Can We Measure Galaxy Environments with Photometric Redshifts?

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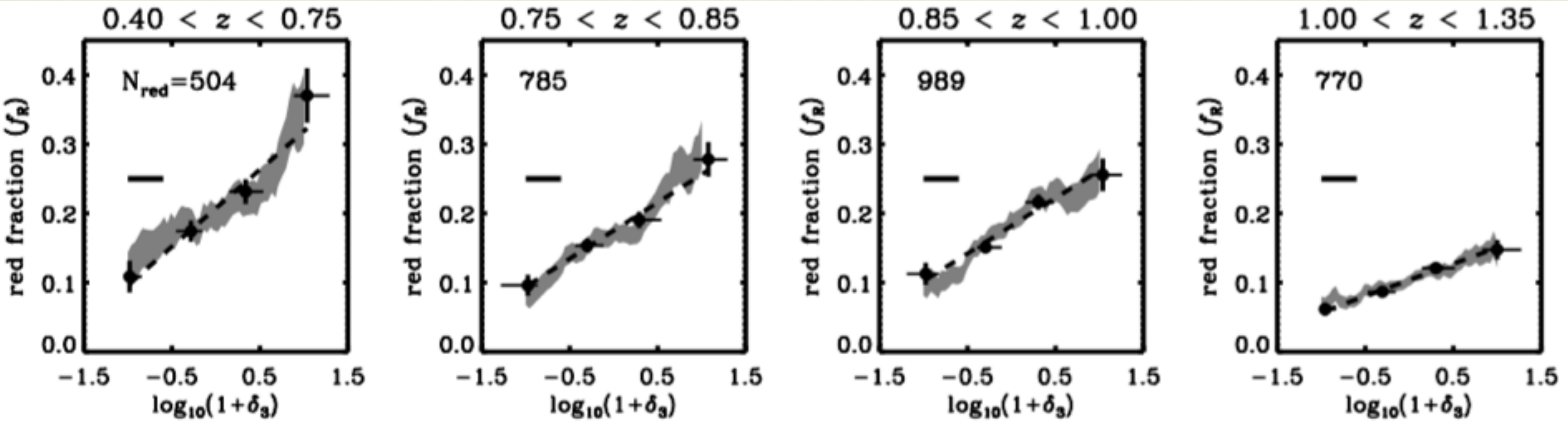
Why we care about Environment?

1. Galaxy properties such as star formation rate, color and morphology are strongly correlated with galaxy environment.

Galaxies located in dense environments, such as galaxy groups and clusters, tend to be redder, elliptical and with lower star formation rates.



(Cooper et al. 2007)

2. Several physical processes, such as ram pressure stripping, galaxy-galaxy mergers and tidal stripping, have been proposed to explain the observed relation between environment and galaxy properties.

Spectral-z vs. Photo-z

	Advantage	Disadvantage
Spectroscopic Samples	High Accuracy SDSS: $\Delta z \sim 0.0005$ (~1 Mpc at z = 0.3)	Small sample size Incompleteness
Photometric Samples	Large sample size reach to fainter mag	Photo-z Uncertainty Pan-STARRS: $\Delta z \sim 0.05$ (~20 Mpc at z = 0.3)

Most of large sky surveys (Pan-STARRS, DES, HSC) do not provide galaxy samples with spectroscopic redshift measurements.

1. Can we use photo-z samples to measure environment reliably?

2. What are the systematics in the environment measurement between spectral-z samples and photo-z samples?

3. What is the optimal choice for density measurement that can reliably recover the underlying environments?

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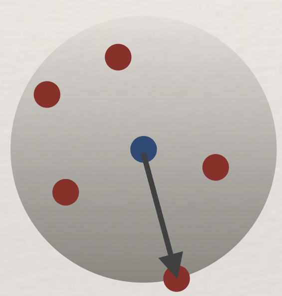
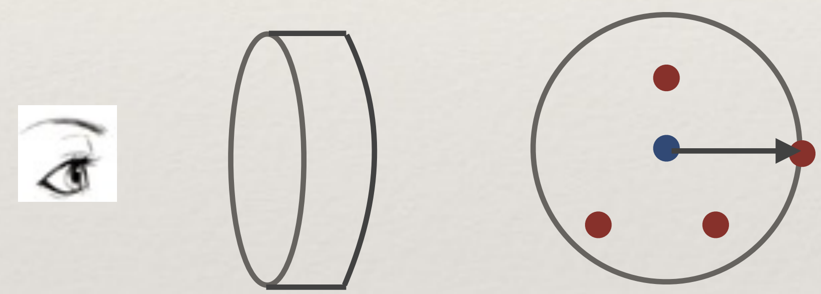
Most of large sky surveys (Pan-STARRS, DES, HSC) do not provide galaxy samples with spectroscopic redshift measurements.

To investigate whether galaxy environments can be measured with photo-z samples, we use Pan-STARRS mock catalog based on Millennium simulation to calculate spectral-z and photo-z environments at first.

Finally, we also use real observation data from Pan-STARRS Medium Deep survey to verify our study.

Definition of Environment

N[th] Nearest Neighbor Method

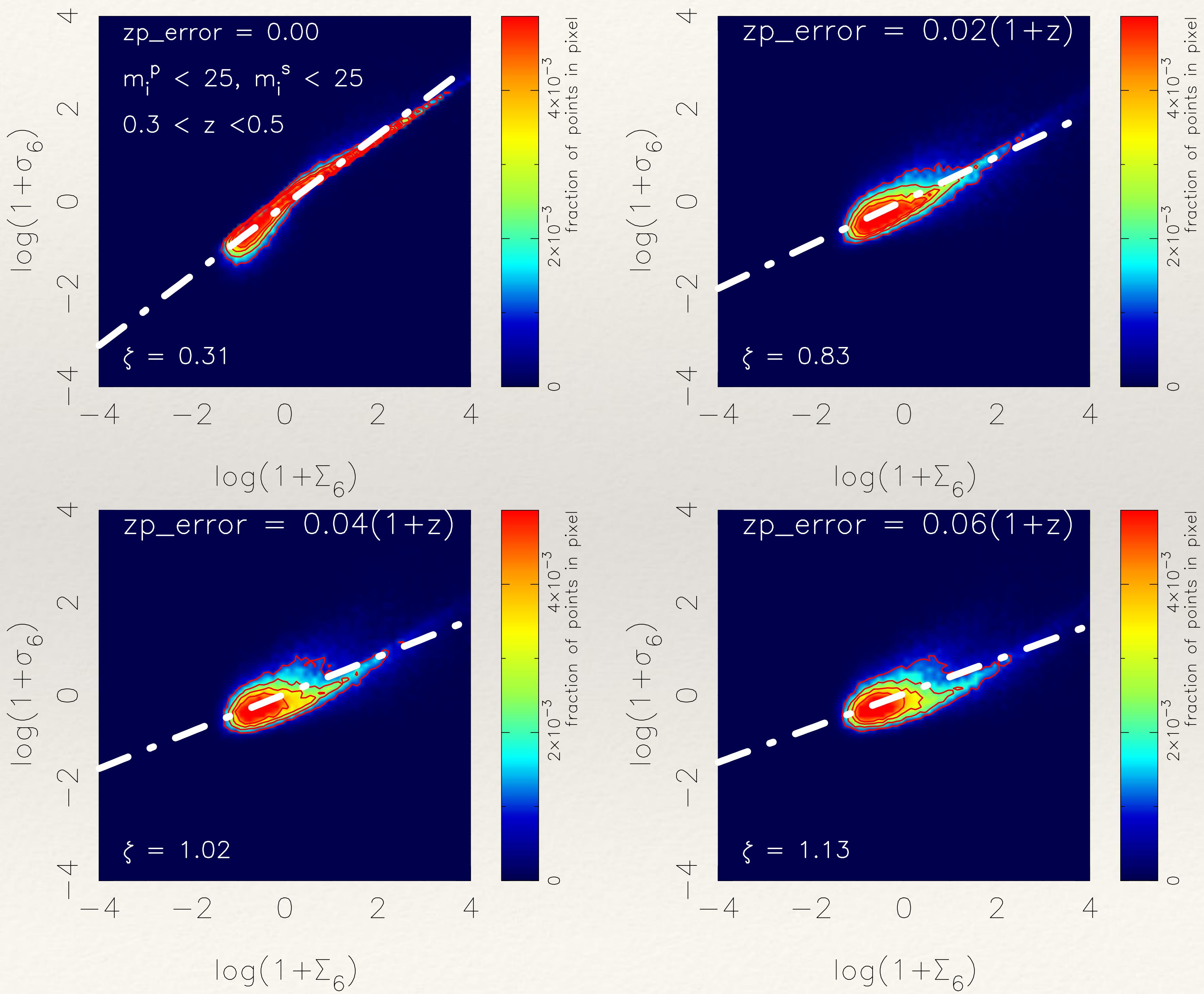
3D real-space Environment	2D Projected Environment
	
