Clustering-redshifts of DESI ELG targets using cross-correlation with eBOSS LRG and Quasars

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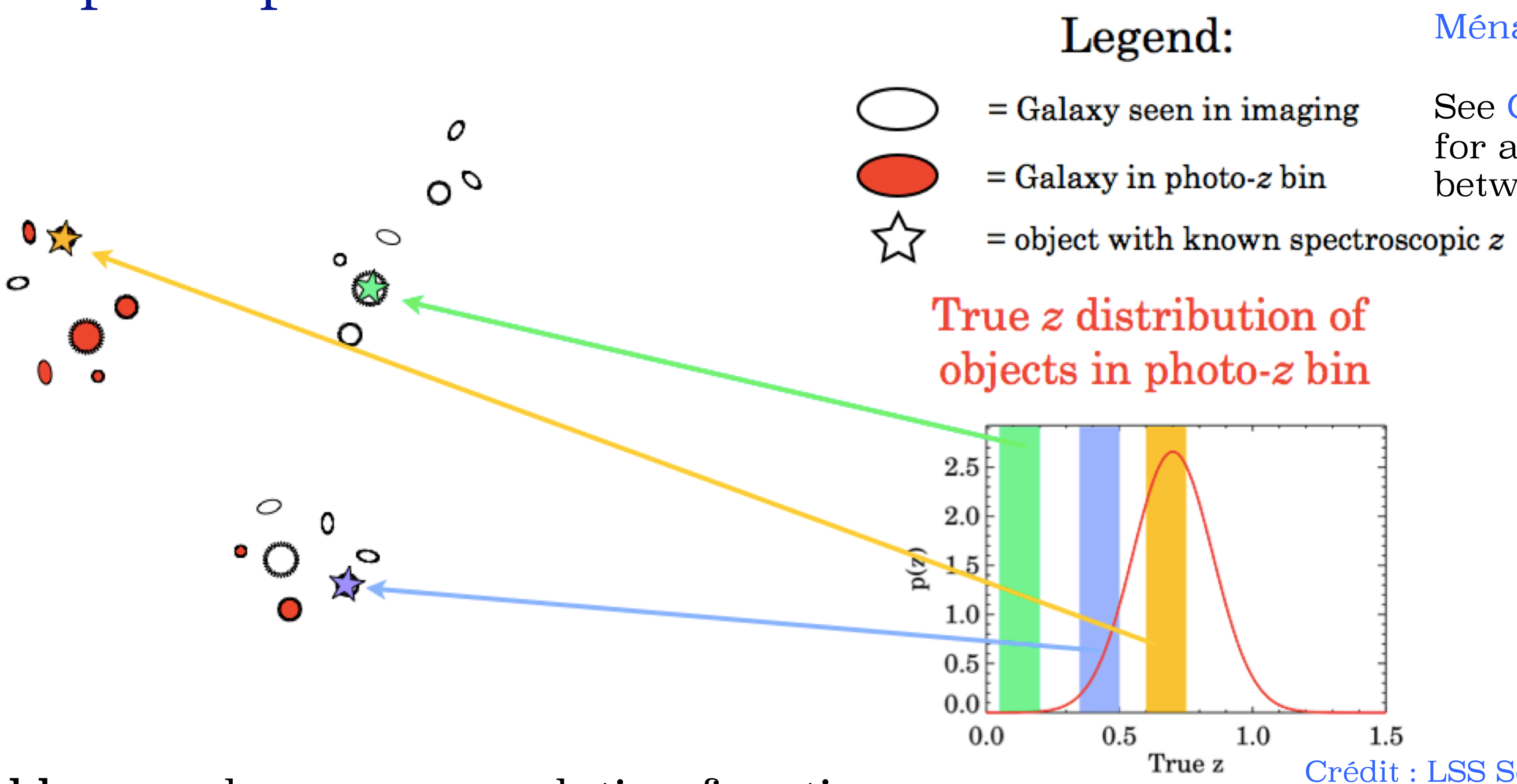
Clustering-redshift
The principle

Newman et al. (2008)
Schmidt et al. (2013)
Ménard et al. (2013)

See Gatti et al. (2013) for a comparison between techniques



Crédit : LSS Science Book 2009

Observable: angular cross-correlation function between a photometric sample and a spectroscopic sample noted: $\omega_{\mathrm{ur}}(\theta, z)$

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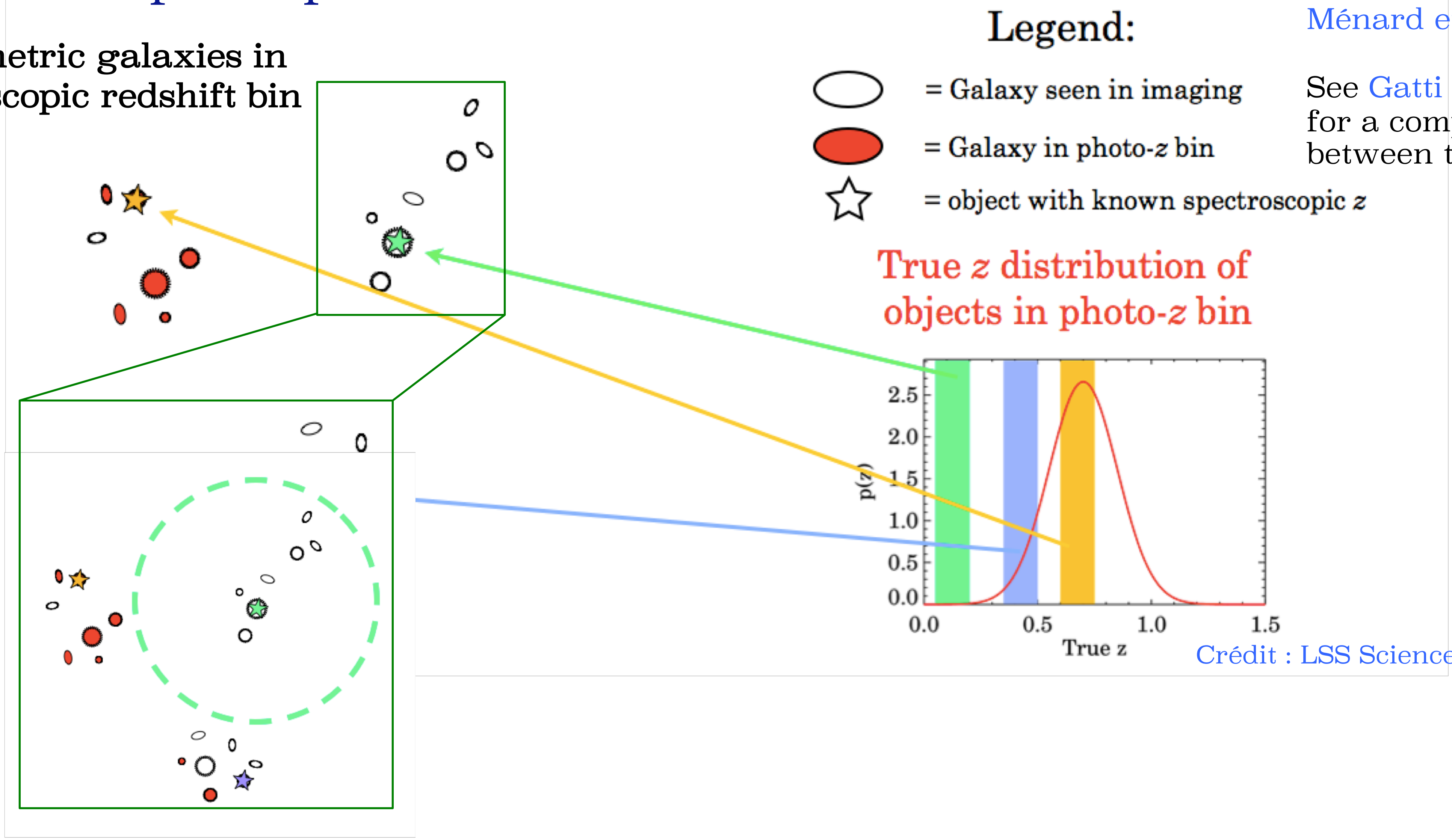
Few photometric galaxies in the spectroscopic redshift bin



