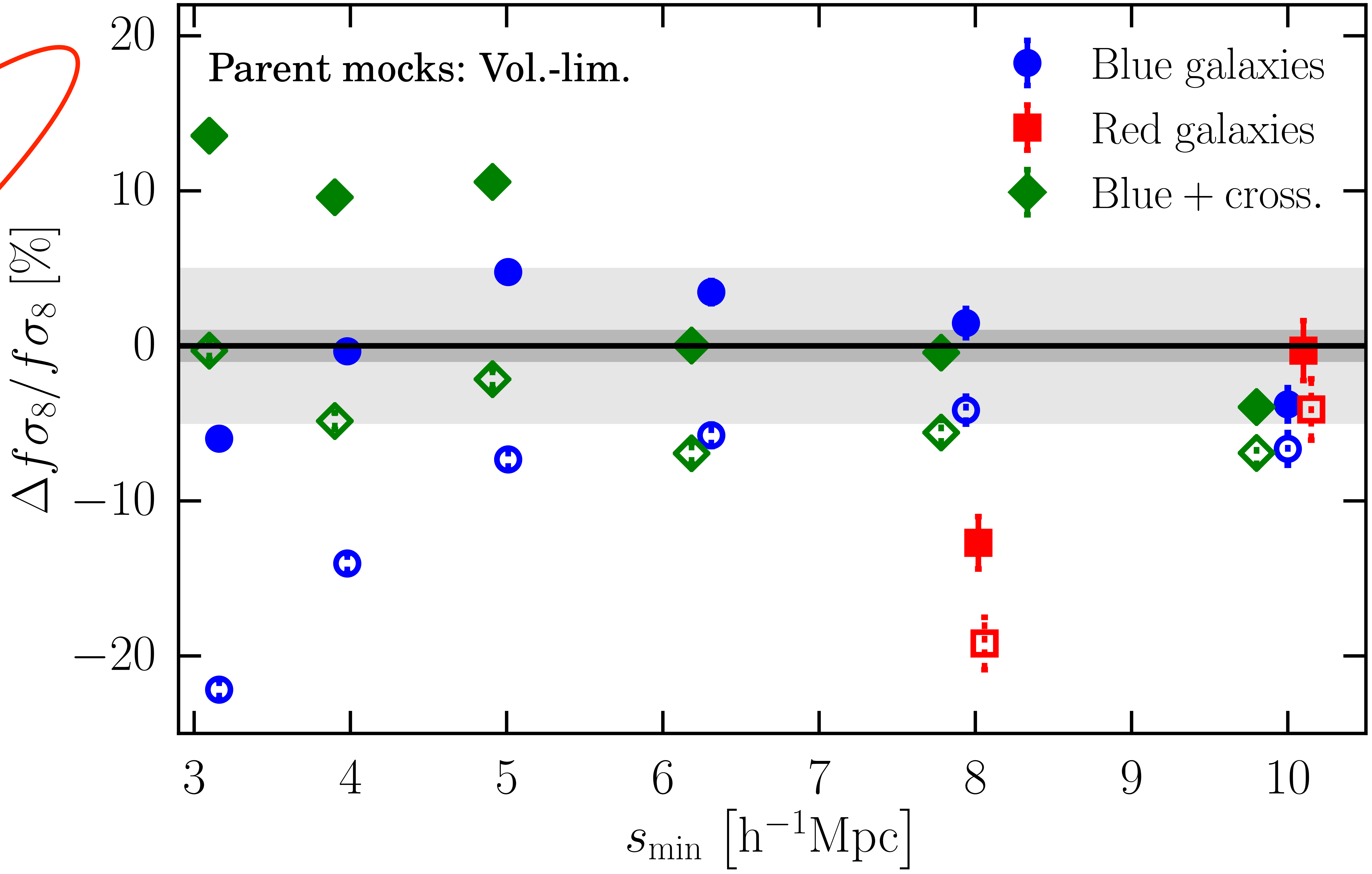
Type	M_0	M_1	N^{W1+W4}	z_{eff}
Blue	-20.18±0.07	-0.45±0.14	~7 625	0.85
Red	-20.76±0.11	-0.20±0.09	~3 652	0.84



MODELLING SYSTEMATICS

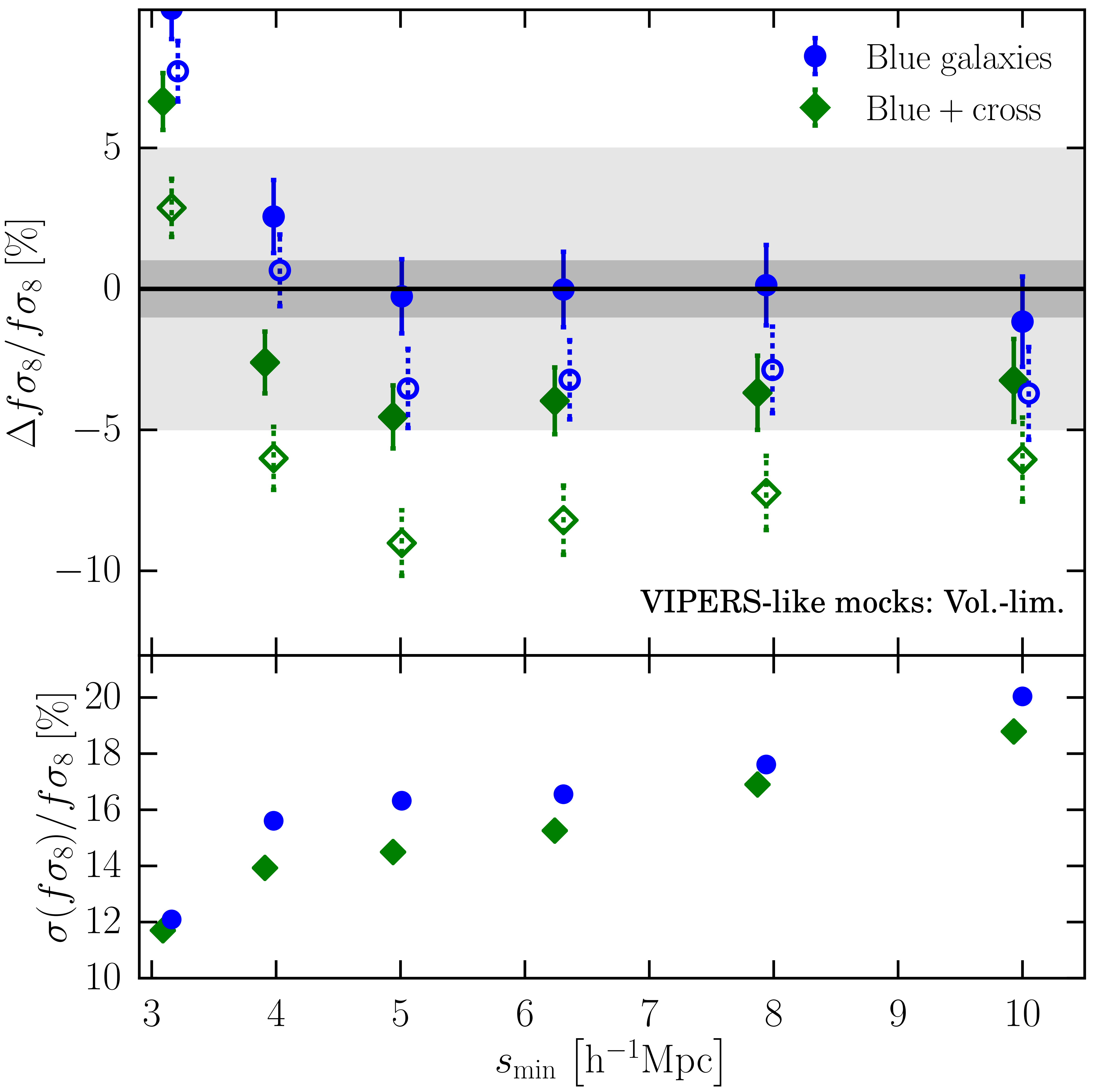
$$P^s(k,\nu) = \left[(b_\mathrm{b}\sigma_8) + (f\sigma_8)\nu^2\right]\left[(b_\mathrm{r}\sigma_8) + (f\sigma_8)\nu^2\right] P_{\delta\delta}(k)$$

No Ang. Selection!



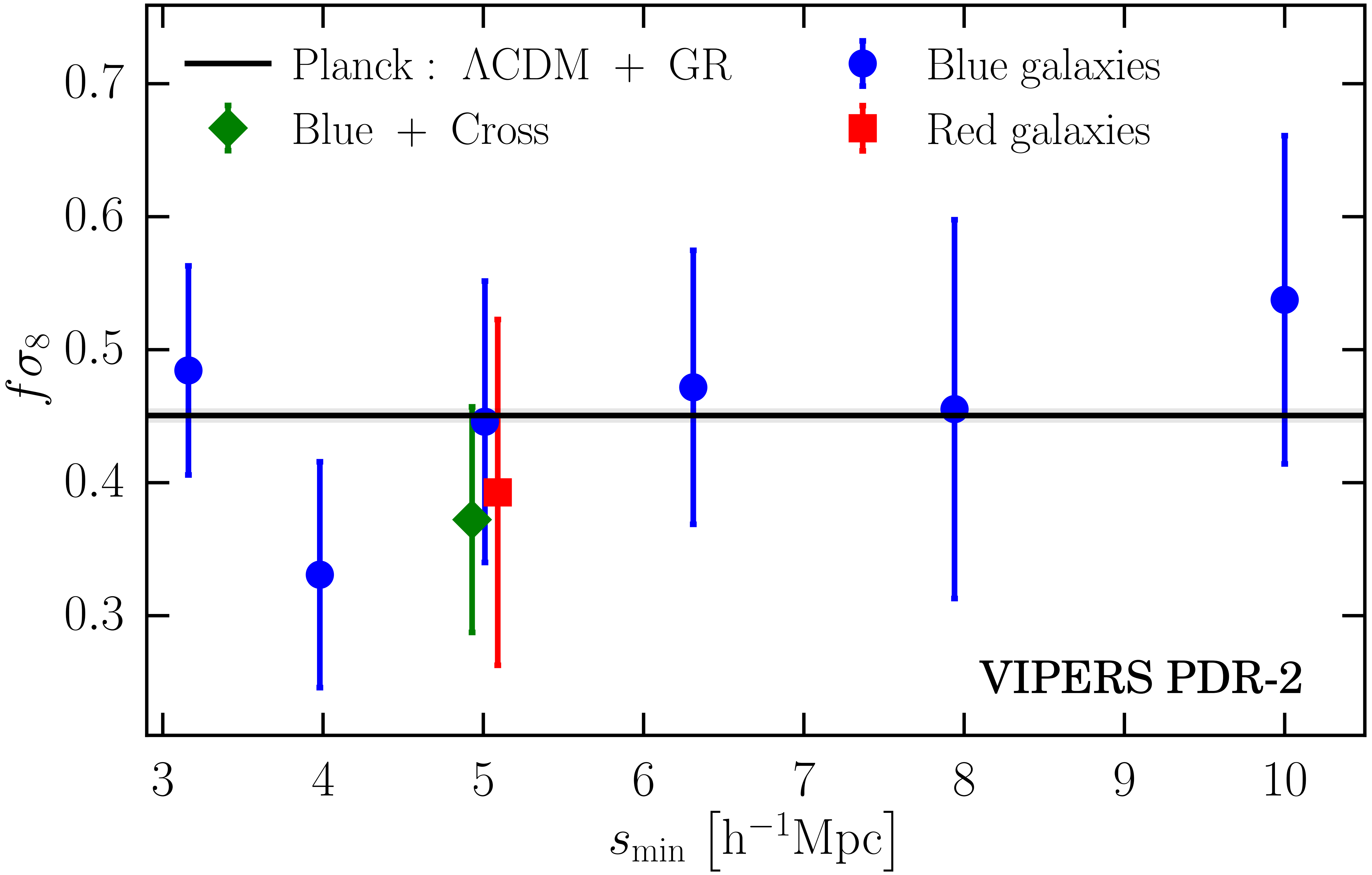
MODELLING SYSTEMATICS

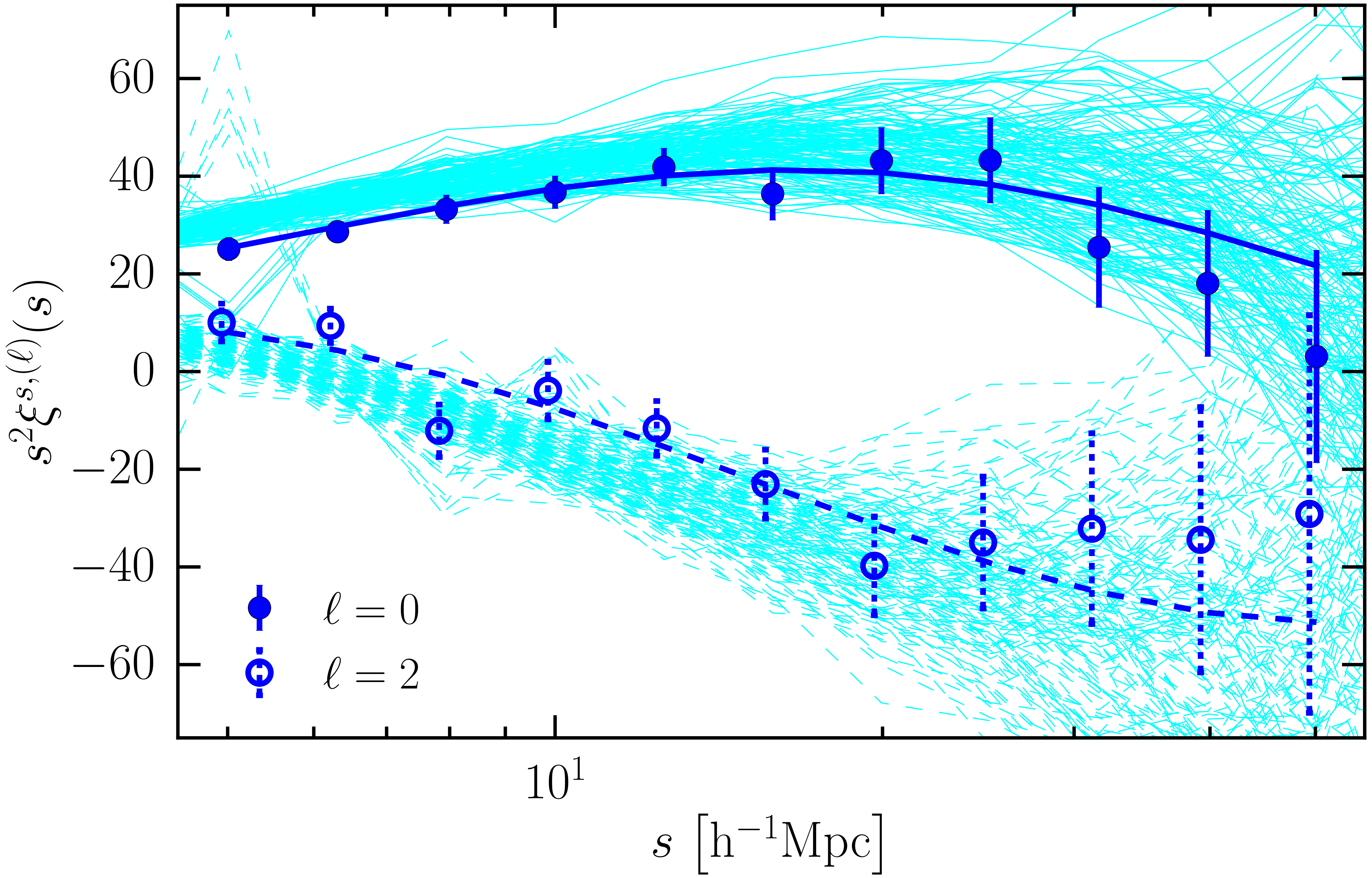
- A second Gaussian damping to model z-err;



