DARK ENERGY SURVEY

Galaxy Clustering and Photometric Redshifts

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Fermilab

Kavli Institute for Cosmological Physics at The University of Chicago

overview

DARK ENERGY SURVEY

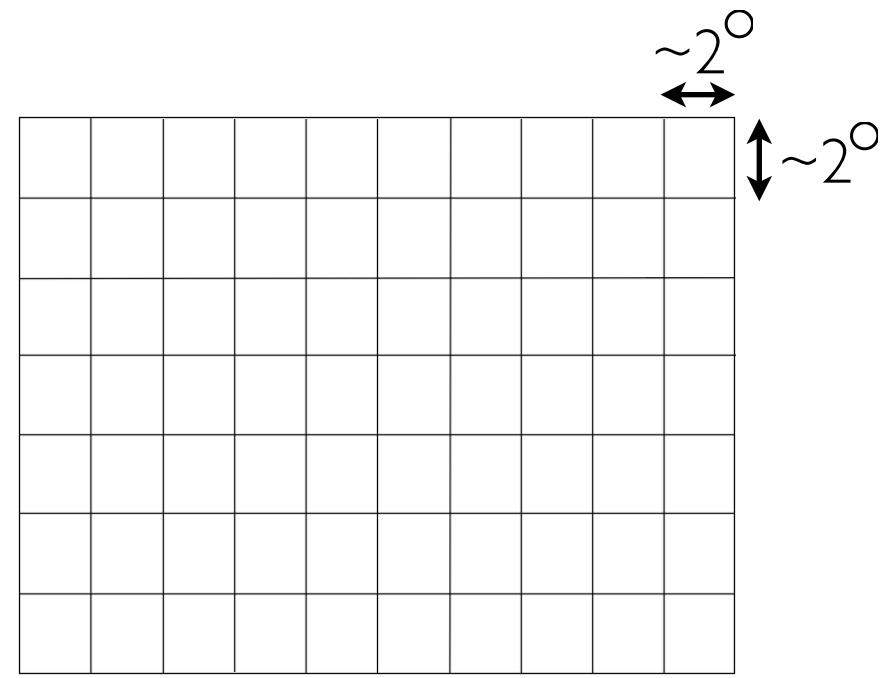
using cross-correlations for DES
- reducing sample-variance requirement
- cross-correlations with clusters

positions of nearby spectroscopic galaxies as priors
- applications for DESpec

testing with the DES mocks

used DES mock v3.04 (~220 sq. deg.)

split into 70 fields roughly ~2x2deg



in each field we measure:

$w_p(r_p)$ of spectroscopic sample (measured in bins of z_{spec})

$w_{pp}(\theta)$ of photometric sample

$w_{sp}(\theta)$ cross-correlation between photometric and spectroscopic samples (measured in bins of z_{spec})

from these correlation functions we determine the redshift distribution

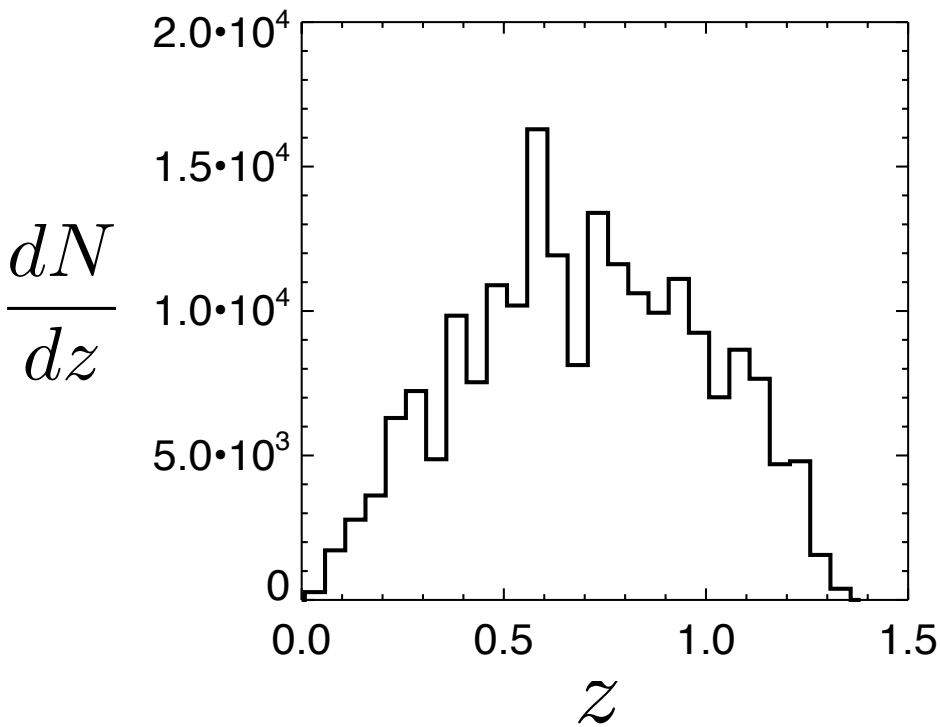
test with realistic spectroscopic distributions

each over 14 fields (44 sq. deg.)

$N_s = 2000$ per field

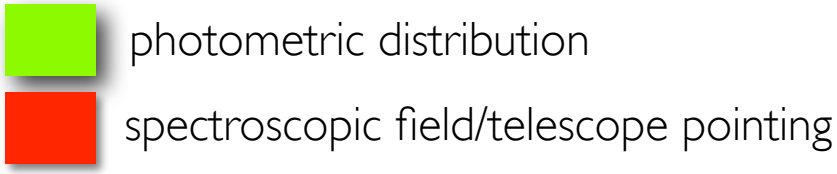
$N_p \approx 200000$ per field

redshift distribution of the spectroscopic sample



complete to i = 22.5

test with realistic spectroscopic distributions



in each field:

case 1

mimics 1 AAT/AAΩ pointing in one DECam pointing

$t \approx 40$ hours

case 2

mimics 4 Magellan/IMACS pointings in one DECam pointing

$t \approx 4$ hours

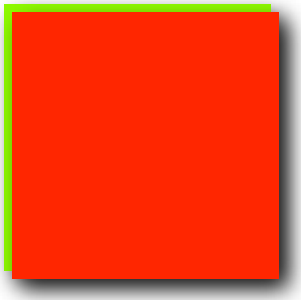
case 3

mimics 16 VLT/VIMOS pointings in one DECam pointing

$t \approx 16$ hours

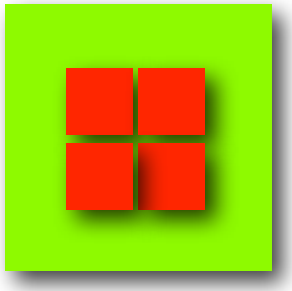
on the sky

z



i = 22.5

z



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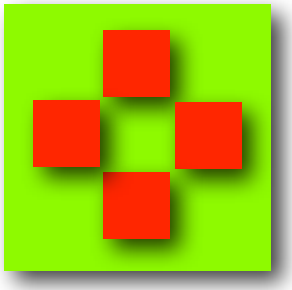
z



