Cluster Cosmology and Redshift Estimates in Dark Energy Experiments

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Outline

- Dark Energy Experiments

- Galaxy Clusters
  - Cosmology
  - Self-Calibration
  - Photo-z Requirements

- Redshift Estimations:
  - Photo-z's
  - Redshift Distributions
  - Photo-z's and cluster detection

- Summary

Dark Energy Experiments

- DES, SPT, SNAP, LSST, etc.
- Probes: Weak Lensing
  Cluster Counts
  Supernova
  Baryon Oscillations

- ➢ All probes require accurate/precise redshifts.
- ➢ Galaxy clusters: Observable-mass
- ➢ DES+SPT : Redshifts!

Clusters: Mass function

- Cluster mass-function exponentially sensitive to linear density perturbations σ

$$\frac{d\bar{n}}{d\ln M} = 0.3\frac{\rho_m}{M}\frac{d\ln\sigma^{-1}}{d\ln M}\exp\left[-\left|\ln\sigma^{-1} + 0.64\right|^{3.82}\right]$$

Jenkins et al. 2001

$\Longrightarrow$ Cluster statistics sensitive to

- Gravity theory (modified gravity)
- Dark Energy components (Λ, Quintessence, ...)
- Primordial nongaussianities, etc.

Clusters: Counts

Density: $$\bar{n}_i = \int_{M_i^{obs}}^{M_{i+1}^{obs}} d\ln M^{obs} \int d\ln M \frac{d\bar{n}}{d\ln M} p(M^{obs} | M)$$

Counts: $$\overline{N}_i = \Delta\Omega \int_{z_i^{phot}}^{z_{i+1}^{phot}} dz^{phot} \int dz \frac{D_A^2(z)}{H(z)} \bar{n}_i(z) p(z^{phot} | z)$$

$p(M^{obs} | M)$ and $p(z^{phot} | z)$: Gaussian

Clusters: Sample Variance

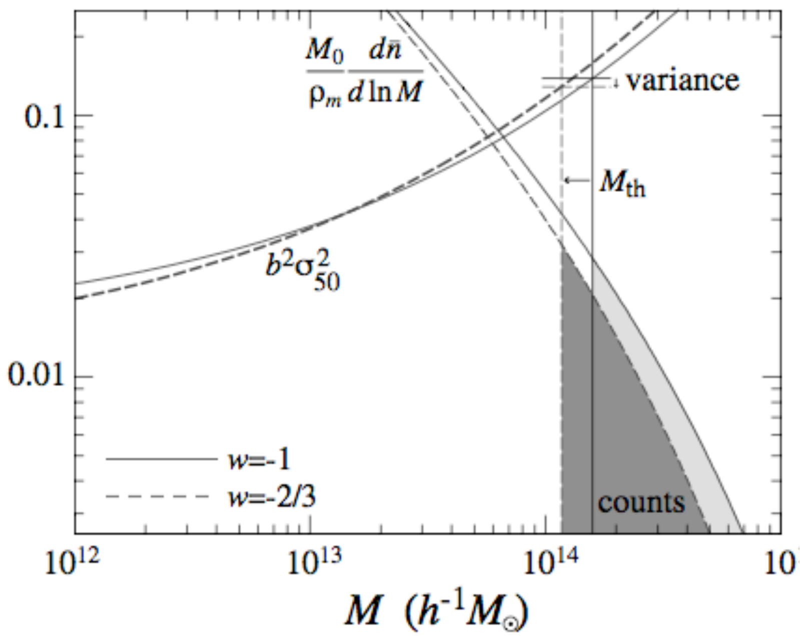
Variance: $$S_{ij} = \left\langle (N_i - \overline{N_i})(N_j - \overline{N_j}) \right\rangle$$

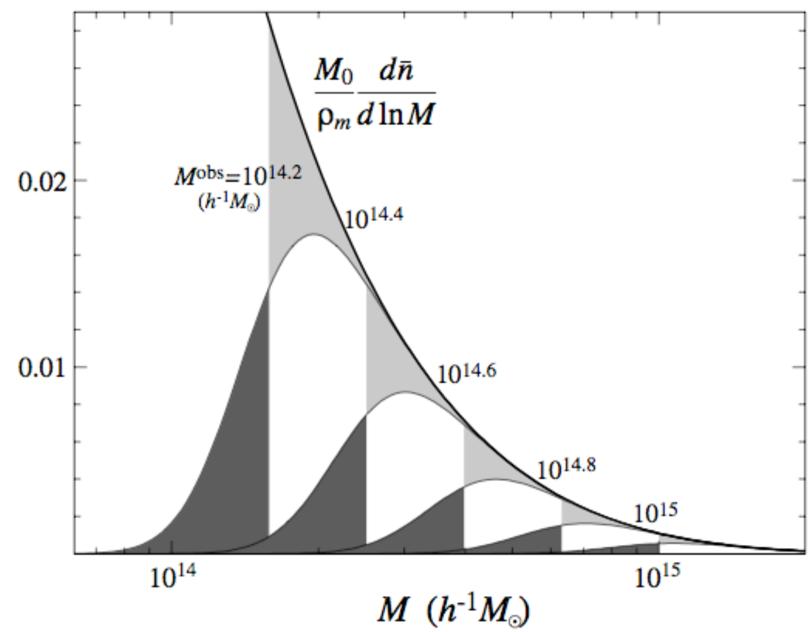
$$= b_i b_j \overline{n}_i \overline{n}_j \int \frac{d^3k}{(2\pi)^3} W_i^*(\vec{k}) W_j(\vec{k}) P(k)$$

Window $W_i(\vec{k})$ is convolved with $p(z^{phot} \mid z)$

Uncertainties

- Mass and redshift uncertainties change observed number counts and are degenerate with Dark Energy.





Lima & Hu 2004

Lima & Hu 2005

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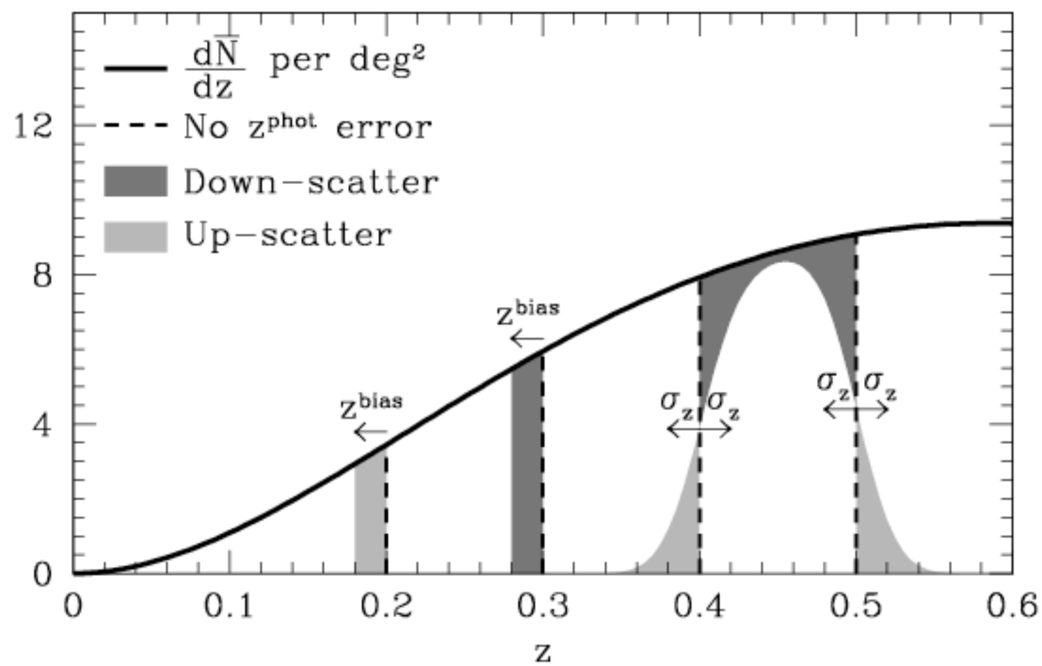
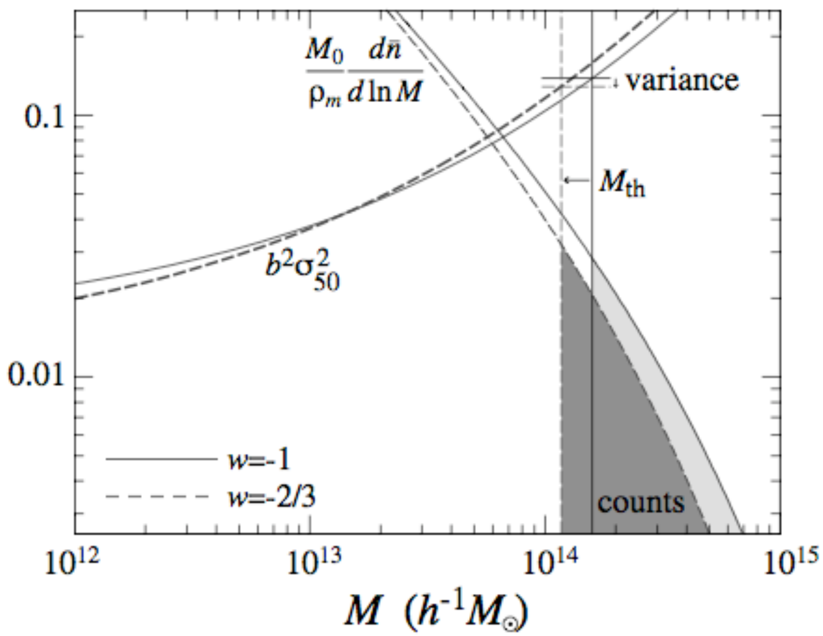