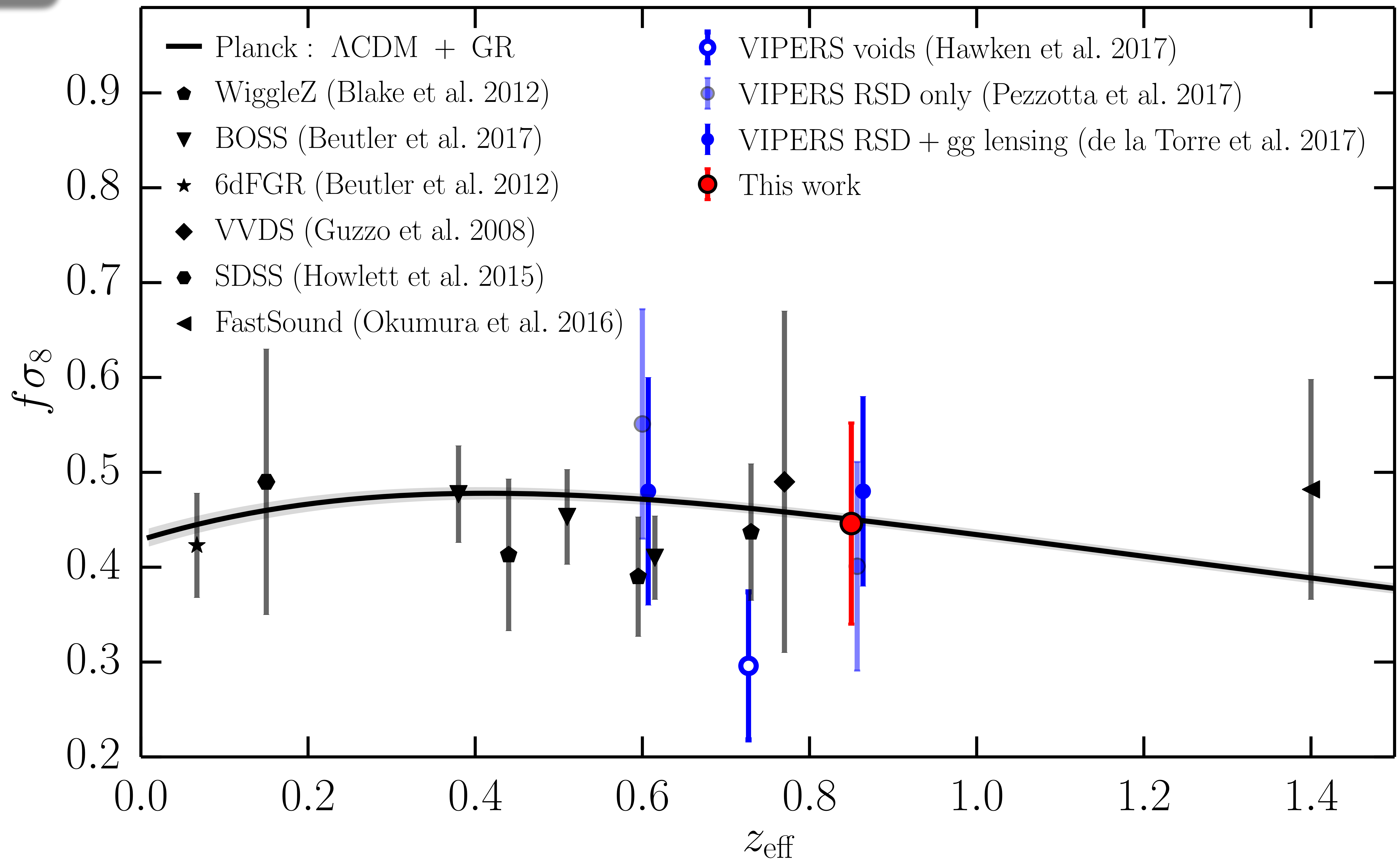
RESULTS

$f\sigma_8\,(z{=}0.85) = 0.45 \pm 0.11$





Results

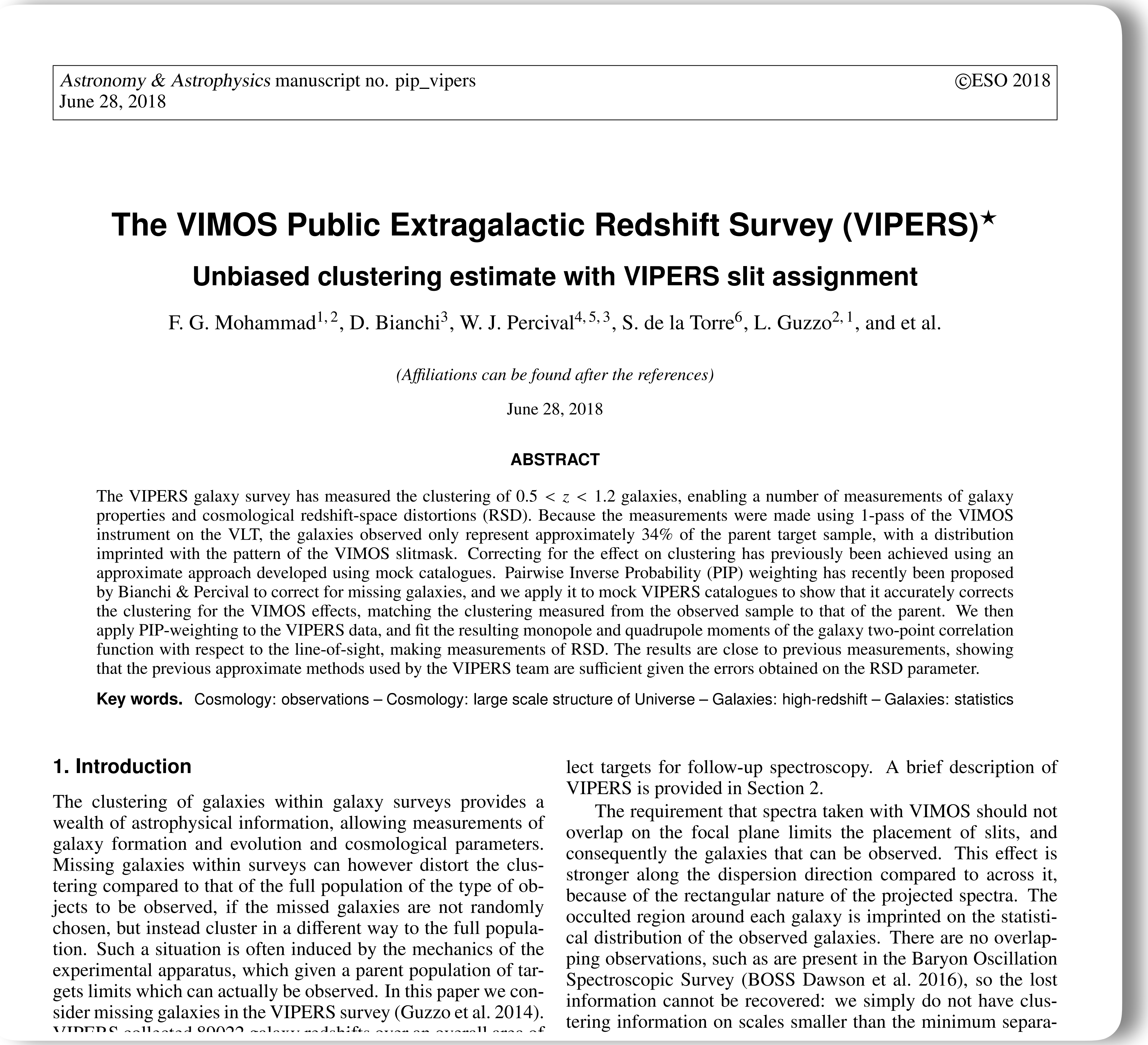


Planck : ΛCDM + GR
WiggleZ (Blake et al. 2012)
BOSS (Beutler et al. 2017)
6dFGR (Beutler et al. 2012)
VVDS (Guzzo et al. 2008)
SDSS (Howlett et al. 2015)
FastSound (Okumura et al. 2016)
VIPERS voids (Hawken et al. 2017)
VIPERS RSD only (Pezzotta et al. 2017)
VIPERS RSD + gg lensing (de la Torre et al. 2017)
This work
$f\sigma_8$
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
$z_{\rm eff}$

CONLCUSIONS

- Accuracy even better then using more sophisticated RSD models on full galaxy sample;
- Competitive statistical precision;
- Promising for planned experiment;
- Attention to details approaching the percent precision cosmology;

UNBIASED CLUSTERING ESTIMATES WITH VIPERS SLIT ASSIGNMENT



Astronomy & Astrophysics manuscript no. pip_vipers
June 28, 2018

The VIMOS Public Extragalactic Redshift Survey (VIPERS)*

Unbiased clustering estimate with VIPERS slit assignment

F. G. Mohammad[1, 2], D. Bianchi[3], W. J. Percival[4, 5, 3], S. de la Torre[6], L. Guzzo[2, 1], and et al.

(Affiliations can be found after the references)

June 28, 2018

ABSTRACT

The VIPERS galaxy survey has measured the clustering of $0.5 < z < 1.2$ galaxies, enabling a number of measurements of galaxy properties and cosmological redshift-space distortions (RSD). Because the measurements were made using 1-pass of the VIMOS instrument on the VLT, the galaxies observed only represent approximately 34% of the parent target sample, with a distribution imprinted with the pattern of the VIMOS slitmask. Correcting for the effect on clustering has previously been achieved using an approximate approach developed using mock catalogues. Pairwise Inverse Probability (PIP) weighting has recently been proposed by Bianchi & Percival to correct for missing galaxies, and we apply it to mock VIPERS catalogues to show that it accurately corrects the clustering for the VIMOS effects, matching the clustering measured from the observed sample to that of the parent. We then apply PIP-weighting to the VIPERS data, and fit the resulting monopole and quadrupole moments of the galaxy two-point correlation function with respect to the line-of-sight, making measurements of RSD. The results are close to previous measurements, showing that the previous approximate methods used by the VIPERS team are sufficient given the errors obtained on the RSD parameter.

Key words. Cosmology: observations – Cosmology: large scale structure of Universe – Galaxies: high-redshift – Galaxies: statistics

1. Introduction

The clustering of galaxies within galaxy surveys provides a wealth of astrophysical information, allowing measurements of galaxy formation and evolution and cosmological parameters. Missing galaxies within surveys can however distort the clustering compared to that of the full population of the type of objects to be observed, if the missed galaxies are not randomly chosen, but instead cluster in a different way to the full population. Such a situation is often induced by the mechanics of the experimental apparatus, which given a parent population of targets limits which can actually be observed. In this paper we consider missing galaxies in the VIPERS survey (Guzzo et al. 2014).

lect targets for follow-up spectroscopy. A brief description of VIPERS is provided in Section 2.