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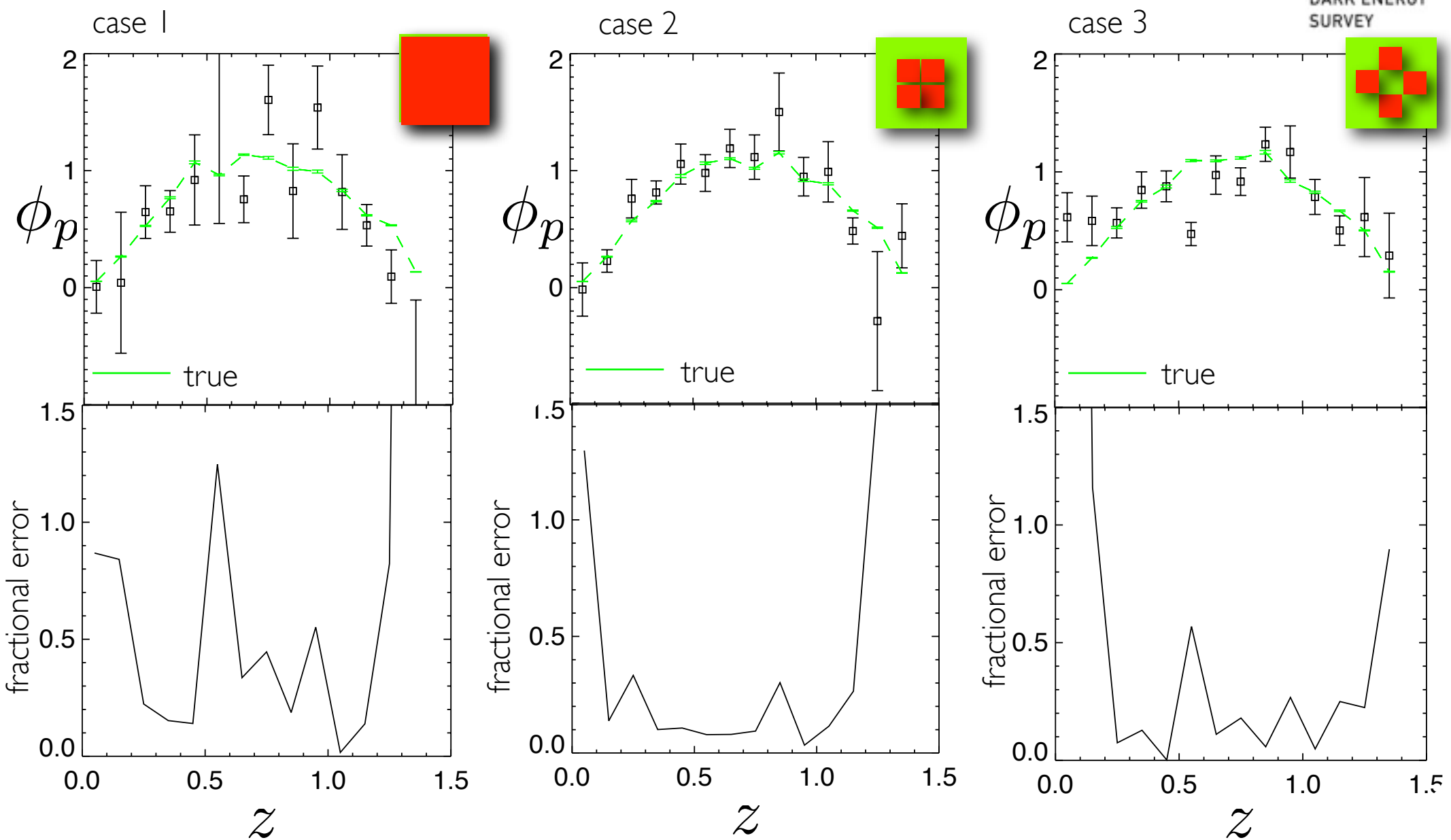
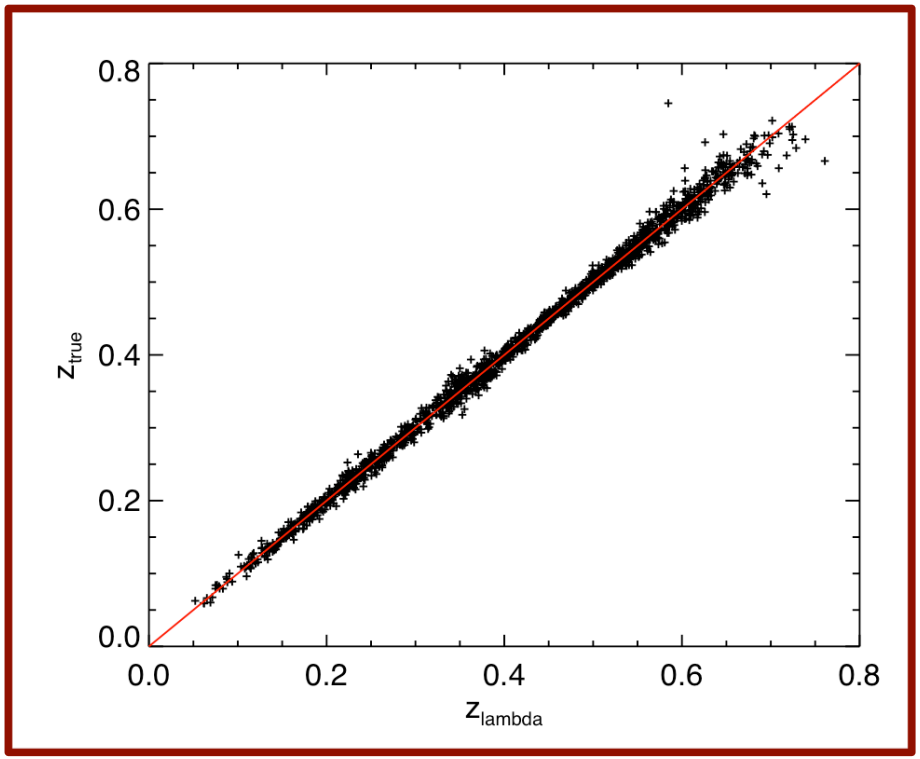
test with realistic spectroscopic distributions

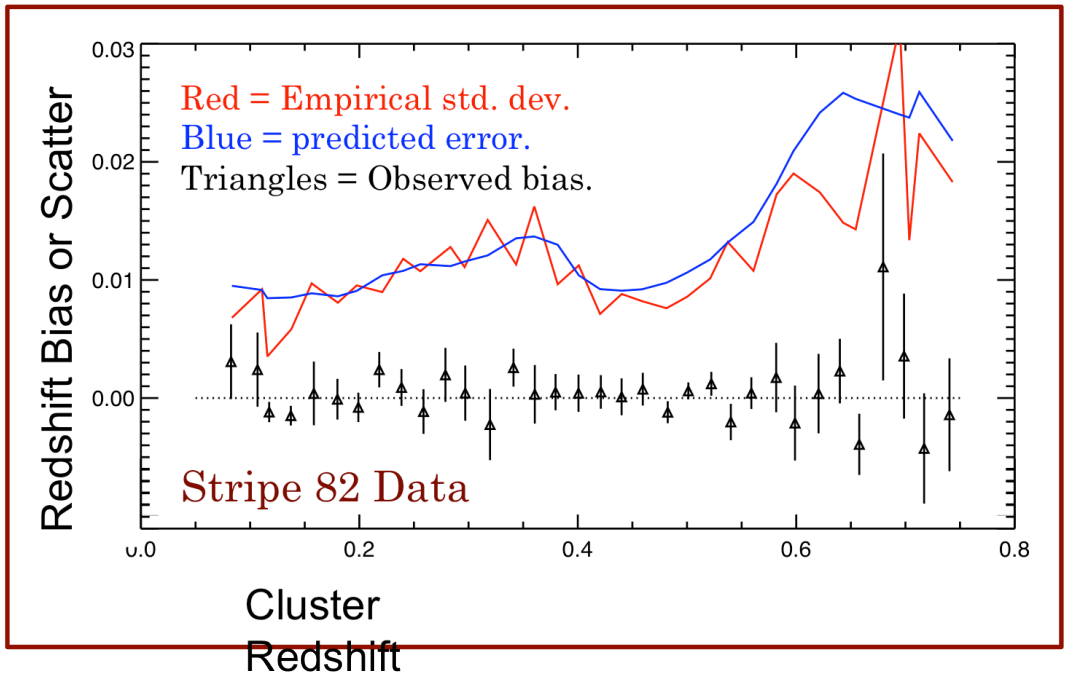


clusters and cross-correlations

cluster photoz: $\delta z \approx 0.01 - 0.02$
no outliers

can use these objects as a psuedo-spectroscopic sample
distributed over entire 5000 sq. deg.





