Cluster mass calibrations with future data sets

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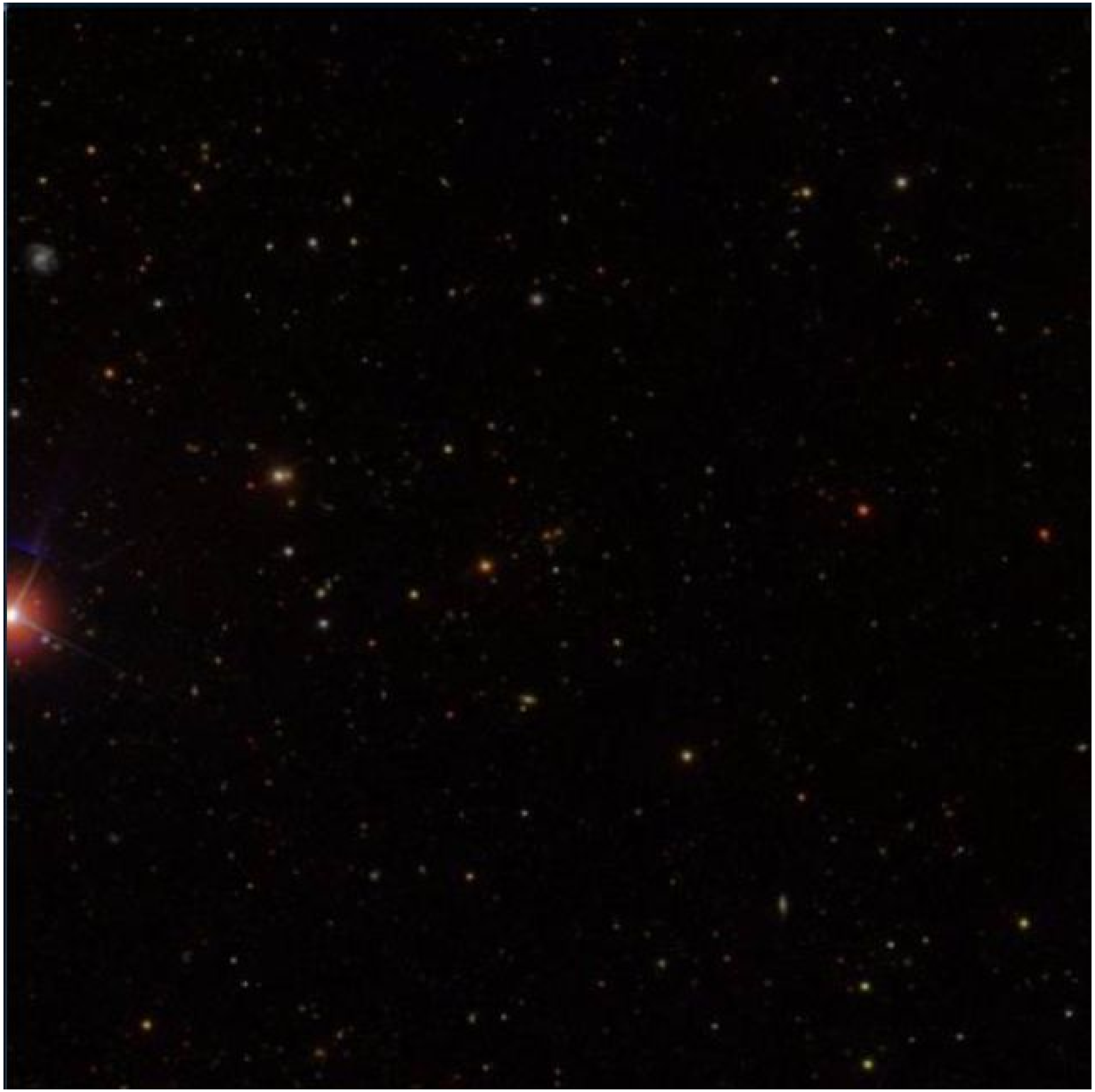


SDSS

Why cluster lensing?