$\Sigma_n = \frac{n+1}{(4/3)\pi r_n^3}$	$\sigma_n = \frac{n+1}{\pi r_n^2}$

$$1 + \rho_{over} = \frac{\rho_i}{\bar{\rho}}$$

Quantifying differences between Environment Measurements

$$\zeta^2 = \frac{1}{N}\sum_{i=1}^{N}(x_i - x_f)^2$$

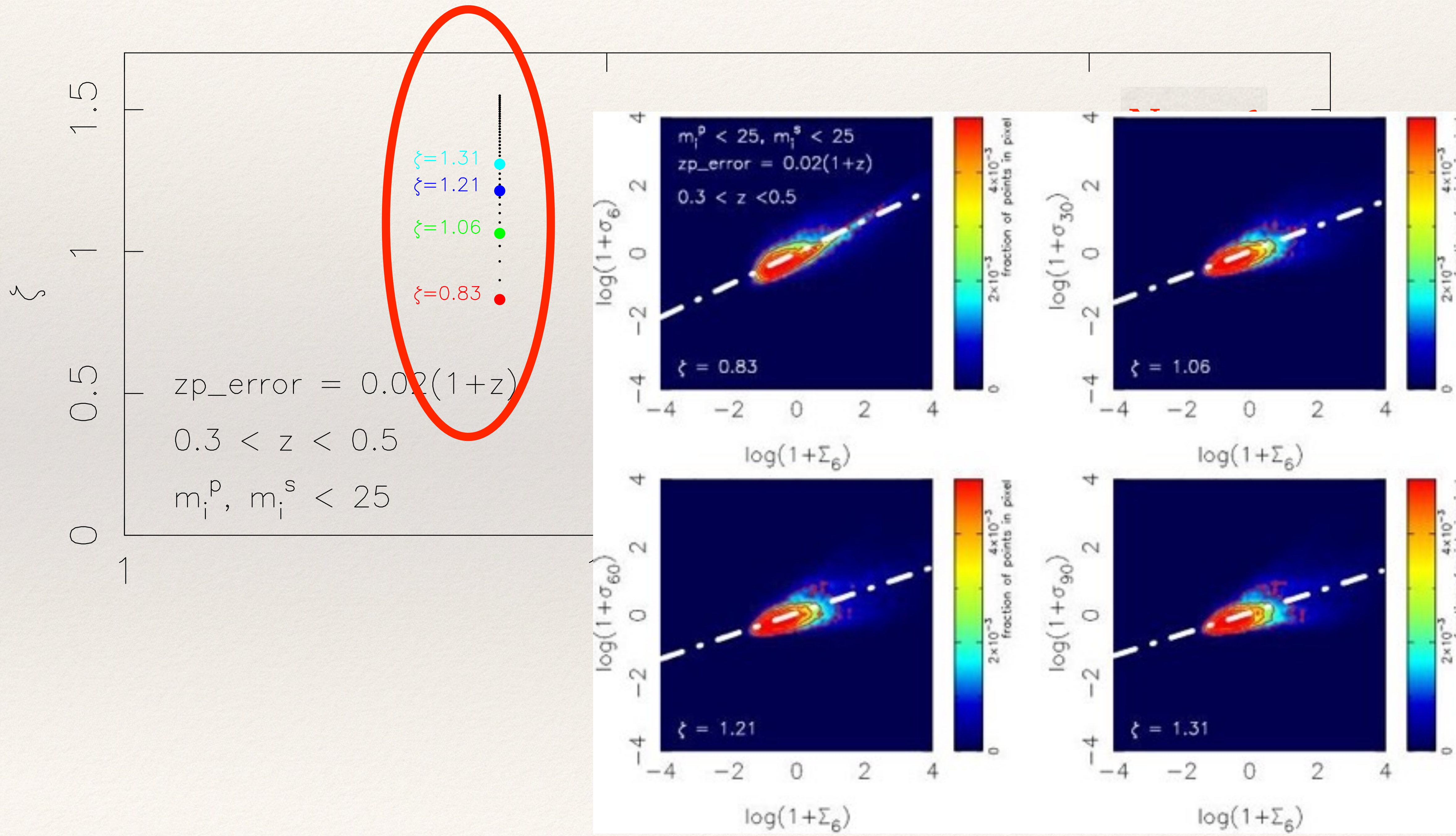
A high (low) ζ indicates a weak (strong) correlation.