from Rozo, Redmapper method

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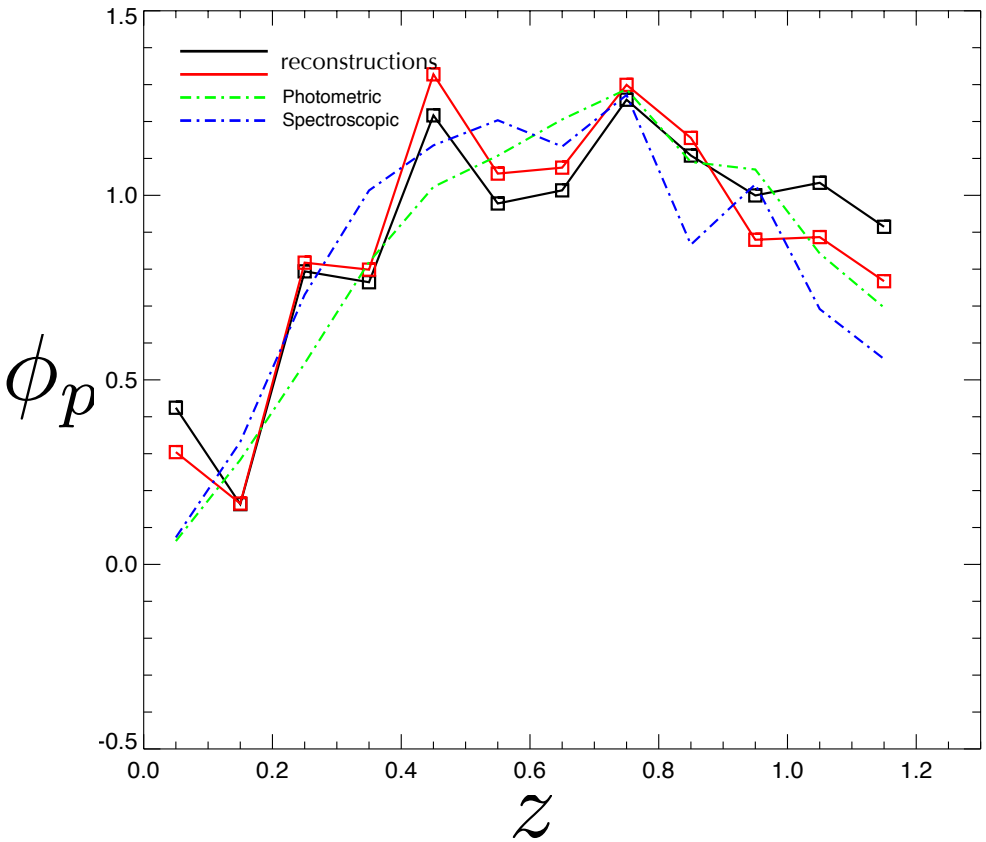
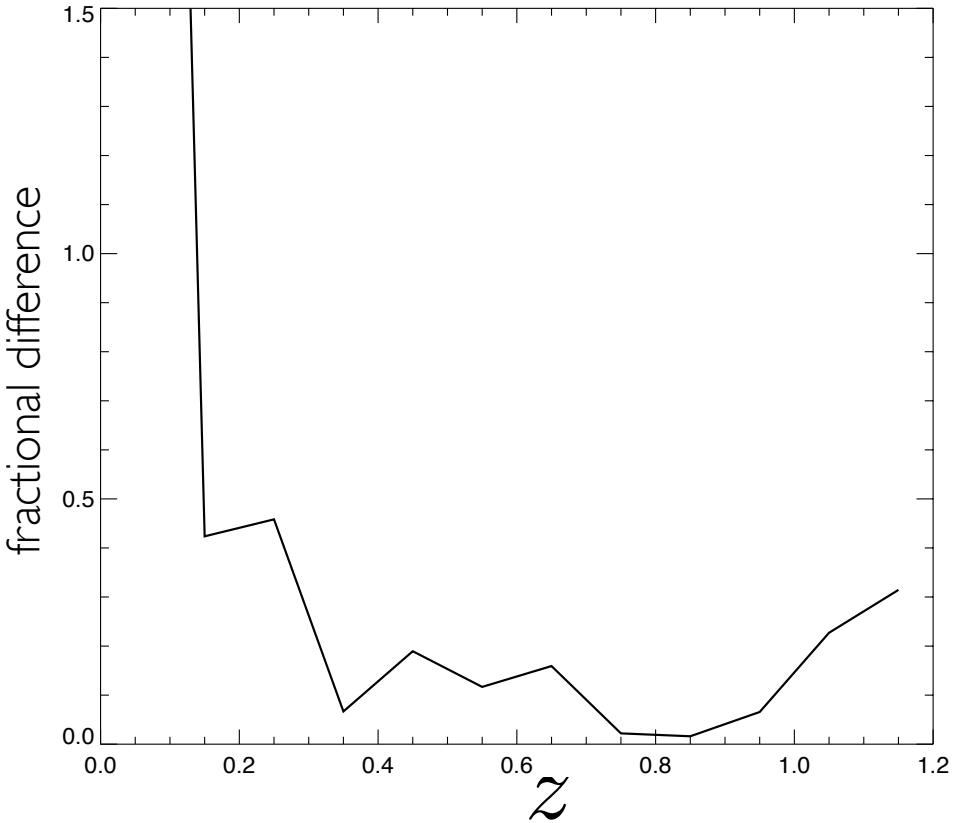
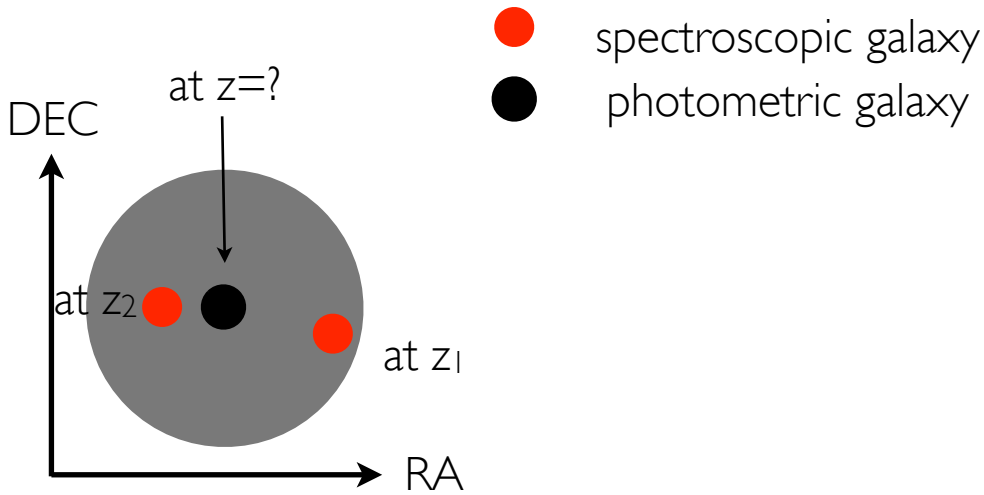
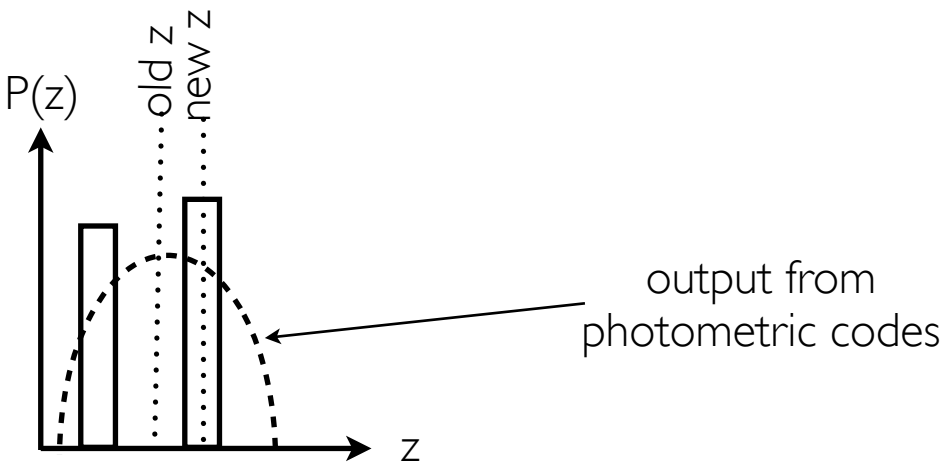




using nearby spectroscopic galaxies as redshift priors

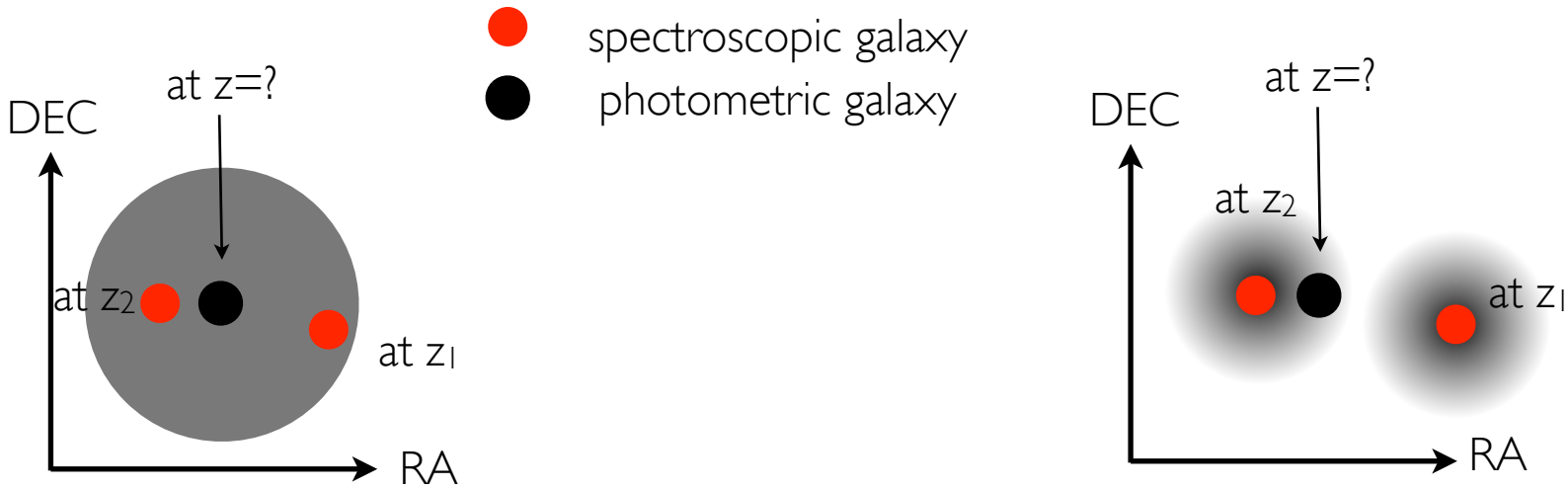


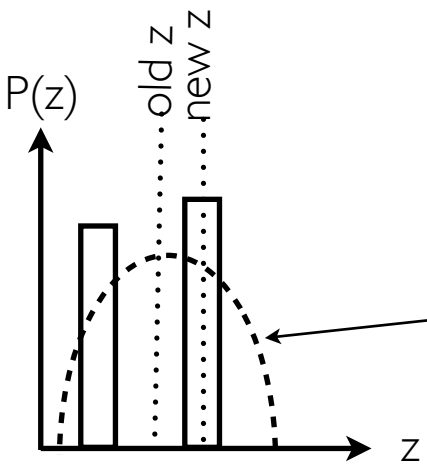


ZADE (used in zCOSMOS)
see: Kovac et al. 2009

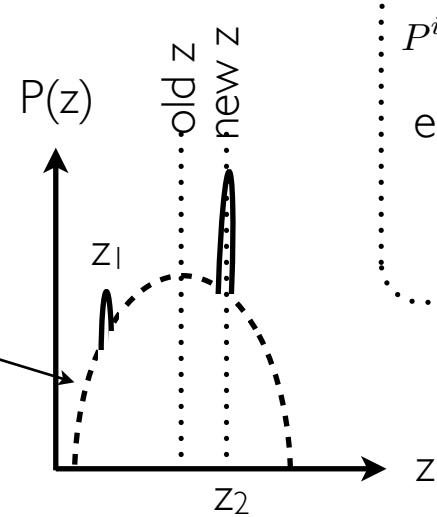
$$P_{\mathrm{ZADE}}(z) = \frac{N_{\mathrm{gals}}(< R_{\mathrm{ZADE}}, z) P_{\mathrm{photometry}}(z)}{\int_0^z N_{\mathrm{gals}}(< R_{\mathrm{ZADE}}, z') P_{\mathrm{photometry}}(z') dz'}$$

