Cluster Cosmology on a 10+ Year Time Scale

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What Can Clusters Do?

Zeroth order personal answer:

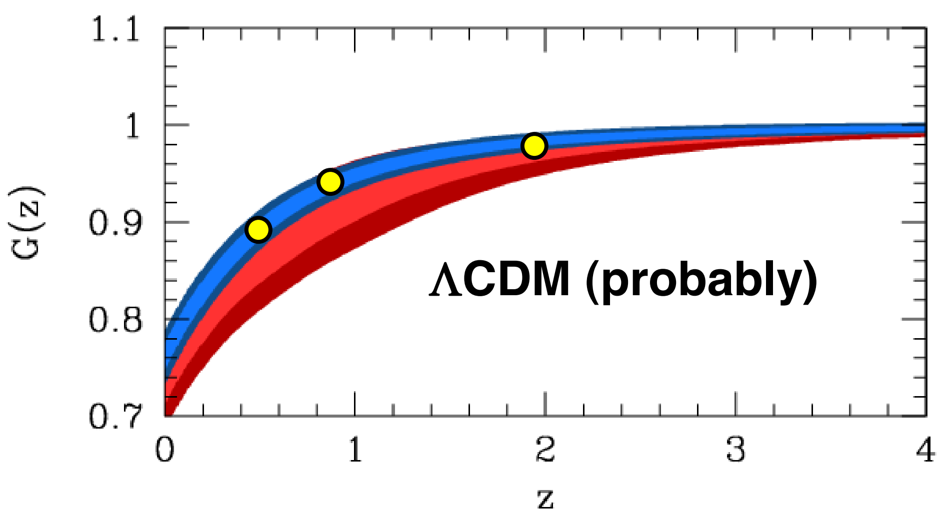
- not geometry- BAO are probably better.
- focus on growth

Abundance: $$\frac{dN}{dM} \sim \frac{\upsilon(M)^{1/2}}{\sigma_8(z)} \exp\left[-\frac{\upsilon(M)}{2\sigma_8^2(z)}\right]$$

This is what we can do.

Why It's Interesting

Clusters can falsify DE+GR



ΛCDM

quintessence

(68 / 95% CL)

Mortonson et al. (2009, 2010)
cluster predictions: Mortonson et al. (2011)
WL predictions: Vanderveld et al. (2012)

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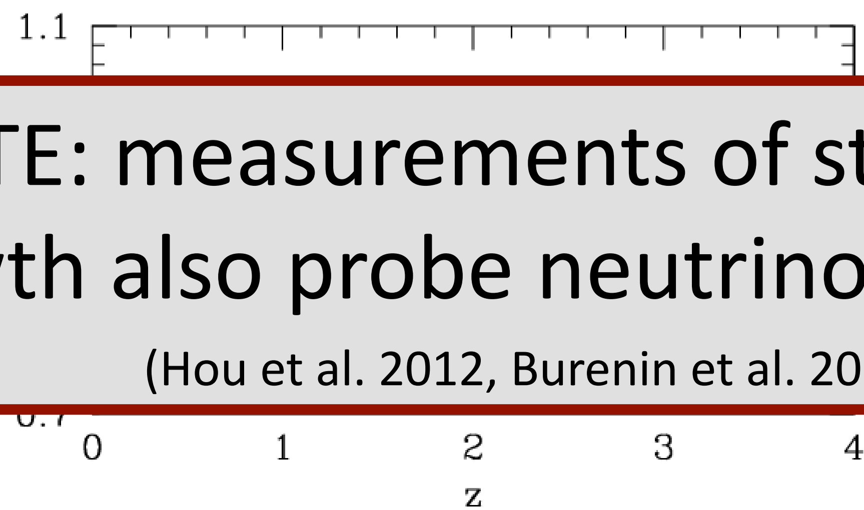


NOTE: measurements of structure growth also probe neutrino masses!

(Hou et al. 2012, Burenin et al. 2013, Rozo et al. 2013).

Mortonson et al. (2009, 2010)
cluster predictions: Mortonson et al. (2011)
WL predictions: Vanderveld et al. (2012)

What's Needed?

Abundance: $$\frac{dN}{dM} \sim \frac{\Omega_m}{M} \frac{\upsilon(M)^{1/2}}{\sigma_8(z)} \exp\left[-\frac{\upsilon(M)}{2\sigma_8^2(z)}\right]$$

N = no. of clusters (cluster detection, redshift)

M = cluster mass (mass calibration)

Quickly cover each in turn.