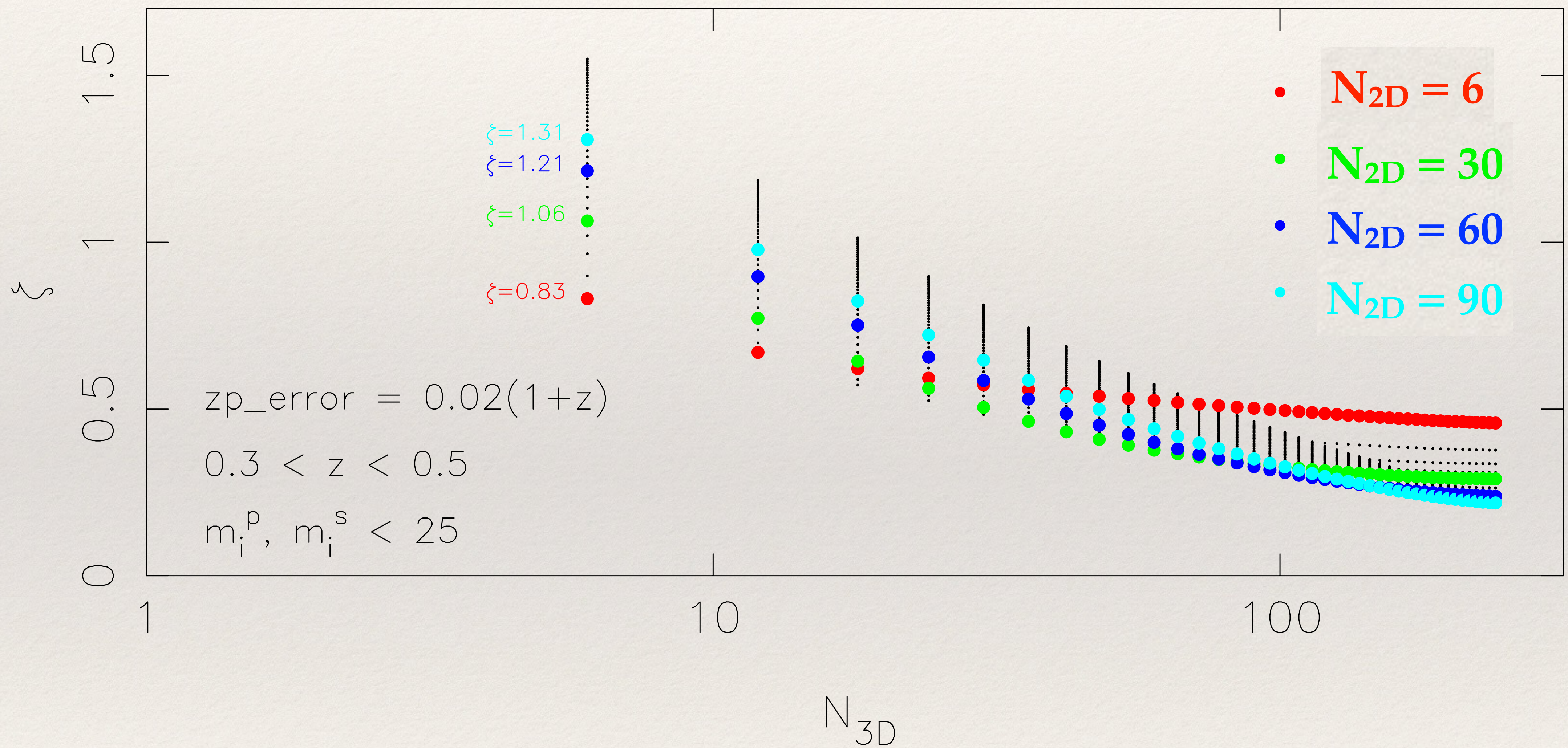
Results

Parameter	Meaning	Influence in measurement
Photo-z Error	Observed Uncertainty	Sensitive to measurement
V_{cut}	Distance of Light-of-Sight	If $\Delta V_{cut} \sim \Delta z$, not sensitive to measurement
N_{2D}	Scale of environment	**Optimized Scheme**
m_i^p	Mag limit for presenting the results	Setting $m_i^p < 25$ in our study
m_i^s	Mag limit for searching the neighbors	Fainter samples are recommended for environment study.

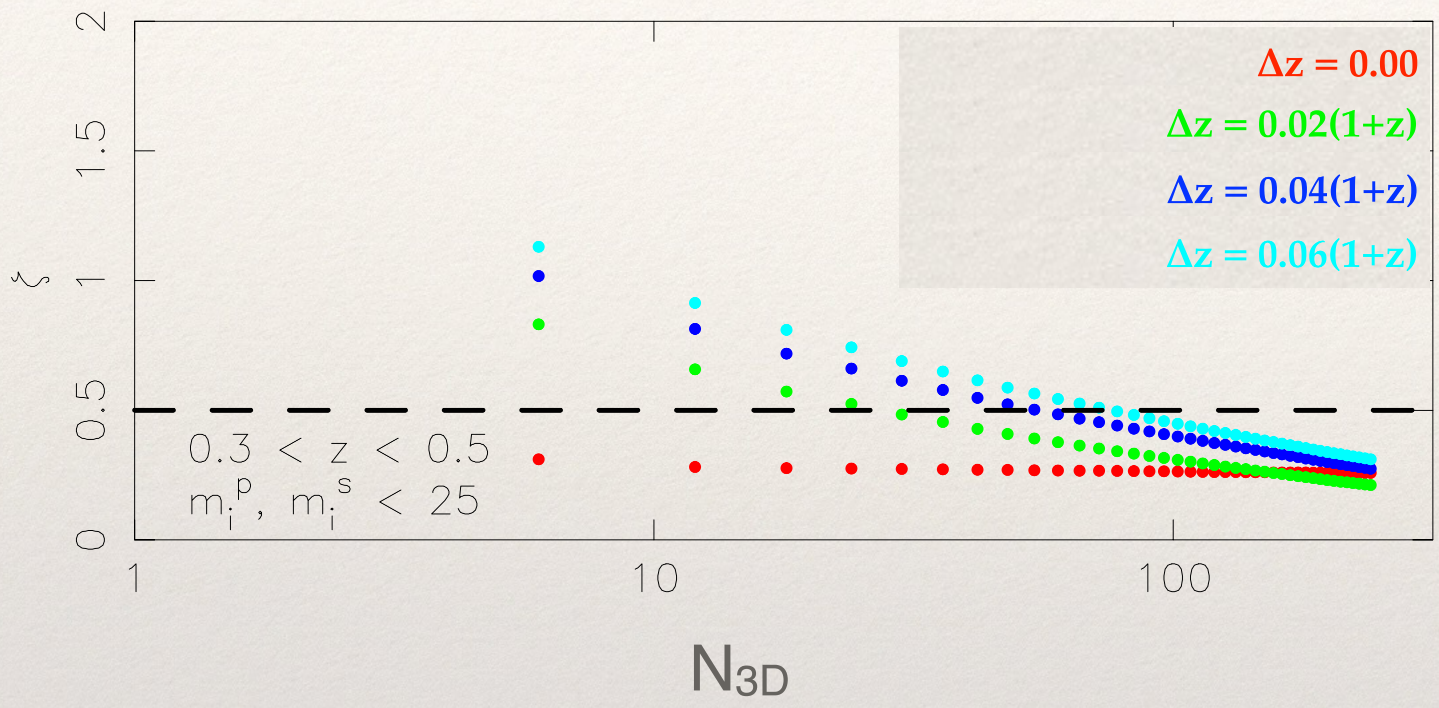
How to optimize the choice of N_{2D}?