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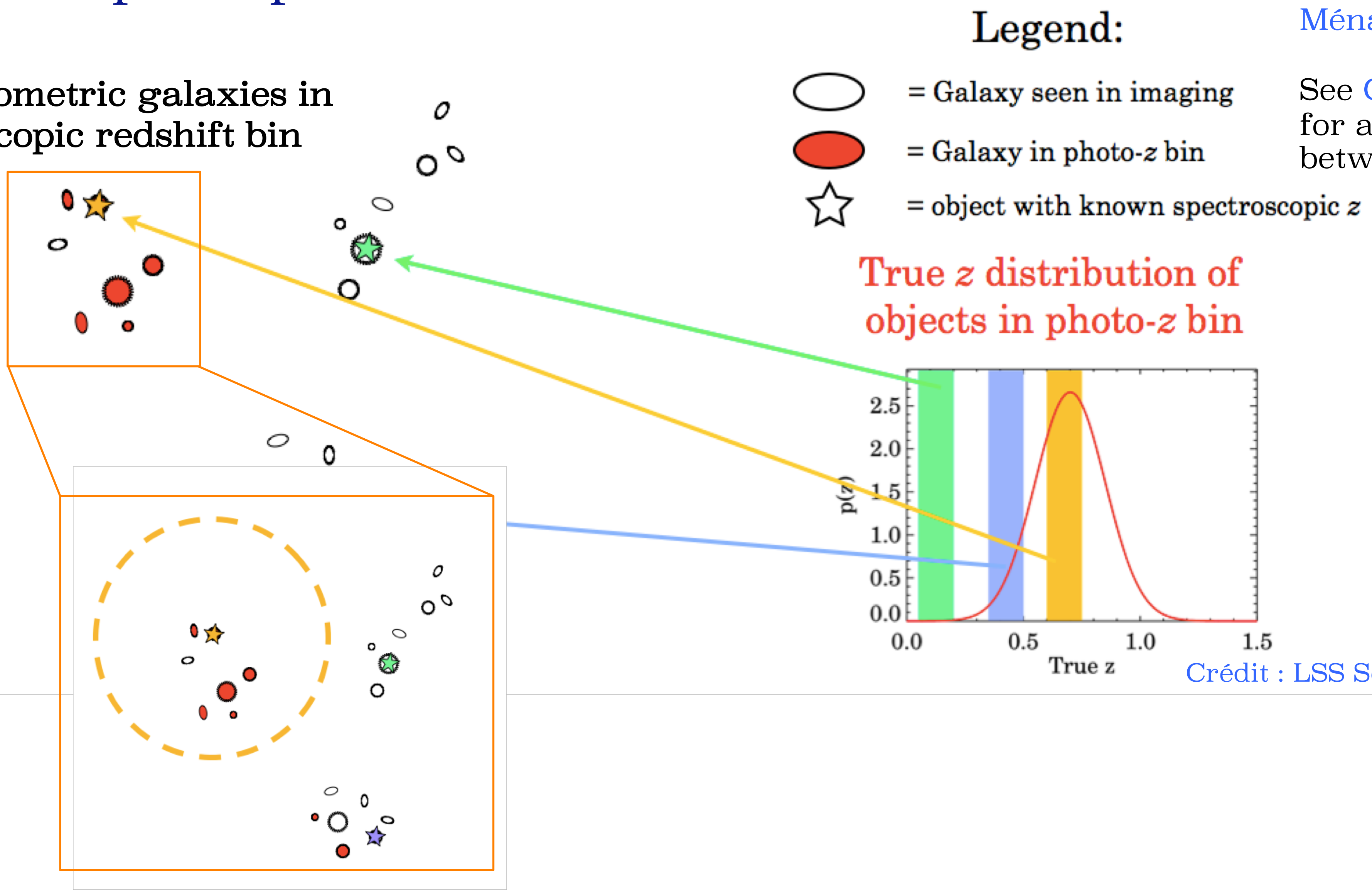