- Astrophysics: learn about cluster dark matter distributions
- Cosmology: learn masses as input to cluster number counts, etc

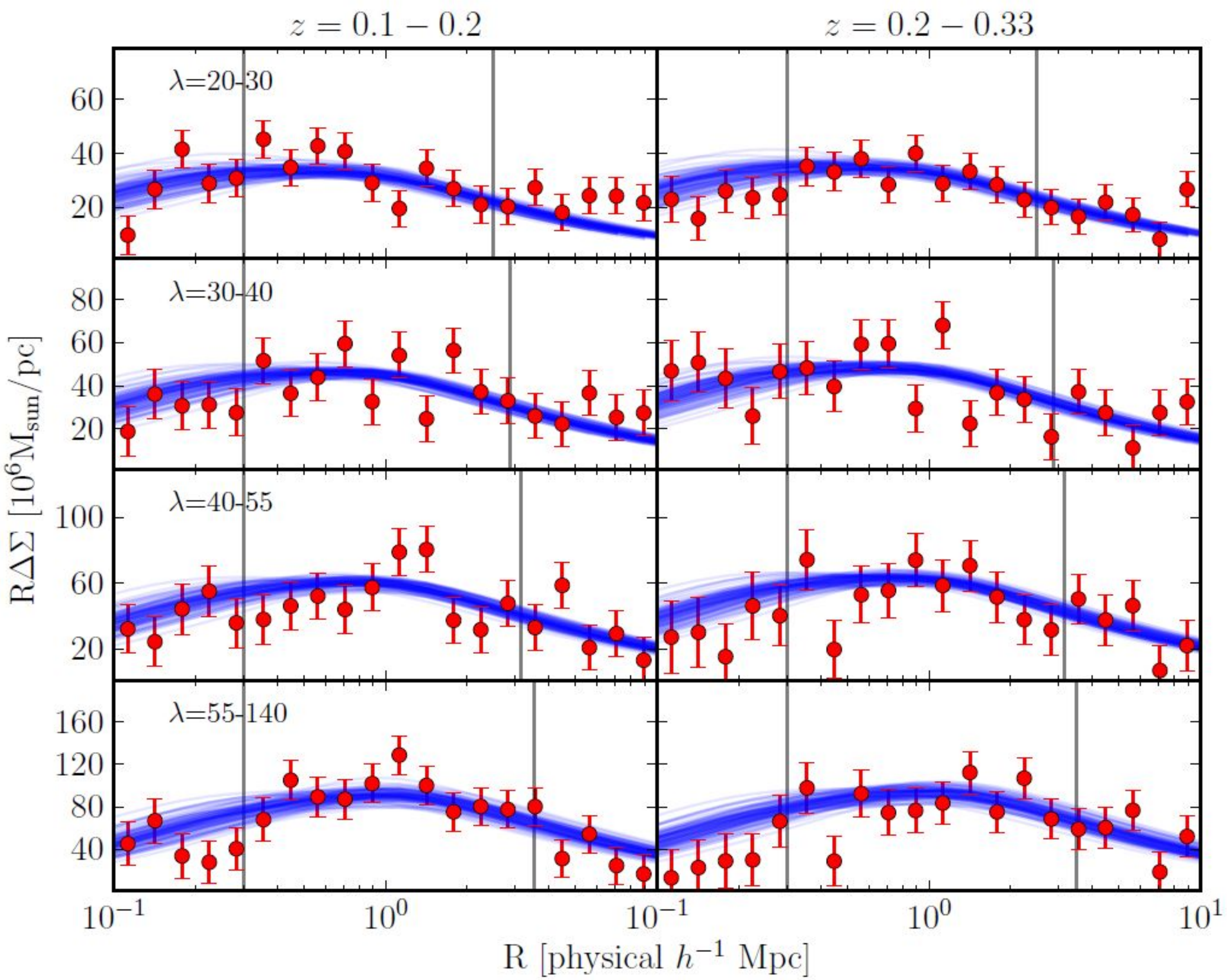
In the thin-lens (linear) limit, lensing is sensitive to a scaled surface mass density:

$$\kappa(\mathbf{R}) = \frac{\Sigma(\mathbf{R})}{\boxed{\frac{c^2}{4\pi G}\frac{D_A(z_{\text{source}})}{D_A(z_{\text{lens}})D_A(z_{\text{lens}},z_{\text{source}})}}} \longrightarrow \Sigma_{\text{cr}}(z_l, z_s)$$

Magnification is sensitive to *κ* directly. Additionally, for extended objects, in the linear regime lensing leads to a distortion called a shear, γ, which we measure using ellipticities *e*.

$$\langle\gamma_t(R)\rangle = \bar{\kappa}(< R) - \langle\kappa(R)\rangle$$

What does a (stacked) lensing signal look like?