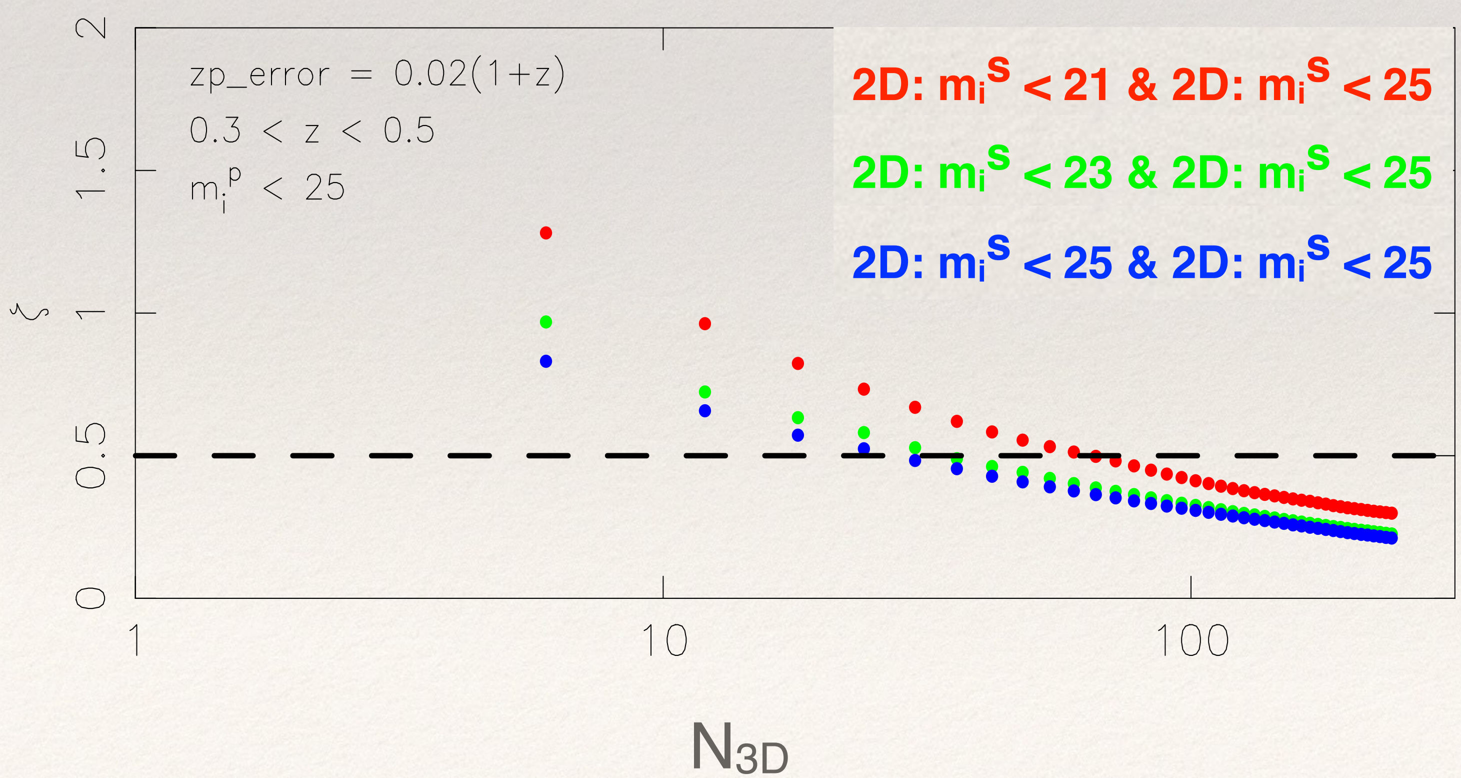
How to optimize the choice of N_{2D}?



Result of Optimized Scheme

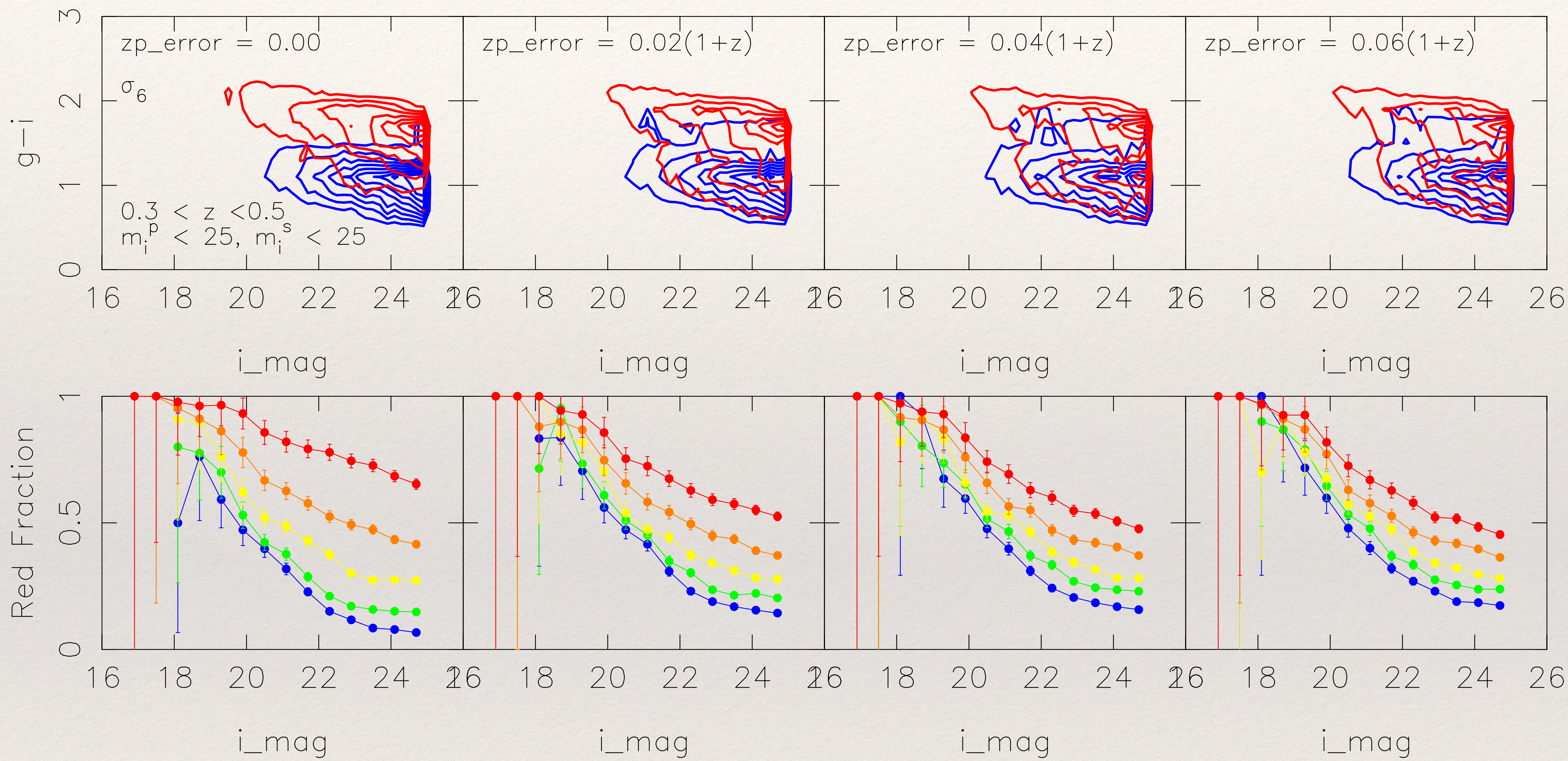


Larger N_{2D} is recommended for greater photo-z errors to achieve the same ζ value.



For given $m_i^p < 25.0$, the 2D environments measured with fainter magnitude limits yield better correlation with the 3D real-space environments.

Color-Magnitude diagram



Red contour: 20% most dense environments.