The requirement that spectra taken with VIMOS should not overlap on the focal plane limits the placement of slits, and consequently the galaxies that can be observed. This effect is stronger along the dispersion direction compared to across it, because of the rectangular nature of the projected spectra. The occulted region around each galaxy is imprinted on the statistical distribution of the observed galaxies. There are no overlapping observations, such as are present in the Baryon Oscillation Spectroscopic Survey (BOSS Dawson et al. 2016), so the lost information cannot be recovered: we simply do not have clustering information on scales smaller than the minimum separa-

Mohammad et al. 2018
(In preparation)

UNBIASED CLUSTERING ESTIMATES WITH VIPERS SLIT ASSIGNMENT

- TSR up-weighting: ~1% level accuracy but parametric, calibrated on mocks;
- PIP + Ang. up-weighting: Non parametric, intrinsically unbiased;
- Test the impact on growth rate estimates;

METHOD

PAIRWISE-INVERSE-PROBABILITY (PIP)

Bianchi & Percival 2017

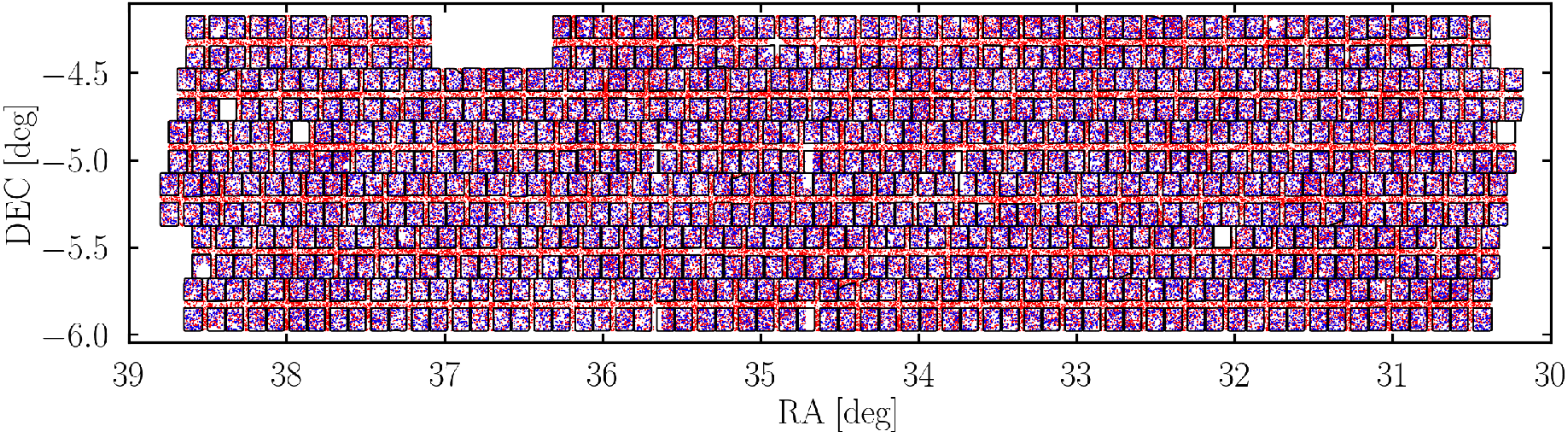
(MNRAS 472.1106B, arXiv 703.02070)

ANGULAR UP-WEIGHTING

Percival & Bianchi 2017

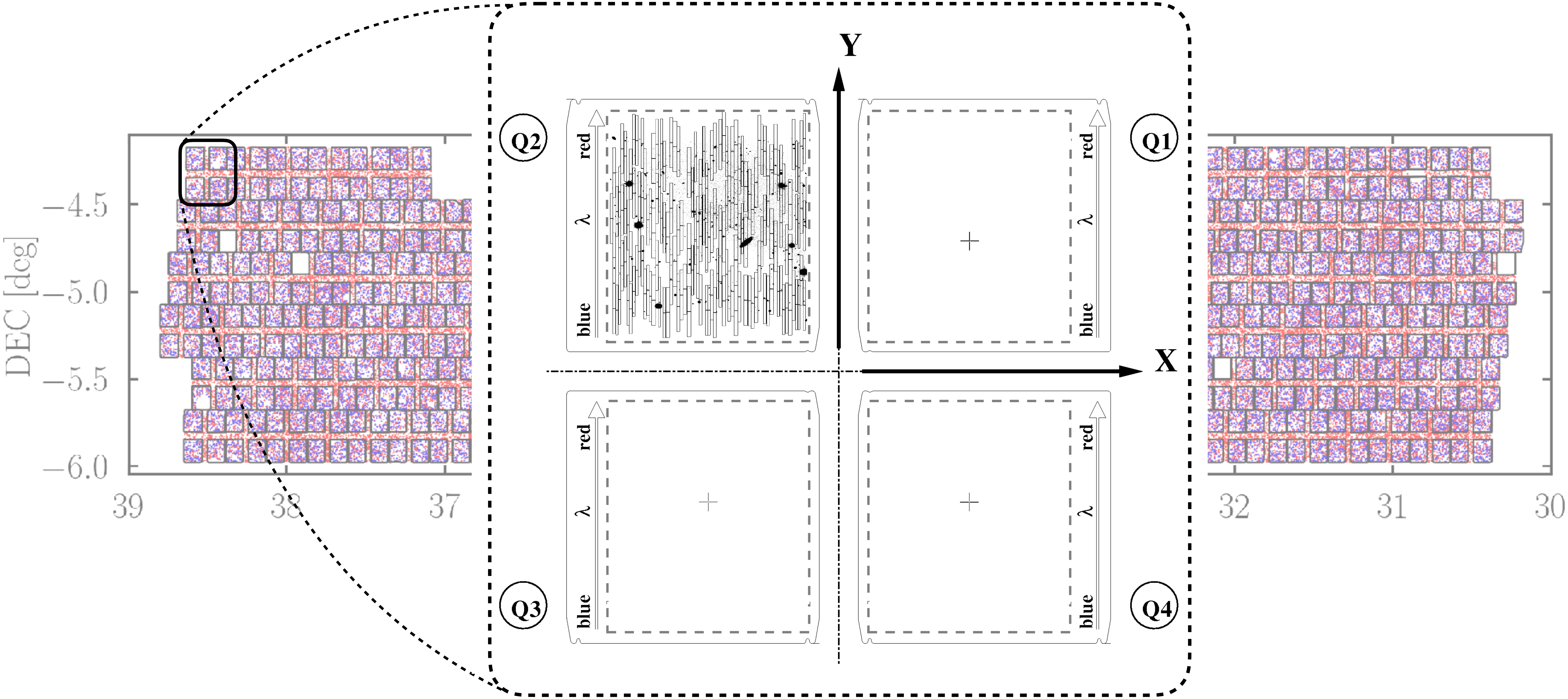
(MNRAS 472L..40P, arXiv 703.02071)

VIPERS OBSERVATIONS



VIPERS OBSERVATIONS

Slit Positioning Optimization Code (SPOC)
Bottini et al. 2004 (PASP..117..996B)



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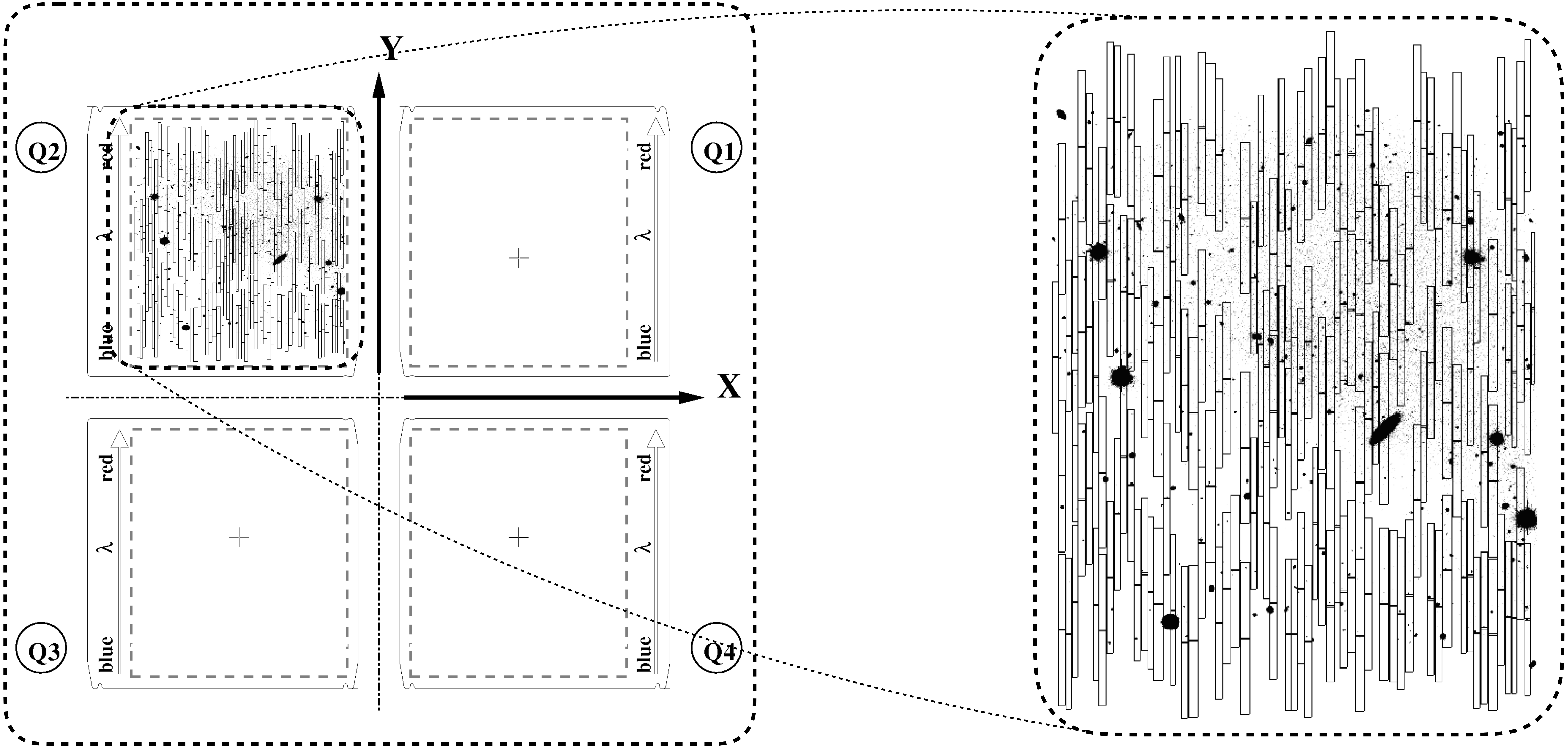

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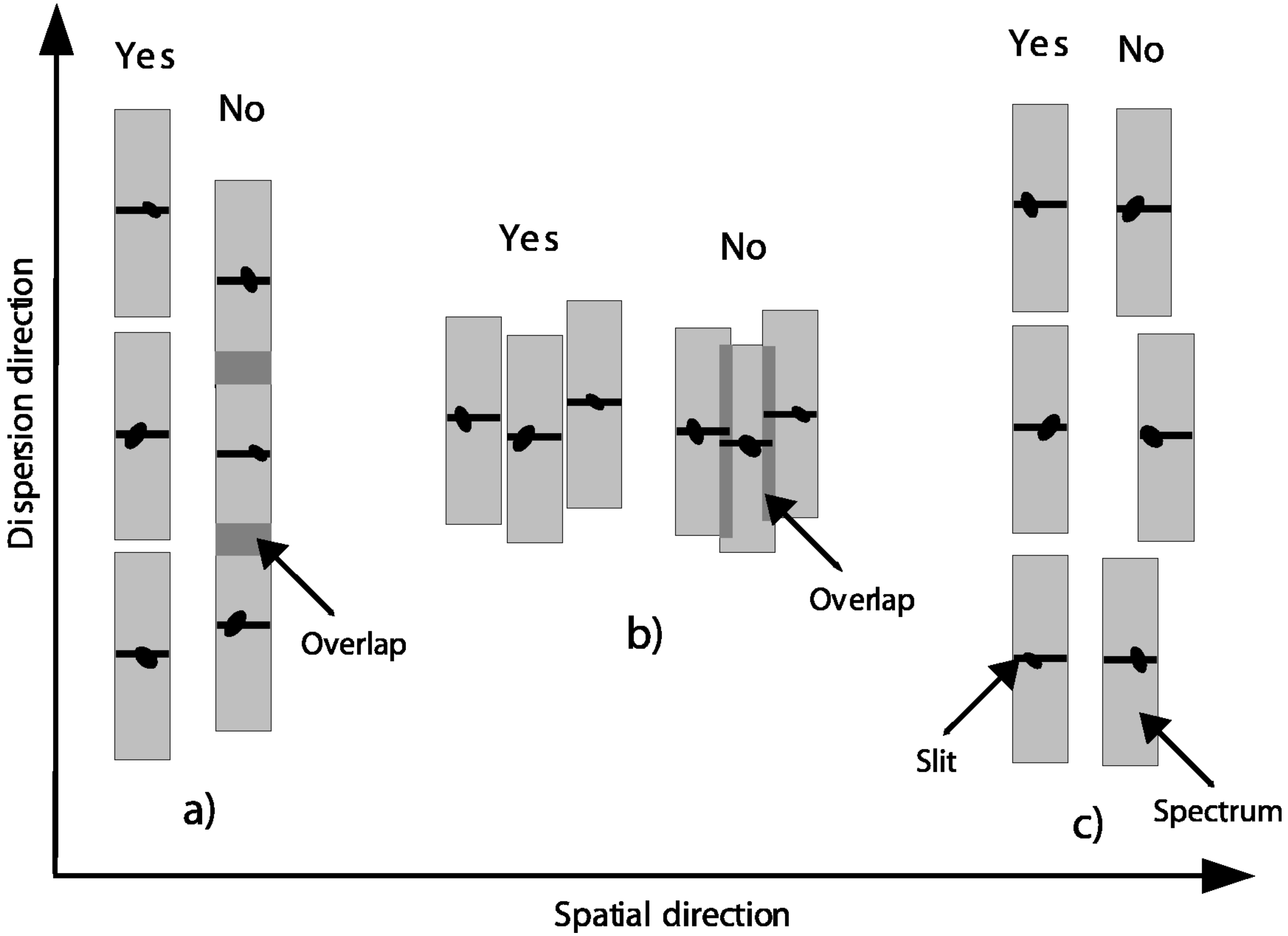
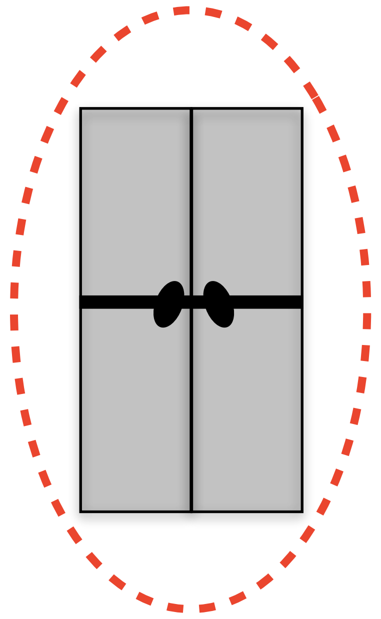




No constraint on ΔRA

WEIGHTED PAIR COUNTS

$$\boxed{DD(\mathbf{s}) = \sum_{\mathbf{x}_m - \mathbf{x}_m \approx \mathbf{s}} \boxed{w_{mn}} \times \boxed{\frac{DD_{\mathrm{par}}(\theta)}{DD(\theta)}}}$$