using nearby spectroscopic galaxies as redshift priors





output from photometric codes



$$P^i(z_s) \propto \int w(\theta) d\Omega$$

each probability relates to 2pt function

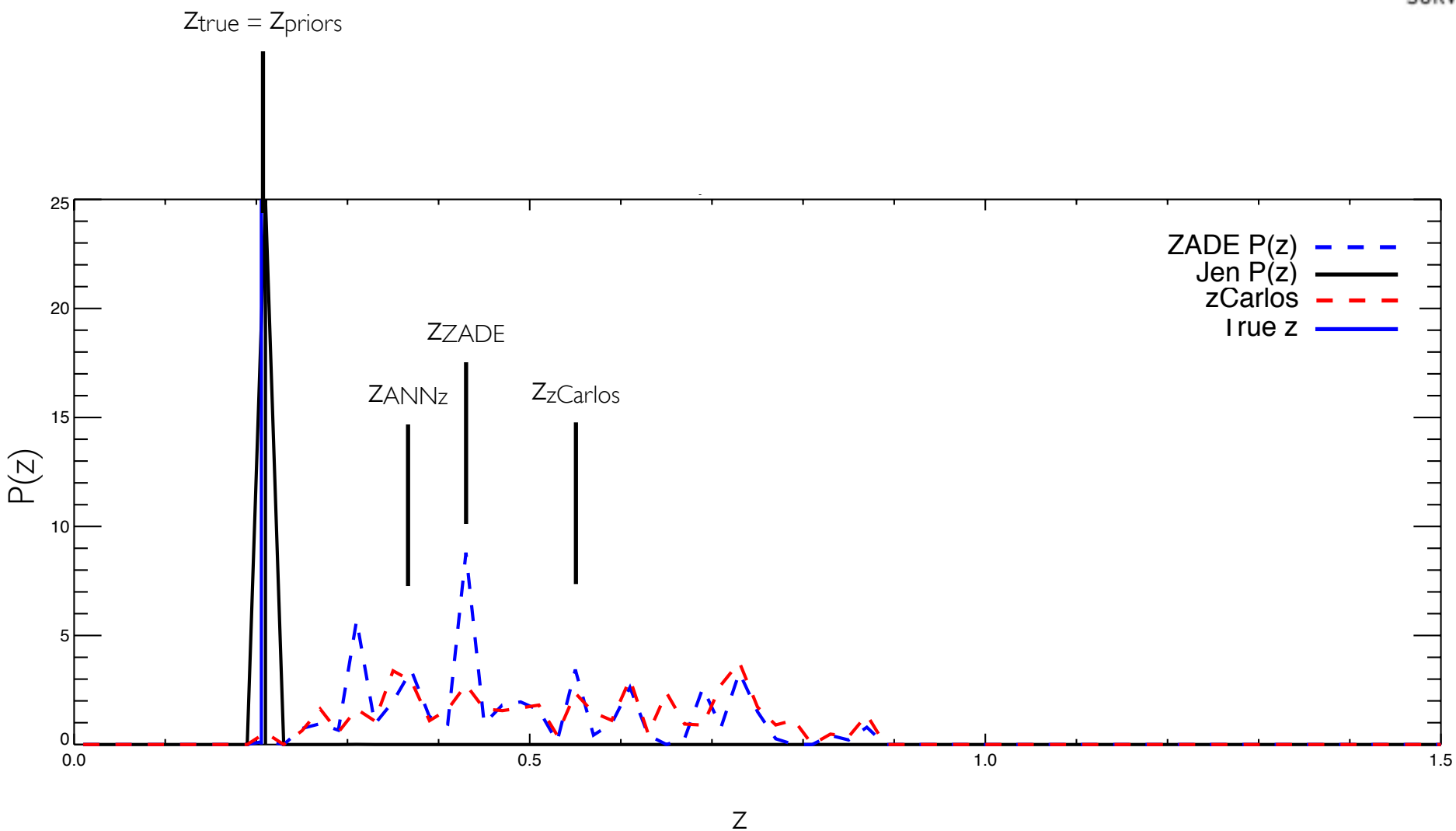
ZADE (used in zCOSMOS)
see: Kovac et al. 2009

$$P_{\rm ZADE}(z) = \frac{N_{\rm gals}(< R_{\rm ZADE}, z) P_{\rm photometry}(z)}{\int_0^z N_{\rm gals}(< R_{\rm ZADE}, z') P_{\rm photometry}(z') dz'}$$

modified method: use clustering to compute a P(z) separately for each spectroscopic galaxy

$$P_{\rm combined}(z) = P_{\rm photometry}(z) * \left(\prod_{i=1}^{N_{\rm nearby\ gals}} P^i(z_s) \right)$$

using nearby spectroscopic galaxies as redshift priors: example

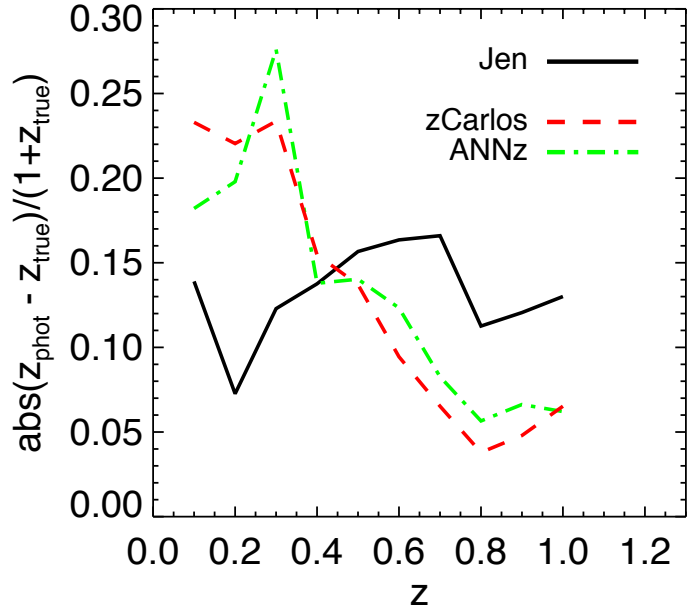


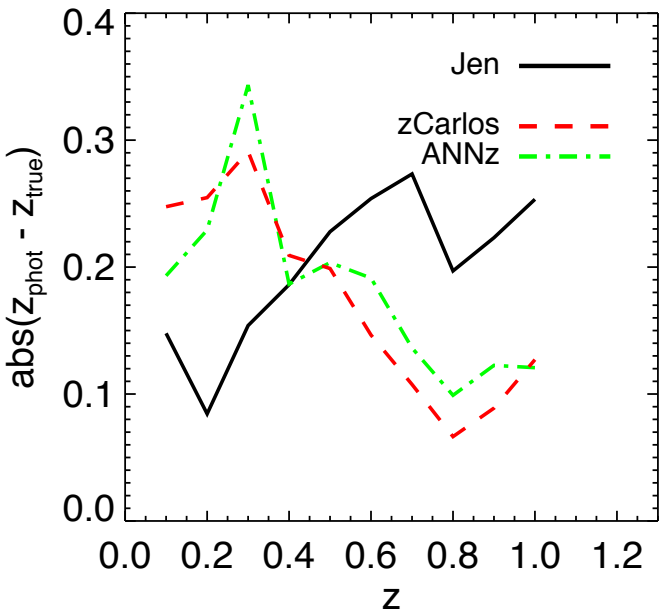
test in DESpec

test using DES v3.04 mock (220 sq. deg.):

2.3% galaxies: "spectroscopic"

2.3% = 7 million spectroscopic DES galaxies / (300 million photometric DES galaxies)





summary

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galaxy clustering can provides additional information, allowing more accurate photometric redshift and redshift distributions

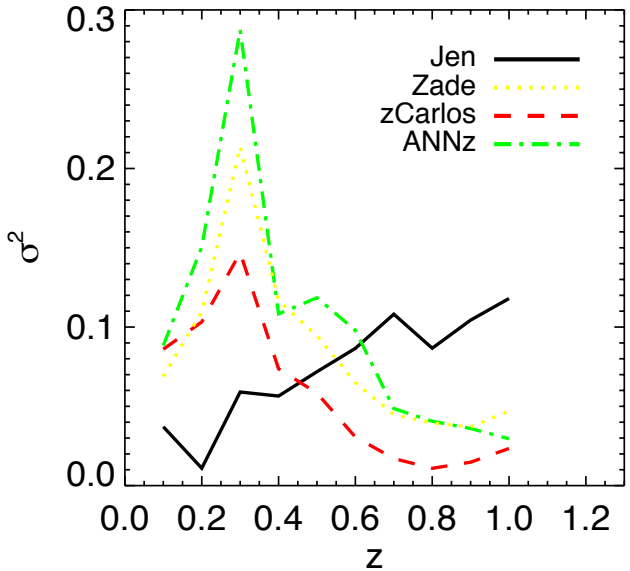
applied to DES, the sample variance issue due to LSS in spectroscopic training sets can be alleviated by using the cross-correlations method, using available spectroscopic data and possibly the DES cluster population

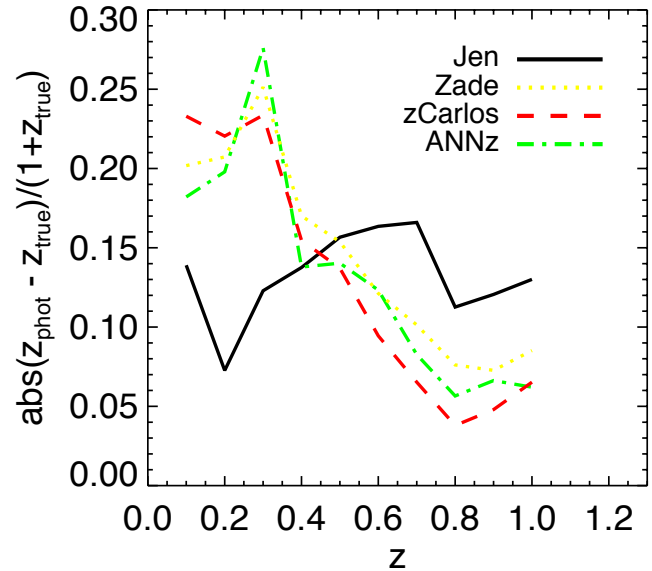
DESpec allows us to use nearby galaxies as a prior - particularly useful at low redshift (can reduces outlier rate for these objects) where photoz's are less accurate due to DES' lack of a u-band