Blue contour: 20% least dense environments.

20% most dense

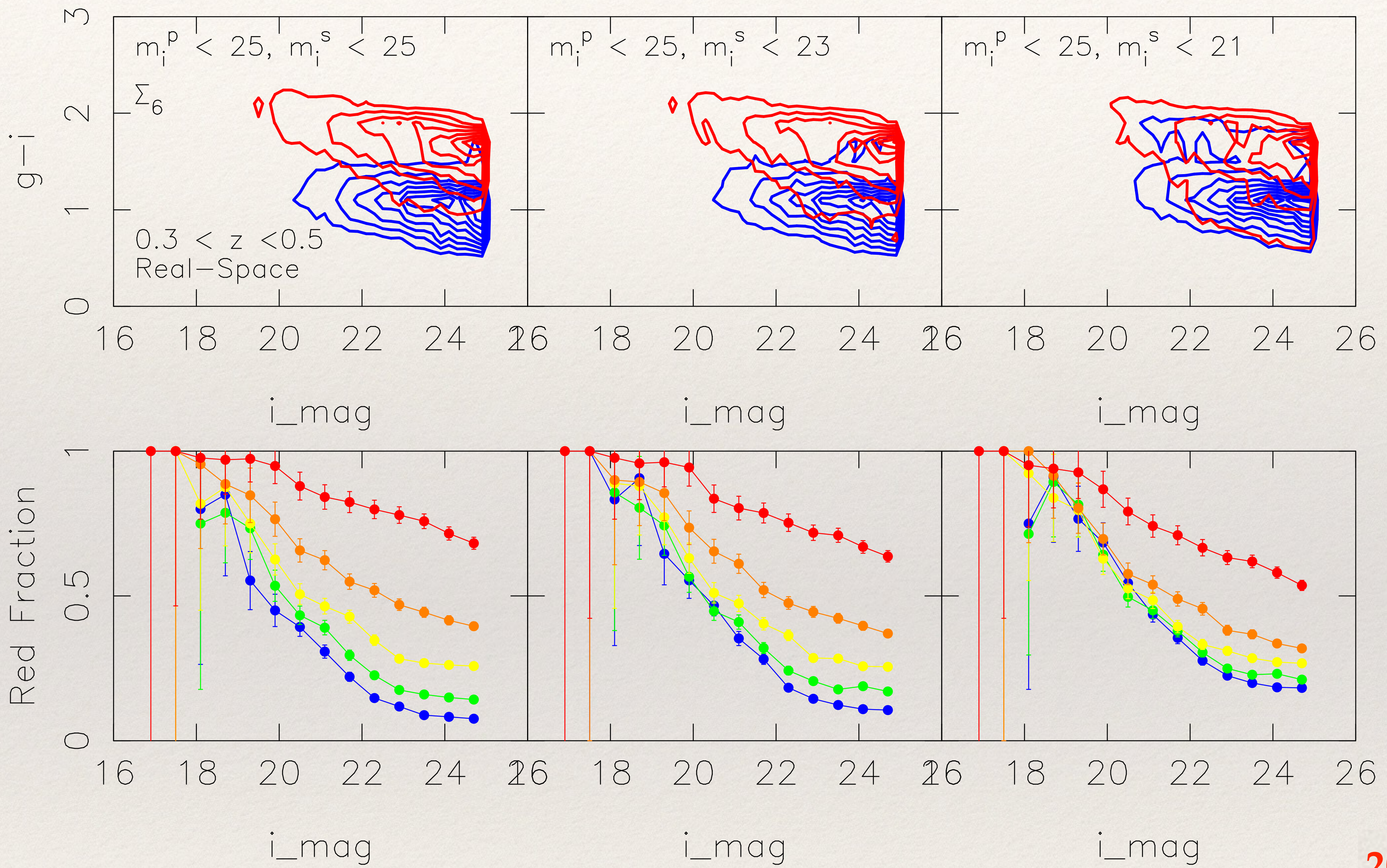
60%~80% densest

40%~60% densest

20%~40% densest

20% least dense

Color-Magnitude diagram



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