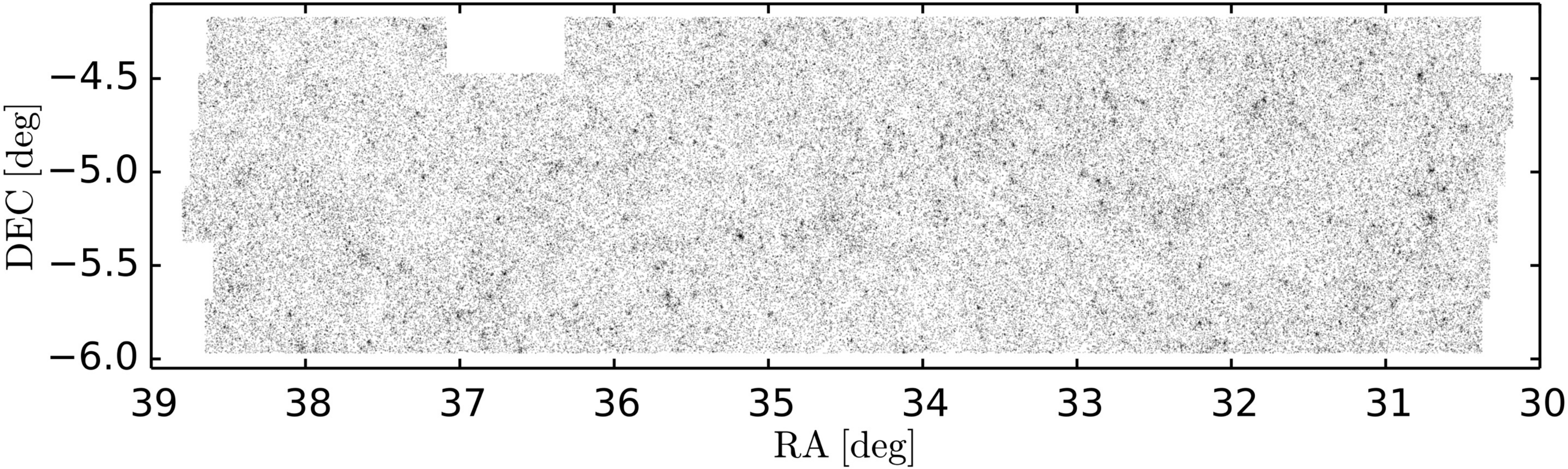
$$\boxed{w_{mn} = \frac{N_{\mathrm{runs}}}{\mathrm{popcnt}\left[w_m^{(b)}\ \&\ w_n^{(b)}\right]}} \quad \boxed{DD(\theta) = \sum_{\mathbf{u_m}\cdot\mathbf{u_n} \approx \cos(\theta)} w_{mn}}$$

Weighted Pair Counts

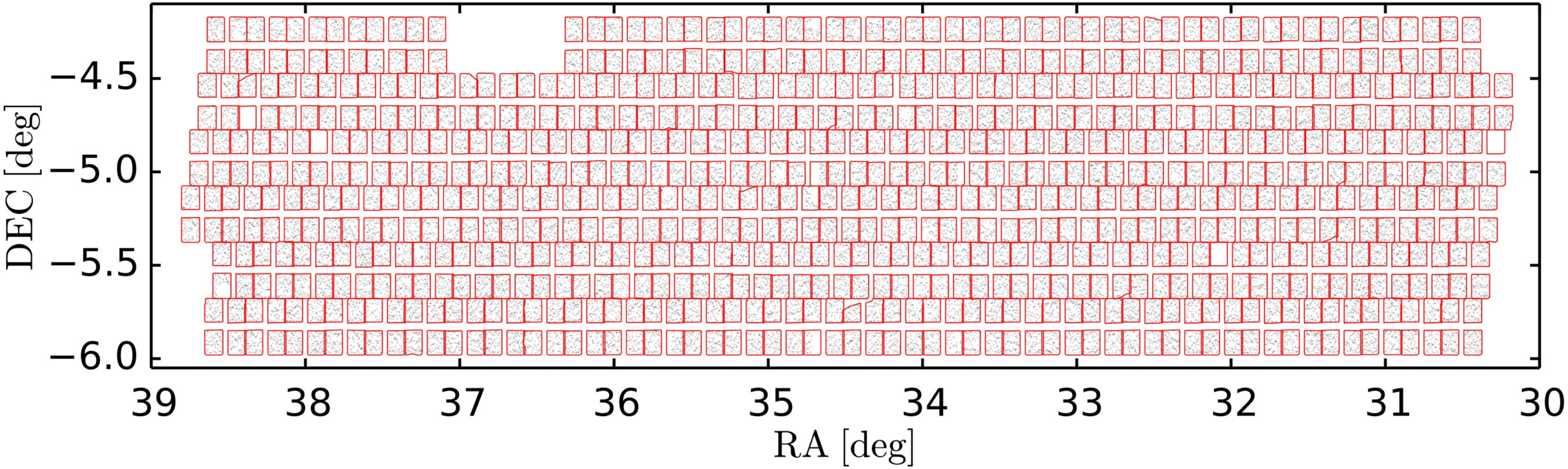
$$DR(\mathbf{s}) = \sum_{\mathbf{x}_m - \mathbf{y}_m \approx \mathbf{s}} \boxed{w_m} \times \boxed{\frac{DR_{\mathrm{par}}(\theta)}{DR(\theta)}}$$

$$\boxed{w_m = \frac{N_{\mathrm{runs}}}{\mathrm{popcnt}\left[w_m^{(b)}\right]}} \boxed{DR(\theta) = \sum_{\mathbf{u_m} \cdot \mathbf{v_n} \approx \cos(\theta)} w_m}$$

VIPERS REALISATIONS



VIPERS Realisations



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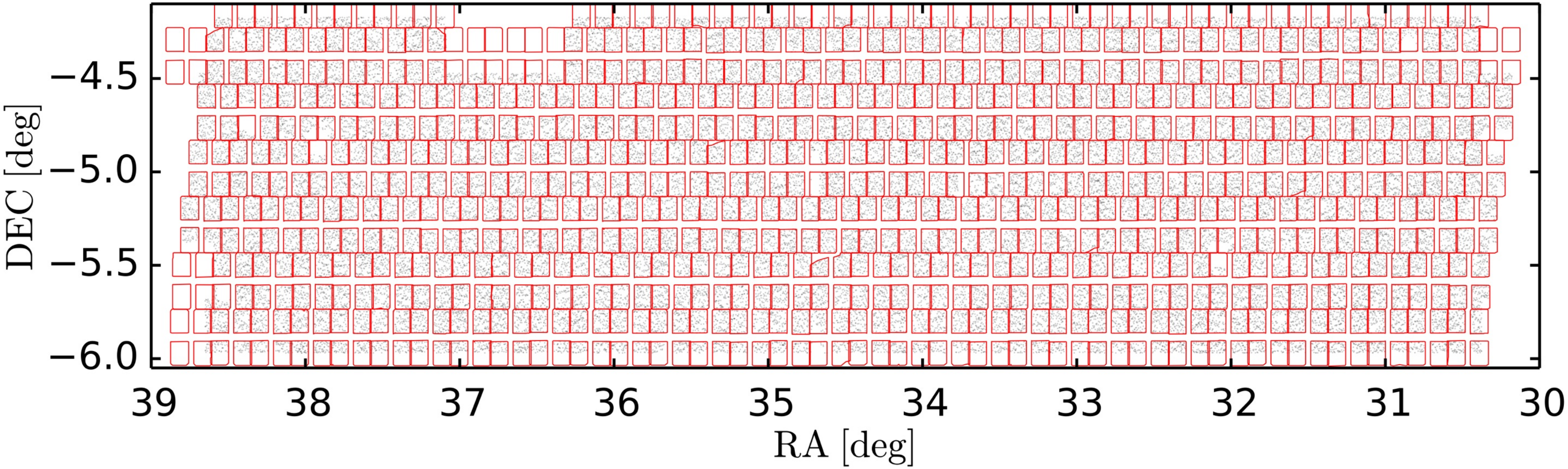
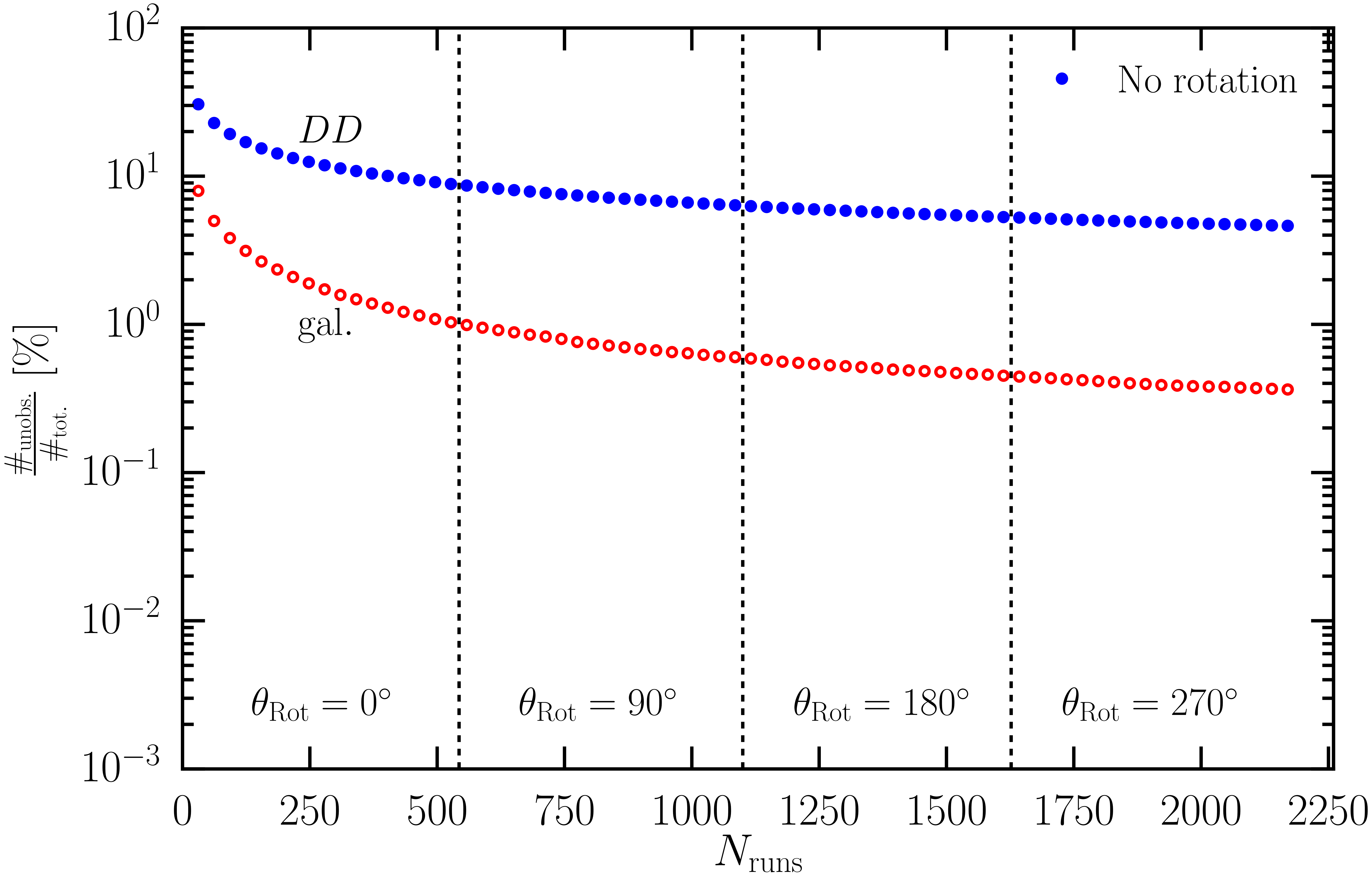


VIPERS REALISATIONS



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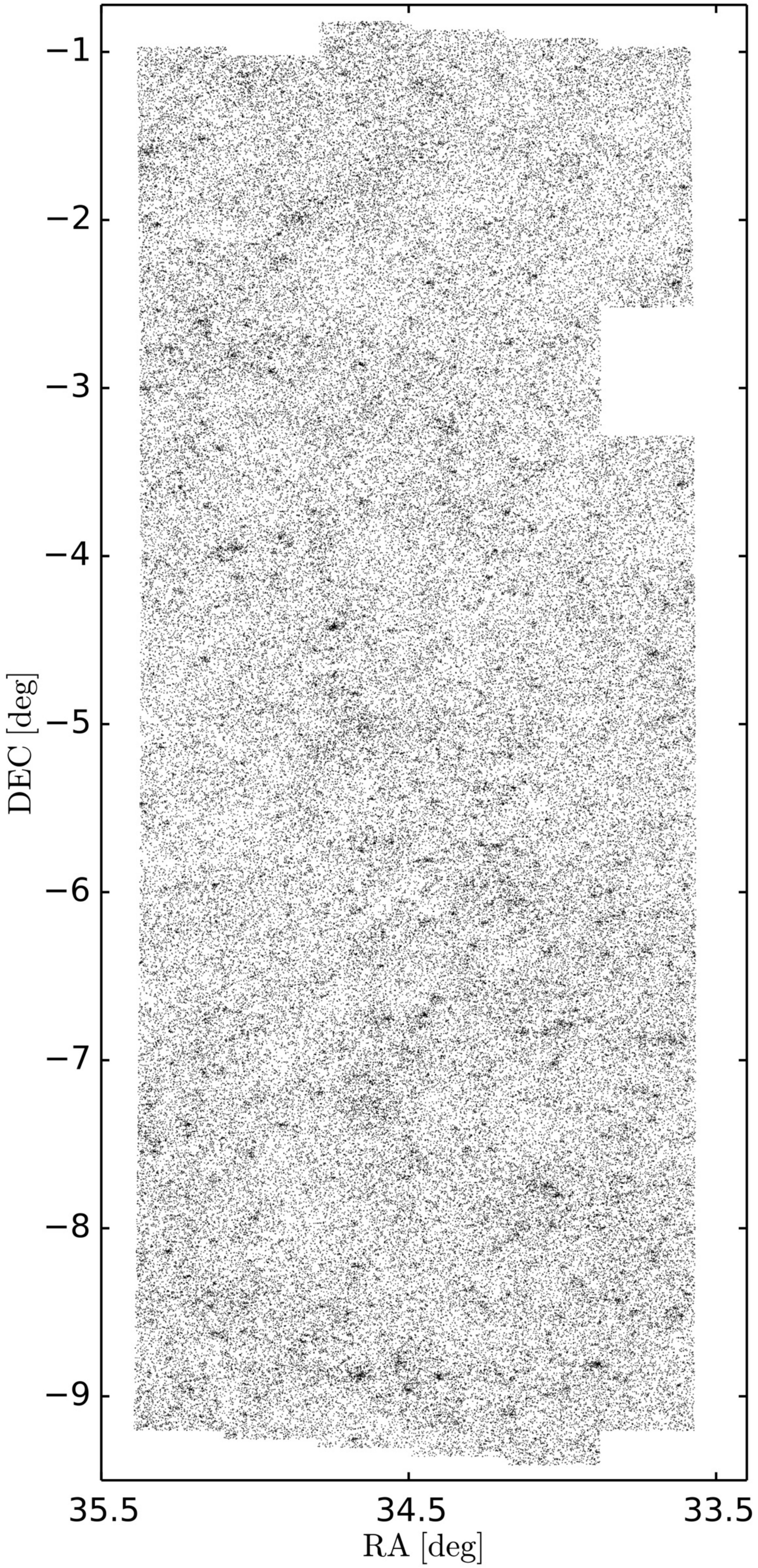