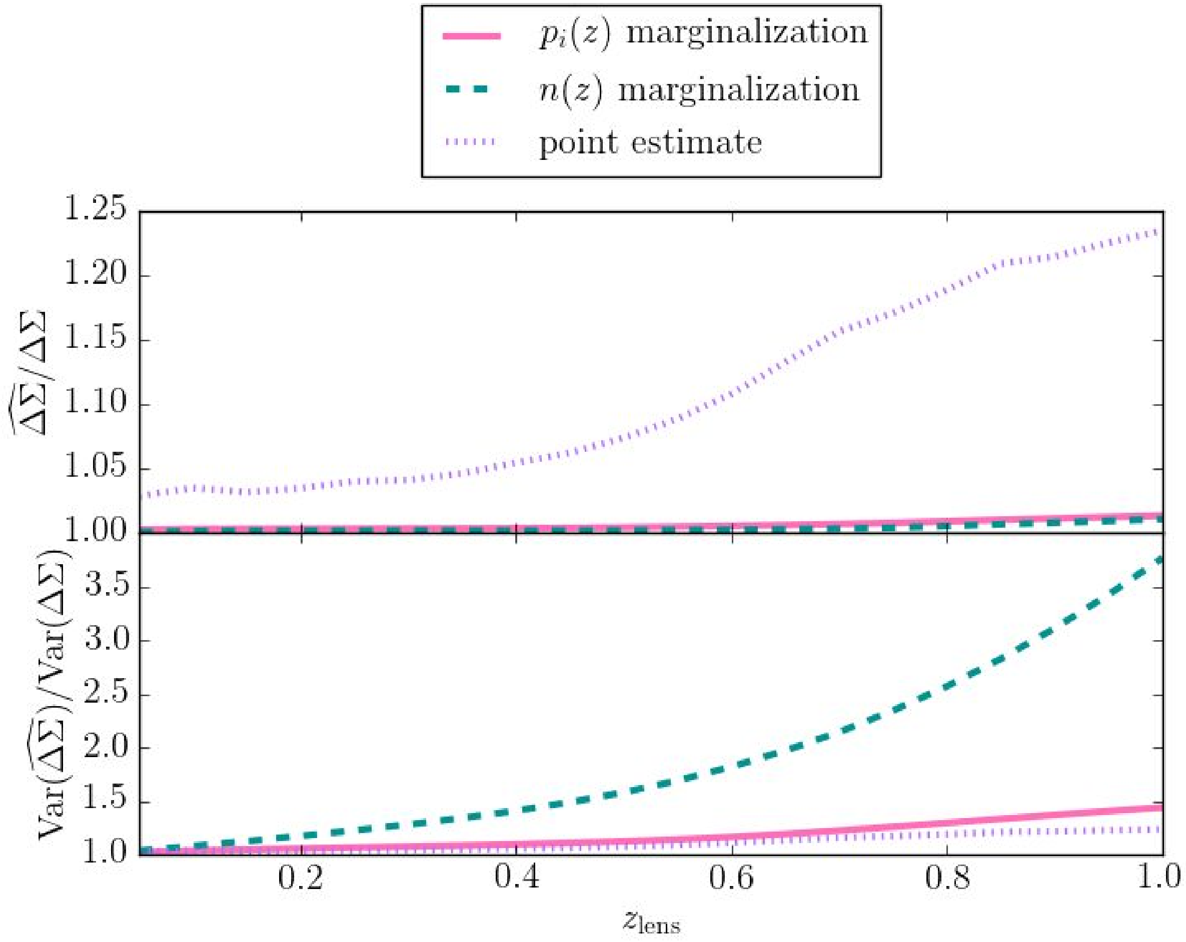
Simet et al 2017, arXiv:1603.06953

Where does uncertainty come from?