Detection

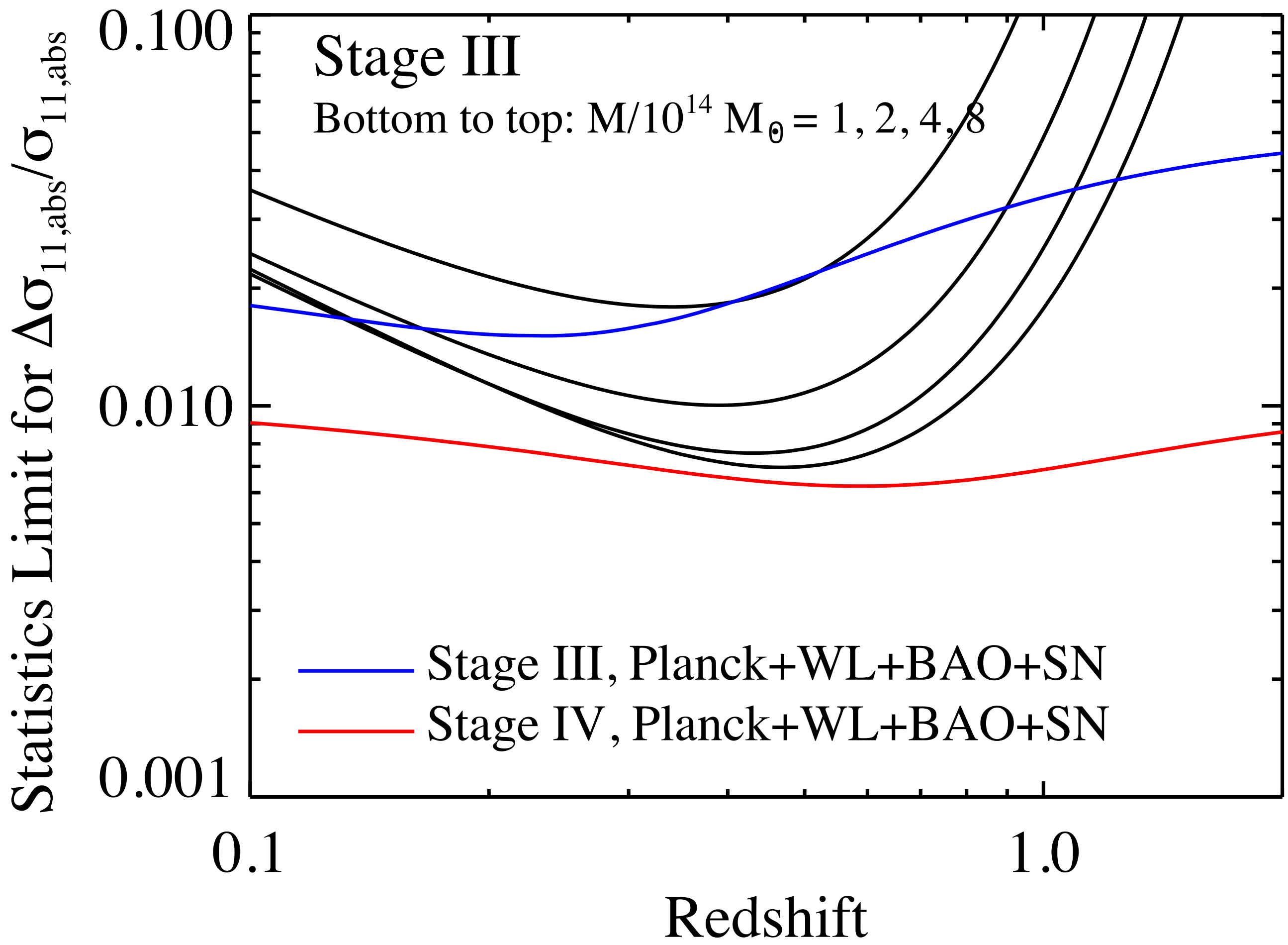
Where's the Information?

Not the most massive systems.

Generically, S/N increases with decreasing mass.

At high mass end, Poisson errors kill you.