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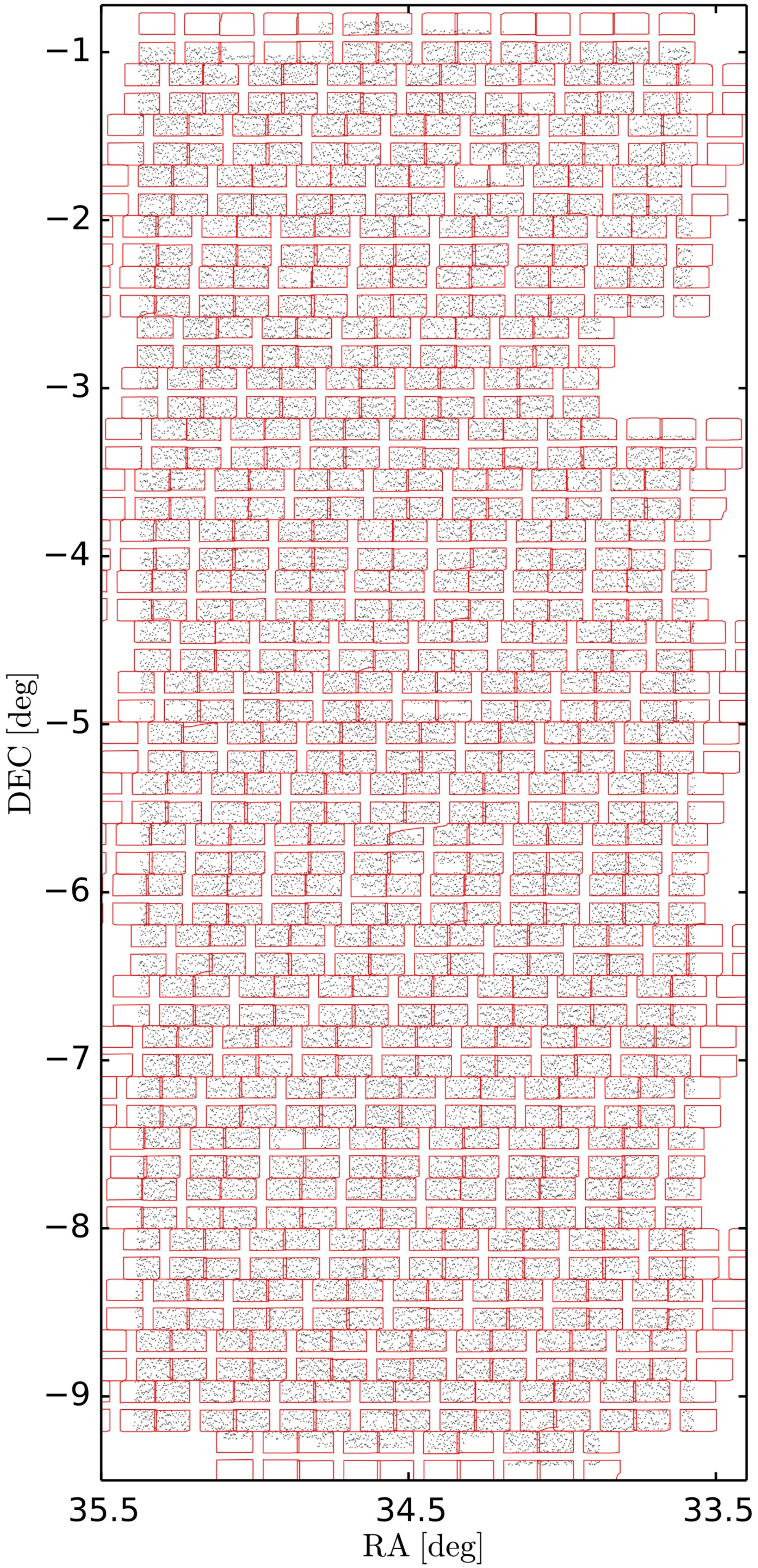
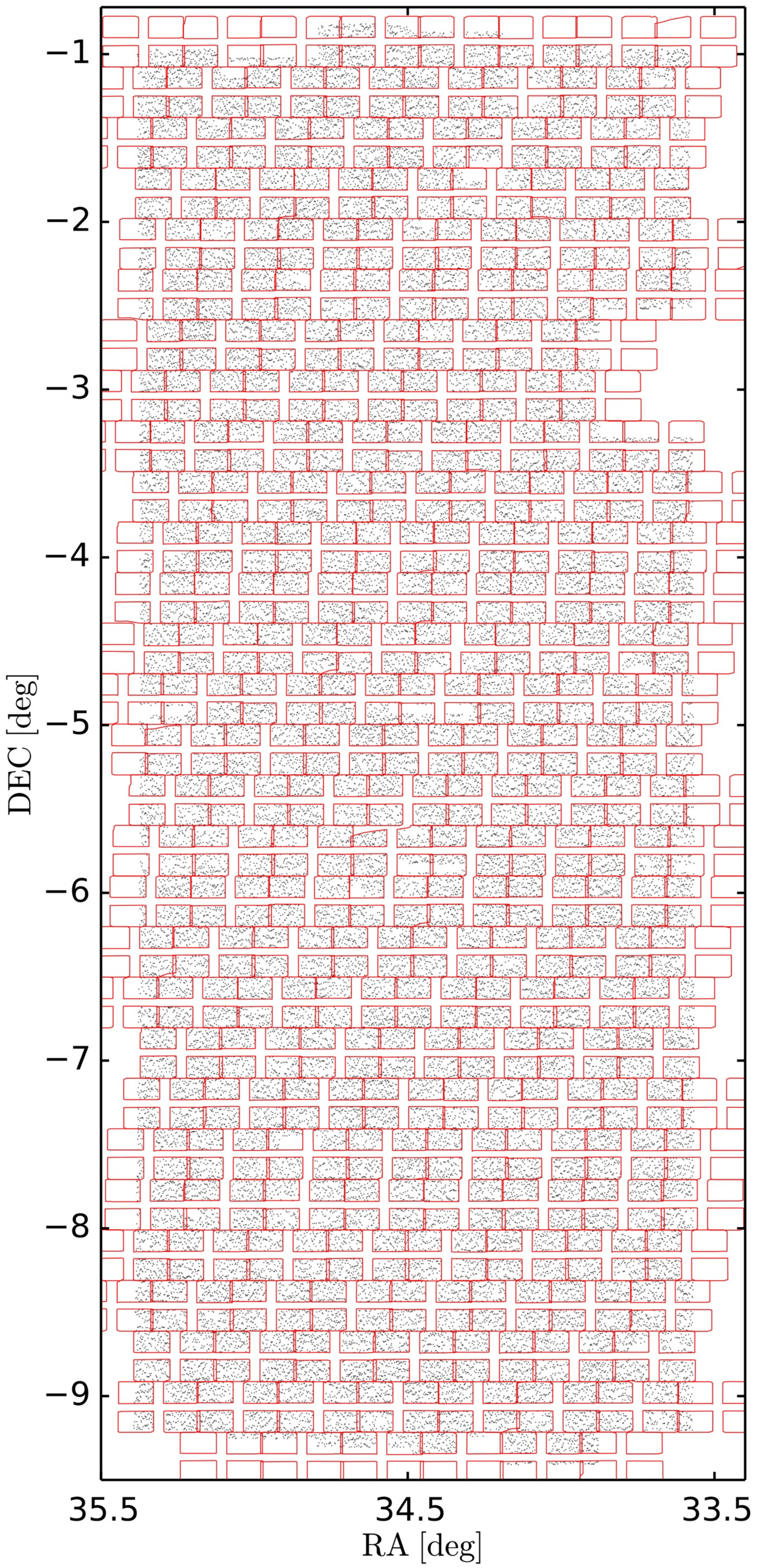


VIPERS REALISATIONS

2170 survey realisations



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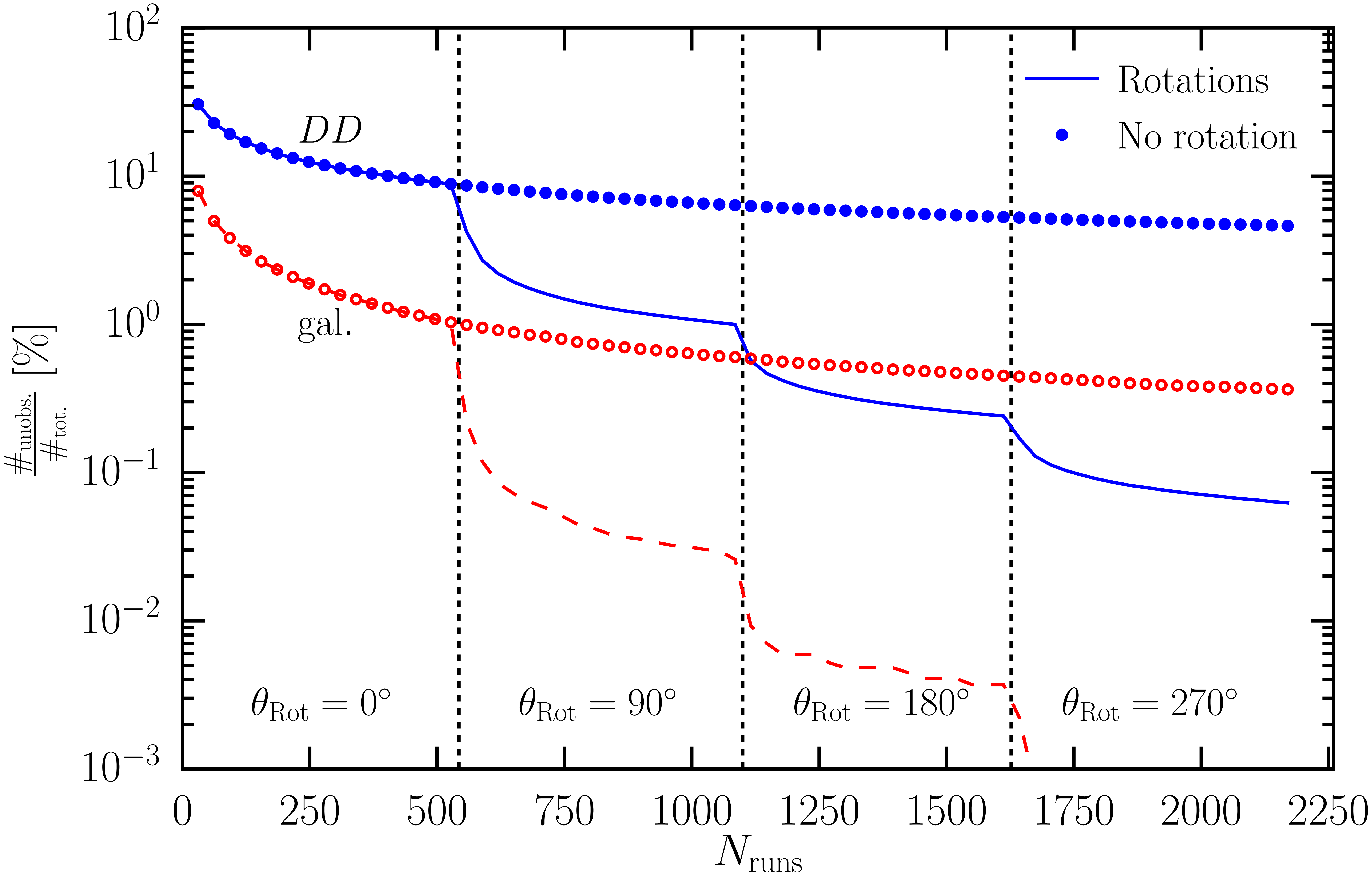
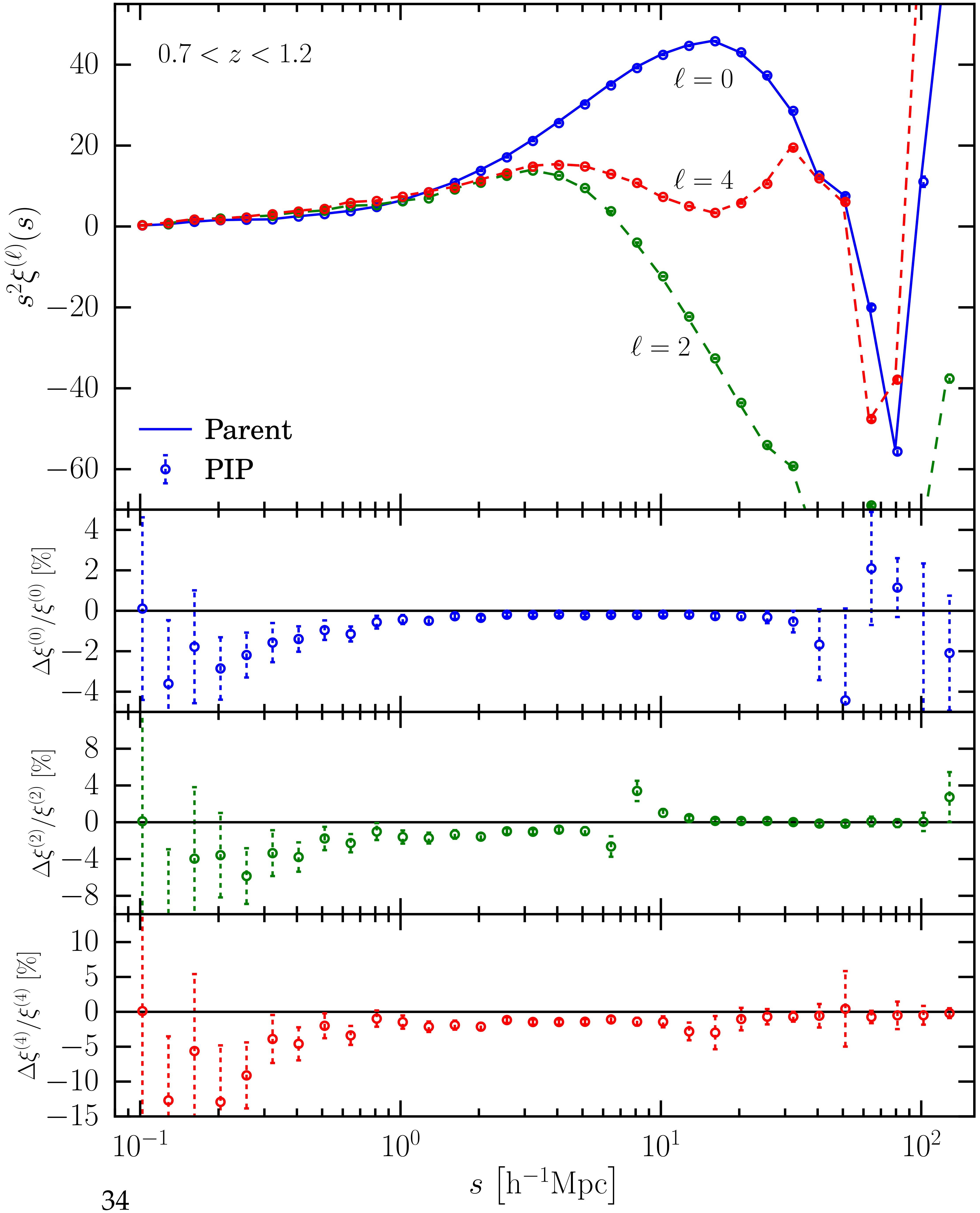