7% total uncertainty

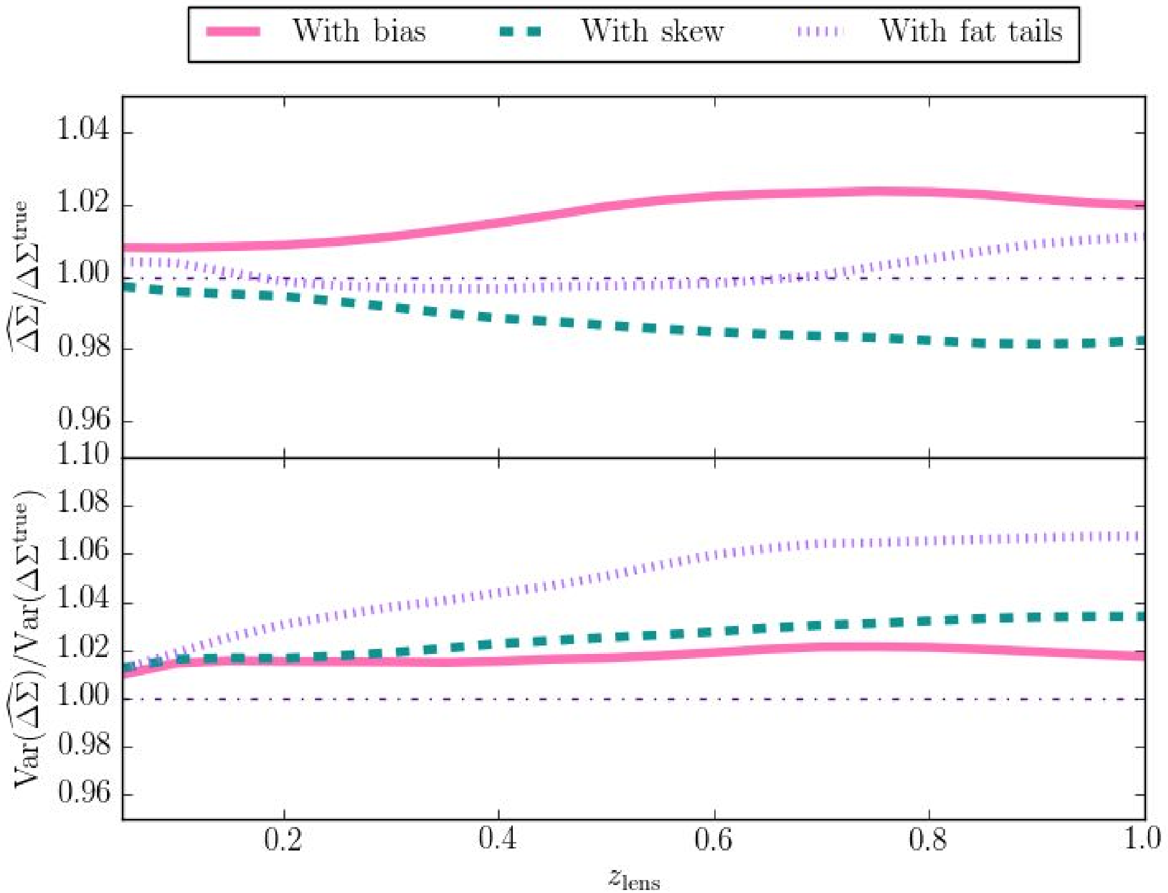
- ~Half statistical
- ~Half systematic
    - ~Half shear and photo-*z*
        - Improved by new shear algorithms, higher-resolution data, higher-precision photometry, new photo-*z* methods
    - ~Half modeling uncertainty
        - Projection effects
        - Shape, slope of dark matter distributions
        - Some observational uncertainties