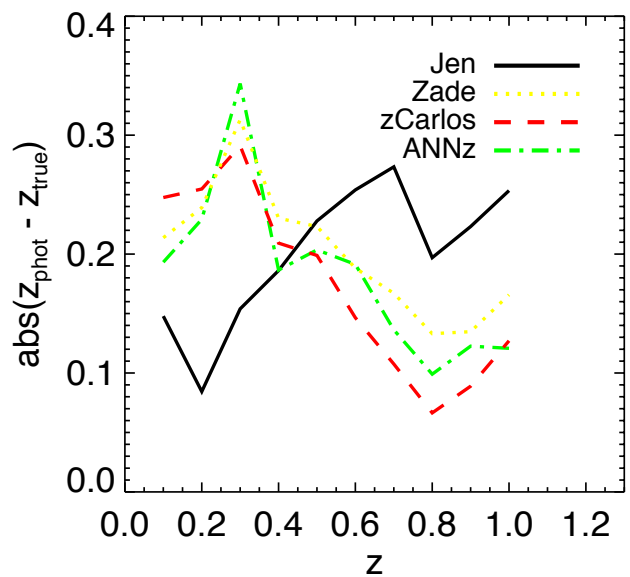
thanks for listening!

Extra

comparison with ZADE





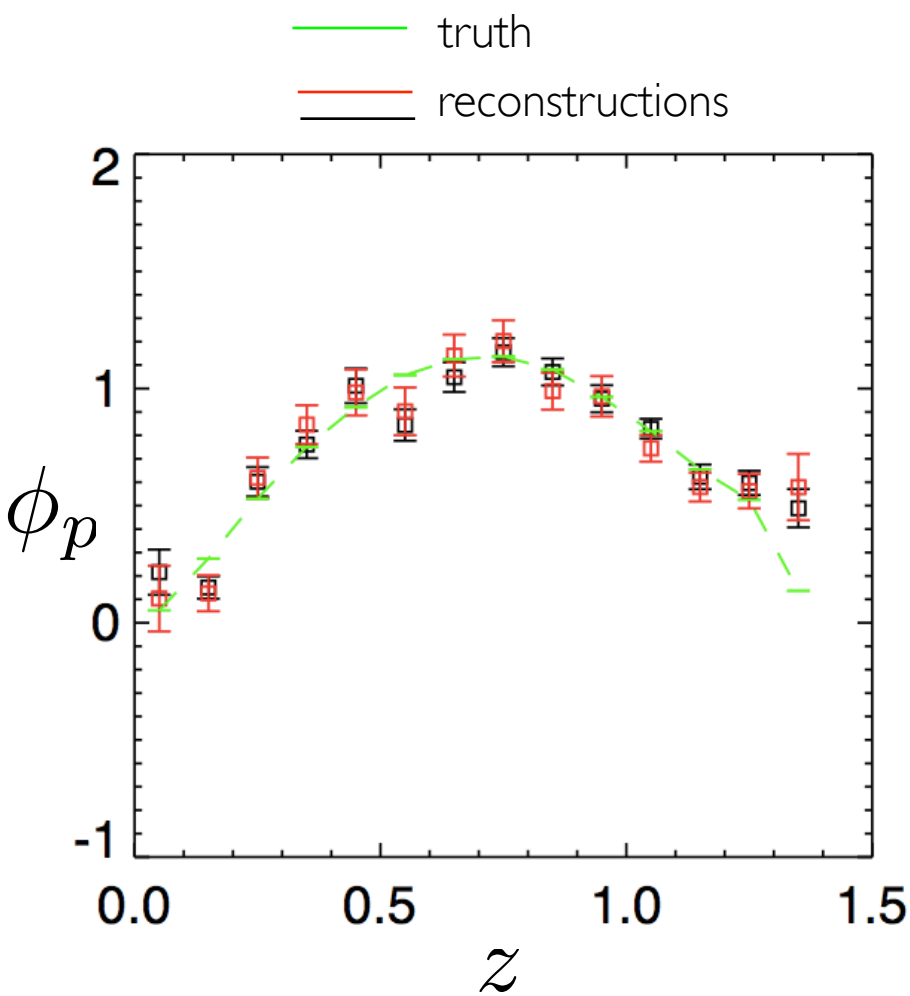


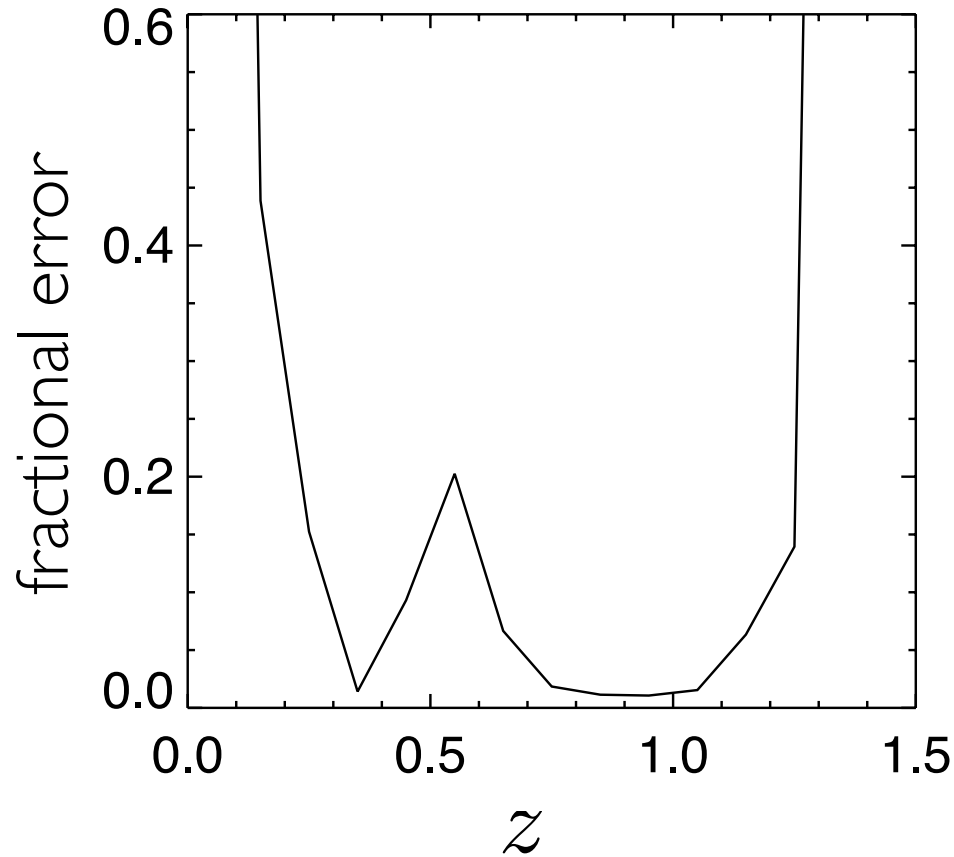
an ideal test

photometric sample: all objects within the DES mock catalog

spectroscopic sample: random subsample of 10% of the objects in the DES mock catalog (mimics an idealized DESpec galaxy redshift survey)