CONSISTENCY TESTS



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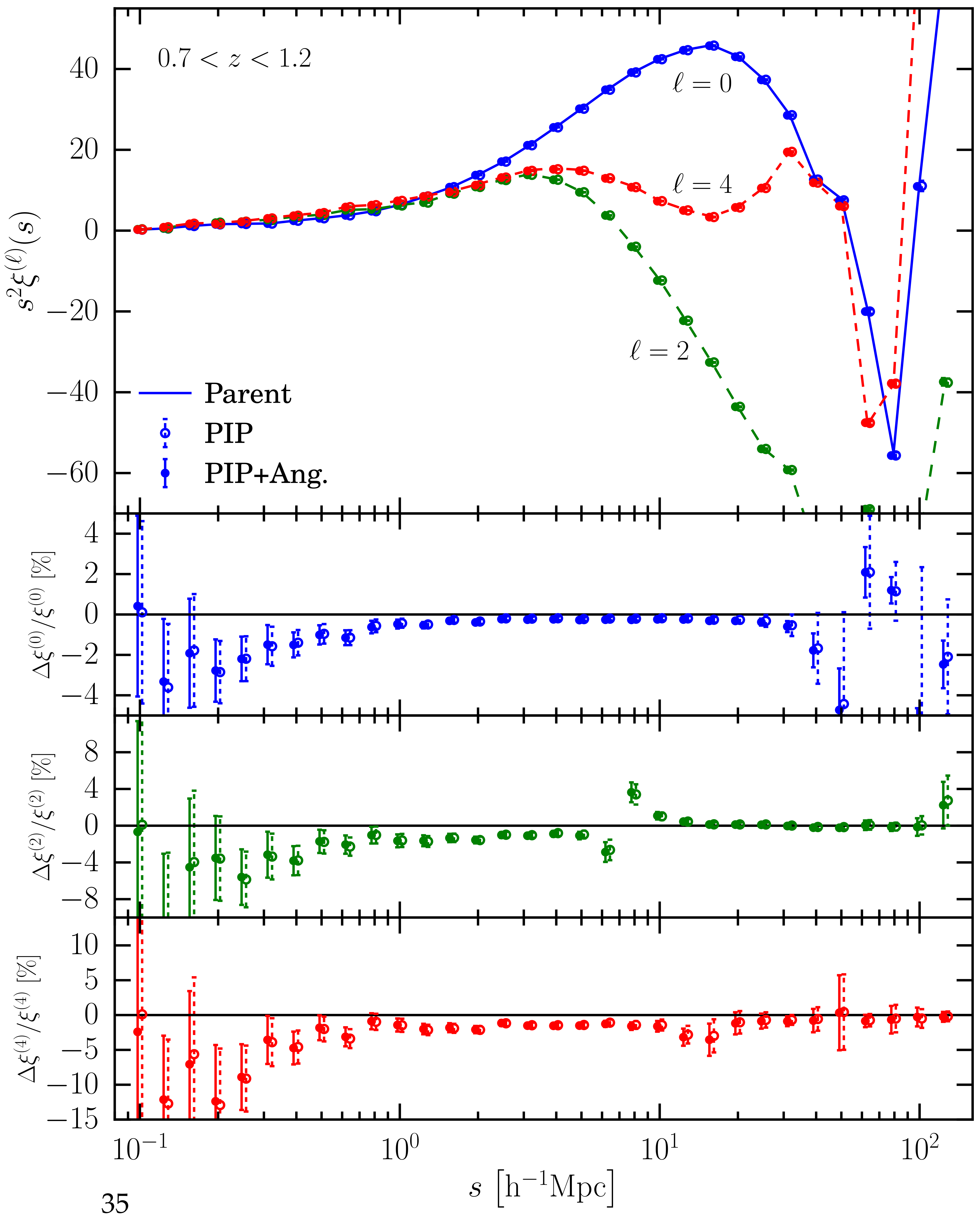
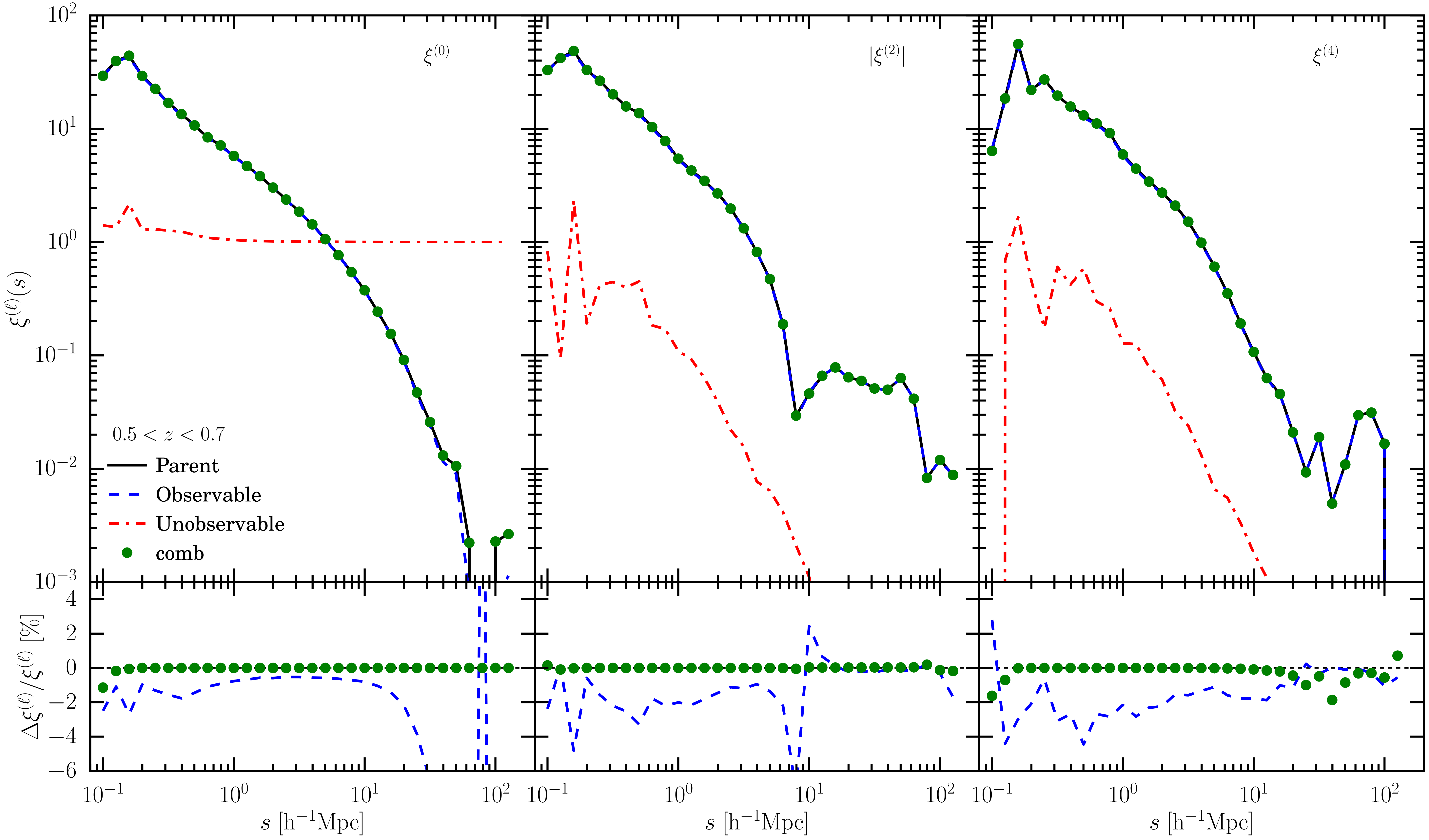


CONSISTENCY TESTS

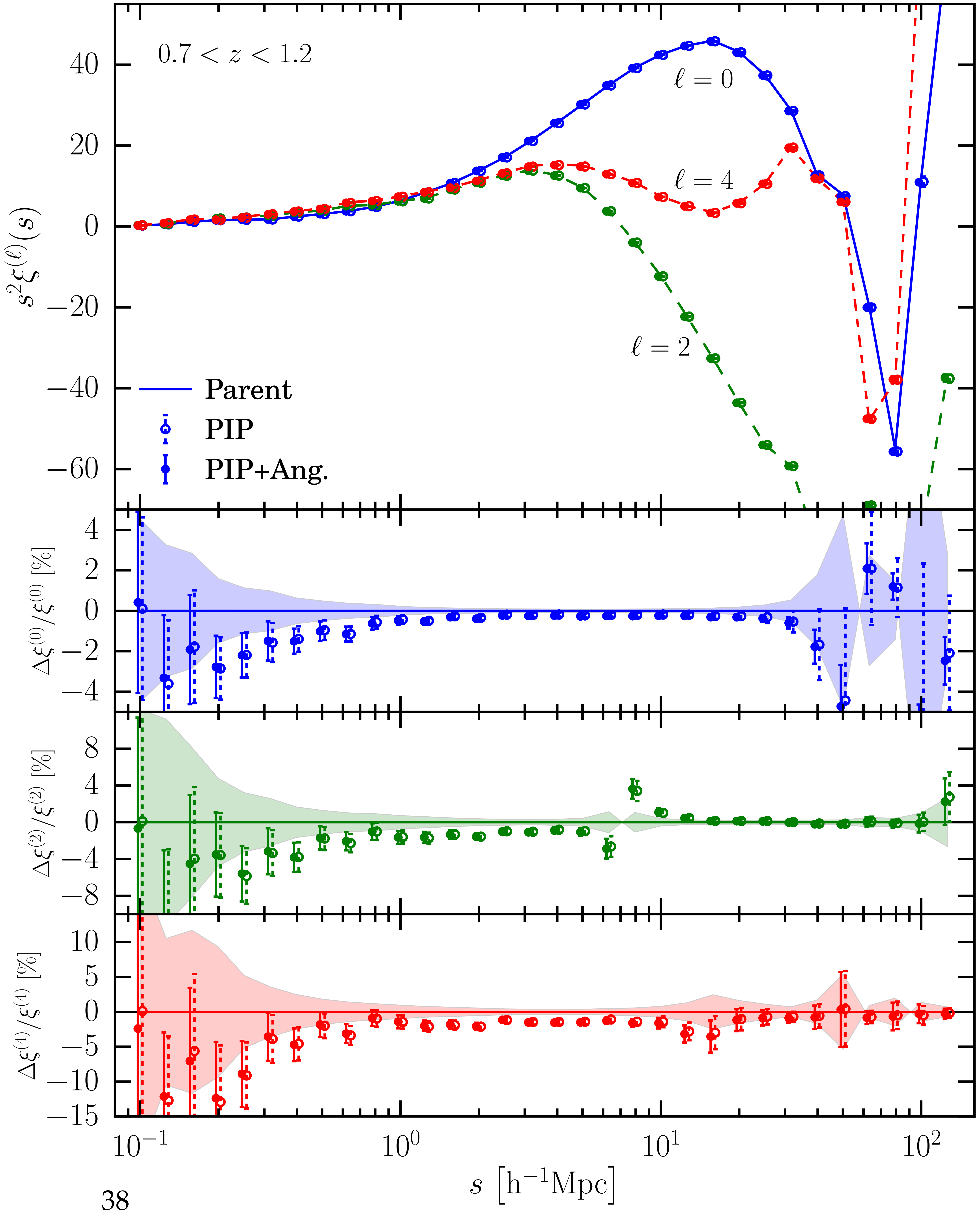
$$\boxed{\xi_{\text{par}}(\mathbf{r}) = \frac{DD_{\text{par}}(r) - 2DR_{\text{par}}(r)}{RR(r)} + 1}$$

$$\xi_{\text{par}}(\mathbf{r}) = \left[\frac{DD_{\text{obs.}}(r) - 2DR_{\text{obs.}}(r)}{RR(r)} + 1\right] + \left[\frac{DD_{\text{unobs.}}(r) - 2DR_{\text{unobs.}}(r)}{RR(r)} + 1\right] - 1$$