Photometric redshift uncertainties



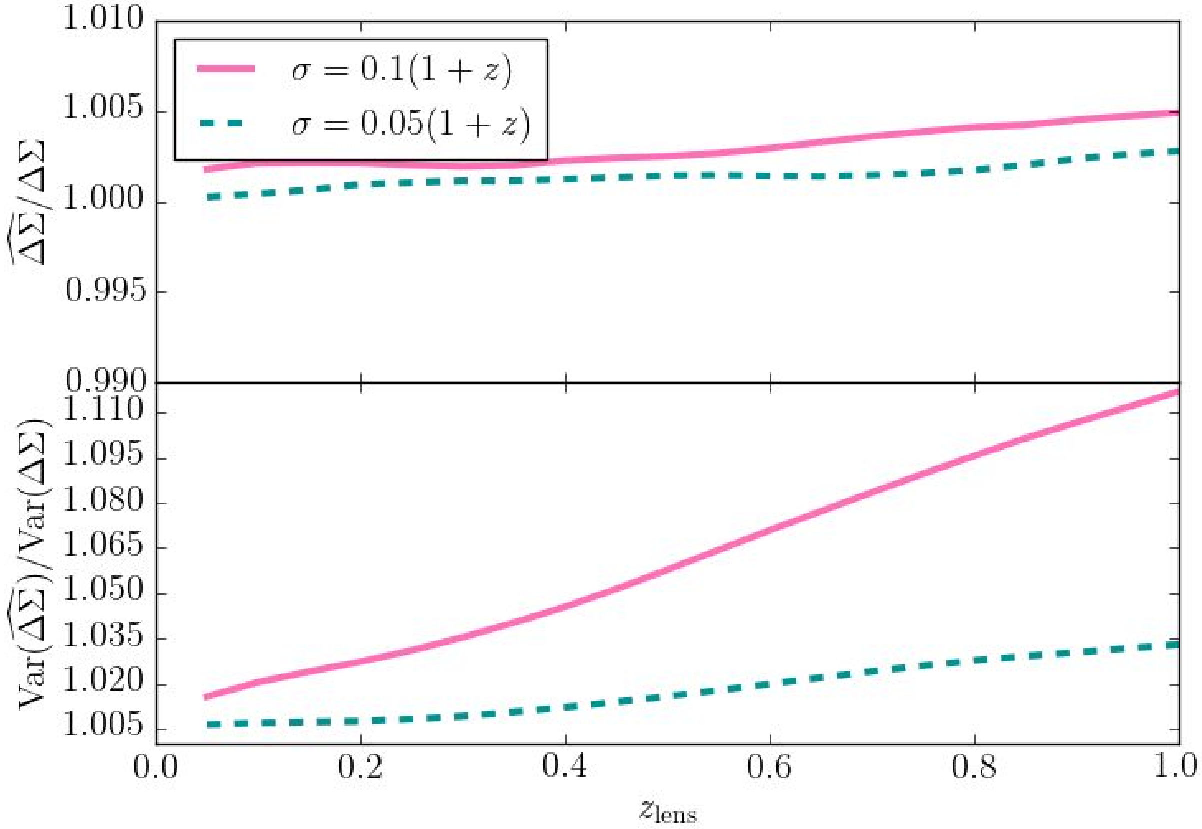
Simet et al. in prep

Photometric redshift errors



Simet et al. in prep

Photometric redshift errors



Simet et al. in prep

Survey comparison

Survey	PSF FWHM (arcsec)	Area (deg^2)	Source galaxy density (per sq arcmin)	Number of objects
Sloan Digital Sky Survey	1.2	10000	1.1	4.0×10^7
KiloDegree Survey	0.65	1500	12	6.5×10^7
Hyper SuprimeCam	0.6	1500	23	1.2×10^8
Dark Energy Survey	0.9	5000	10	2.0×10^8
WFIRST	0.13	2200	45	3.6×10^8
Euclid	0.13	15000	30	1.6×10^9
Large Synoptic Survey Telescope	0.7	18000	40	2.6×10^9

Cross-correlation vs individual measurements

Cross-correlation:

- Can get signal even if each lens is low S/N
- Some pernicious effects average out
- Can statistically correct for, e.g., contamination and centroiding errors

Individual:

- No lossy compression
- Easier to compare to outside measurements (eg X-ray, SZ)
- Can measure scatter

Doing both is a great way to check our prescriptions for dealing with modeling systematics!

Magnification

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Magnification

Magnification is a change in observed number density:

$$n_{\rm obs}(\vec{\theta}) = n_0(\vec{\theta})[1 + (2\beta_f + \beta_r - 2)\kappa]$$

$$\beta_f = -\left.\frac{\partial \ln n_{\rm obs}}{\partial \ln f}\right|_{\substack{f=f_{\rm min} \\ r=r_{\rm min}}} ; \quad \beta_r = -\left.\frac{\partial \ln n_{\rm obs}}{\partial \ln r}\right|_{\substack{f=f_{\rm min} \\ r=r_{\rm min}}}$$

Since there are many more small and faint things, deeper surveys & surveys with smaller PSFs will be able to measure this effect more easily.

Schmidt et al. 2009

Tomography (lensing as a function of redshift)