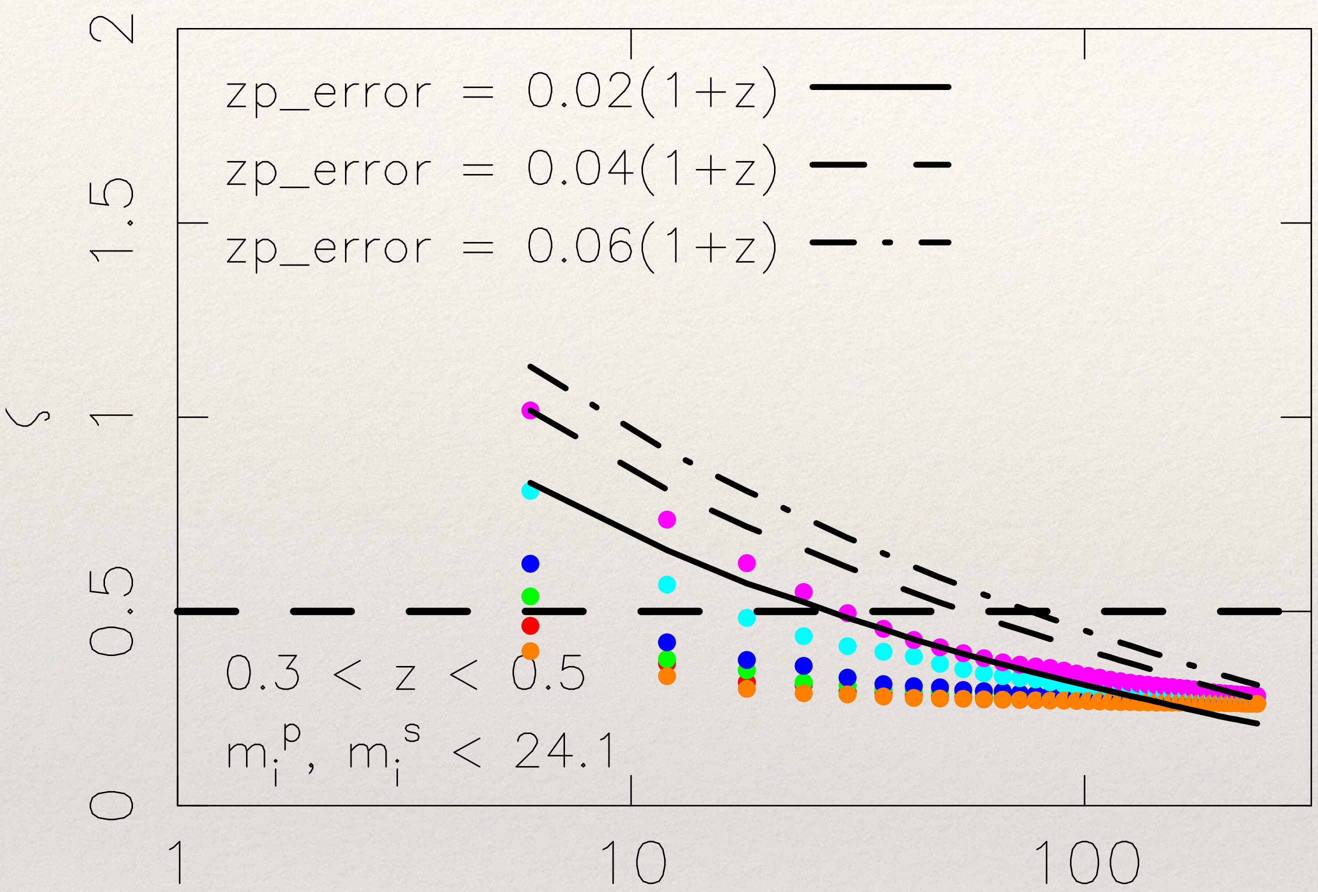
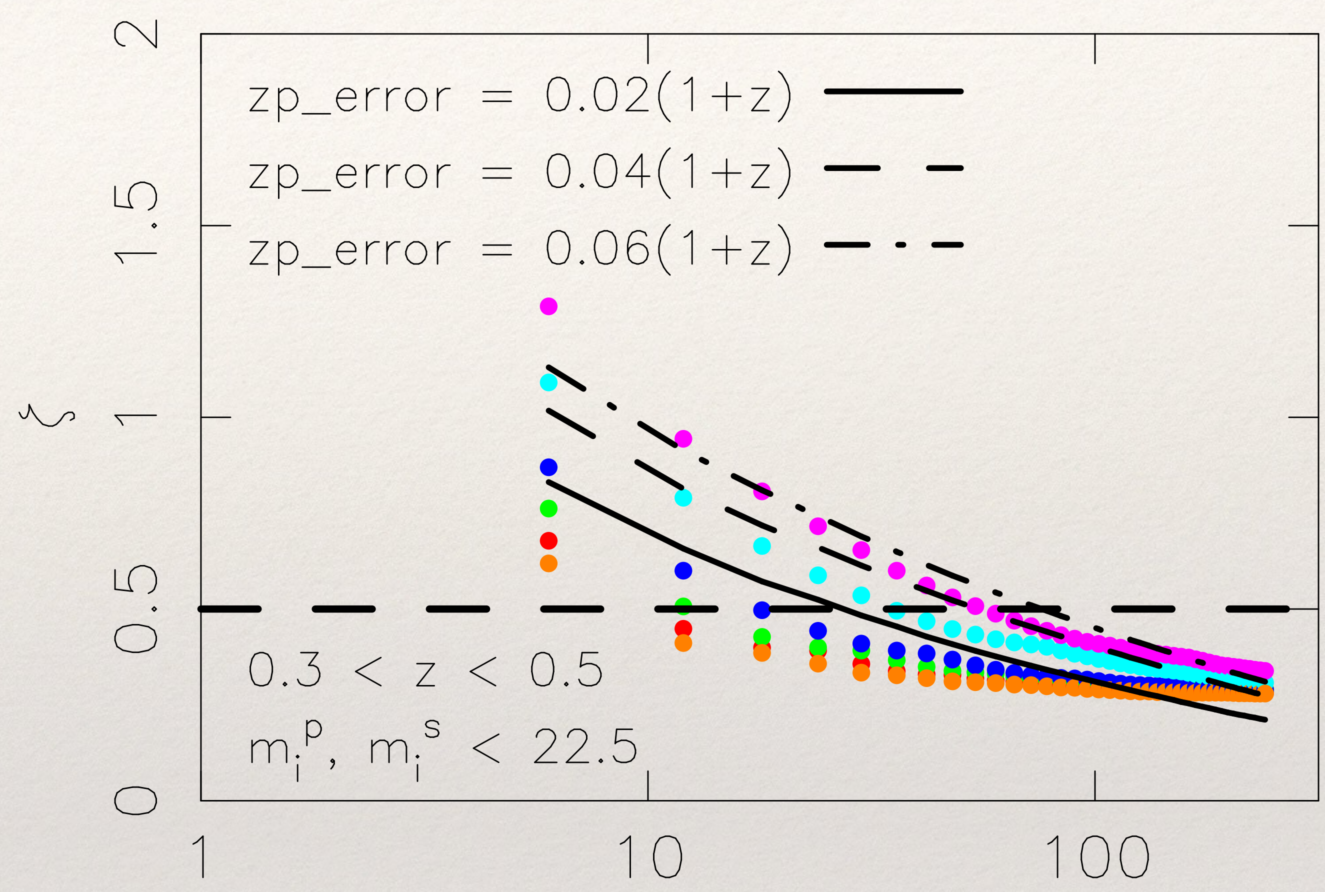
Comparison with Spectroscopic Observation



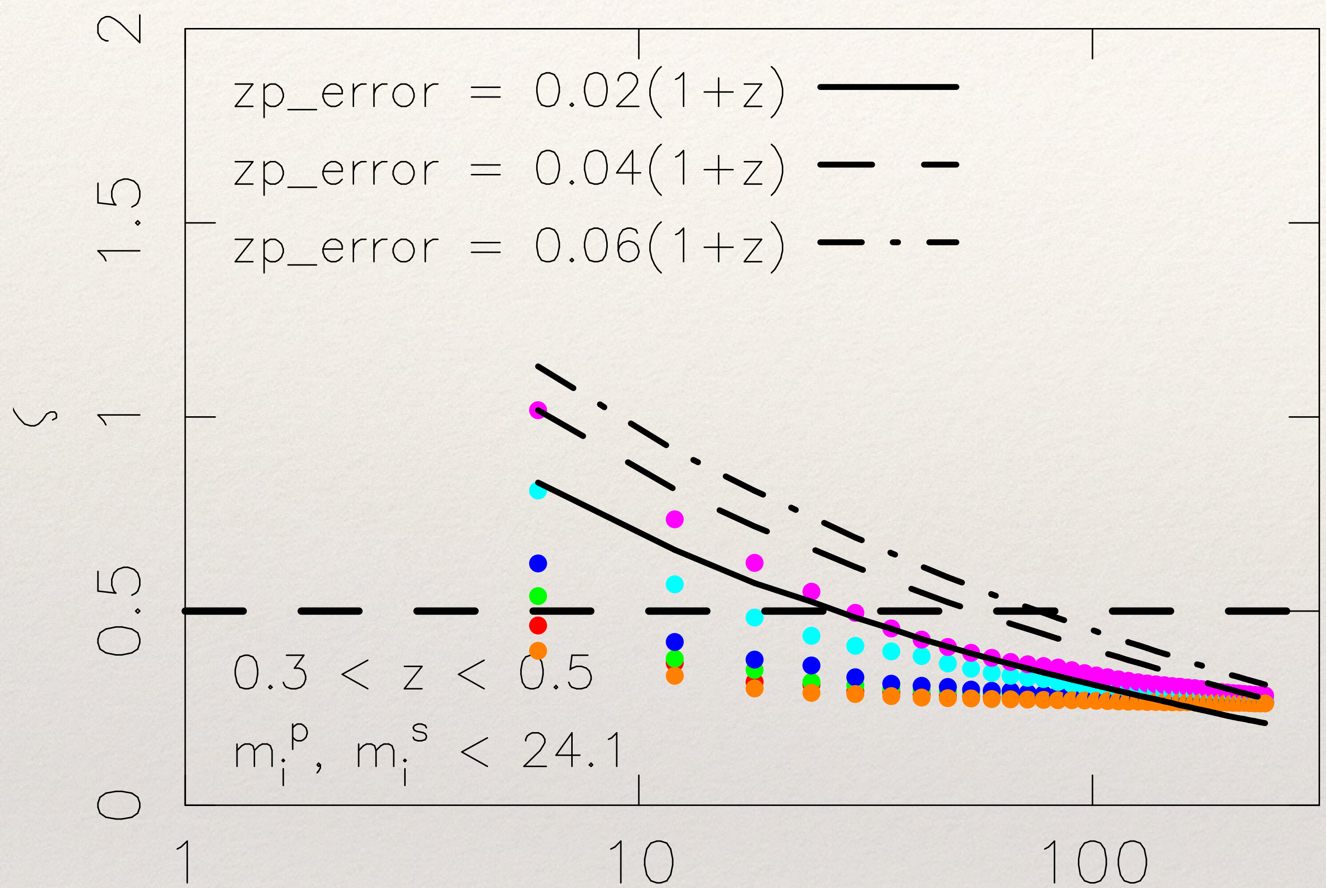
DEEP2: R-band < 24.1 and 50% sampling rate