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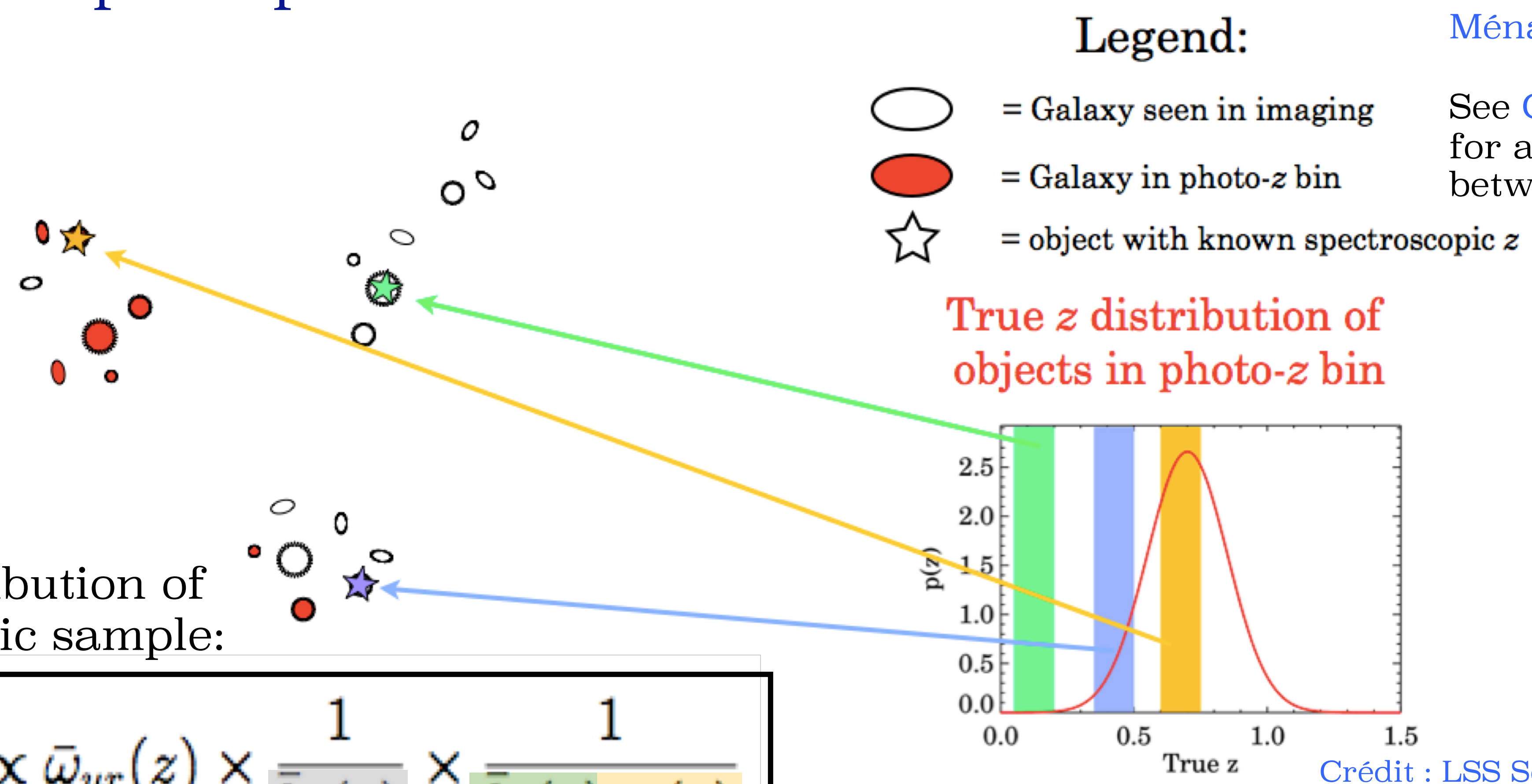

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Redshift distribution of the photometric sample:

$$\boxed{\frac{dN_u}{dz}(z) \propto \bar{\omega}_{ur}(z) \times \frac{1}{\bar{b}_u(z)} \times \frac{1}{\bar{b}_r(z)\,\bar{\omega}(z)}}$$

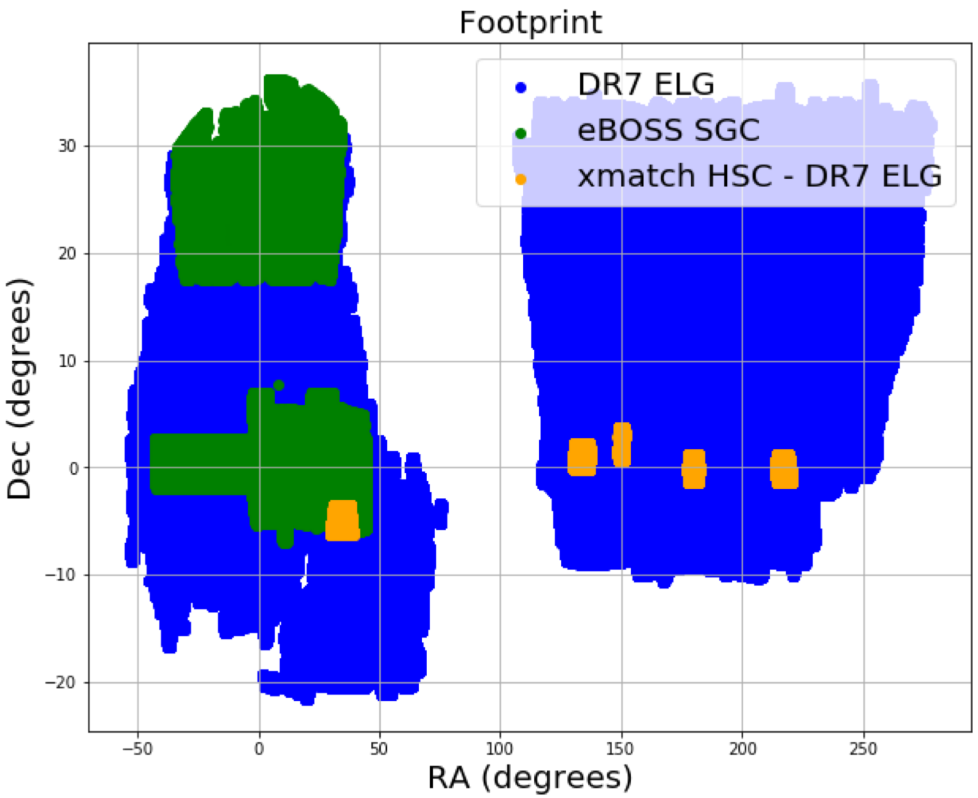
Integrated cross-correlation: $\bar{\omega}_{ur}(z) = \int_{\theta_{min}}^{\theta_{max}} d\theta \; W(\theta)\; \omega_{ur}(\theta, z)$