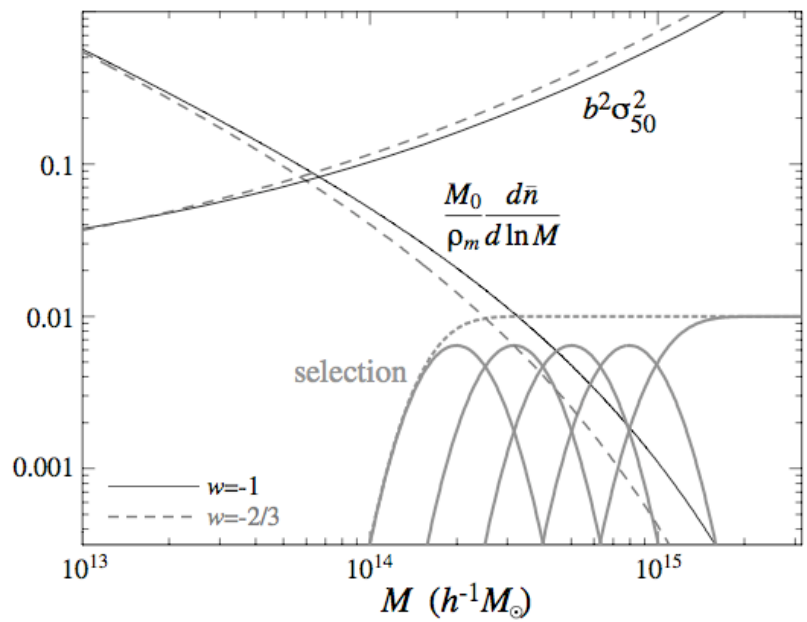
Lima & Hu 2007

Self-Calibration: Consistency

• Clustering: Consistency between counts and sample variance breaks degeneracies between shifts in mass and DE parameters.

• Shape: Consistency between theoretical predictions and observed counts as a function of mass (shape of mass function) allows calibration of the scatter in mass-observable.

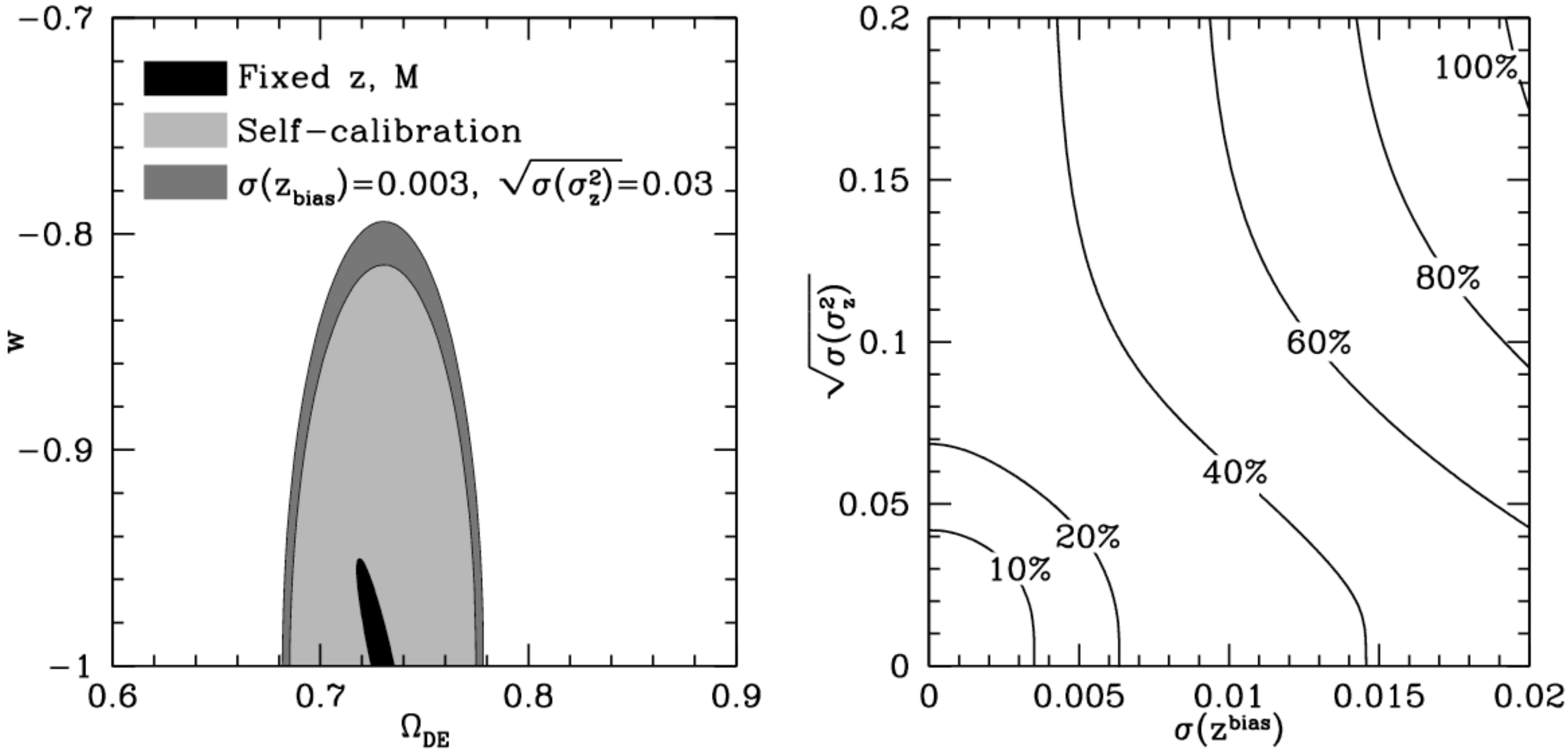




Constraints

- SPT like, $4000\ \deg^2$, $z_{max} = 2$, $\Delta z = 0.1$
  $M_{th} = 10^{14.2}$ solar masses
- Flat universe
- WMAP 1yr cosmology
- Priors of 1% on cosmological parameters (not Dark Energy).
- Constant w

Self-Calibration: Photo-z Requirements



Lima & Hu 2007

Training Set Requirements

- Fiducial:

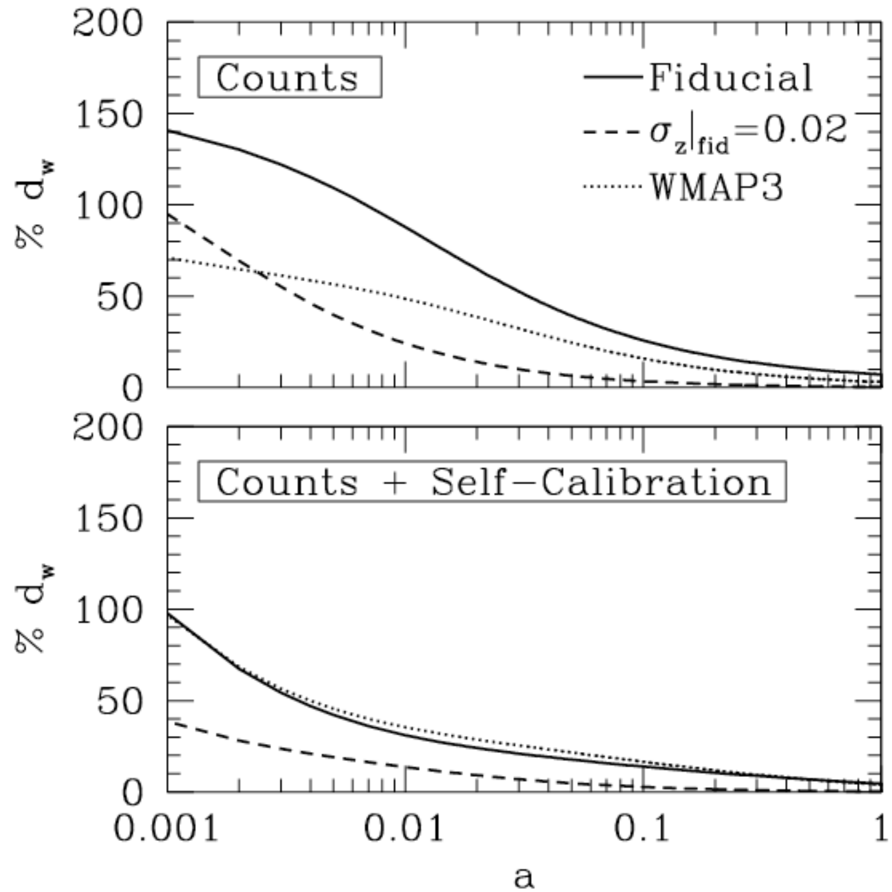
 - WMAP 1yr

 - $\sigma_z = 0.03(1+z)$

- Training Calibrators:

$$\sigma(z_{bias,i}) = \frac{\sigma_{z,i}}{\sqrt{N_{spec,i}}}$$

$$N_{spec,i} = aN_i$$



Lima & Hu 2007

Photometric Redshifts

- Probe strong spectral features (4000 A break)