Stage III



Weinberg et al. 2012

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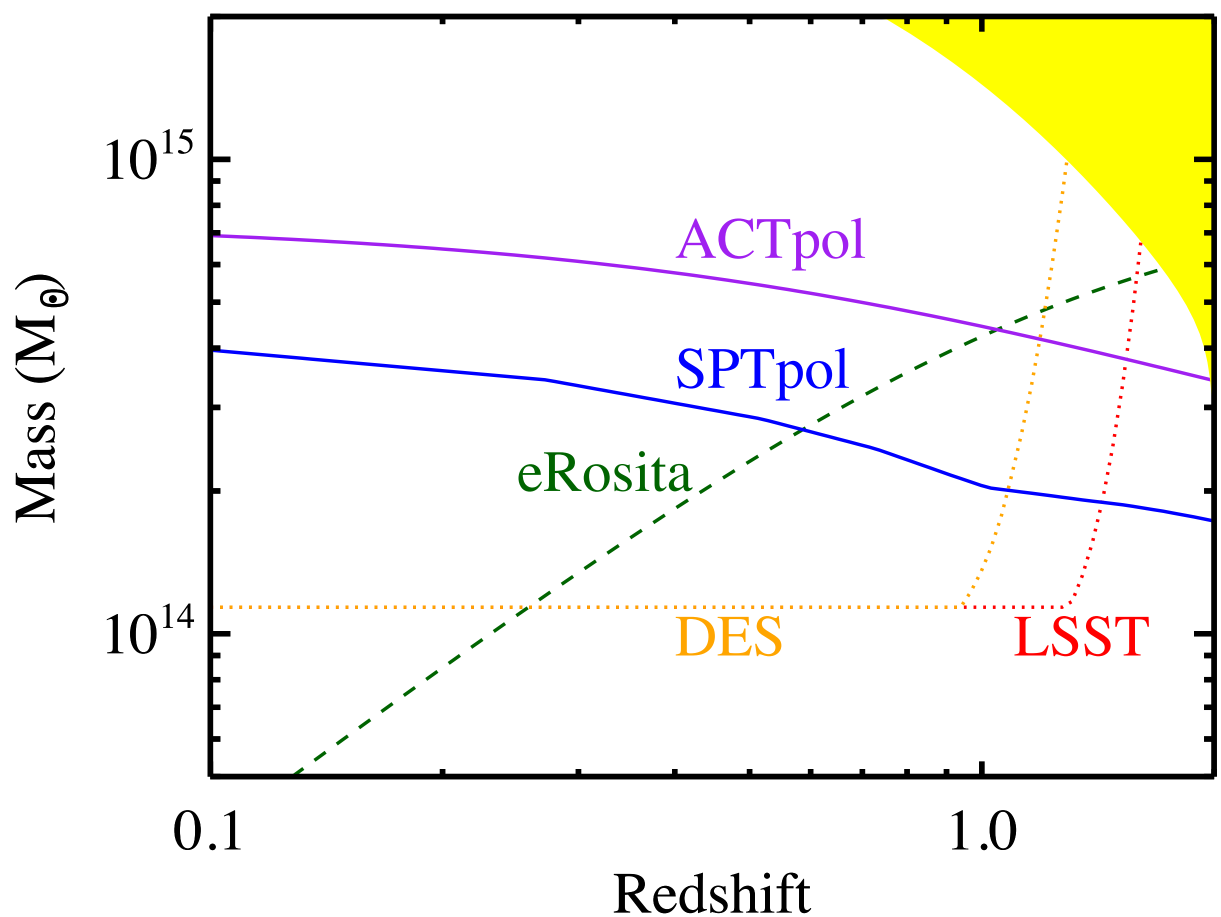
Want to detect low mass systems. How?

Detection Thresholds



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- suggests optical is the way to go.
- caveat: X-rays is full sky -> more total clusters!

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- caveat on the caveat:
  how do you calibrate mass/redshift? – optical

Cluster Detection

In the long run, expect to be driven by optical detection.

Is it really feasible? (Rykoff et al. 2013, Rozo et al. 2013)

Photoz's are well controlled.