$(\theta_{min}, \theta_{max}) \rightarrow (r_{p,min}, r_{p,max})$

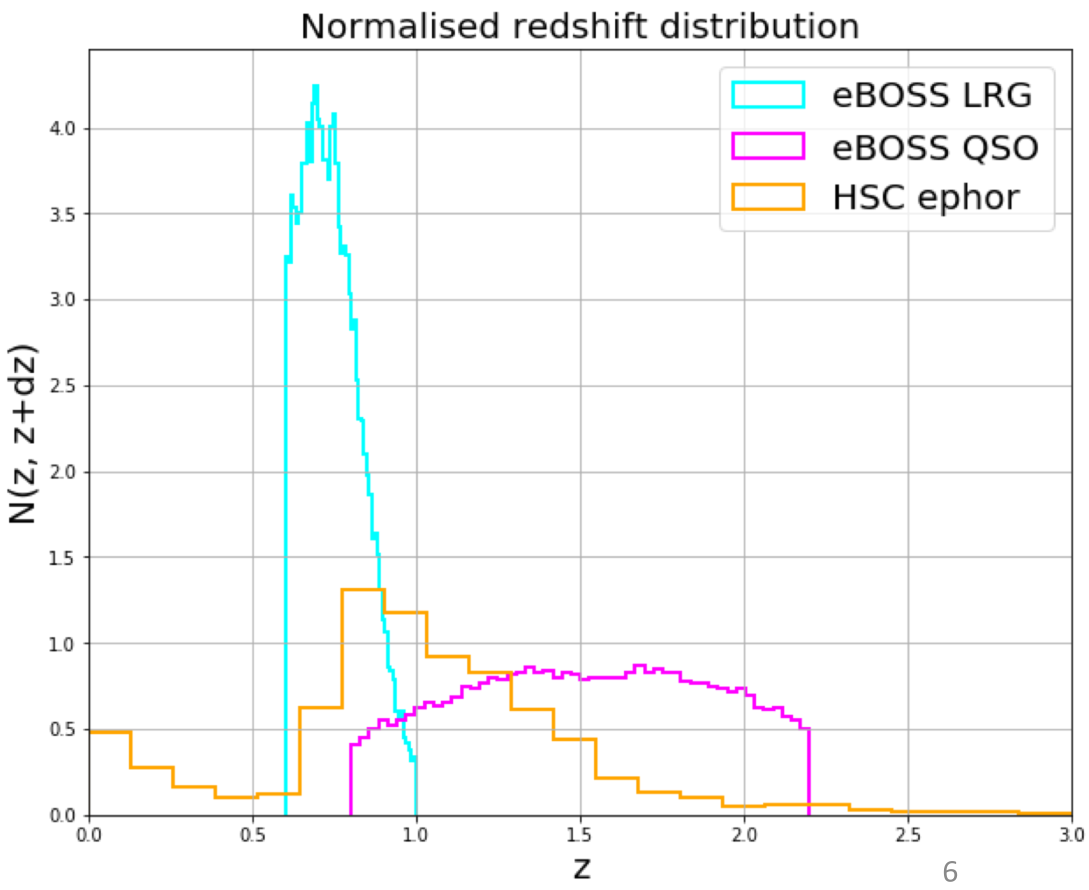
In this project, we adopt the formalism of Ménard et al. (2013)

Clustering-redshift for DESI ELG targets
Catalogues

Photometric sample:
Legacy Surveys DR7 ELG targets (~2.2 x 10^7 objects)
- Version dr7.1/0.27.0
- Sanity flags (nobs, allmasks)
- Stellar cuts from Anand based on GAIA/DR2
- Objects flagged when in DES footprint
- Photo-z from match with HSC/DR1 (~190 000 objects)



Spectroscopic sample:
eBOSS v4 SGC (~1.5 x 10^5 objects)
- 54 135 LRG
- 96 551 Quasars



Clustering-redshift for DESI ELG targets
Photometric redshifts

IMAGING SURVEYS

SDSS (14,055 deg²)
u=22.15, g=23.13, r=22.7, i=22.2. z=20.71

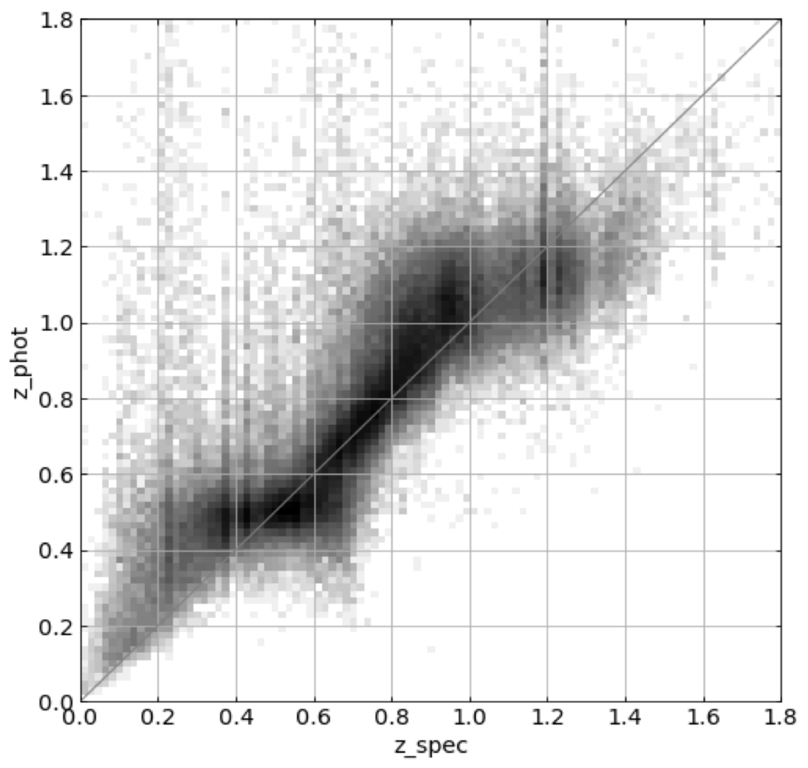
Legacy Surveys (14,000 deg²) DECaLS/BASS/MzLS
g=24.7, r=24, z=23.0