- Difference in flux through filters as the galaxy is redshifted.

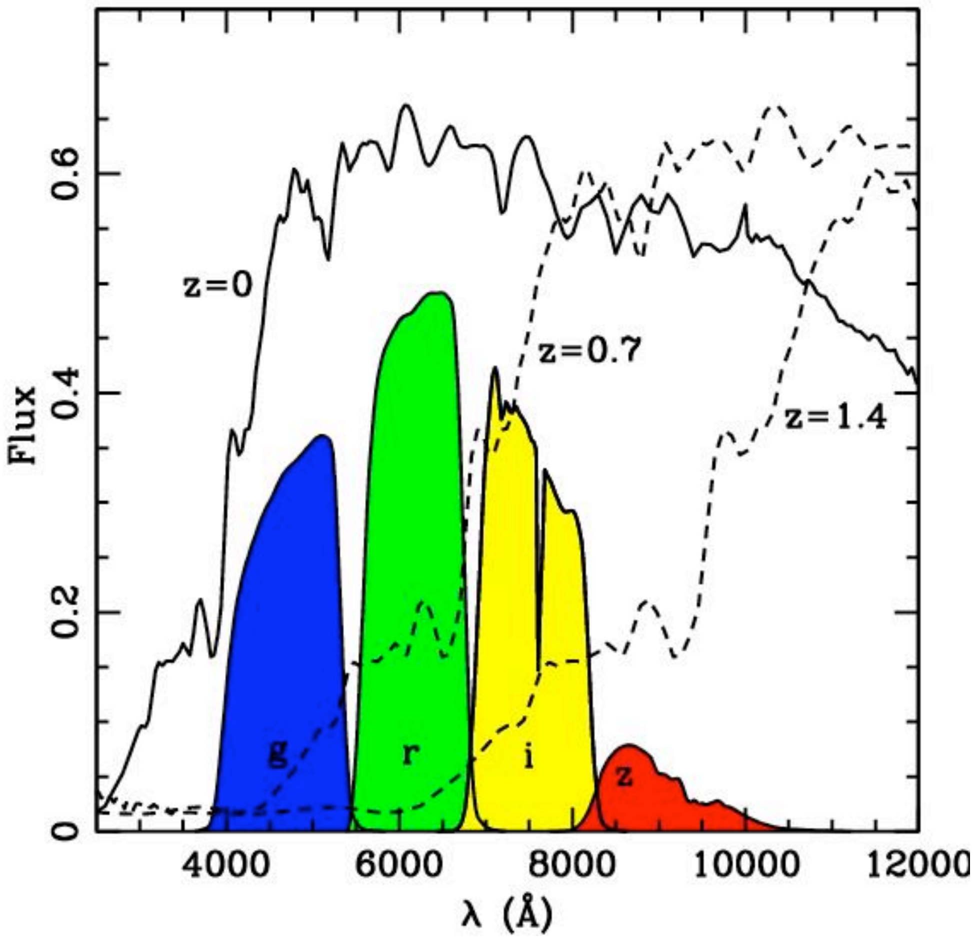


Photo-z Methods

- Template Fitting Methods

➢ Use a set of standard SEDs (templates)

➢ Compute filter fluxes of redshifted templates

➢ Match to observed fluxes (χ^2 minimization)