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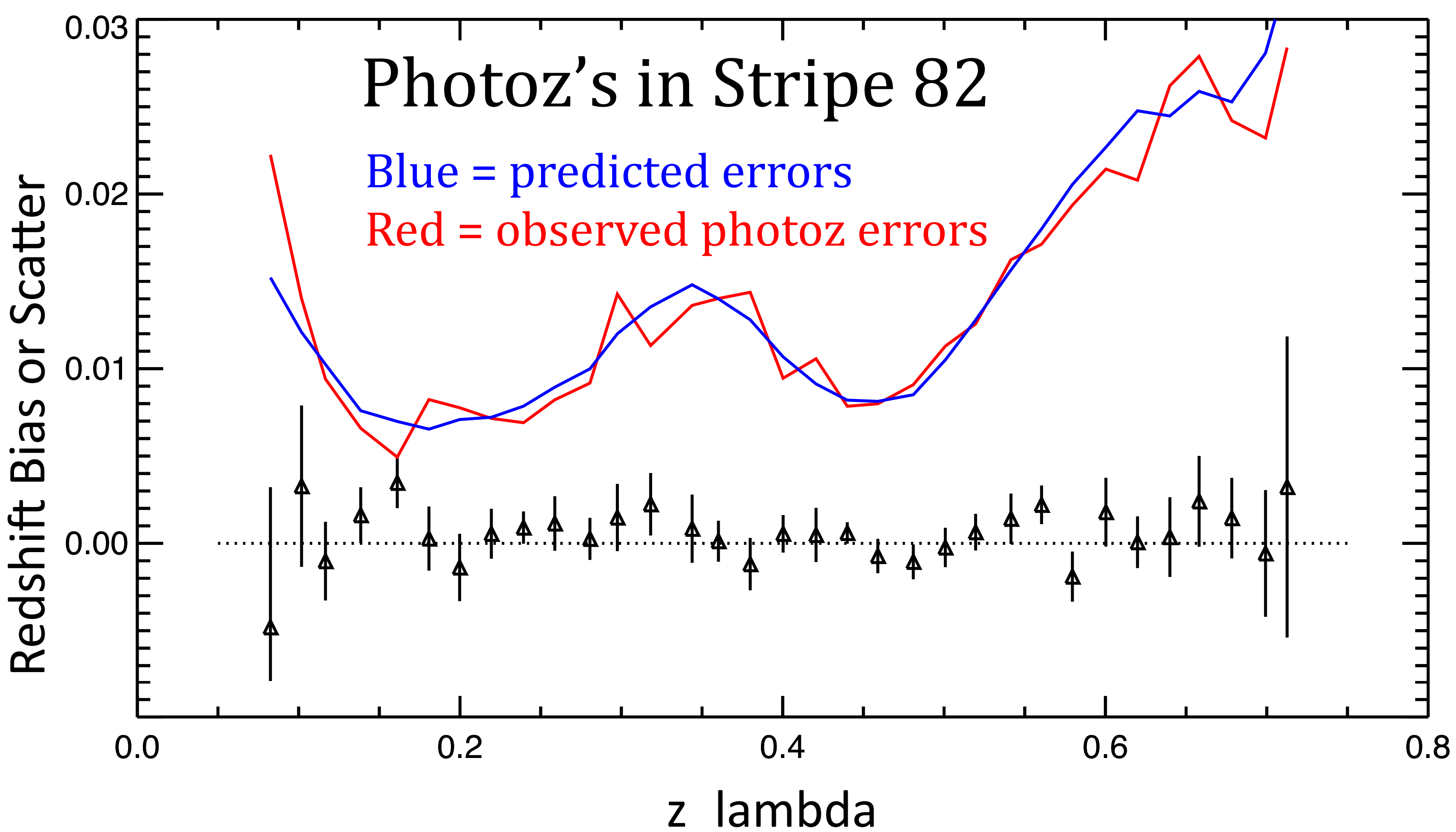
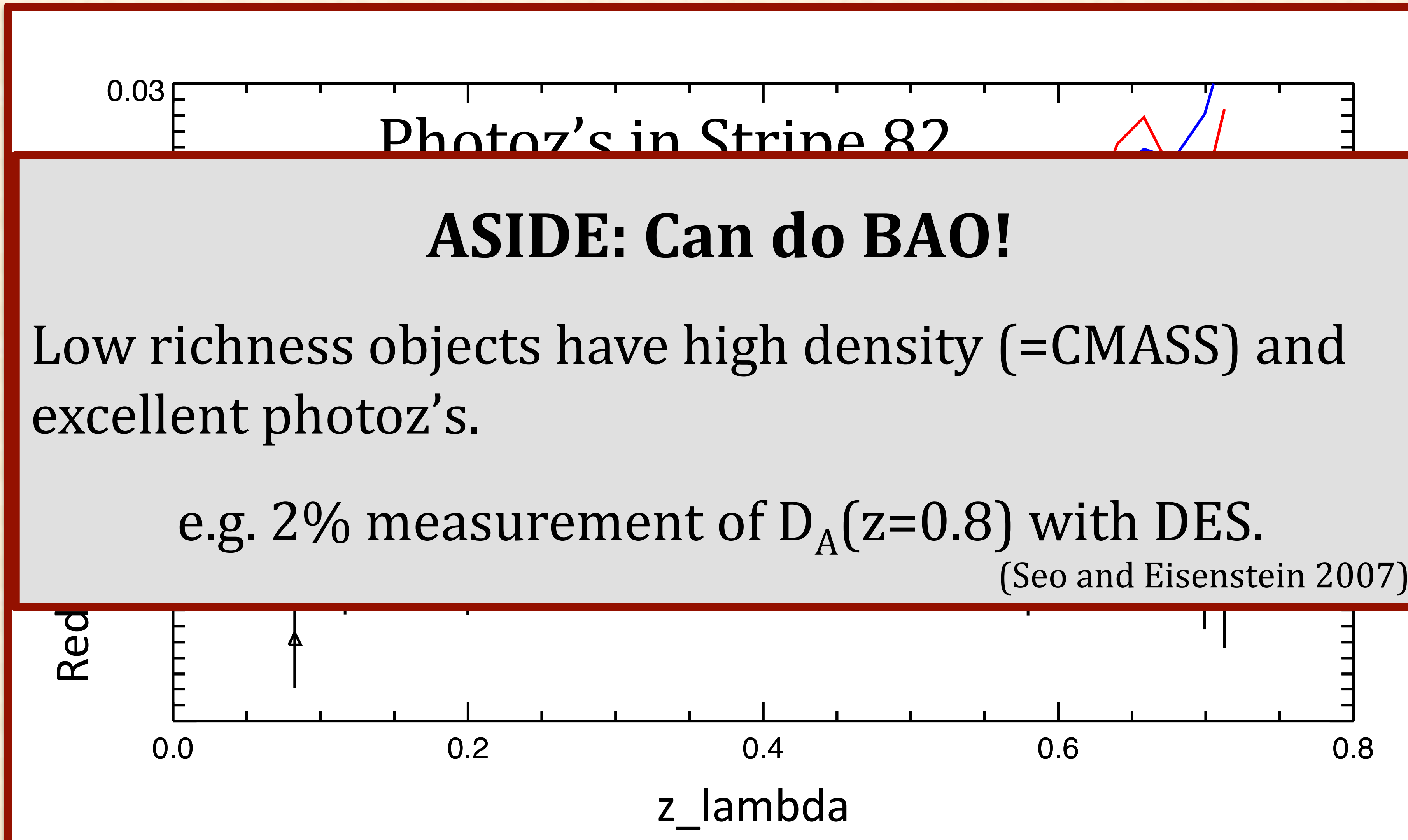