HSC (wide, 1400 deg²)
g=26.5, r=26.1, i=25.9, z=25.1, y=24.4

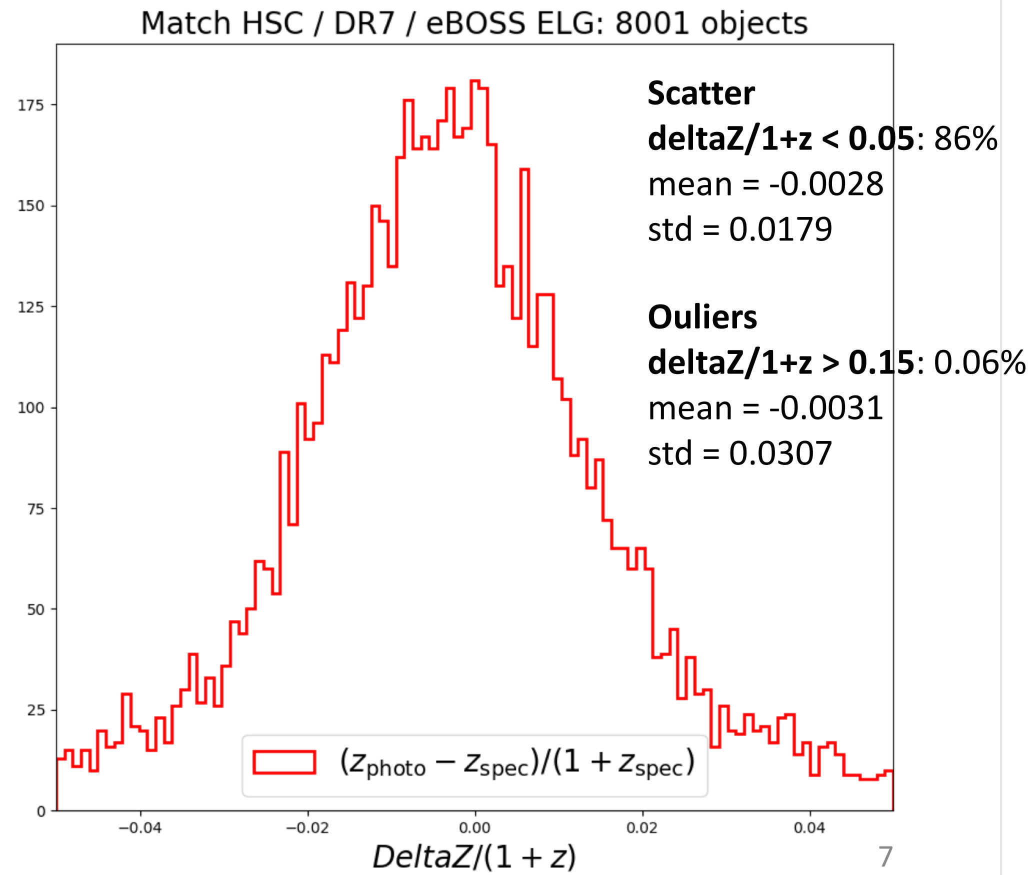
DES (5,000 deg²)
g=26.5, r=26.0, i=25.3
z=24.7, Y=23.0

Next generation: LSST

Problem: Not possible to have good photometric redshift for Legacy Surveys because only 3 bands g,r,z and photometry too shallow, especially for faint objects ($z_{mag} > 21.0$)
→ Photometric redshifts for objects that match HSC data only



Credit: Rongpu Zhou



Clustering-redshift for DESI ELG targets
Which applications?

1. Check the **redshift distribution of the DESI ELG targets** for different Target Selections

→ Ensure that nP > 1 up to z ~1.3
→ Test 2nd generation selections

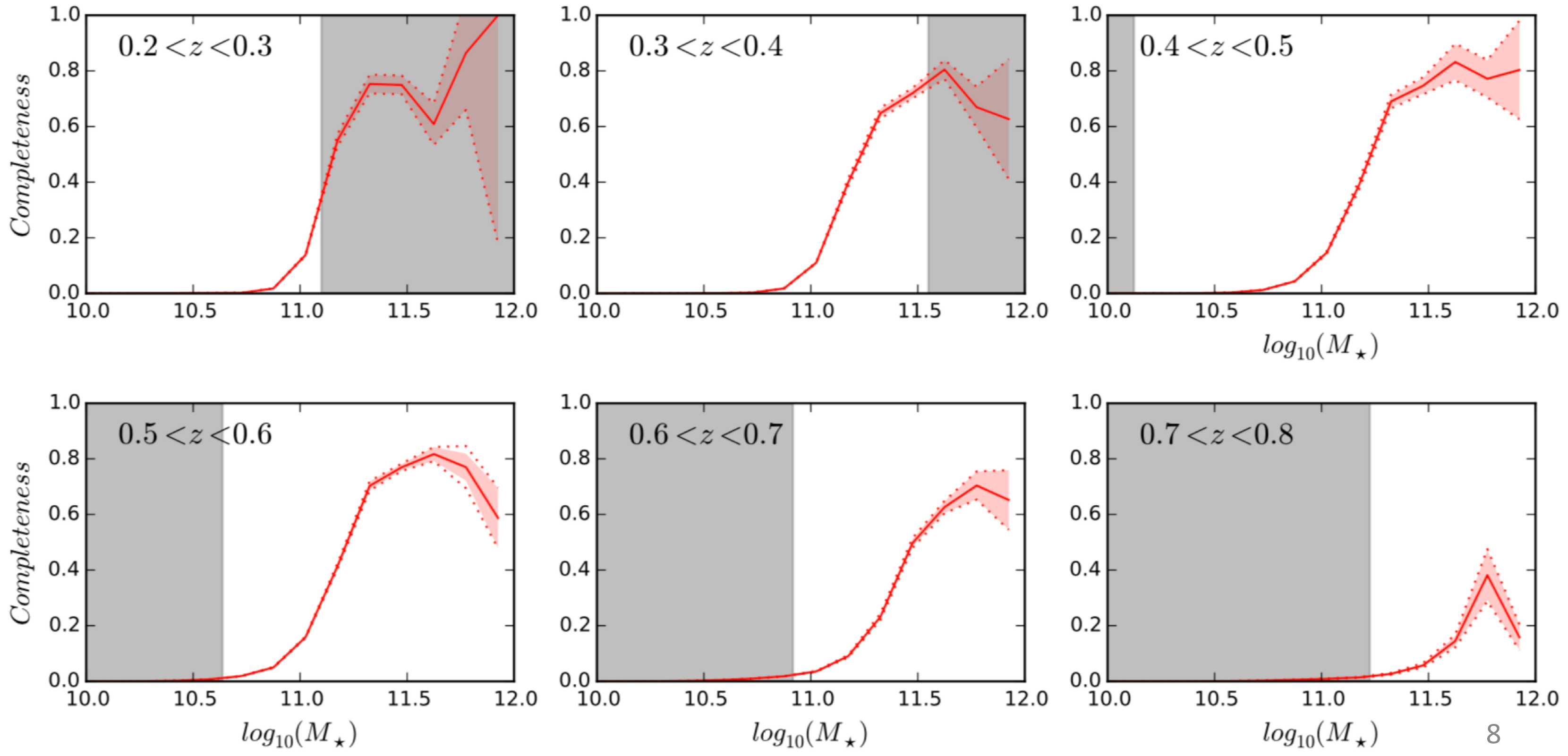
2. Compute the **stellar mass function** to g=23.xx over a large area

→ Obtain reliable measurement at high masses (limited by sample variance)