➢ Output type and redshift

- Training Set Methods

➢ Determine functional relation between m and z_{phot} using a training set

$$z_{phot} = z_{phot}(m,c)$$

Comparing Photo-z Methods

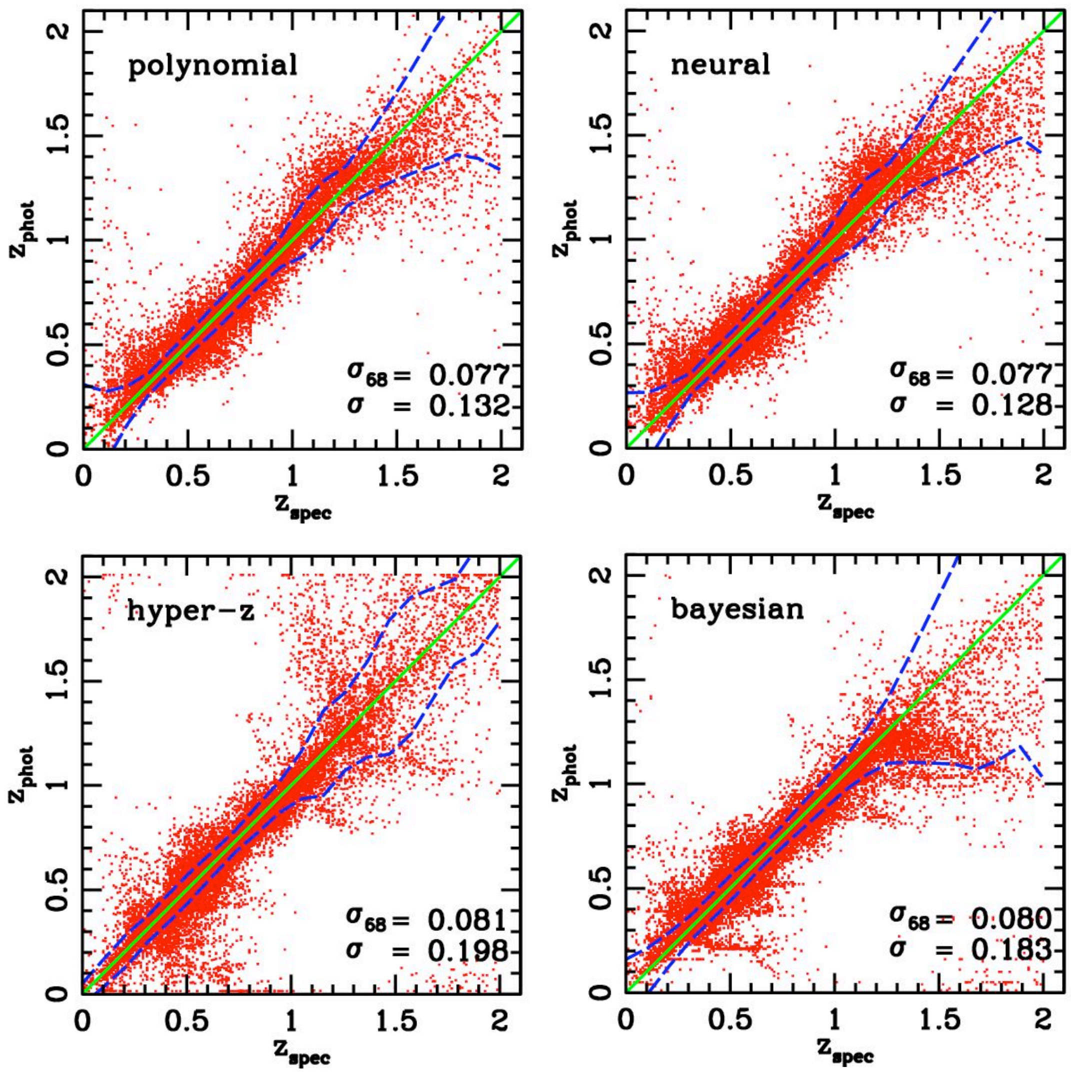
DES
griz filters

$$\sigma^2 = \frac{1}{N}\sum_{i=1}^{N}\left(z^i_{phot} - z^i_{spec}\right)^2$$

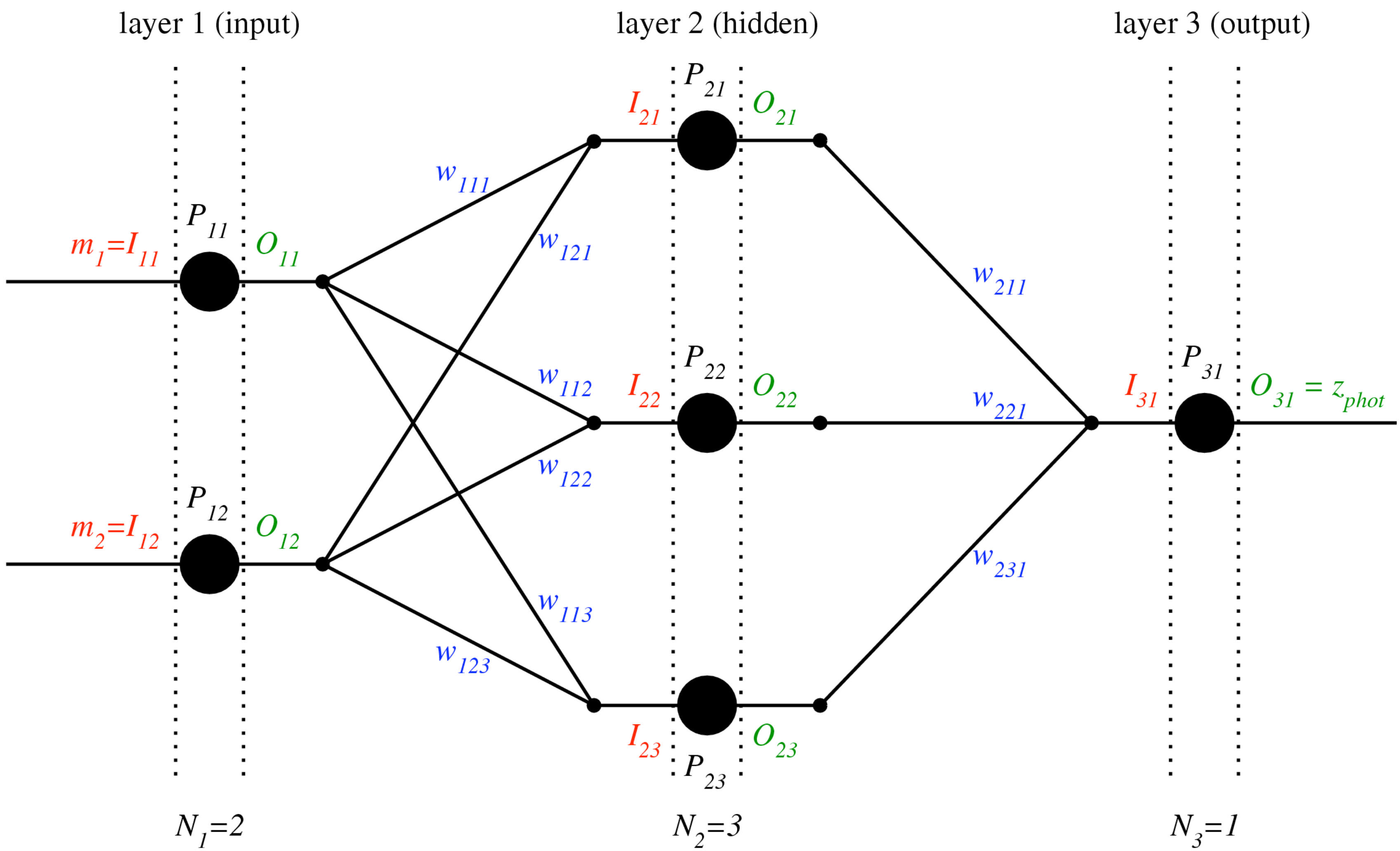
$\sigma_{68} = 68\%$ confidence region

Limiting Magnitudes

g	24.6
r	24.1
i	24.0
z	23.65



Neural Network Photo-z's



DES (Optical)

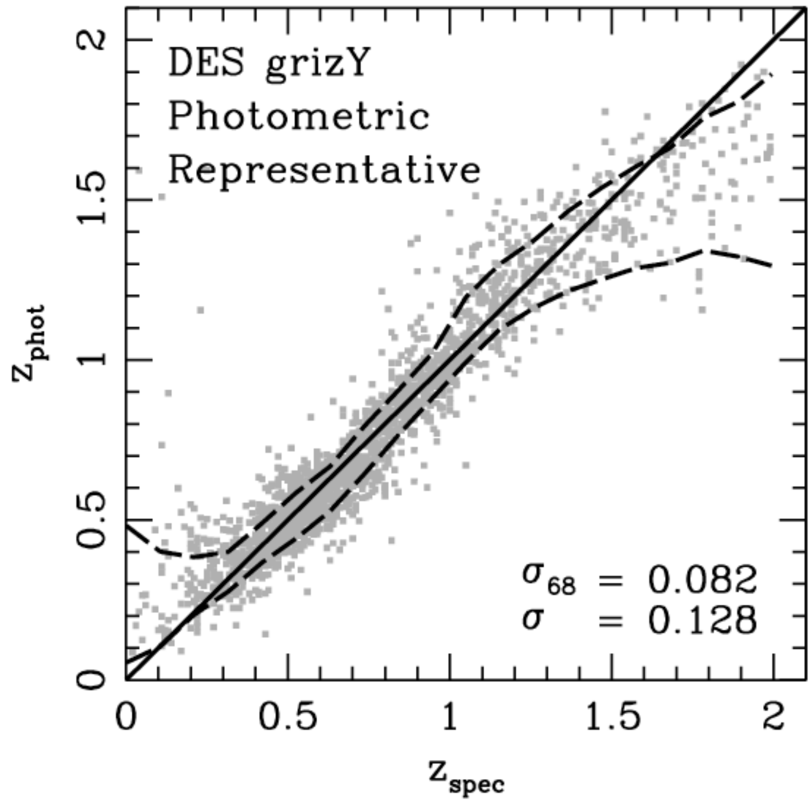
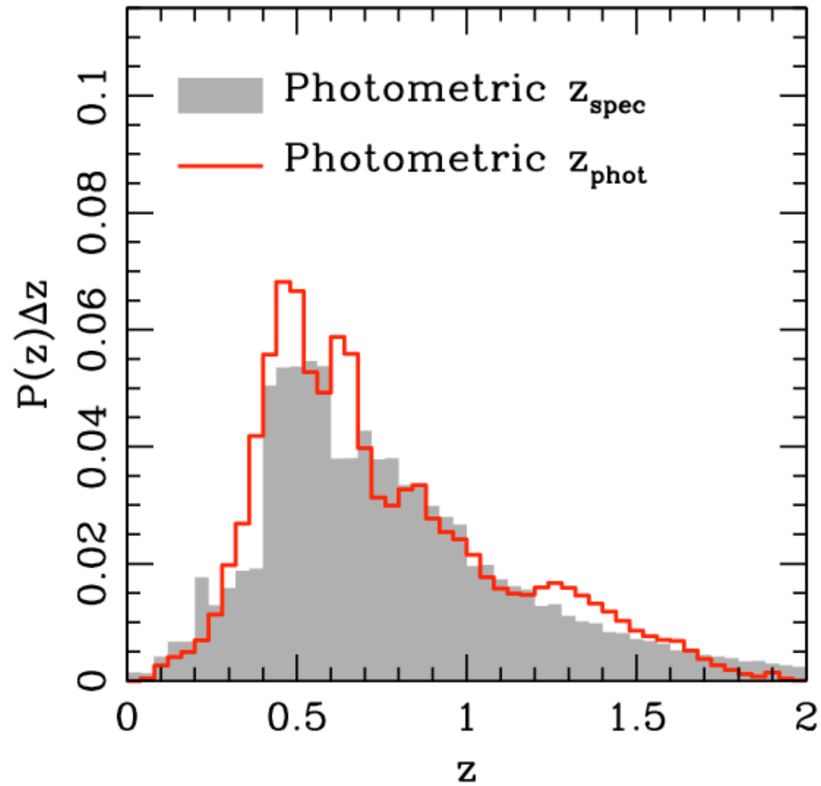
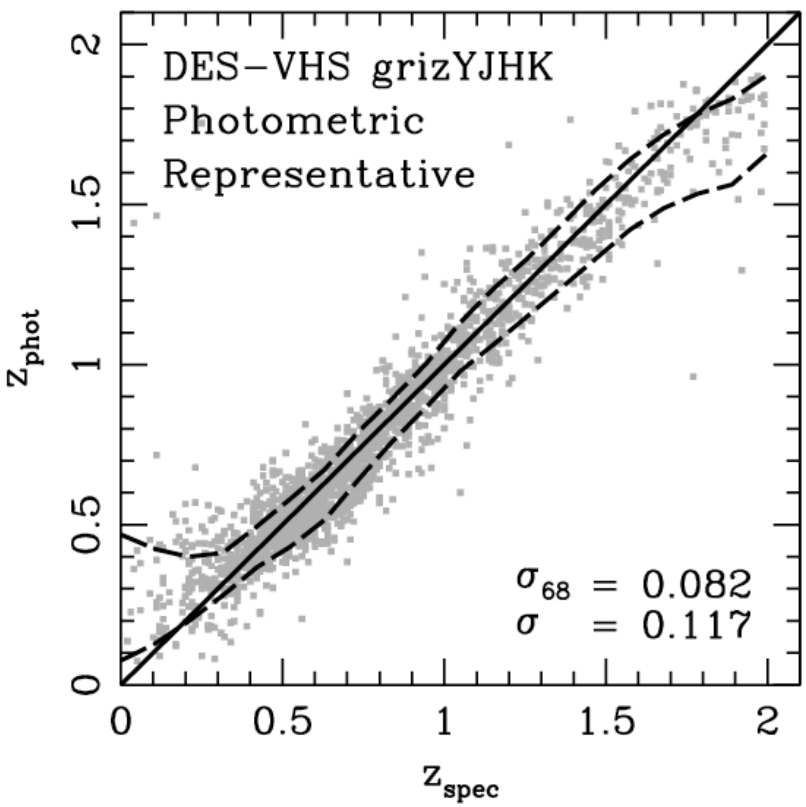