Photoz’s are Well Controlled



ASIDE: Can do BAO!

Low richness objects have high density (=CMASS) and excellent photoz’s.

e.g. 2% measurement of $D_A(z=0.8)$ with DES.

(Seo and Eisenstein 2007)

Cluster Detection

In the long run, expect to be driven by optical detection.

Photoz's are well controlled.

Projection effects: <5%, but can be modeled.
Expect <1% errors in the end.

Cluster centering: dominant systematic.
solvable? multi-wavelength data.

Does it need to be solved? -> can be self-calibrated.
(Oguri and Takada 2010).

Alternatively, rely on larger scales.
(Mandelbaum et al. 2010, Zu et al. 2012)

Mass Calibration

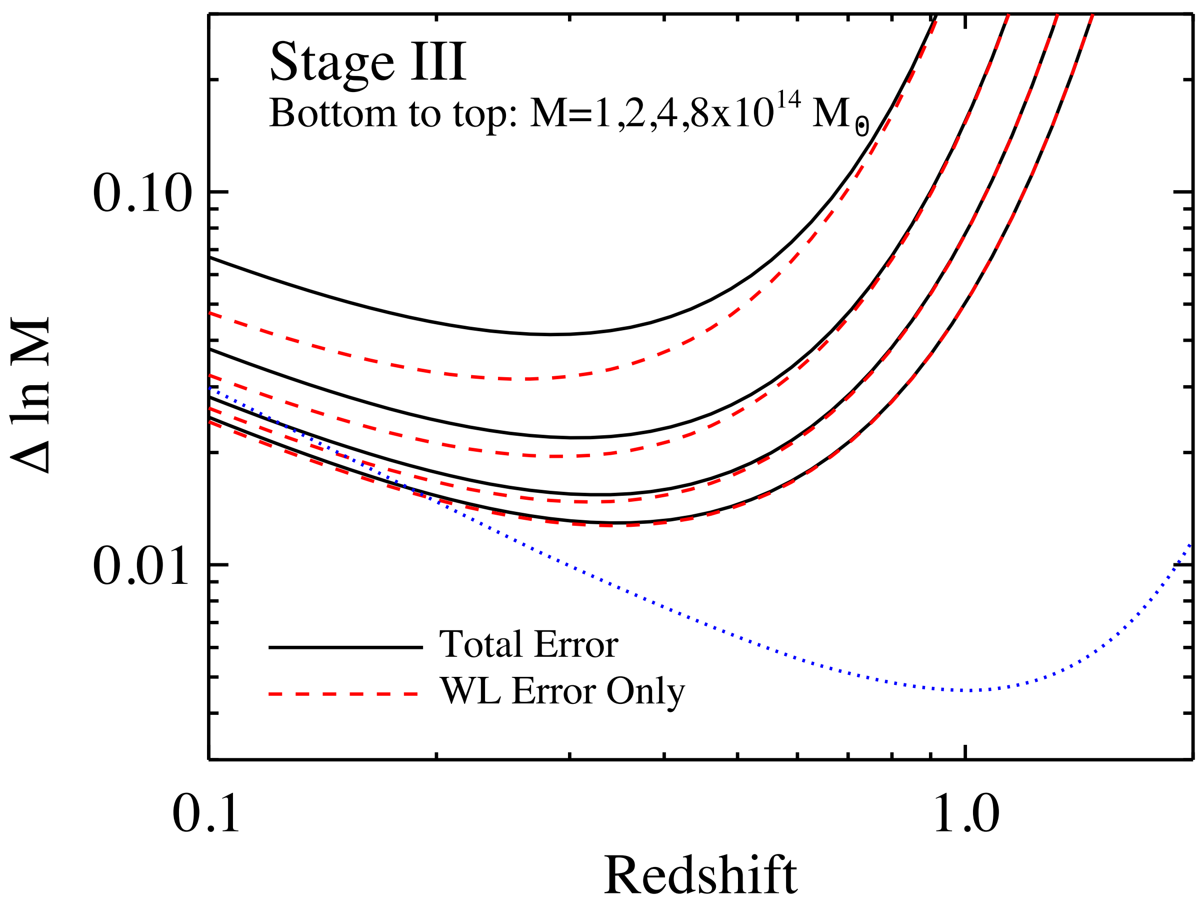
Methods

Dynamical methods (hydrostatic/velocity dispersion) are hard.

Require *a priori* calibration of hydrostatic/velocity bias at the ~0.5-2% level.

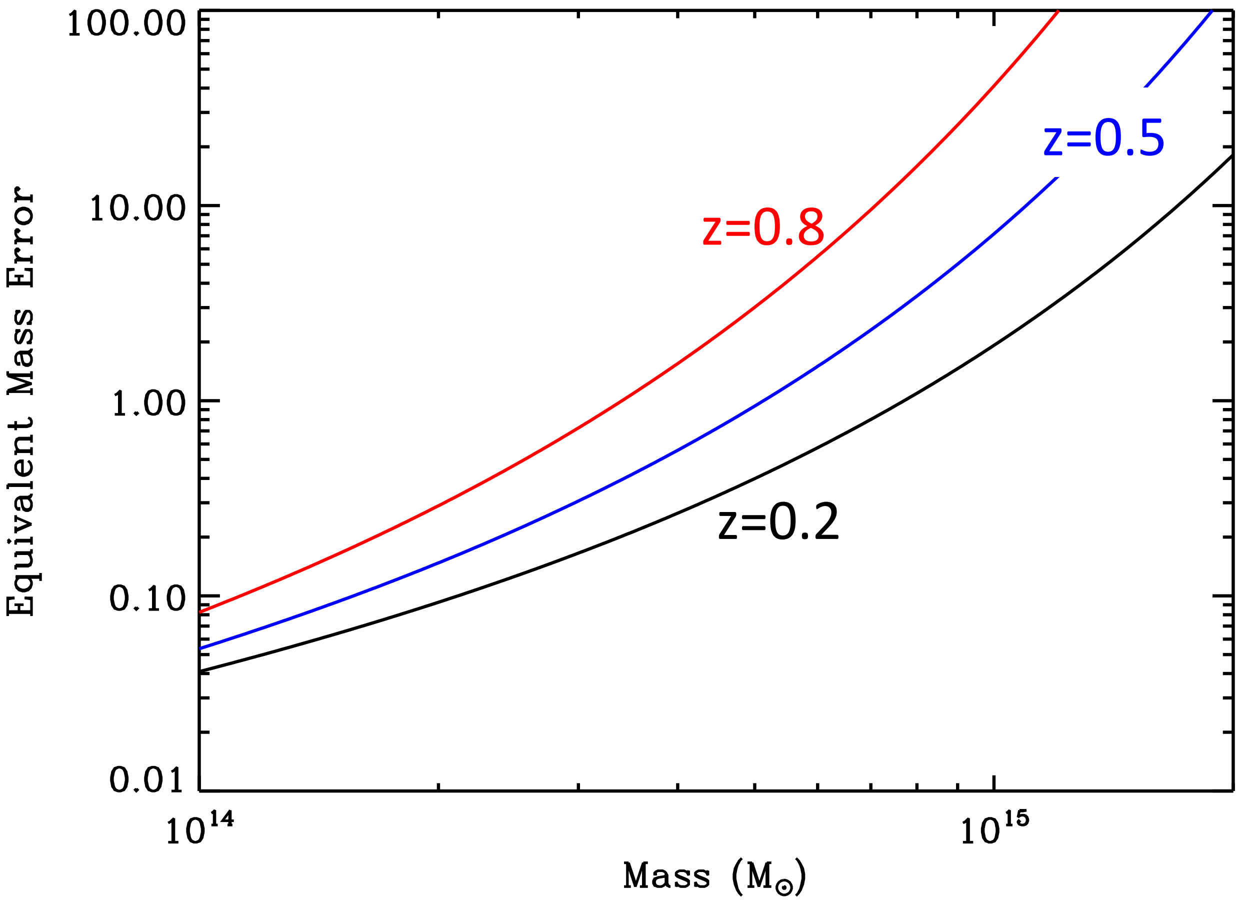
Rely on weak lensing and/or clustering.