→ Compute the **completeness of the ELG sample** as a function of stellar mass (useful to improve the modelling of the galaxy-halo connection)

Bates et al. (2019)

For 0.2 < z < 0.7, 80% complete above M ~ $10^{11.4}$ M_{sun}



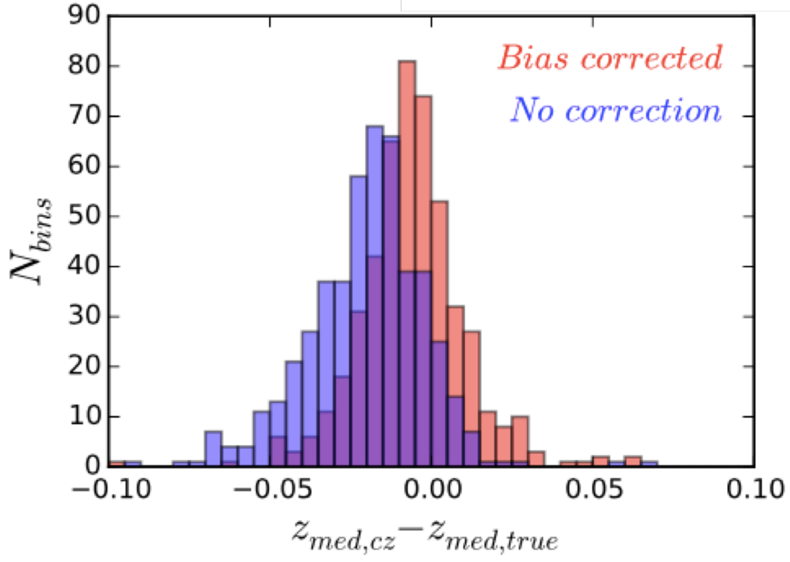
Clustering-redshift for DESI ELG targets
Challenge: Photometric bias evolution with redshift

We don’t have access to the bias evolution with redshift of the photometric sample

But we can
1. Adopt a **local approach** to decrease the effect
→ Bin in magnitude and colour

2. Measure it from **auto-correlation** using **simulated data**

$$\frac{dN_u}{dz}(z) \propto \frac{\bar{\omega}_{ur}(z)}{\sqrt{\bar{\omega}_{uu}(z)\bar{\omega}_{rr}(z)}}$$



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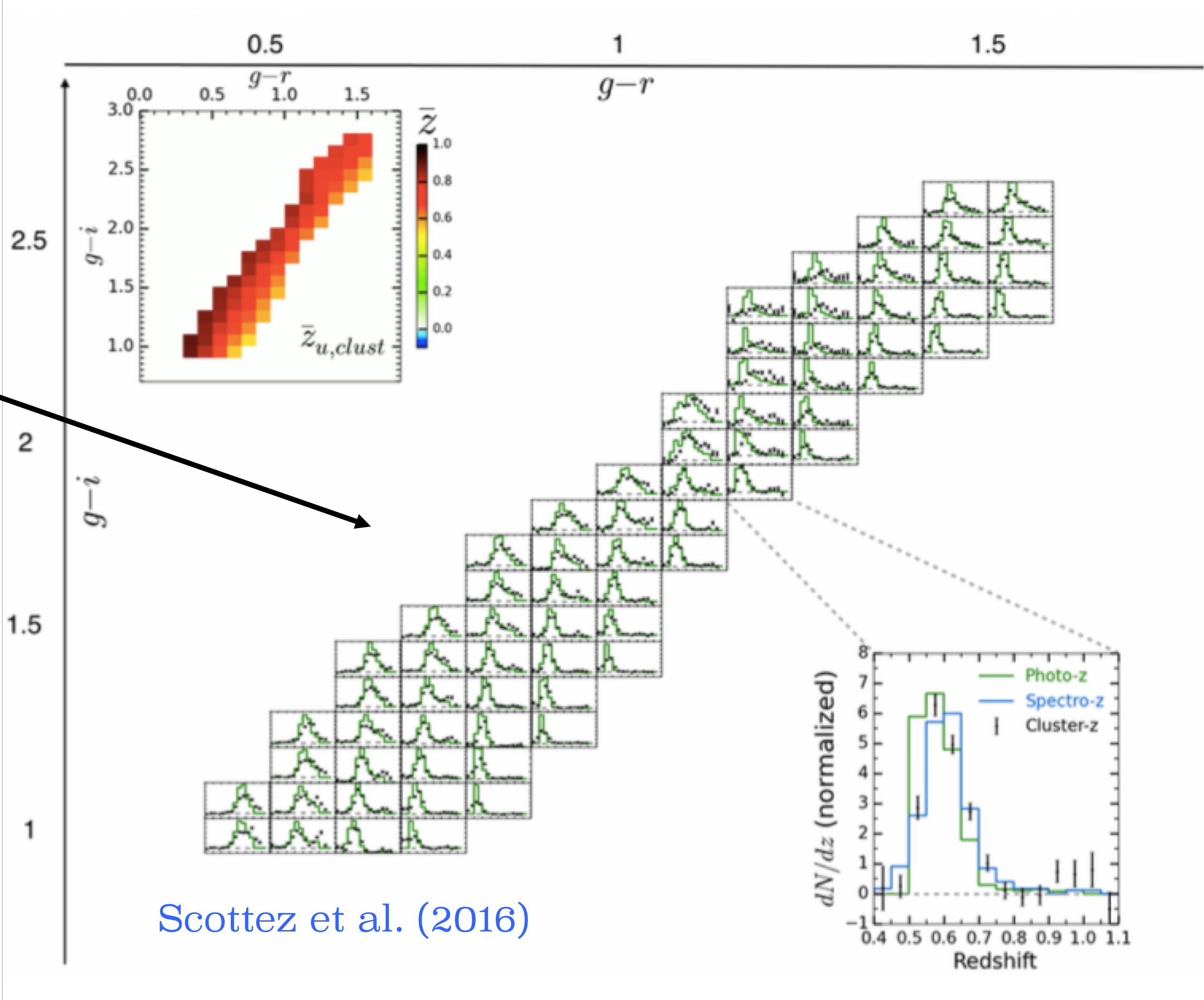


Scottez et al. (2016)