zCOSMOS: i-band < 22.5 and 30% sampling rate

Completeness: 100%
Completeness: 80%
Completeness: 60%
Completeness: 40%
Completeness: 20%
Completeness: 10%

Comparison with Spectroscopic Observation



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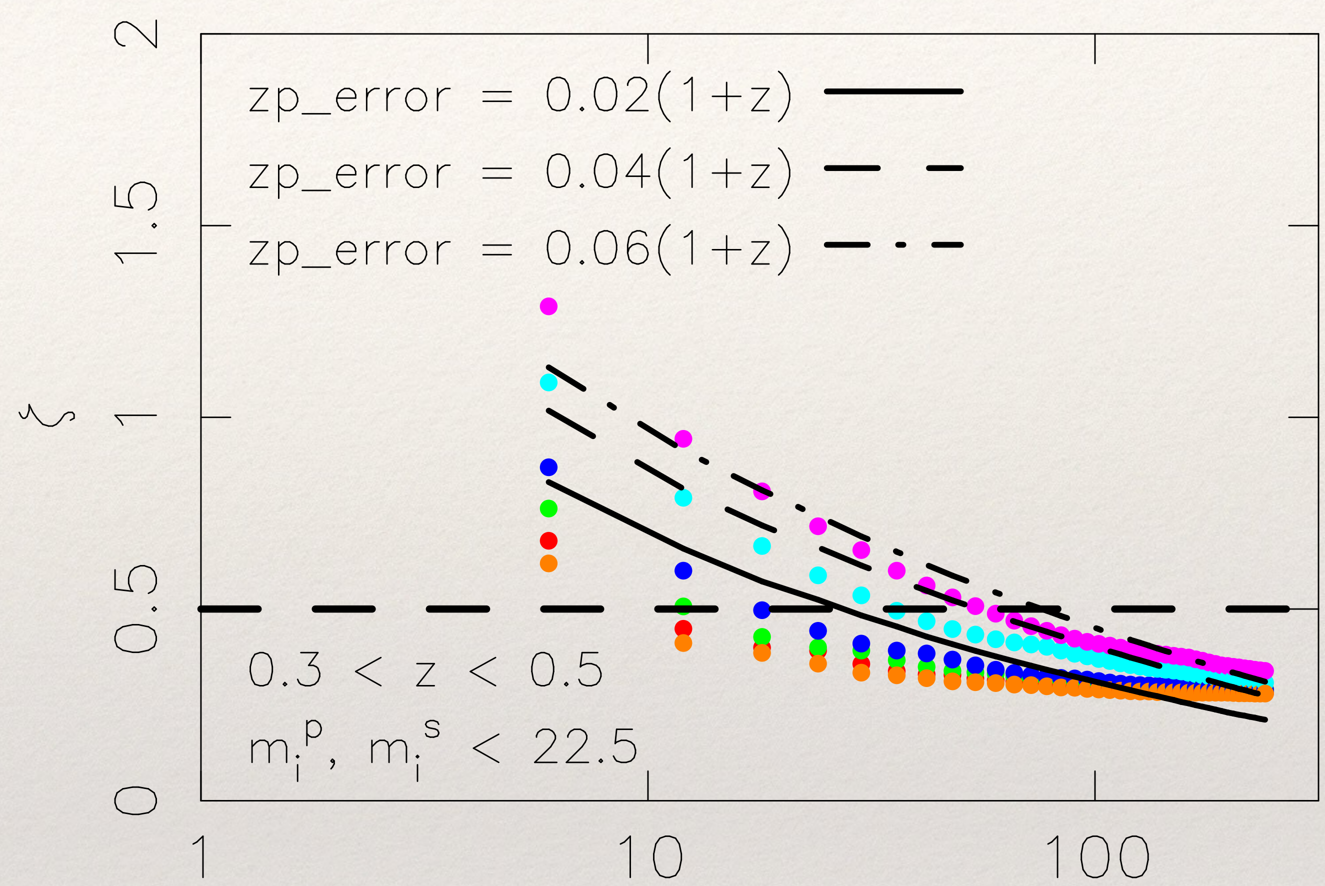
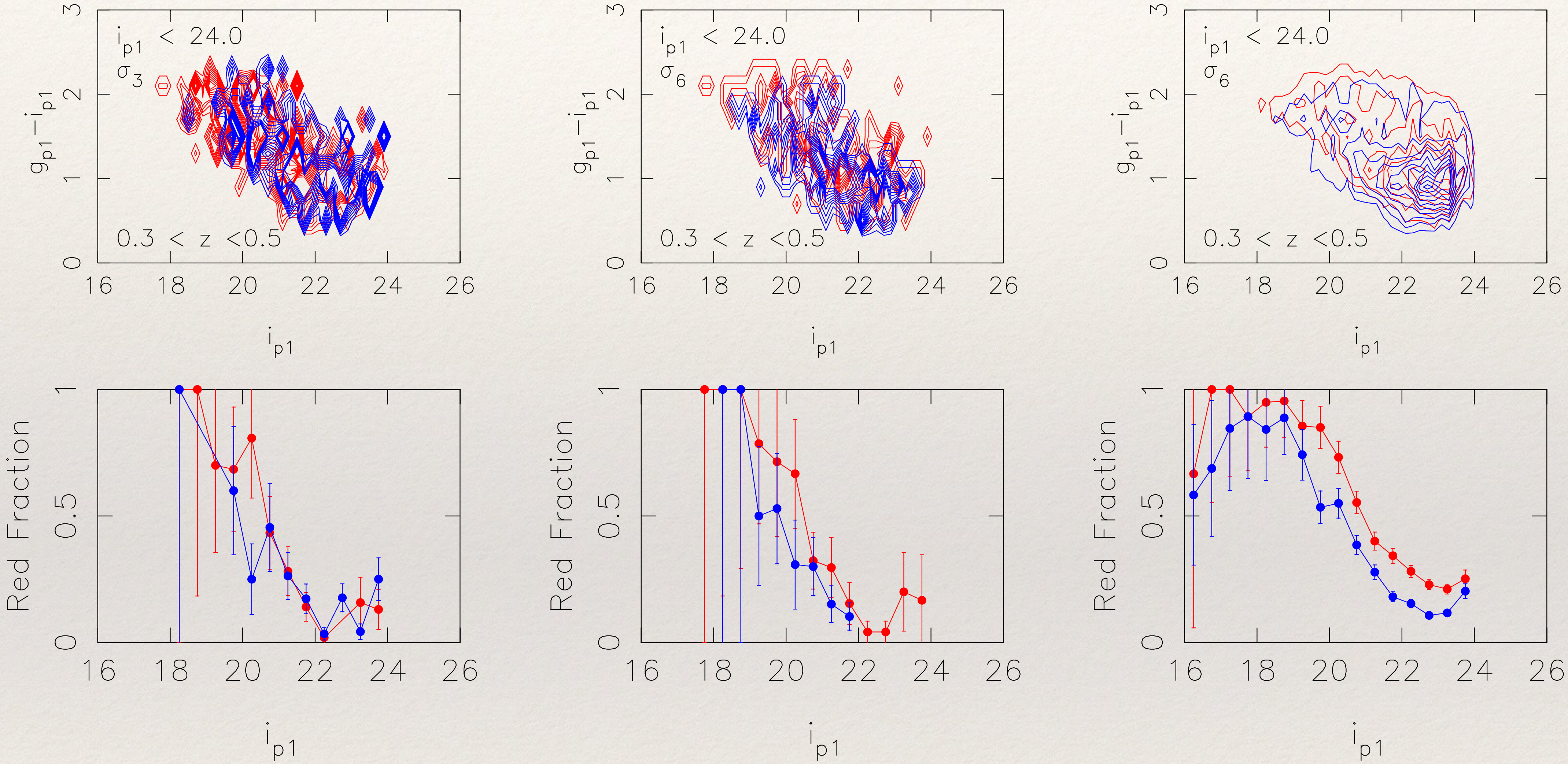