Weak Lensing Errors



Weinberg et al. 2012

Clustering Errors



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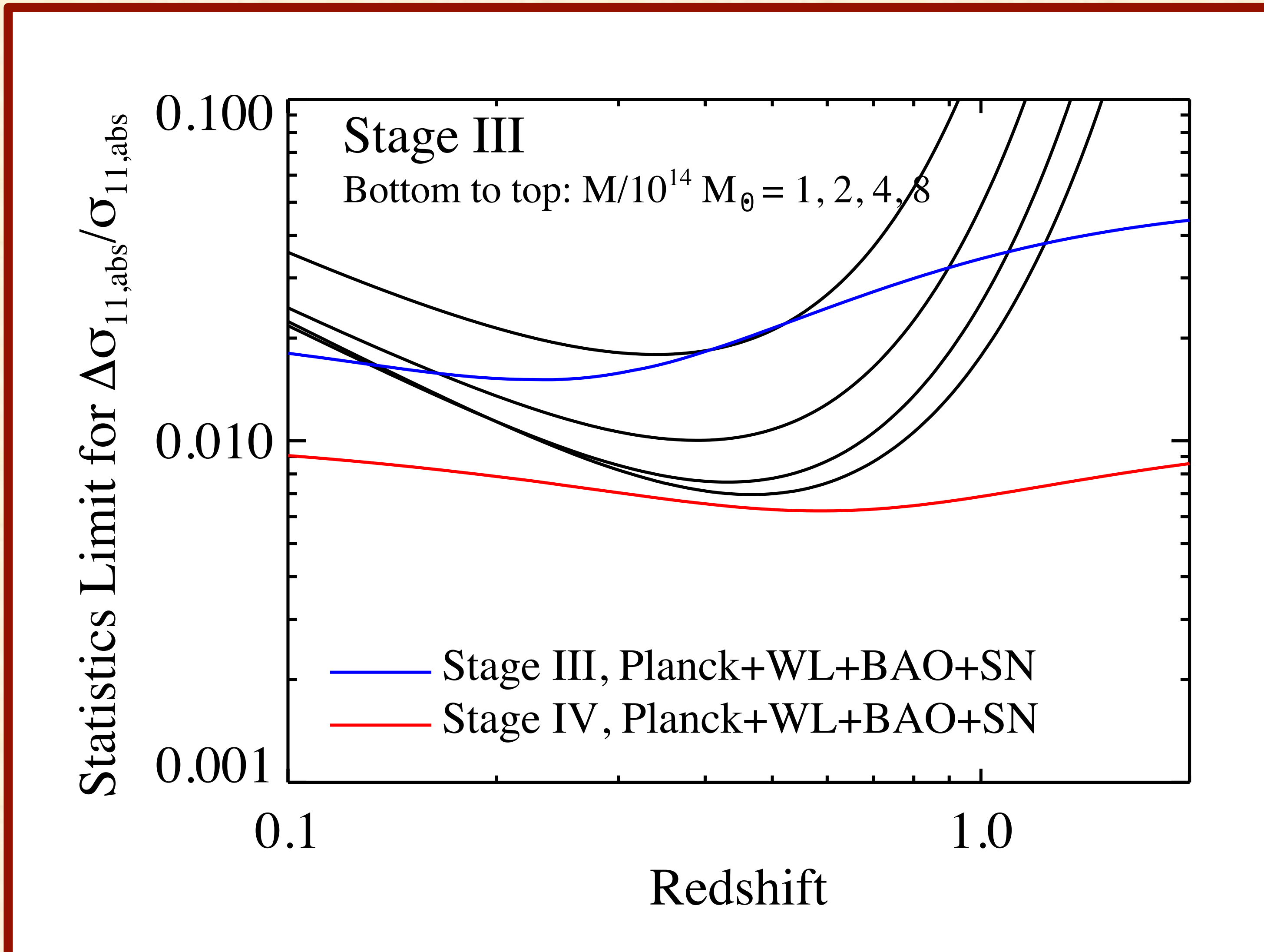
WL works best -> clustering helps with mass *scatter.*

Caveat: is correlation with a CMASS-like spectroscopic sample may be better?

Clustering-only method has much reduced systematics!

Stage III Constraints



Weinberg et al. 2012

WL Systematics

All the standard lists of WL systematics:

- shear estimates (self-calibration with magnification?)
- source photoz's (correlation method? CMB lensing?)
- intrinsic alignments
- source occultation, de-blending…

Cluster centering.

- fixable with X-ray/SZ (also helps scatter, projections)
- expect improvements from optical
    - centering probabilities, equivalent to P(z).
    - auto-flagging of errors, enable after-burners.