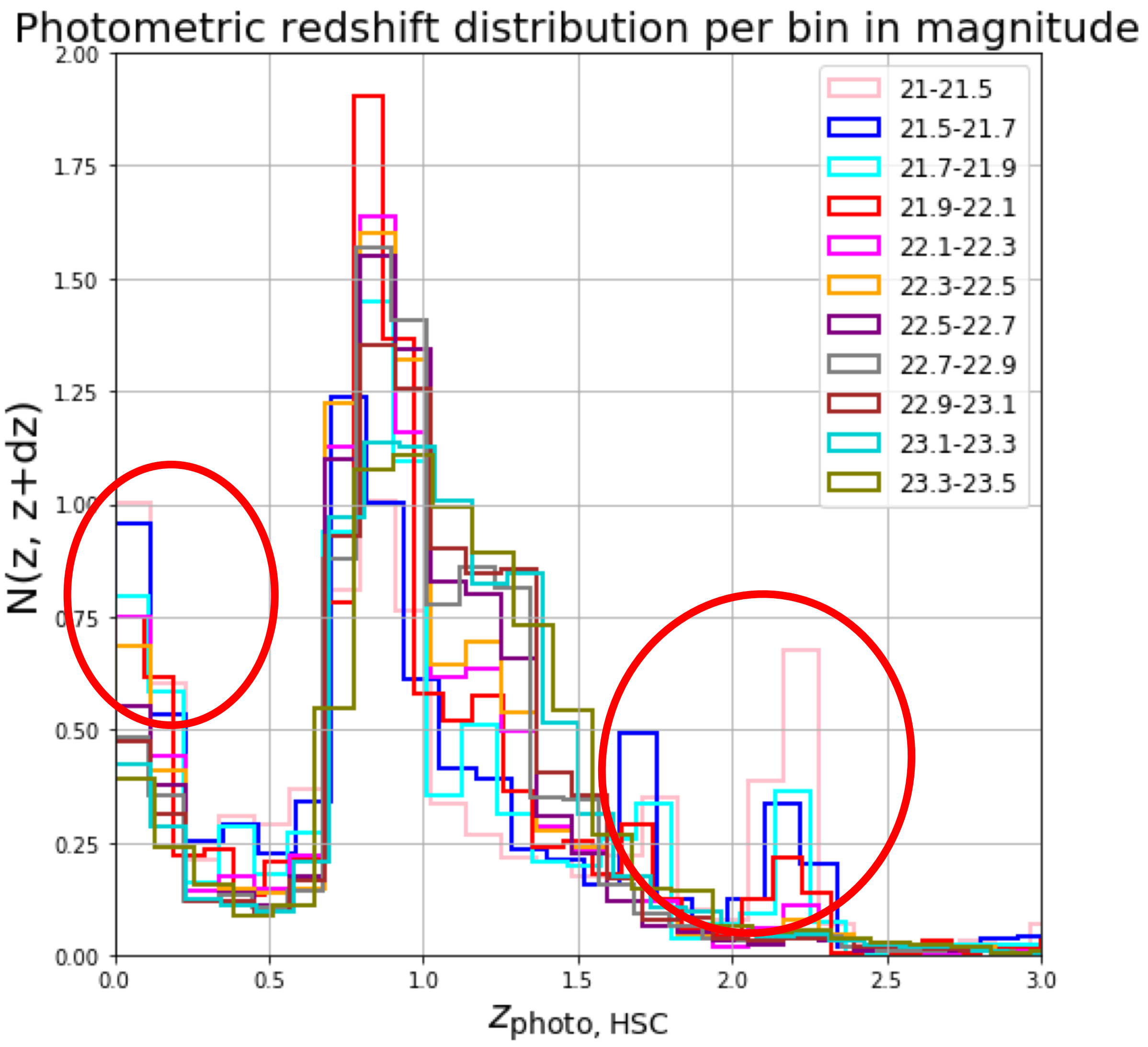
DR7 DESI ELG photometric sample

Stellar contamination and something else?

→ tails at low-z (z<0.5) and high-z (z~2), more important for the 2 brightest bins

Stellar contamination?
Look at cross-correlation with stars
Ongoing with Tycho2 and GAIA stars

PSF objects?
Which fraction in the DR7 ELG sample?



DR7 DESI ELG photometric sample

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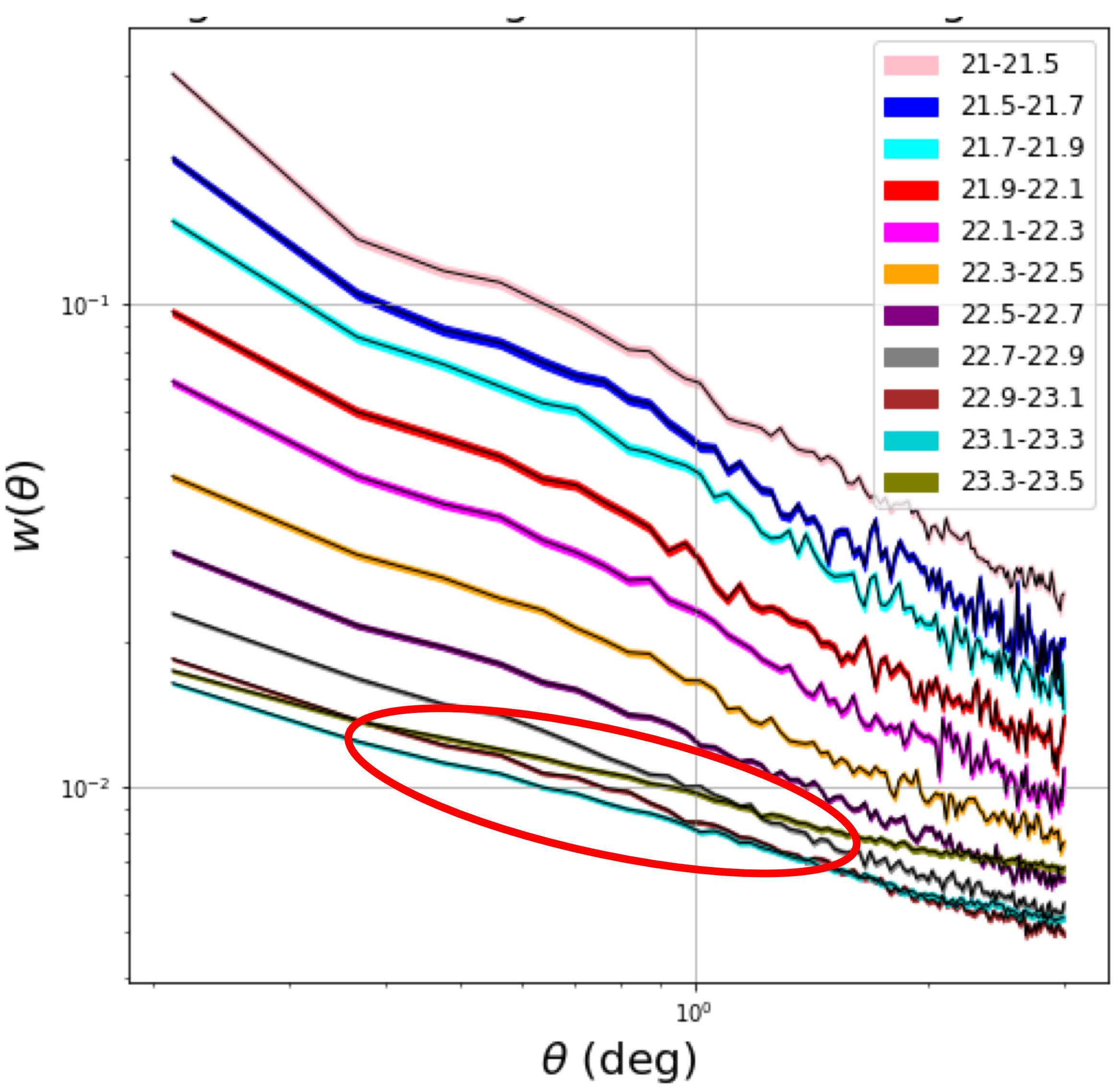