Photo-z bias

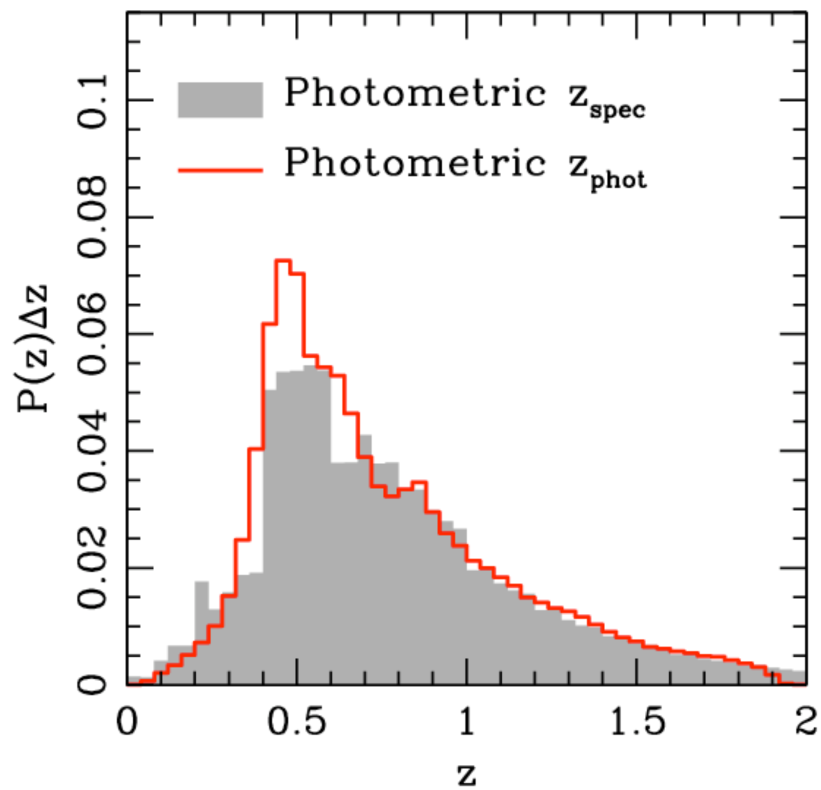


Multi-peaked distribution

DES-VHS (Optical + IR)

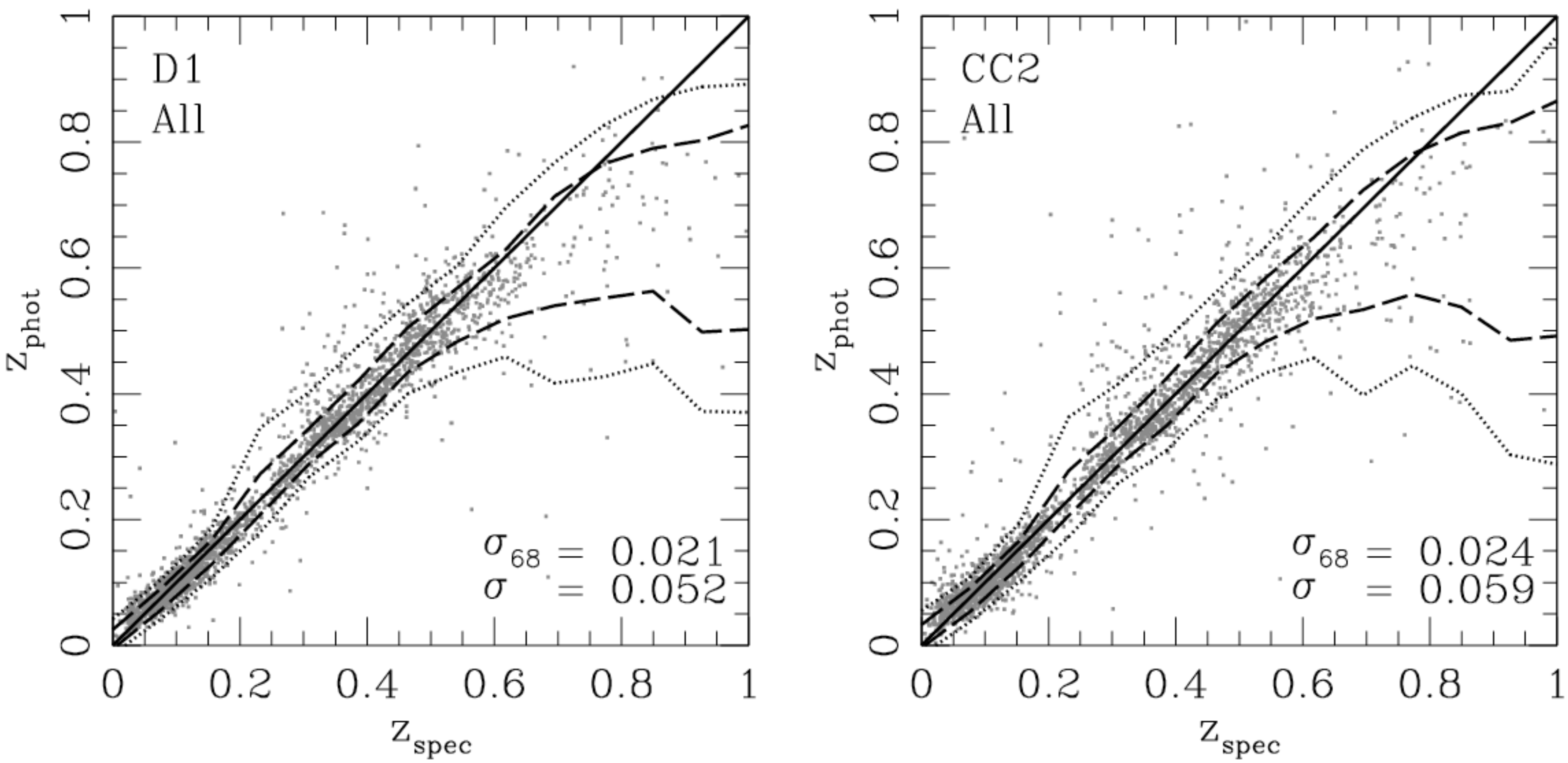


Less photo-z bias



Less multiple peaks

SDSS DR6



Oyaizu, Lima et al. 2008

Redshift Distributions

- Photo-z biases $\Longrightarrow$ Multiple peaks in $P(z)$

- Deconvolution (requires regularization)