an ideal test





all 70 fields

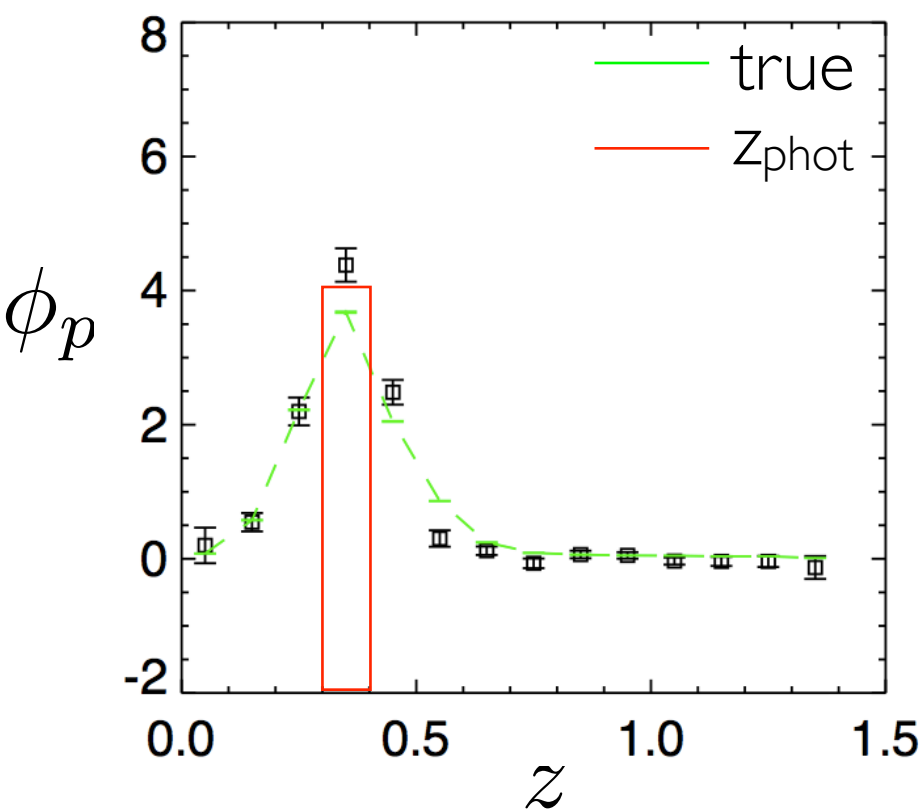
no photometric information is used here

testing the photo-zs

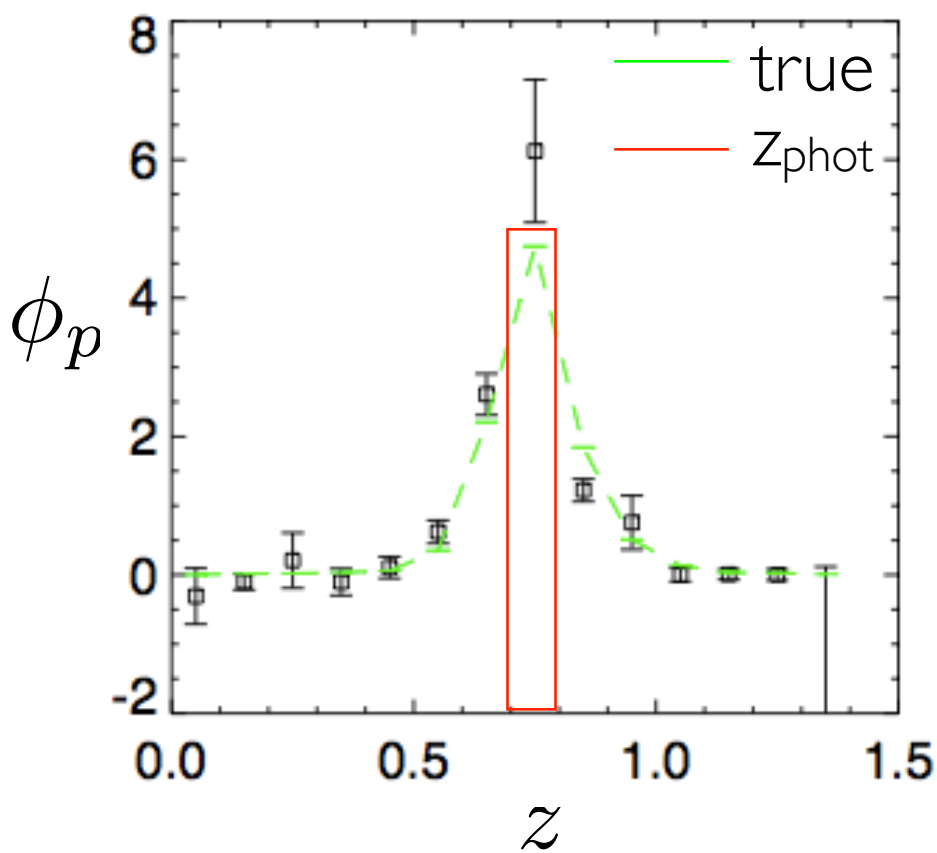
select galaxies in bins of photometric redshift and reconstruct the true redshift distribution in that bin

reconstructed from 220 sq. deg. using representative spectroscopic sample

$0.3 < z_{phot} < 0.4$



$0.7 < z_{phot} < 0.8$



photometric redshift calibration for DES

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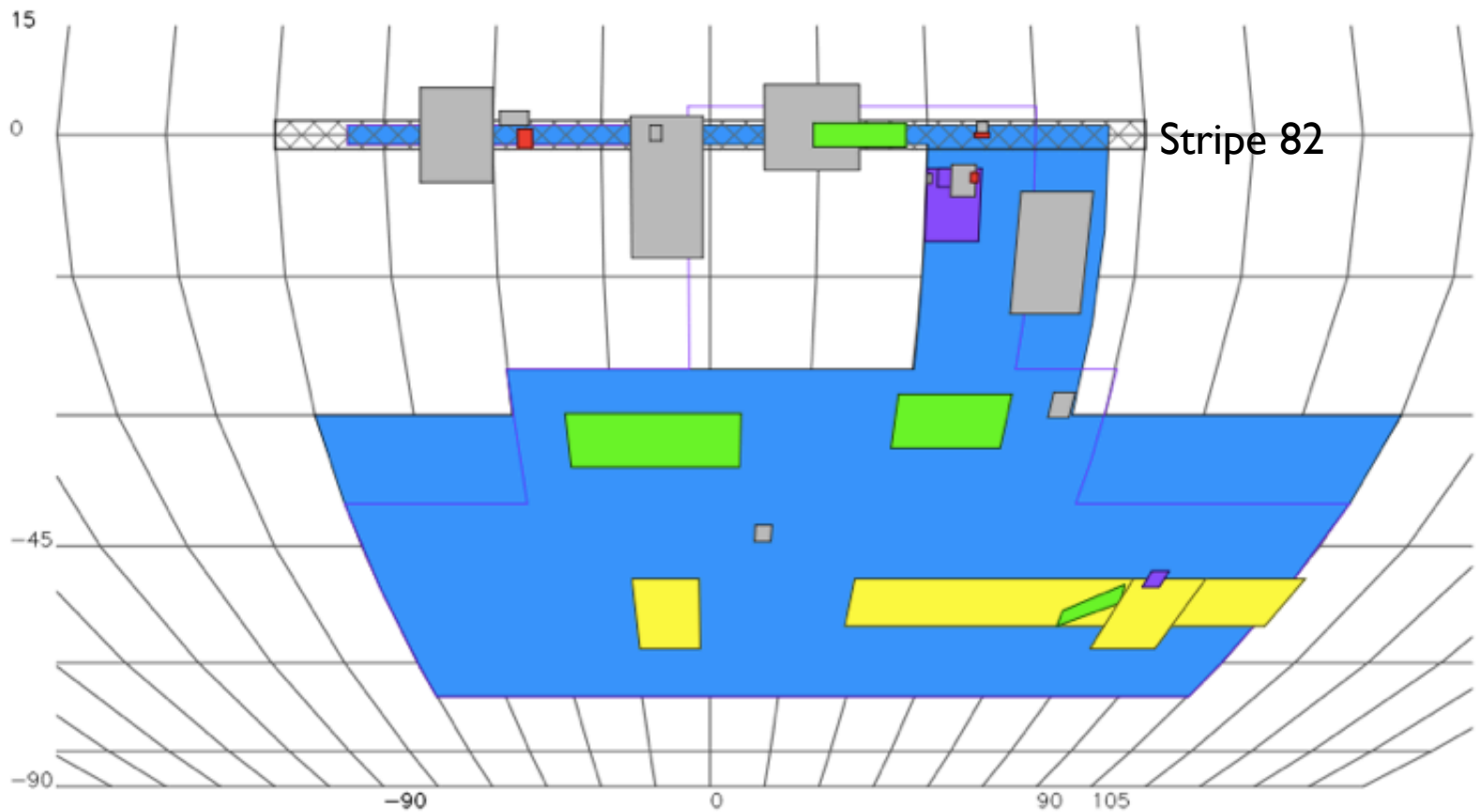
many training sets exist already within the DES footprint