Evolution of the angular clustering with magnitude

Errors from 100 jackknife regions

→ **Expected behaviour except for the 2 faintest bins**

Star contamination?

Different origins?

Clustering-redshift for DESI ELG targets
To summarise

1. Catalogue preparation
- Spectroscopic samples: divide into redshift bins of width $\Delta z = 0.01$ (40 bins for LRG, 140 bins for Quasars)
- Photometric sample: divide into g-band bins, for each g-band bin divide into g-r and then r-z such that each colour bin contains at least 100,000 galaxies → 199 bins in total

$$\frac{S}{N} \simeq \frac{\delta z_c}{\sqrt{\delta z_i}} \theta_{max} \sqrt{\frac{\mathrm{dN_r}}{\mathrm{dz}} n_u}$$

δz_c clustering scale = 0.001
δz_c spectro-z bin width = 0.01
θ_{max} = 0.3 deg
n_u = 2400 targets / deg^2
dN_r / dz = 1.5 x 10^5 spectroscopic objects

2. Compute clustering-redshifts for each colour bin

$$\frac{dN_u}{dz}(z) \propto \frac{\bar{\omega}_{ur}(z)}{\sqrt{\bar{\omega}_{uu}(z)\bar{\omega}_{rr}(z)}}$$

where $\bar{\omega}_{\mathrm{ur}}(z) = \int_{\theta_{\mathrm{min}}}^{\theta_{\mathrm{max}}} \mathrm{d}\theta \; W(\theta) \; \omega_{\mathrm{ur}}(\theta, z)$

$r_{p,min}$ = 0.5 Mpc < r_p < $r_{p,max}$ = 2 Mpc

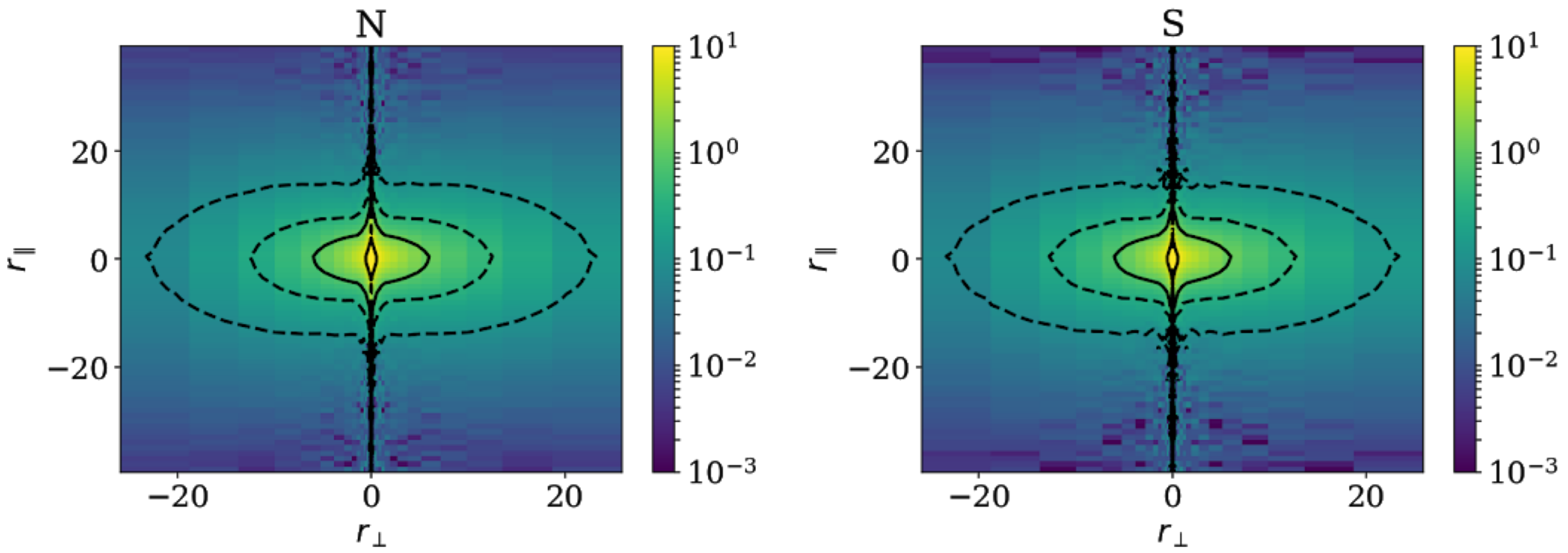
Cross-correlation between each colour bin and spectro-z bin

Auto-correlation:
- Spectroscopic samples: need to correct for fiber-collisions and close-pairs to use very small scales
- Photometric sample: need simulated data

Clustering-redshift for DESI ELG targets
Next steps

1. **Validate the clustering-redshift technique**
   - Comparison with photometric redshifts: HSC / DES
   - Apply the technique to different photometric samples with DESI ELGs selected using different Target Selection algorithms
   - Test on simulations: **Buzzard mock**

2. **Compute the stellar mass function using semi-analytical models (SAMs)**



ELG small-scale clustering, plot from Shadab Alam @DESI C3 telecon

Buzzard mock (DeRose et al. 2019**):**
N-body simulation(s) with empirical model for galaxies
14,000 deg^2 full DESI footprint
Have galaxy luminosities, colours, SEDs, shapes and full ray-tracing for weak-lensing statistics
Also DES photometric redshifts