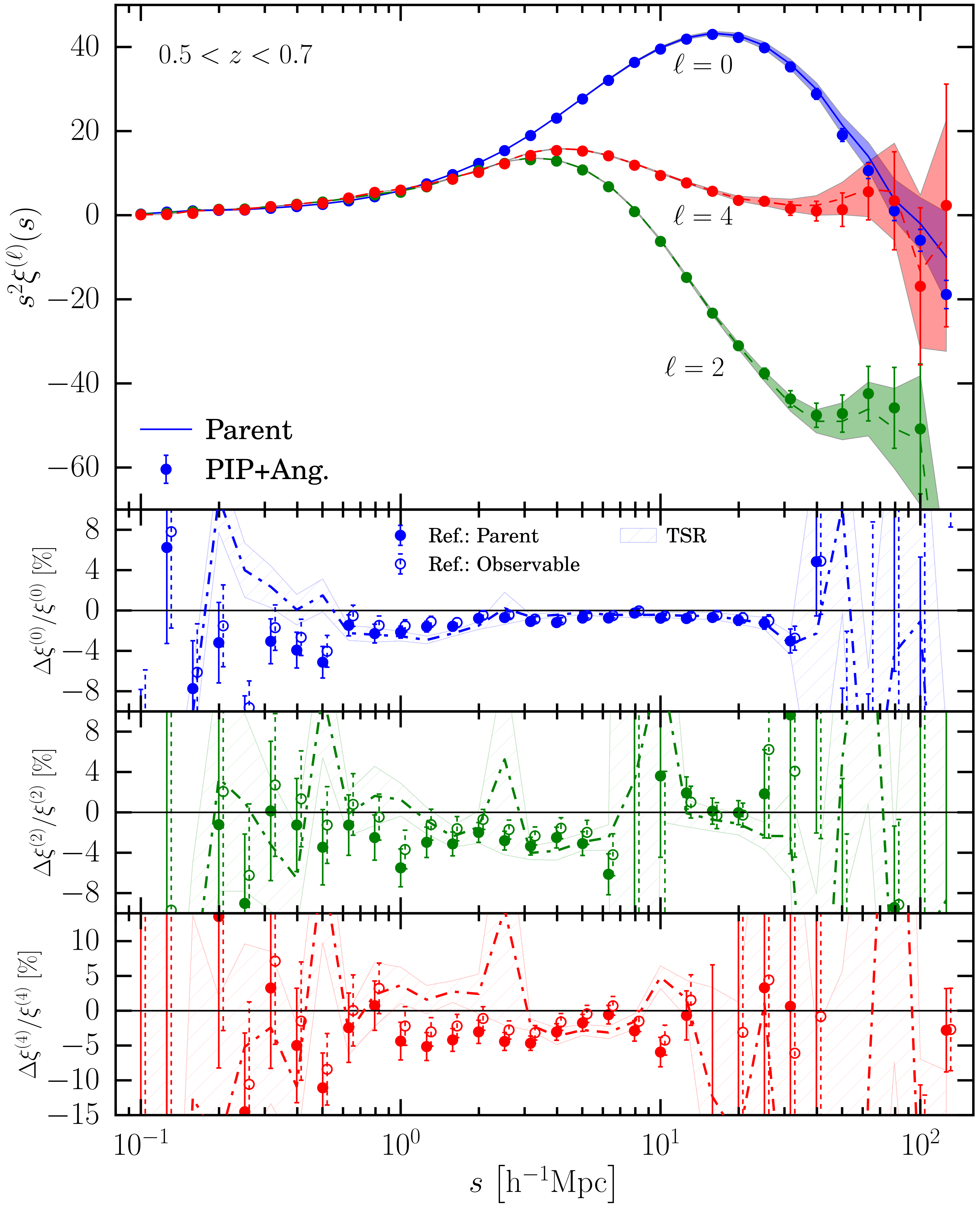
CONSISTENCY TESTS

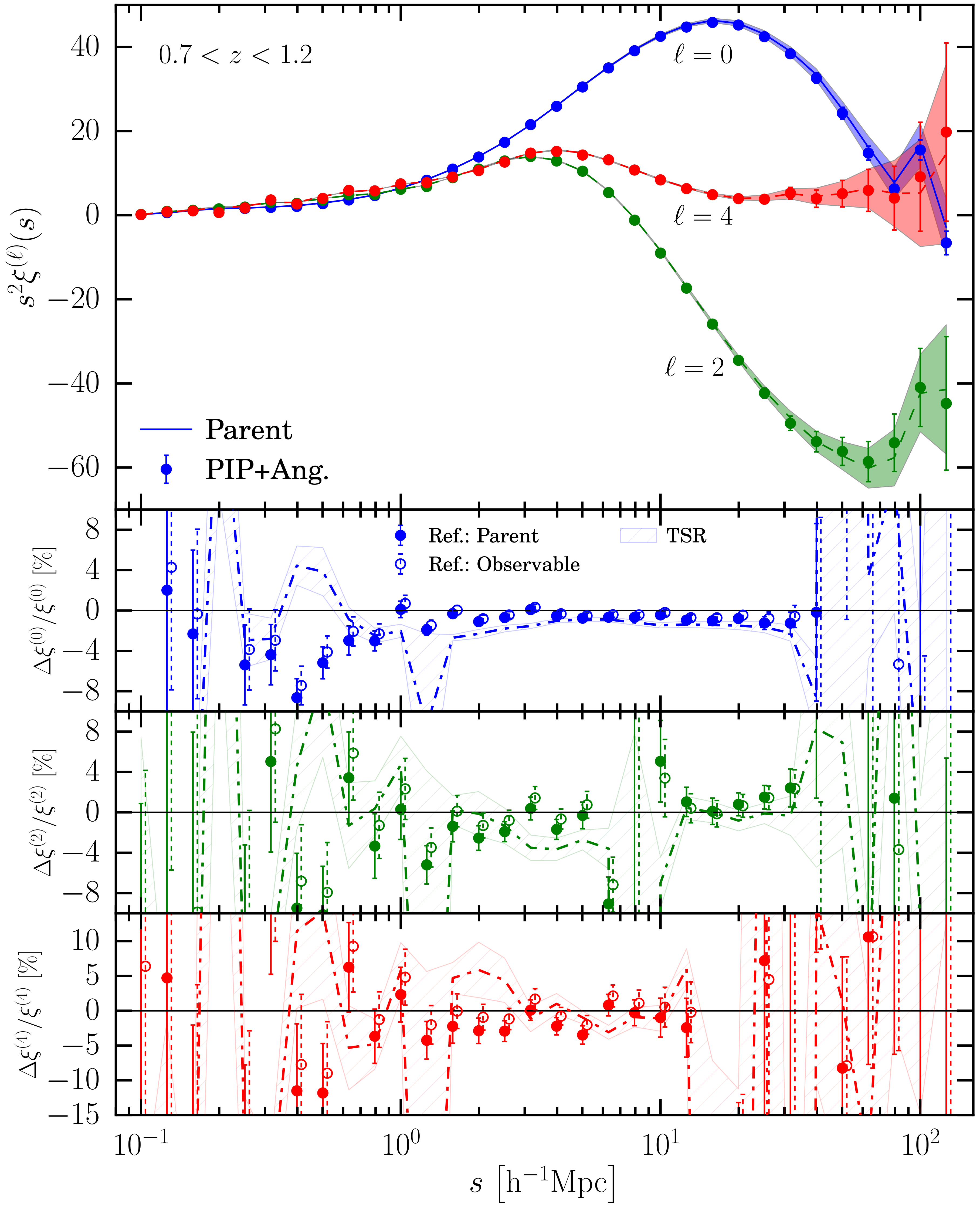


CONSISTENCY TESTS



OBS. SYSTEMATIC BIAS





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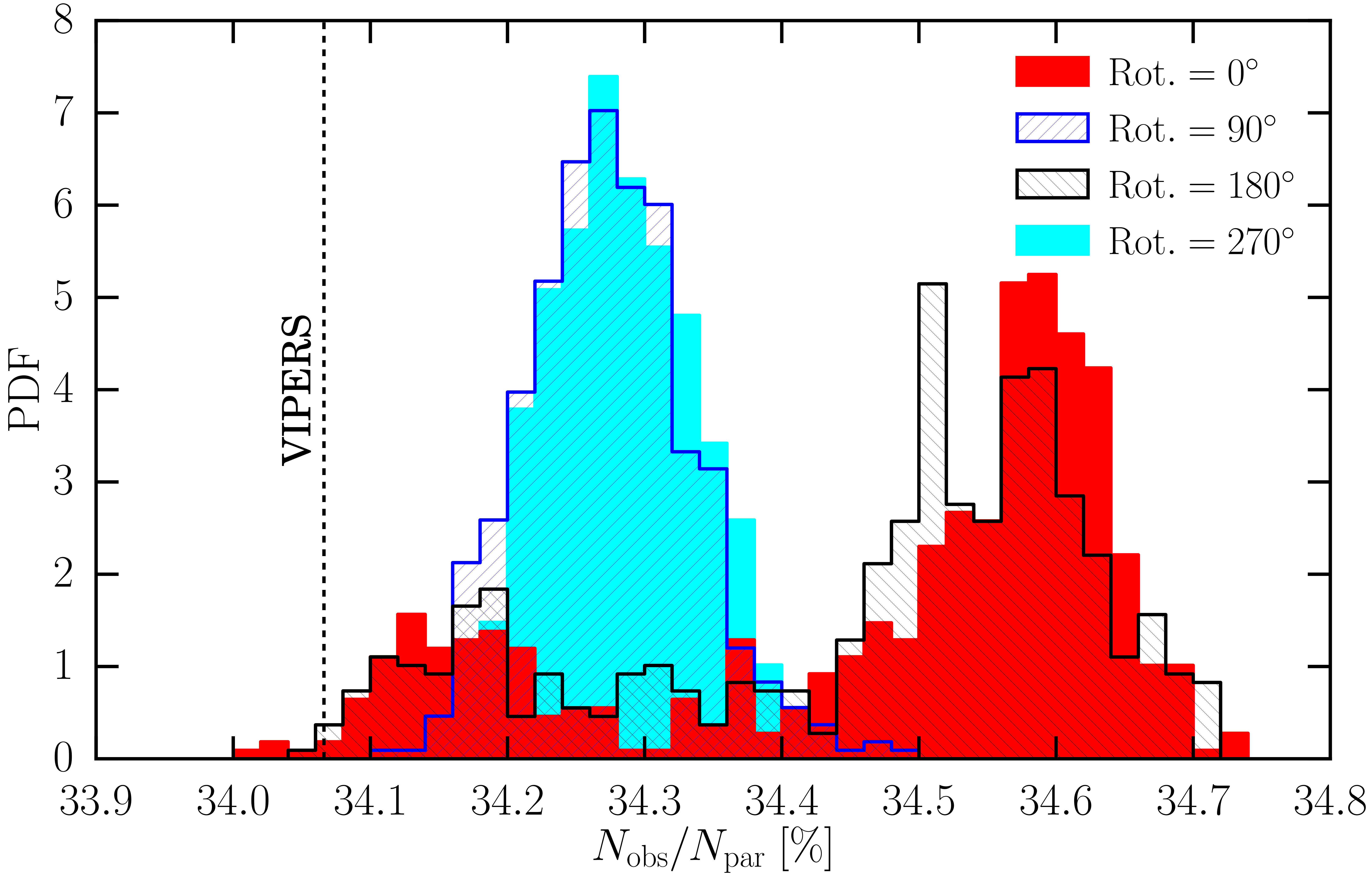
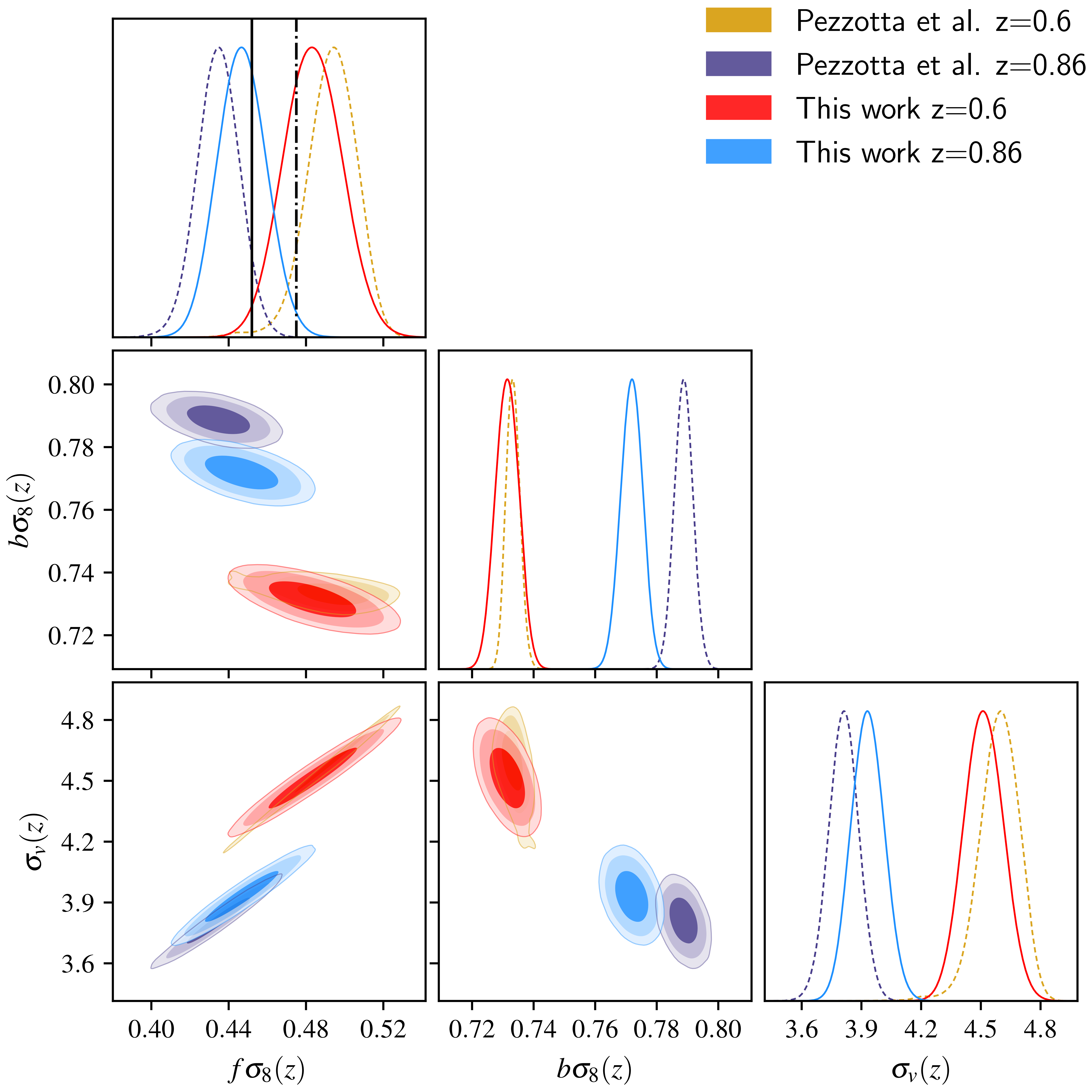