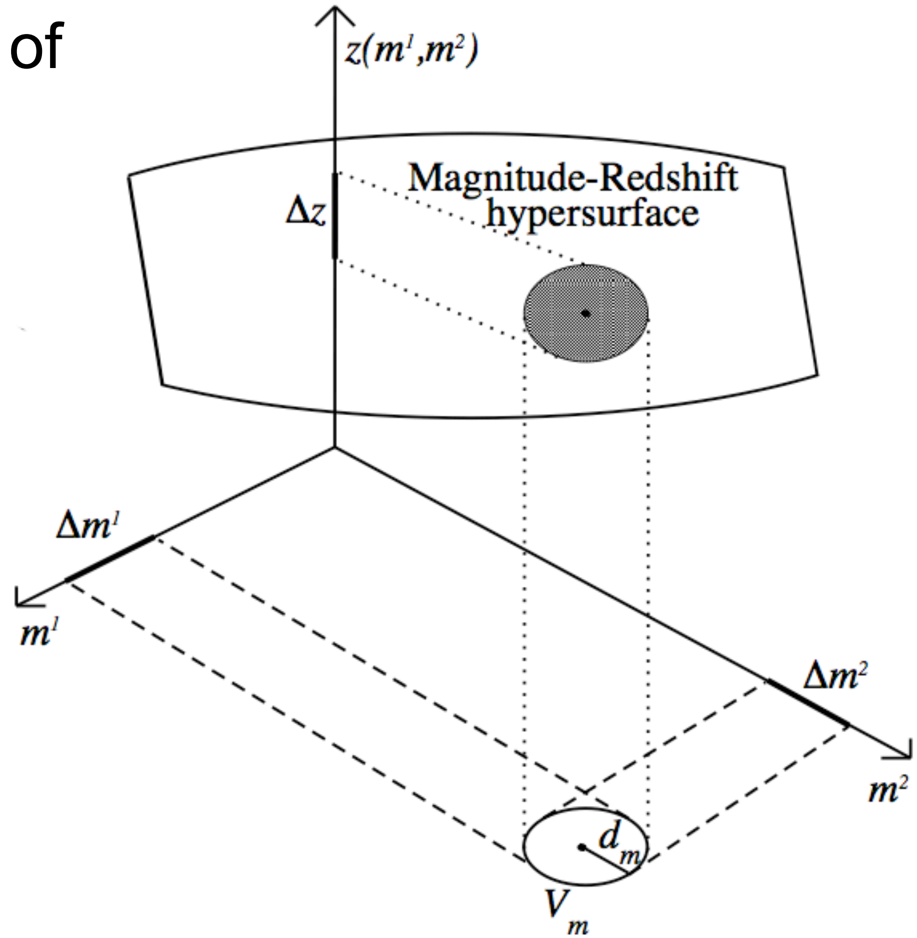
- Weighting method:
  - Assigns weights to training set objects
  - Match distributions of photometric observables in the training and photometric sets.

- Weights: ratio of object's densities within the training and photometric sets.

Weights

Fixed hypervolume in space of observables. Weights:

$$W \propto \frac{N_P}{N_T}$$



N_T : Neighbors in Training

N_P : Neighbors in Photometric

Weights x Photo-z's

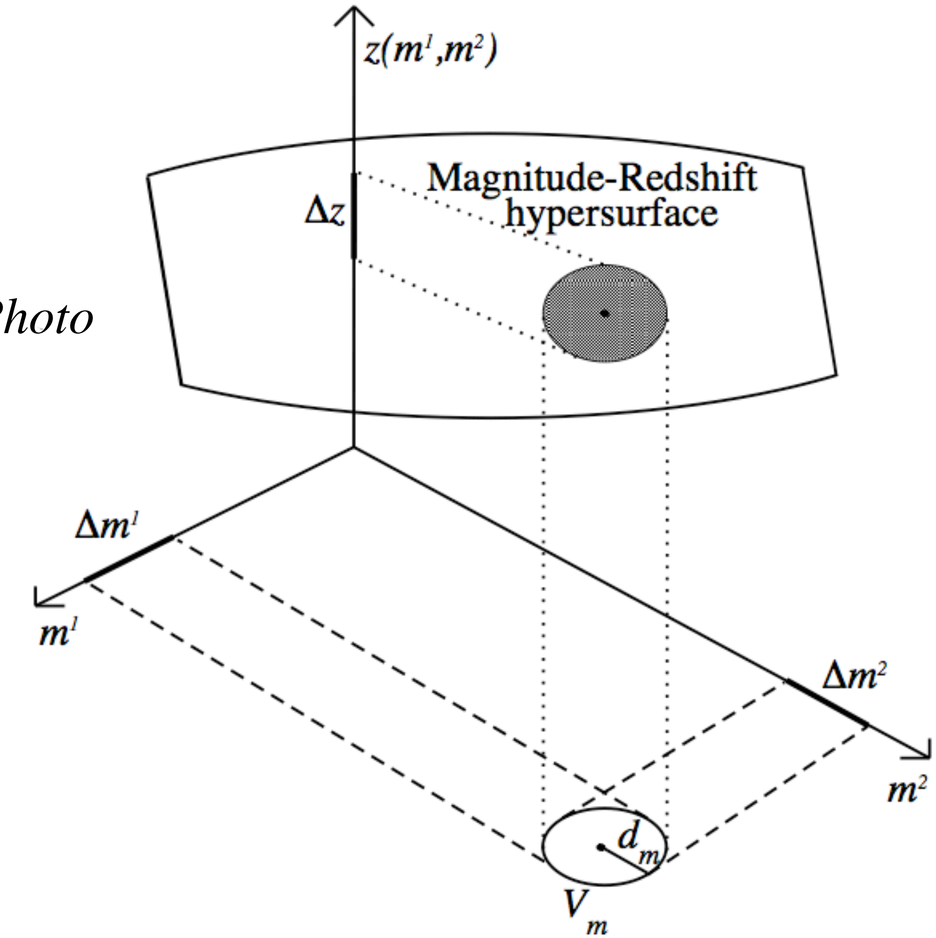
Requirements

- Weights:

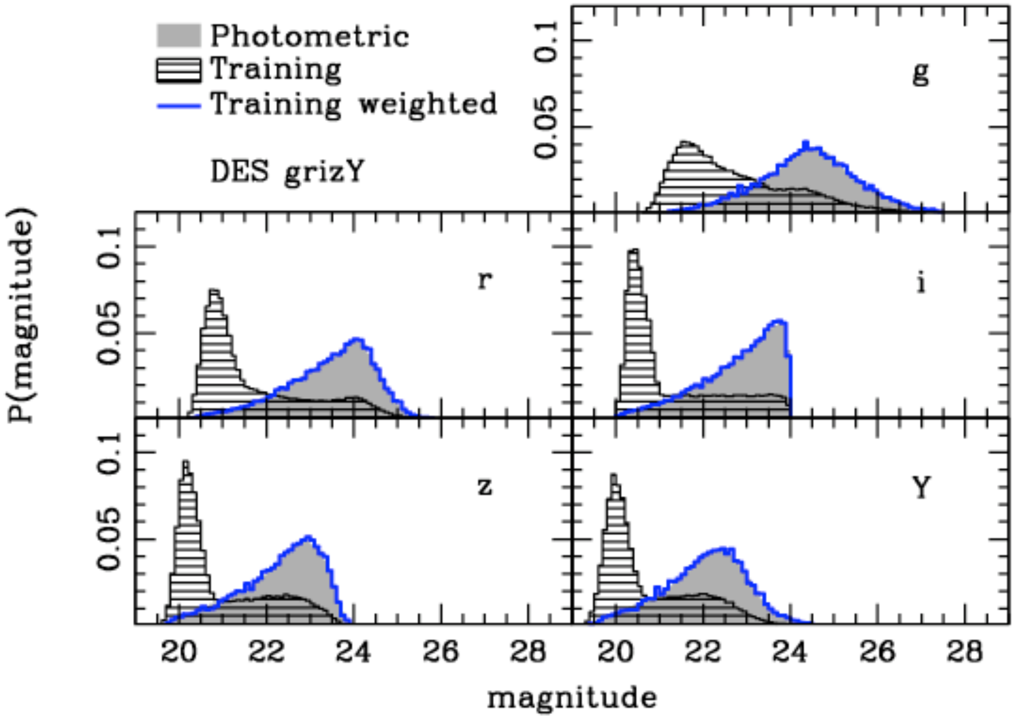
$$P(z \mid m)^{Train} = P(z \mid m)^{Photo}$$