Clustering only constraints can still be powerful!

Cunha et al. 2009.

You May Say That I'm a Dreamer

The FoM from BAO, SN, and WL improves by nearly a factor of two when clusters are added, *without any prior knowledge on the cluster mass-observable nuisance parameter*. Measurements of the growth index of linear perturbations γ improve by a factor of several.

Cunha, Huterer, and Frieman 2009.

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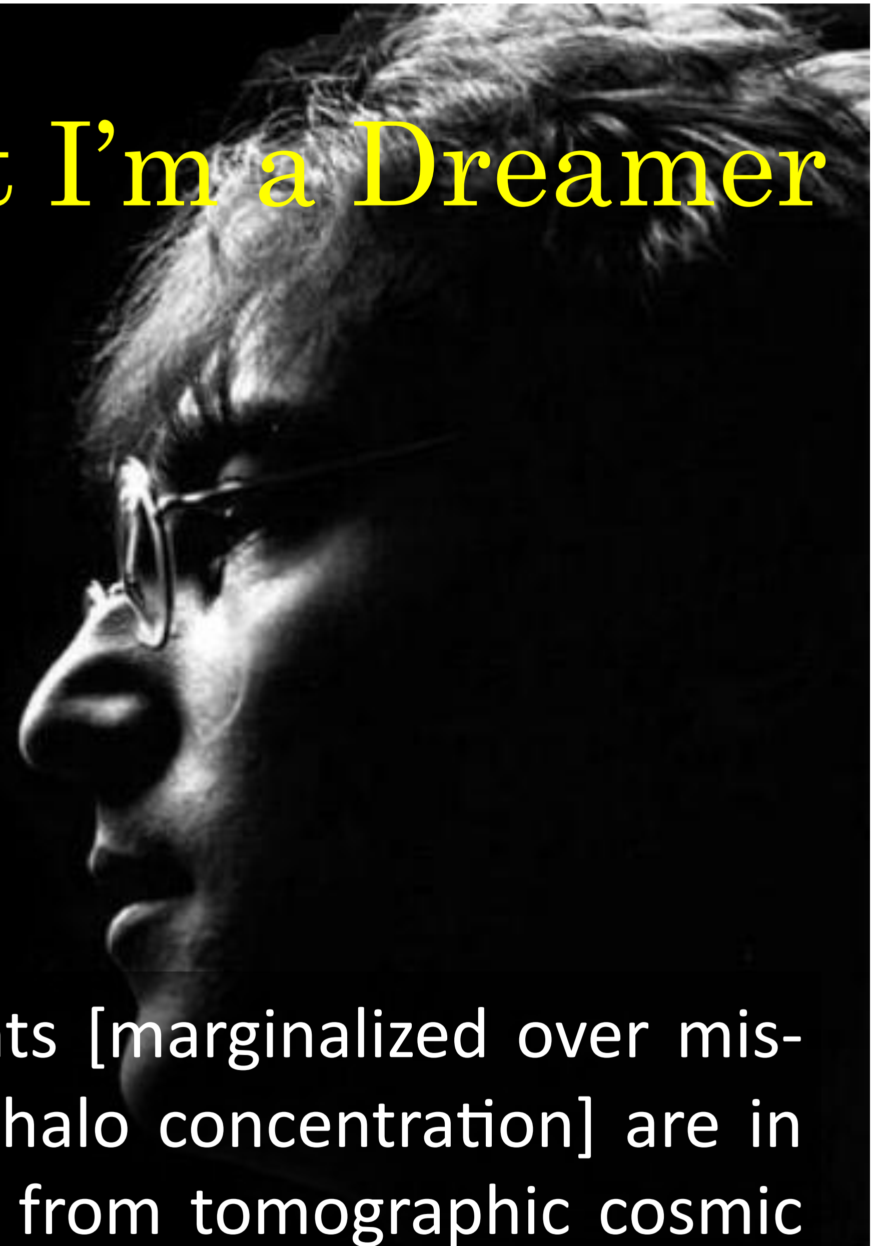

The resulting [cluster] constraints [marginalized over mis-centering, source redshift, and halo concentration] are in fact quite comparable to those from tomographic cosmic shear *without any marginalization over systematic errors*.

Oguri and Takada 2010.

What’s Missing?

What's Missing

LSST could use IR to extend cluster selection to z>1.

- available for Euclid/WFIRST

Spectroscopy of cluster galaxies:

- **central galaxies**: no photoz error, RSD w/ clusters, possibly help with miscentering/projections
- **2 most-central galaxies:** better centering, should minimize projections.
- **Few galaxies**: small scale CF can be compared to Cl-Shear correlation to study non-GR models.

LRG-like overlap: enable cross-correlation self-calibration.