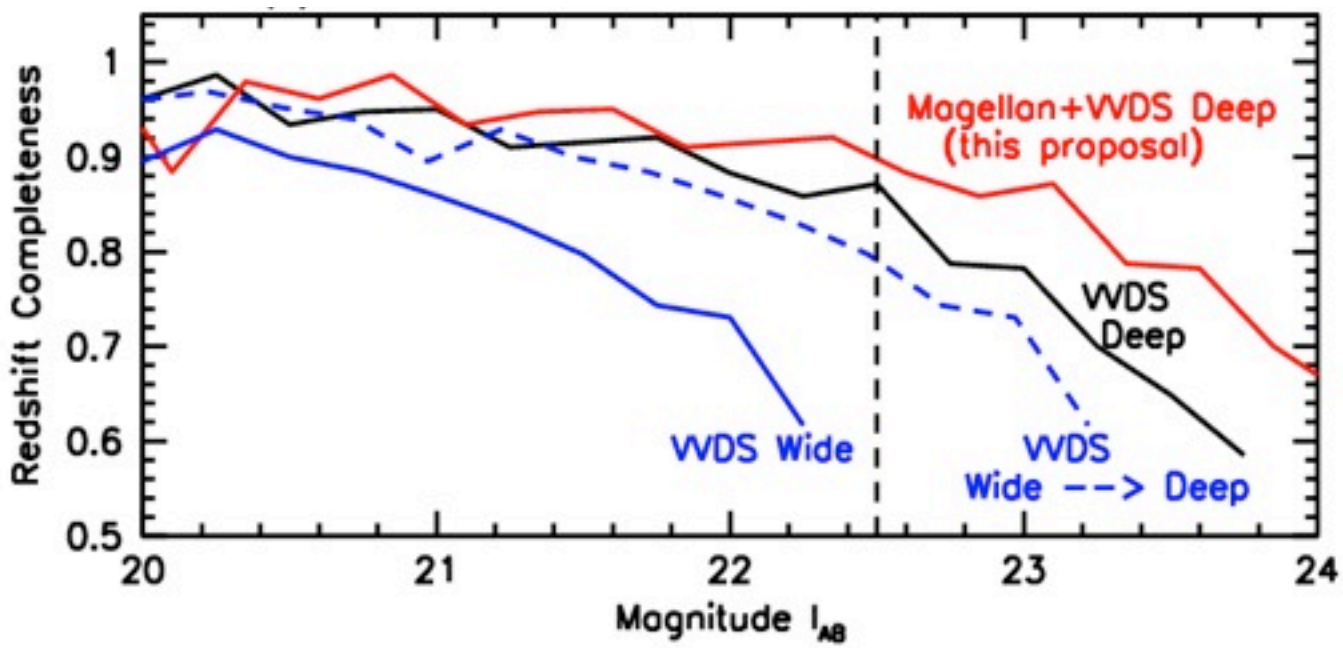


spectroscopic training sets

imaging survey deep survey intermediate survey infrared survey SZ survey

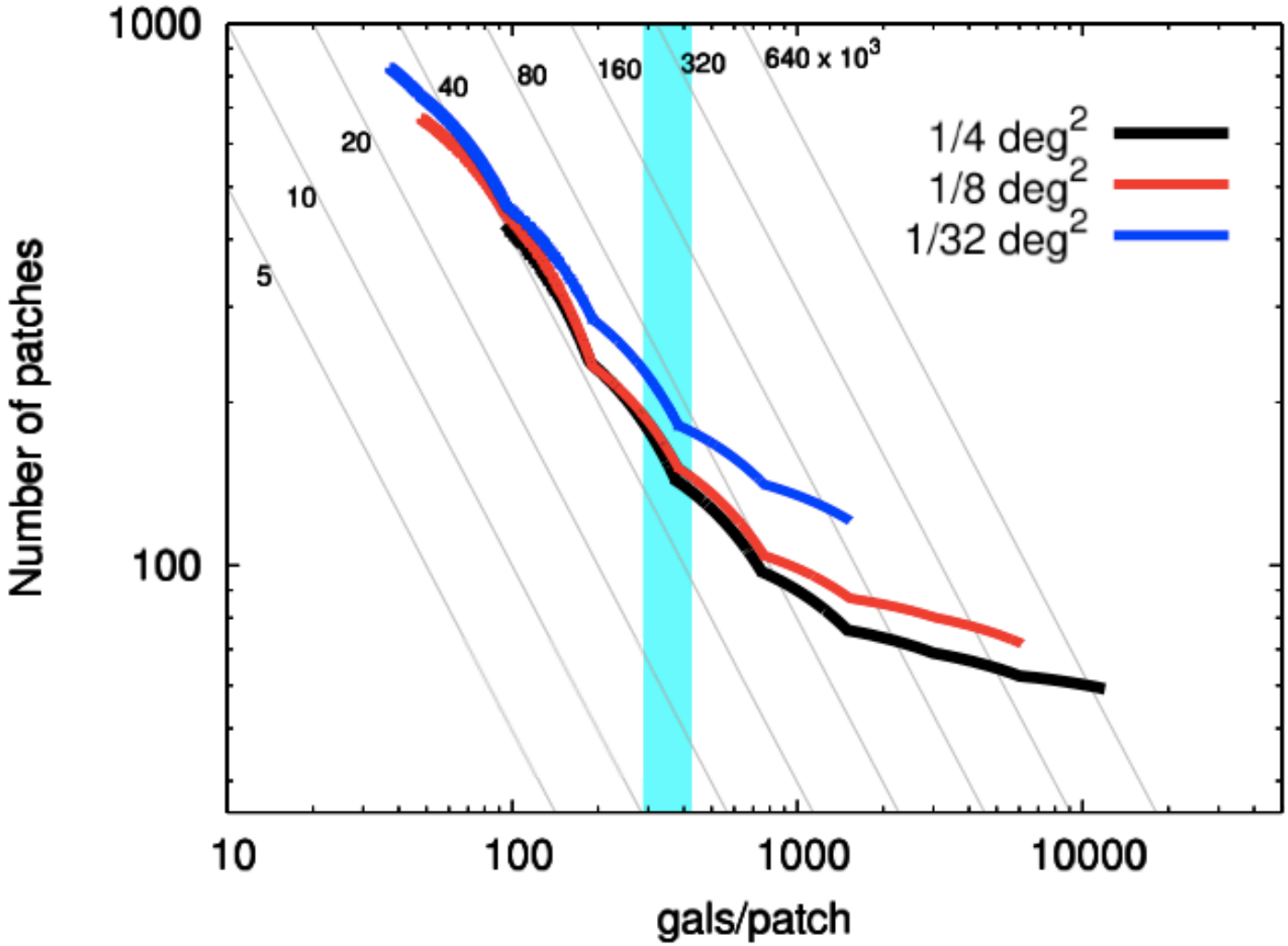
issue 1: incompleteness

training sets not complete down to DES photometric limit i=24



partially mitigate this problem by getting more redshifts at faint end: proposed a program of multislit spectroscopy to improve the spectroscopic training sets on Magellan/IMACS (Frieman, Lin, Kessler & Helsby)

issue 2: sample variance



sample variance effects due to fluctuations in LSS in spectroscopic training sets

Cunha *et al.* (2011)

issue 2: sample variance

knowledge of true photometric distribution can reduce followup requirement:

currently do not know this, want to find this

$$P(z_s^i|z_p^j) = P(z_p^j|z_s^i)\frac{N_s^i}{N_p^j}$$

Eqn 21
Cunha *et al.* (2011)

known

impact of LSS greater on $P(z_s^i|z_p^j)$ than $P(z_p^j|z_s^i)$

issue 2: sample variance

knowledge of true photometric distribution can reduce followup requirement:

currently do not know this, want to find this

$$P(z_s^i|z_p^j) = P(z_p^j|z_s^i)\frac{N_s^i}{N_p^j}$$

Eqn 21
Cunha *et al.* (2011)

"Contamination"
Objects in a photometric bin that are from the wrong spectroscopic bin

known

impact of LSS greater on $P(z_s^i|z_p^j)$ than $P(z_p^j|z_s^i)$

issue 2: sample variance

knowledge of true photometric distribution can reduce followup requirement:

"Leakage"
Objects in a spectroscopic bin placed into the wrong photometric bin

currently do not know this, want to find this

$$P(z_s^i|z_p^j) = P(z_p^j|z_s^i)\frac{N_s^i}{N_p^j}$$

Eqn 21
Cunha *et al.* (2011)

"Contamination"
Objects in a photometric bin that are from the wrong spectroscopic bin

known

impact of LSS greater on $P(z_s^i|z_p^j)$ than $P(z_p^j|z_s^i)$

spectroscopic datasets

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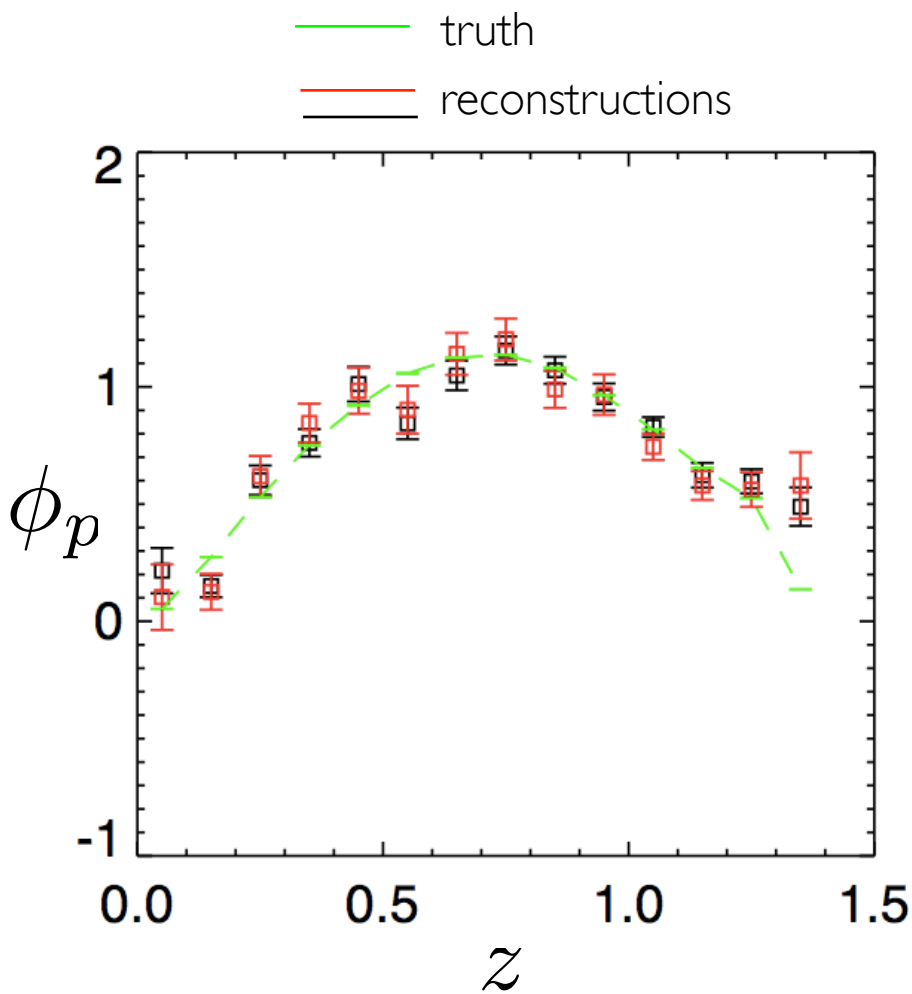
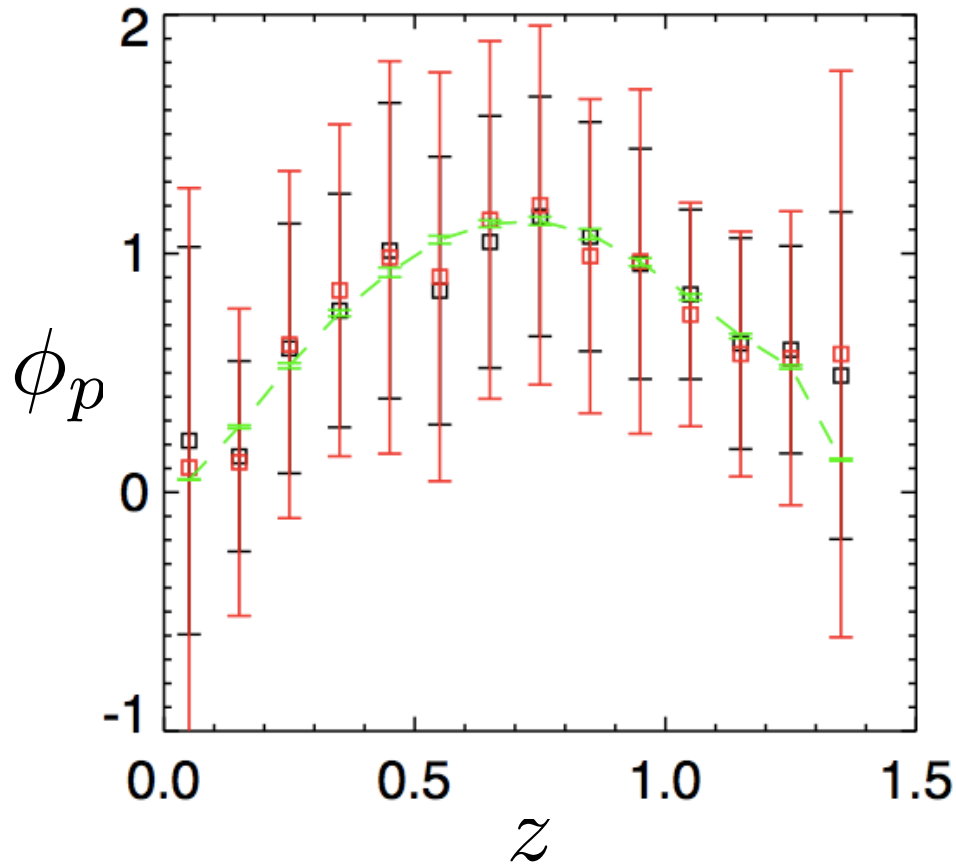
from DES science verification document (docdb-6255):