- Photo-z's:

$$P(z \mid m) = \delta(z \mid m)$$

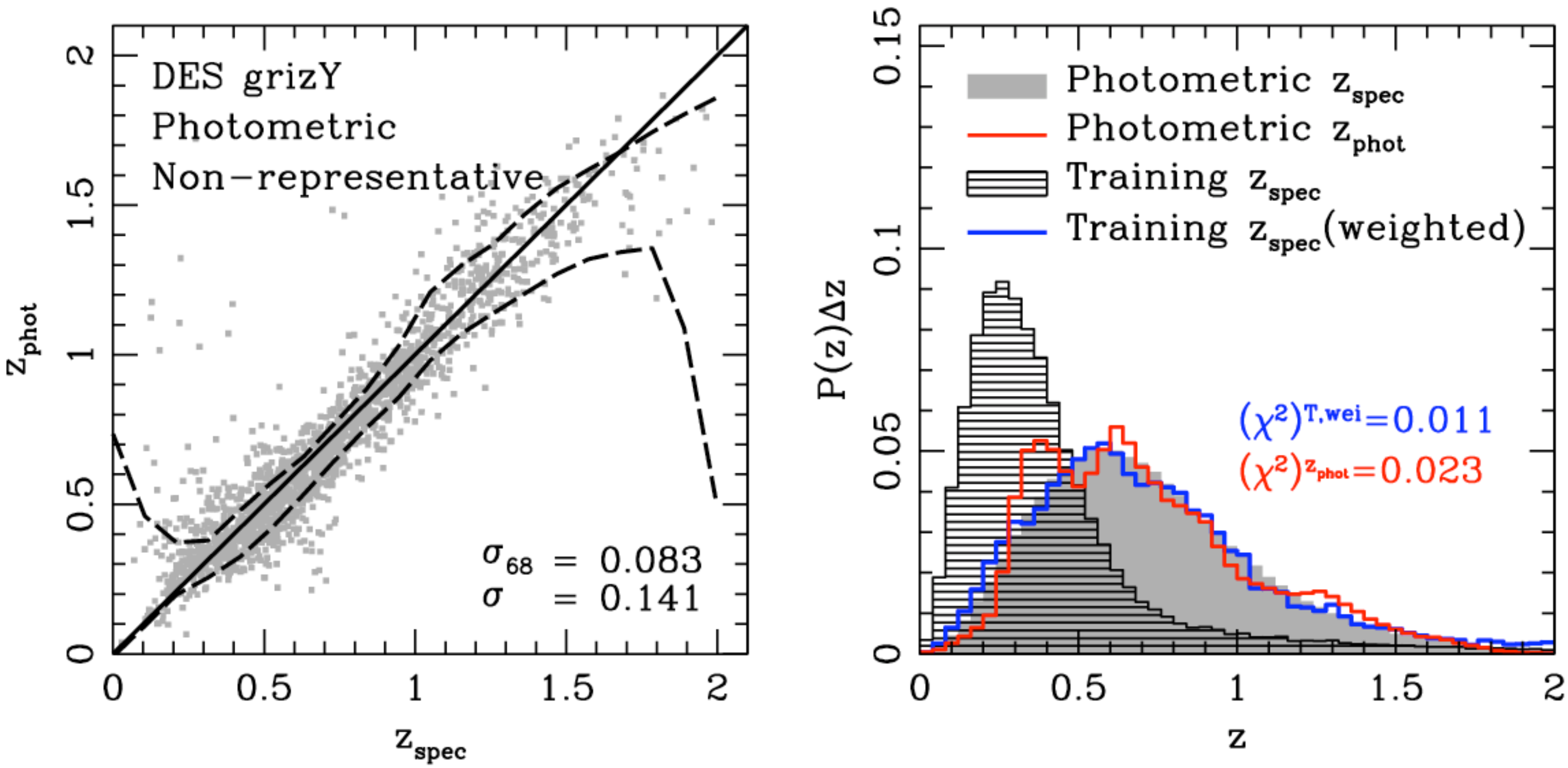


Matching Observables: DES



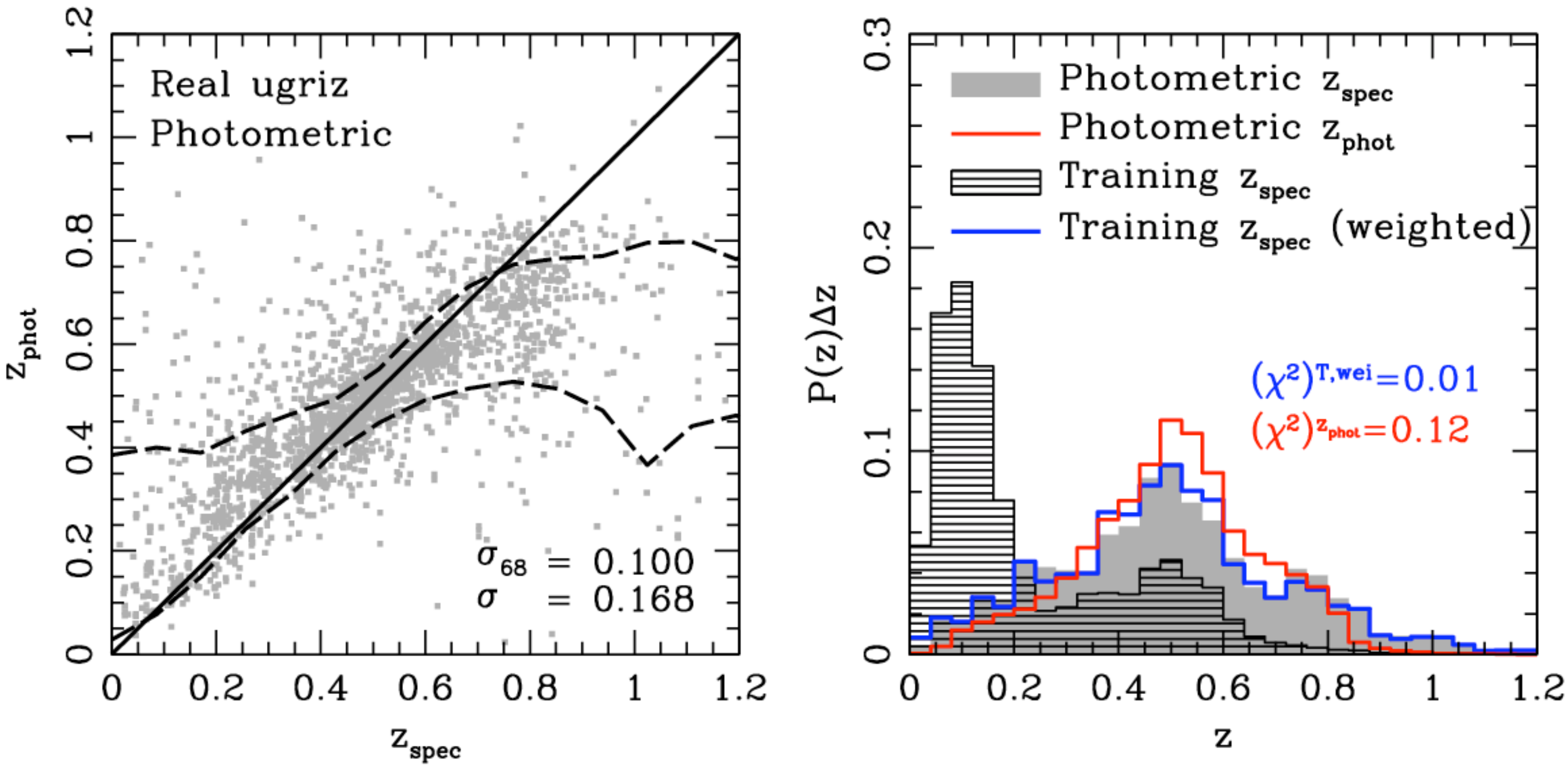
Lima et al. 2008

Redshift Reconstruction (DES)



Lima et al. 2008

Redshift Reconstruction (SDSS)



Lima et al. 2008

Weights: Further applications

- Improve photo-z codes by using information of redshift distribution (prior).

- Provide natural regularization for Deconvolution methods

- Estimate realistic photo-z errors (weighted) in the photometric set.

- Use neighbors and weights to assign a probability $p(z)$ to objects in the photometric set, in addition to a photo-z.