THEORETICAL SYSTEMATICS

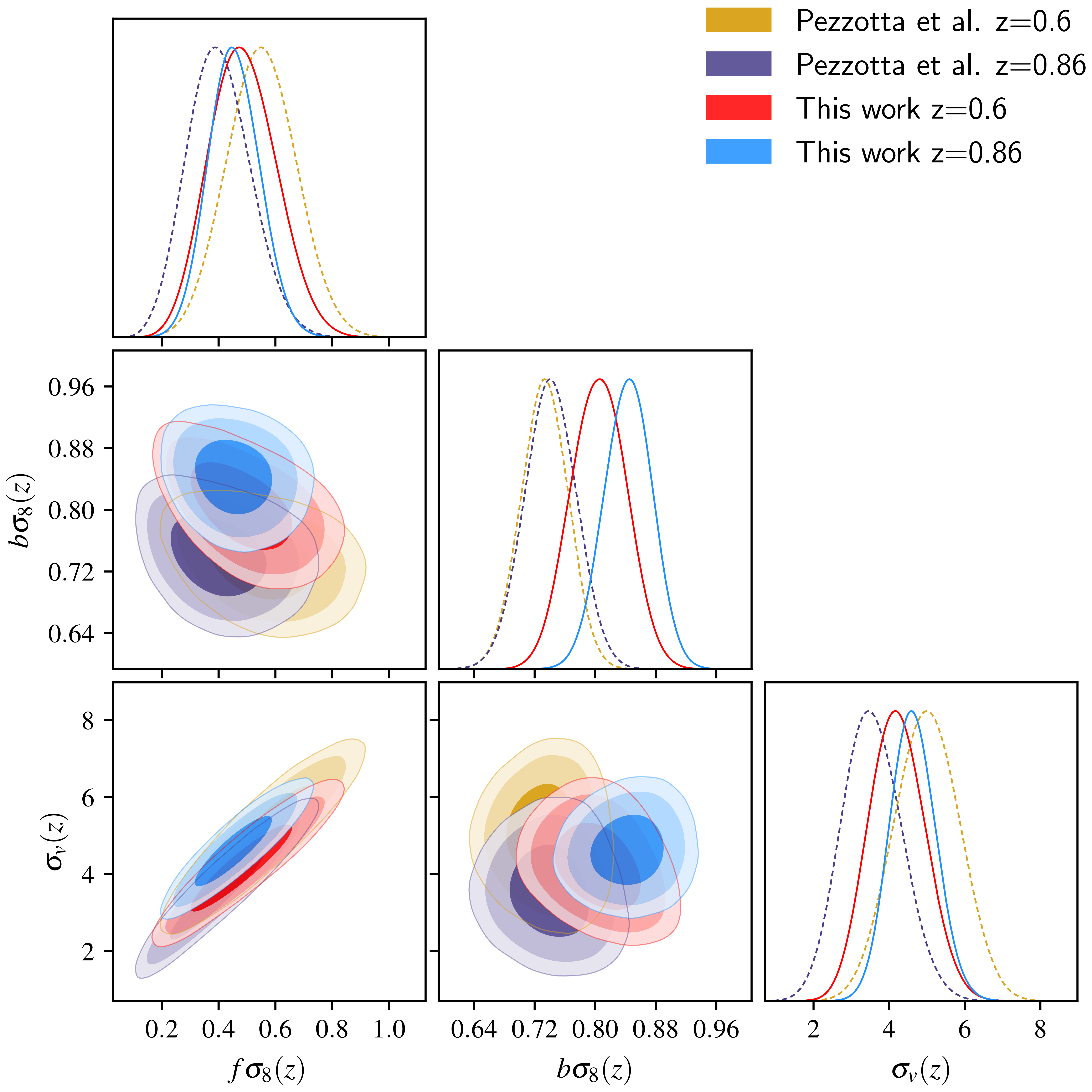
TNS Model (Taruya et al. 2010)

$$P^s\left(k,\mu_k\right)=D\left(k\mu_k\sigma_{12}\right)\left[b^2P_{\delta\delta}+2\mu_k^2fbP_{\delta\theta}+\mu_k^4f^2P_{\theta\theta}+A\left(k,\mu_k,f,b\right)+B\left(k,\mu_k,f,b\right)\right]$$

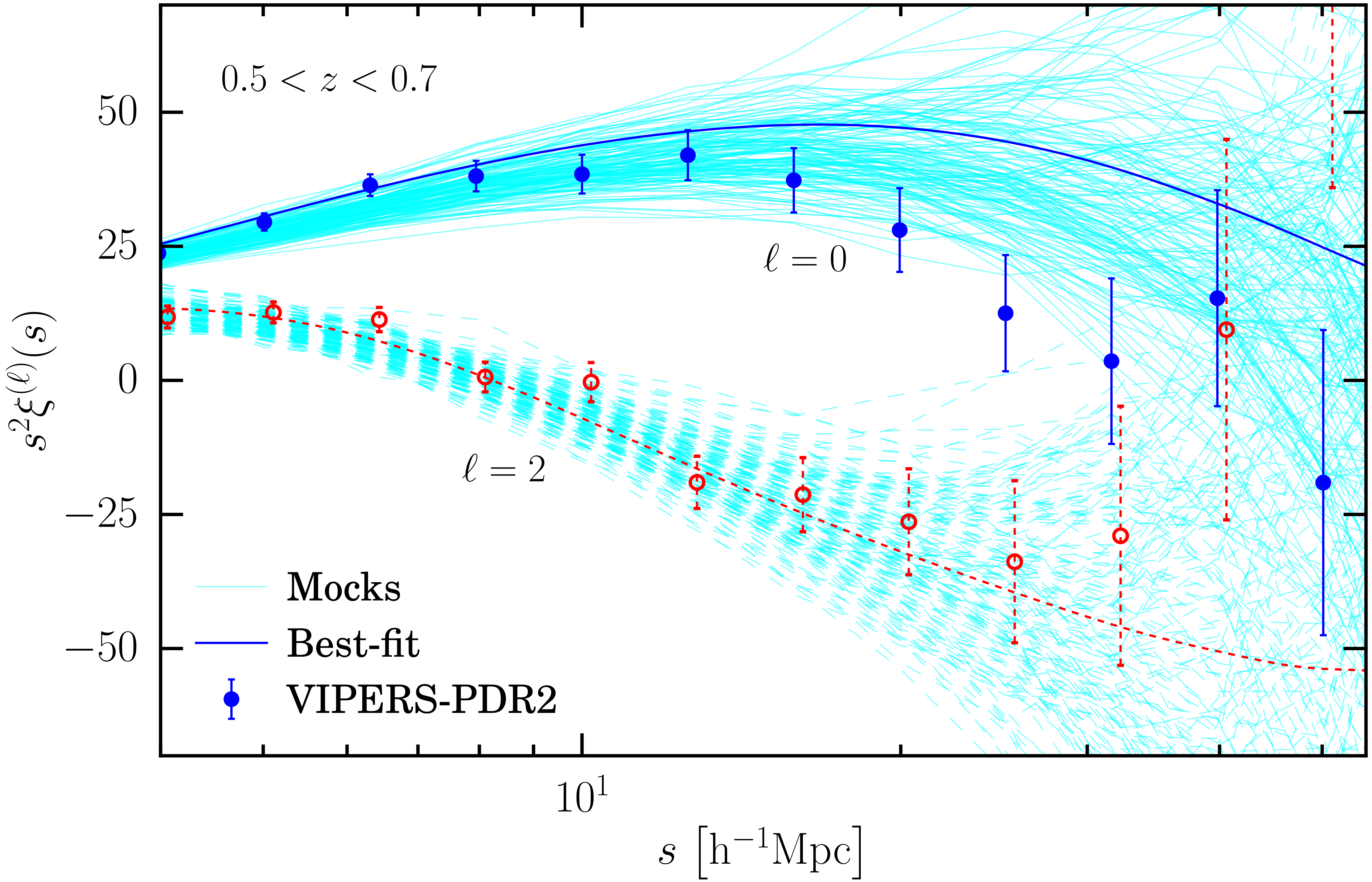
THEORETICAL SYSTEMATICS



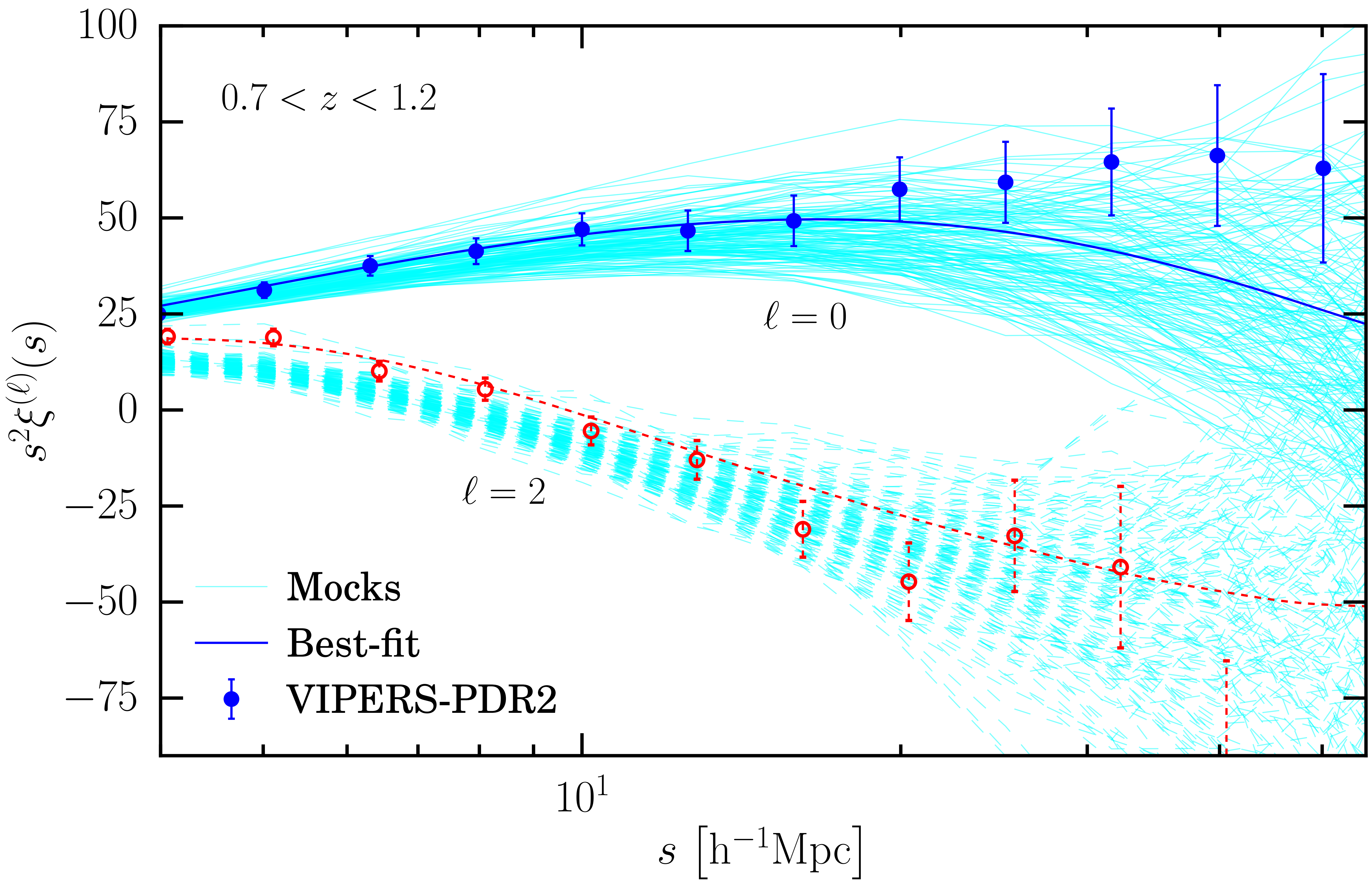
GROWTH RATE ESTIMATES



BEST-FIT MODELS



BEST-FIT MODELS



CONCLUSIONS

- Potentially unbiased estimates of the 2PCF;
- Sub-percent level accuracy on scales larger than 1Mpc/h;
- Confirm the robustness of TSR method but non-parametric;
- Confirm growth rate estimates in VIPERS-PDR2 paper release;