Table 3 and Fig. 2 show a number of other ancillary DES-overlapping data sets of interest. Starting from the south, the two vertical rectangular yellow regions are the SPT deep fields, and the long horizontal yellow region indicates the ACT SZ survey. Purple regions represent intermediate-scale deep imaging surveys; the one overlapping the eastern SPT deep field (West is to the left, East to the right in this plot) is the DEEPLens F3 field. Green areas are infrared surveys, and the angled green area is the Akari Deep Field South with its Herschel Hermes field. The two green regions at $\delta \approx -40^\circ$ are Herschel Atlas fields. Grey regions represent spectroscopic surveys useful for photometric redshift training in the DES, and the lone square just north of the Western SPT deep field is a Primus field, Elias S1. The grey region to the right of the Atlas fields is another Primus field, CFDS-SWIRE. Farther north, the four large grey regions are WiggleZ fields. Starting in the West on the equator, first comes the the WiggleZ 22hr field, followed in grey by the Vipers CFHLS W4 field, the VVDS shallow field, the DEEP2 and Primus survey 23hr fields colocated inside the WiggleZ 0hr field, the WiggleZ 1hr field overlapped by the green SHELA Spitzer survey region, and continuing on the equator the DEEP2 2hr field in red and the associated Primus field in grey. Just beneath them are two purple regions: the larger is the CFHTLS W1 field and the smaller is the DEEPLens F6 field. The grey region inside the purple region is the Primus XMM-LSS field, and the adjoining red square is the VVDS deep field. Almost too small to see is the grey Vipers field to the left of the F6 field. Finally the large grey region in the East is the WiggleZ 3hr field.

an ideal test



all 70 fields



single field

no photometric information is used to recover these distributions

the newman method

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method to reconstruct the true redshift distribution of a sample by using its clustering properties

requires two samples: spectroscopic sample and "photometric" sample

samples must overlap in redshift and on the sky

less sensitive to incompleteness than redshift estimation based on photometry methods; thus is particularly useful at faint end, where spectroscopy is difficult/expensive

can only reconstruct the distribution, not individual galaxy redshifts

Newman (2008)

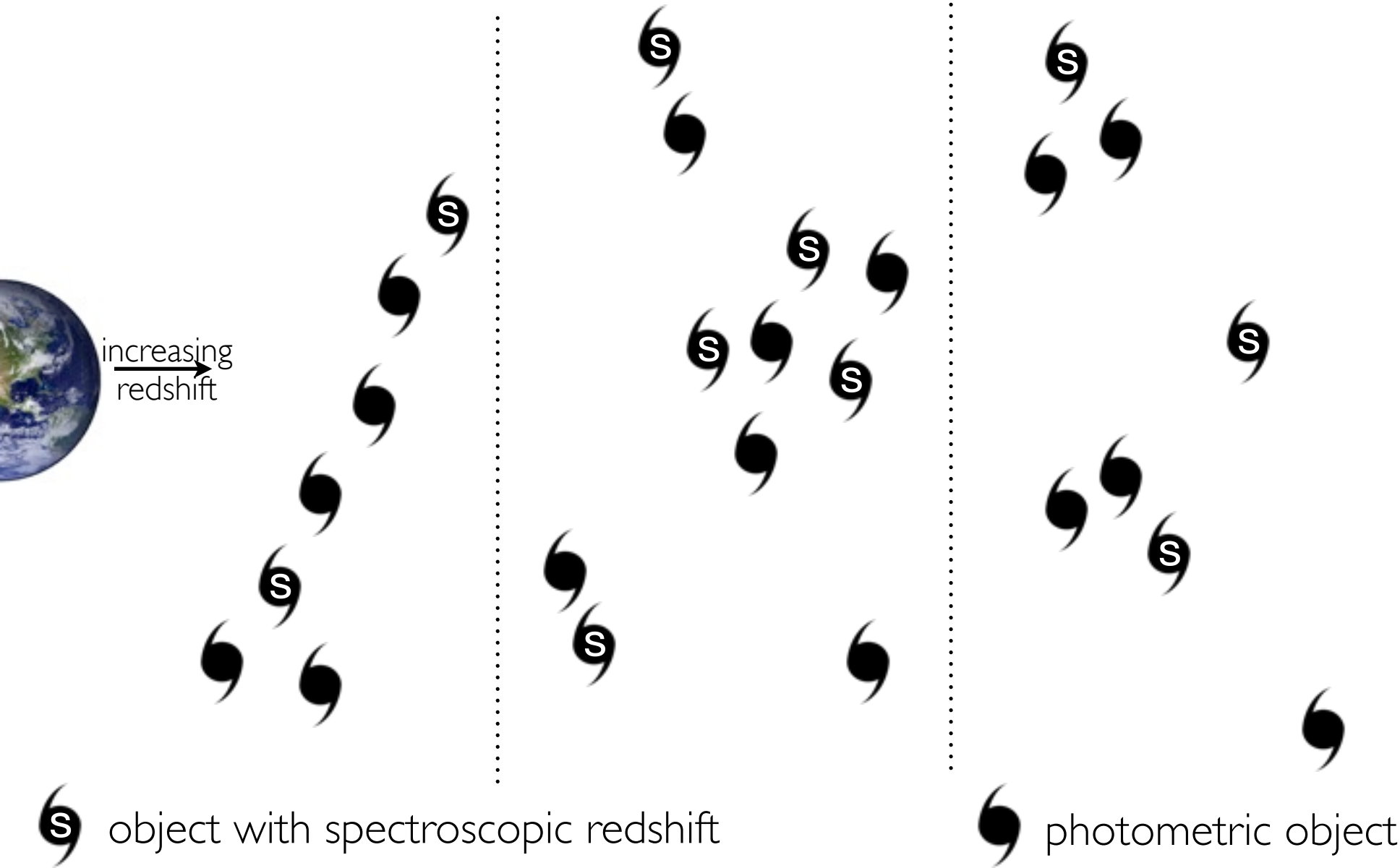
the newman method: why does this work?

object with spectroscopic redshift

photometric object

the newman method: why does this work?

measure $w_{sp}(\theta, z_{spec})$ (in bins of spectroscopic redshift)



the newman method: what's going on here

measure $w_{sp}(\theta, z_{spec})$ (in bins of spectroscopic redshift)

$$w_{sp}(\theta, z_{spec}) = \int \xi_{sp} \phi_p(z) dz$$

solve for $\phi_p(z)$

$$\phi_p(z) \equiv \frac{\frac{dN_p}{dz d\Omega}}{\int_0^\infty \frac{dN_p}{dz' d\Omega} dz'}$$

the newman method: what's going on here

measure $w_{sp}(\theta, z_{spec})$ (in bins of spectroscopic redshift)

$$\underbrace{\boxed{w_{sp}(\theta, z_{spec})}}_{\text{we measure this}} = \int \xi_{sp} \underbrace{\boxed{\phi_p(z)}}_{\text{we want this}} dz$$

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assume $\xi_{sp} \propto \xi_{ss}$ which we can measure in the spectroscopic sample

solve for $\phi_p(z)$

$$\phi_p(z) \equiv \frac{\frac{dN_p}{dz d\Omega}}{\int_0^\infty \frac{dN_p}{dz' d\Omega} dz'}$$