zCOSMOS: i-band < 22.5 and 30% sampling rate

We find that a deep (i < 25) photometric redshift survey with error = 0.02 yields a comparable performance of density measurement to a shallower i < 24.1 (22.5) spectroscopic sample with 20% (40%) sampling rate.

Color-Density Relation for Pan-STARRS Data



DEEP2 EGS	Pan-STARRS EGS	Pan-STARRS
Spectral-z: ~0.5deg2	Photo-z: ~0.5deg2	Photo-z: ~5deg2

Although the photo-z uncertainty in general worsen the density measurement, the random errors can be largely improved given the large volumes probed by a photometric survey.

Conclusions

- Using photo-z samples, galaxy environments are still measurable if suitable parameters are used in calculation.
- The deep (i ~ 25) photometric redshift survey with photo-z error = 0.02(1+z) yields a comparable performance of density measurement to a shallower i ~ 22.5 (24.1) spectroscopic sample with 40% (20%) sampling rate.
- Using data from ~ 5deg^2 of survey area, our results show that it is possible to measure local density and to probe the color-density relation in the PS-MDS, confirming the simulation results. The color-density relation, however, quickly degrades for data covering smaller areas.

Thank you

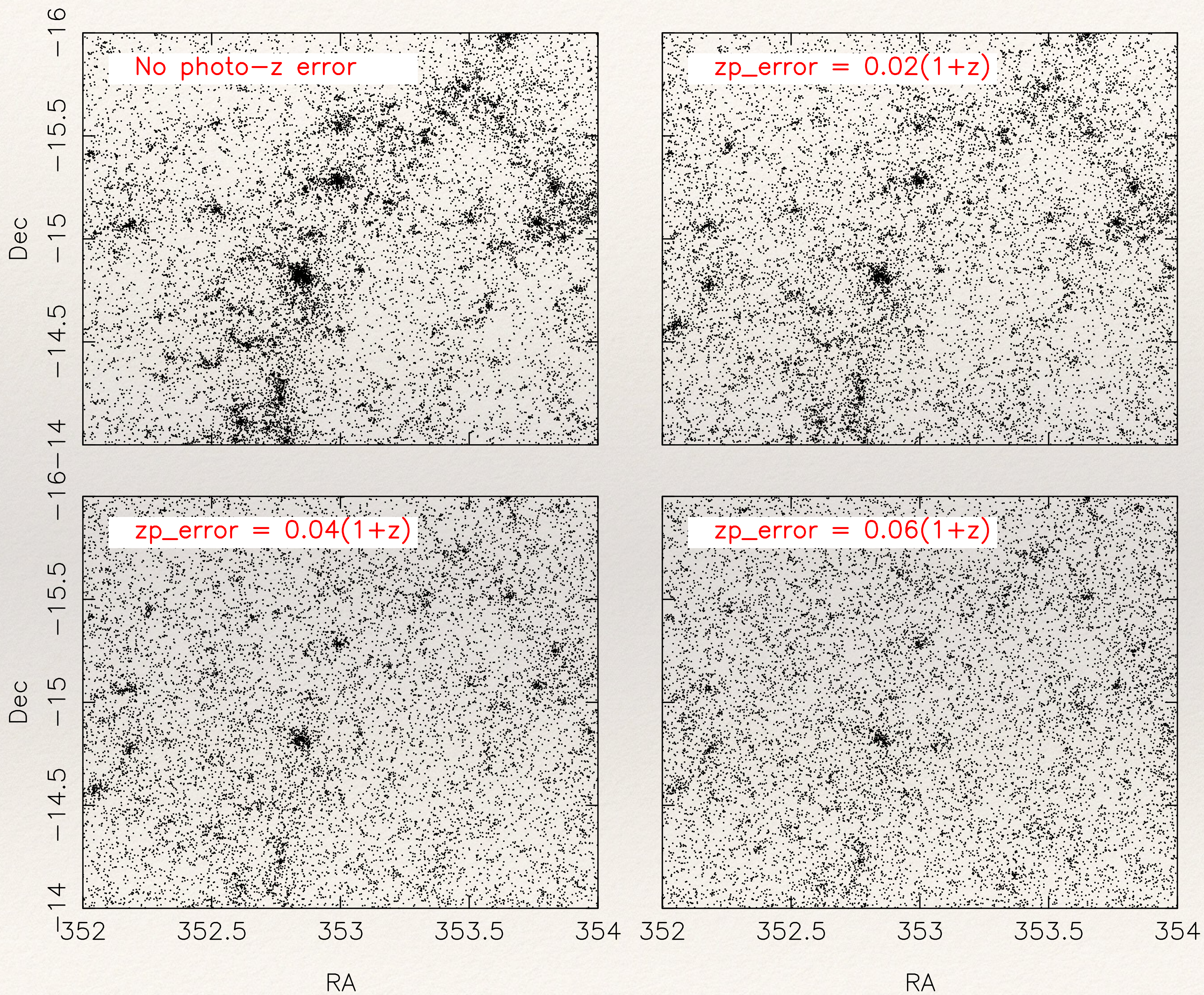
To save time, I skip lots of details in this presentation.

More details are available from arXiv:1501.01398

Any questions are welcome, during the tea time break or by E-mail.

E-mail: cclai@asiaa.sinica.edu.tw

How galaxy environment is influenced by the photo-z uncertainties?



0.3 < z < 0.35

How to correctly define real-space environments