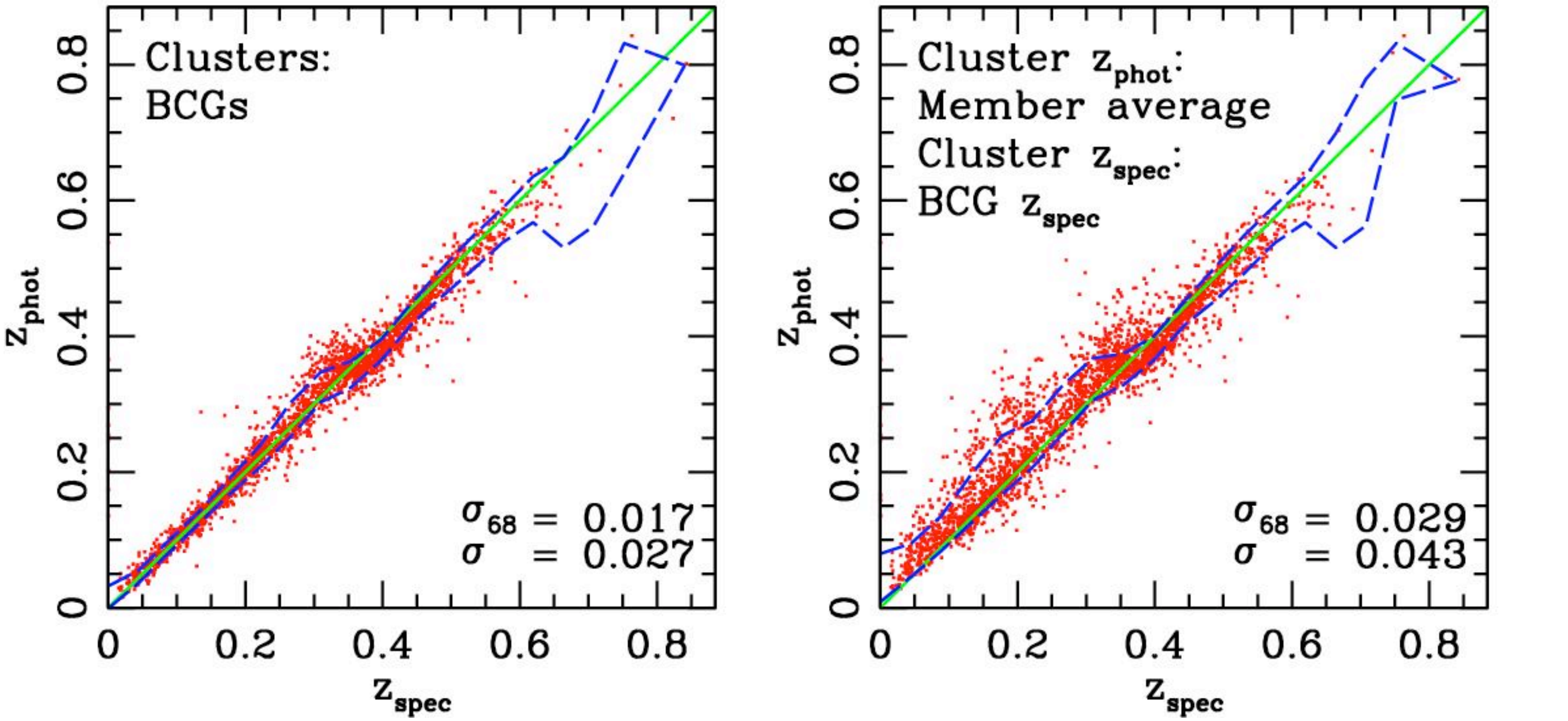
Cunha, Lima et al. in prep.

Cluster Finders and Photo-zs

- Red sequence cluster finder: Jiangang Hao
  - Improved version of maxBCG Koester et al. 2007
  - Find BCGs : overdensities in space and color.
  - Find associated members in angular aperture.

- CO-ADDED SDSS data: 5 run

Cluster Photo-zs: Definitions



Removing Interlopers

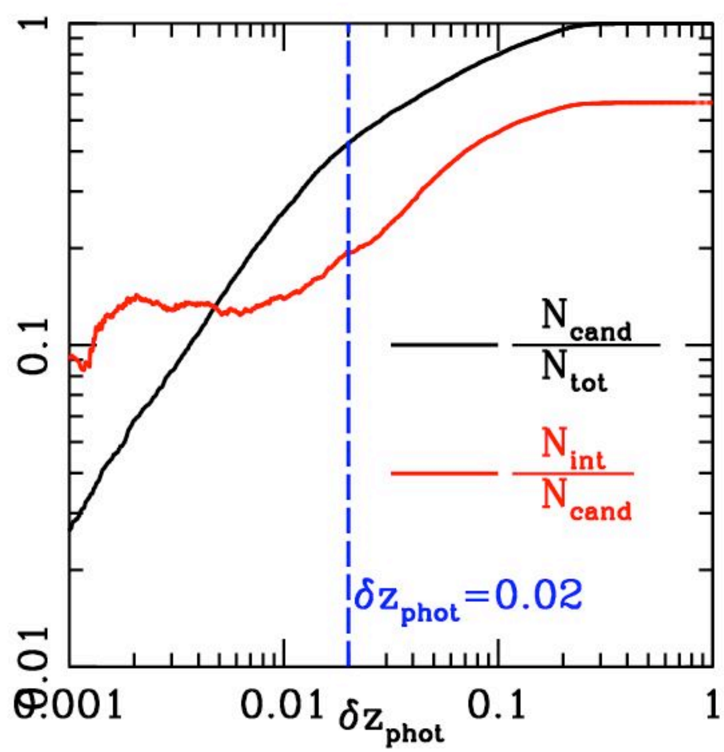
$$\Delta_{z_{spec}} = (z_{spec} - \mathrm{BCG}z_{spec})$$
$$\Delta_{z_{phot}} = (z_{phot} - \mathrm{BCG}z_{phot})$$

N_{tot} : All galaxies

N_{cand} : $|\Delta_{\mathrm{z_{phot}}}| < \delta z_{phot}$

N_{int} : $|\Delta_{\mathrm{z_{spec}}}| > 0.01$

≈ 3000 Km/s



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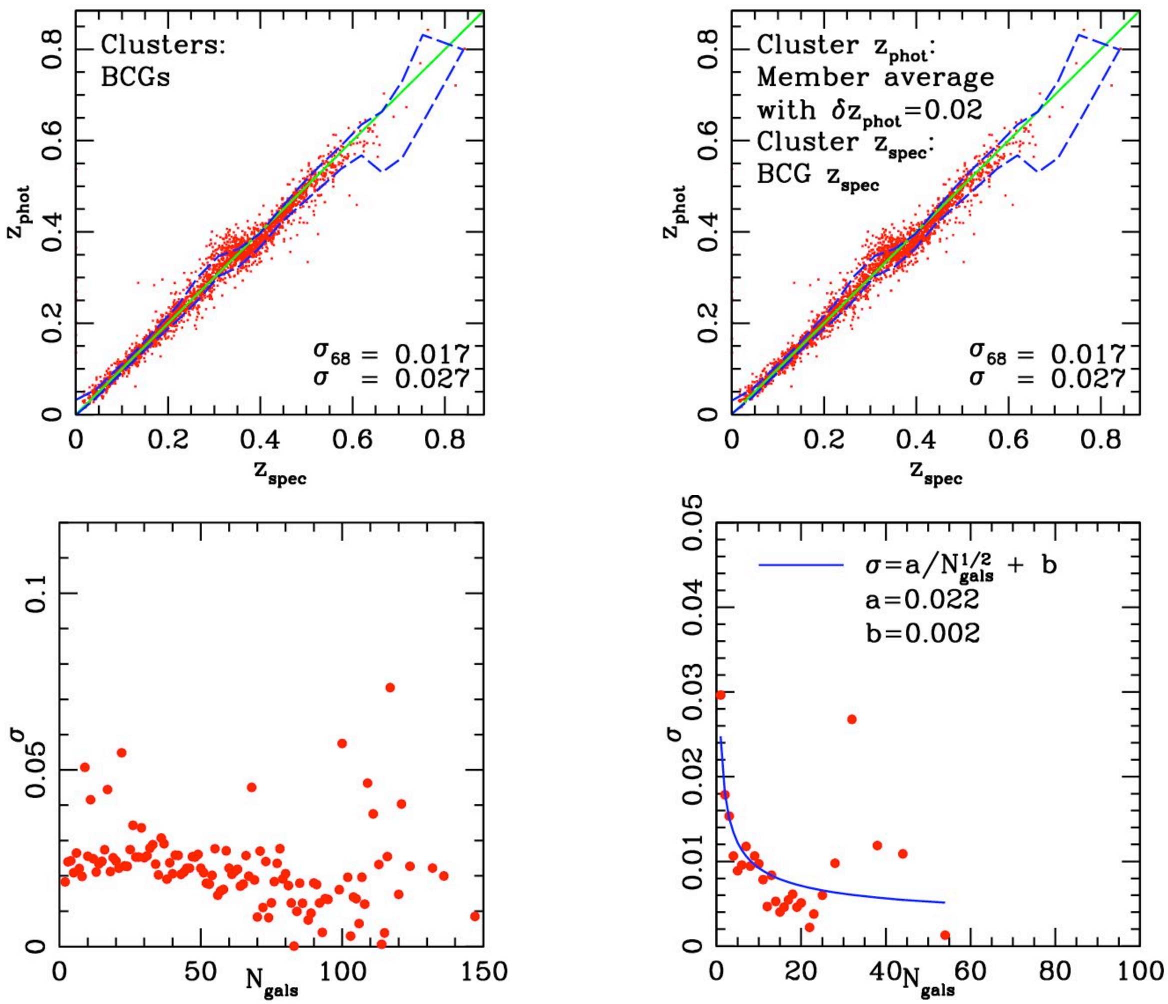

Summary

- Cluster Cosmology: Mass-observable, self-calibration, redshift requirements.
- Photo-z methods: neural network. Applications to DES and SDSS.
- Redshift Distribution: Weighting Method.
- Applications of weights.
- Photo-z's and cluster finders