CMB Halo Lensing

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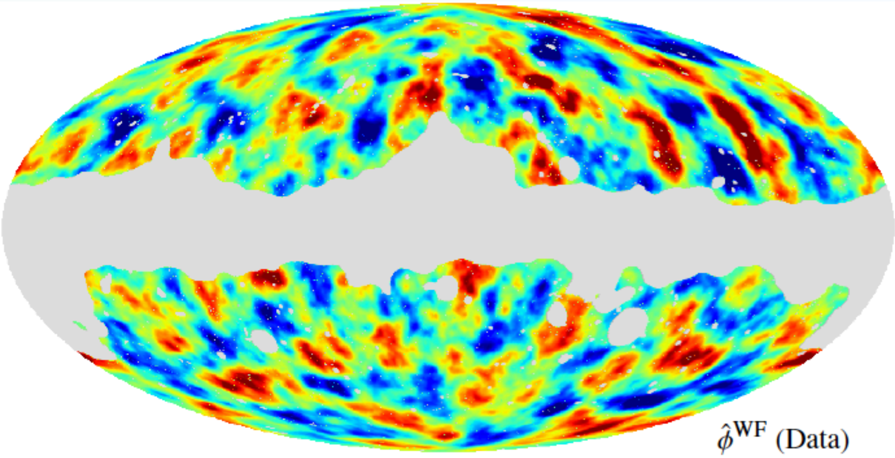
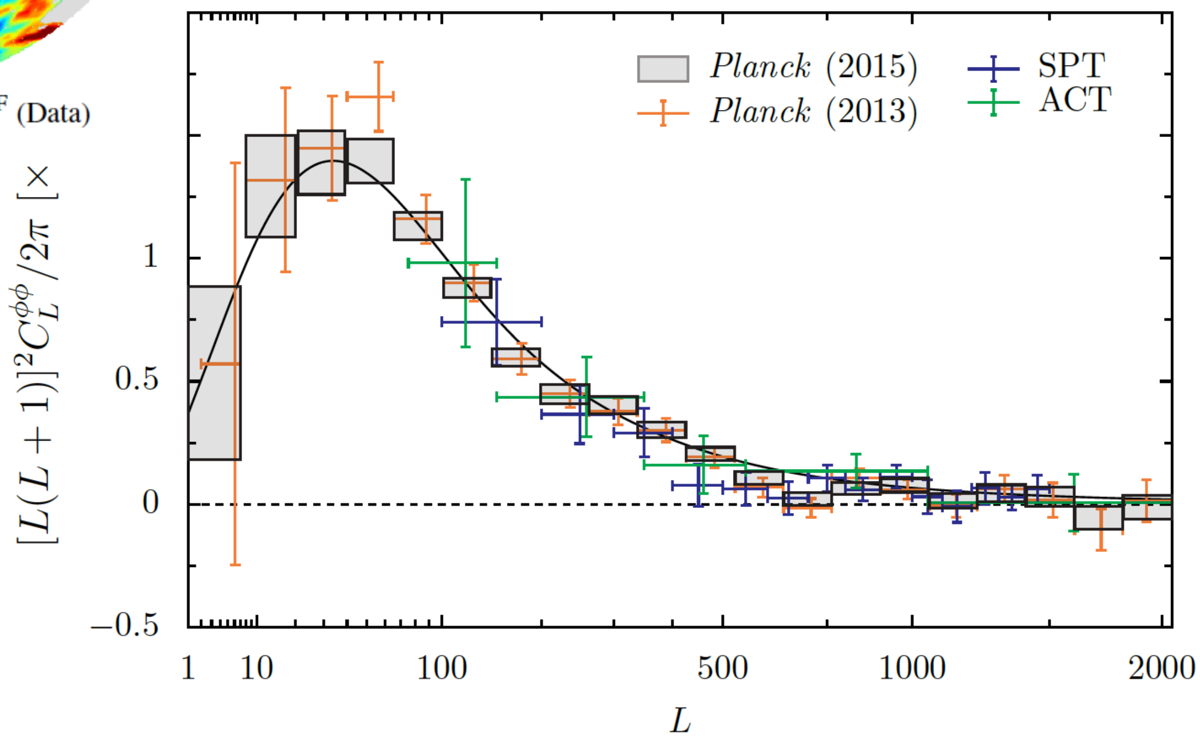
CMB Lensing



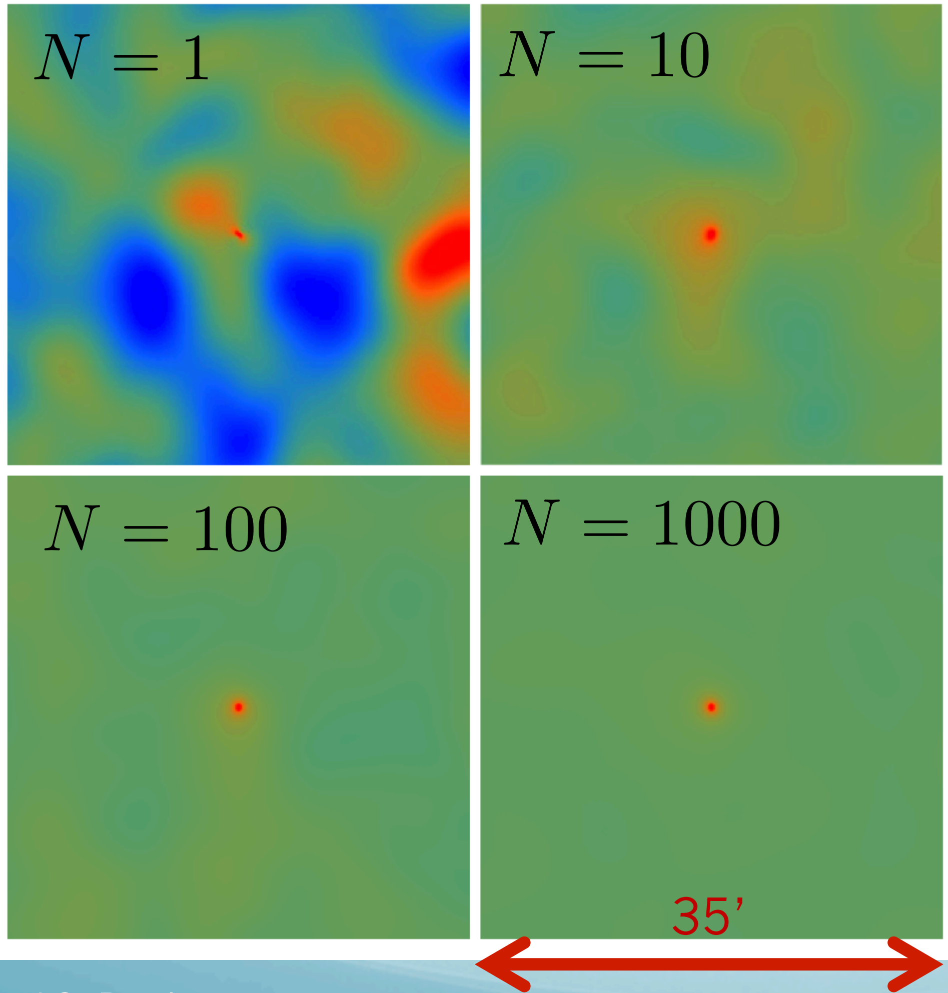
Planck Coll. XV (2015)



Analog of cosmic shear

CMB Halo Lensing

Hu, DeDeo & Vale (2007)



CMB lensing around pre-selected objects and binned/stacked

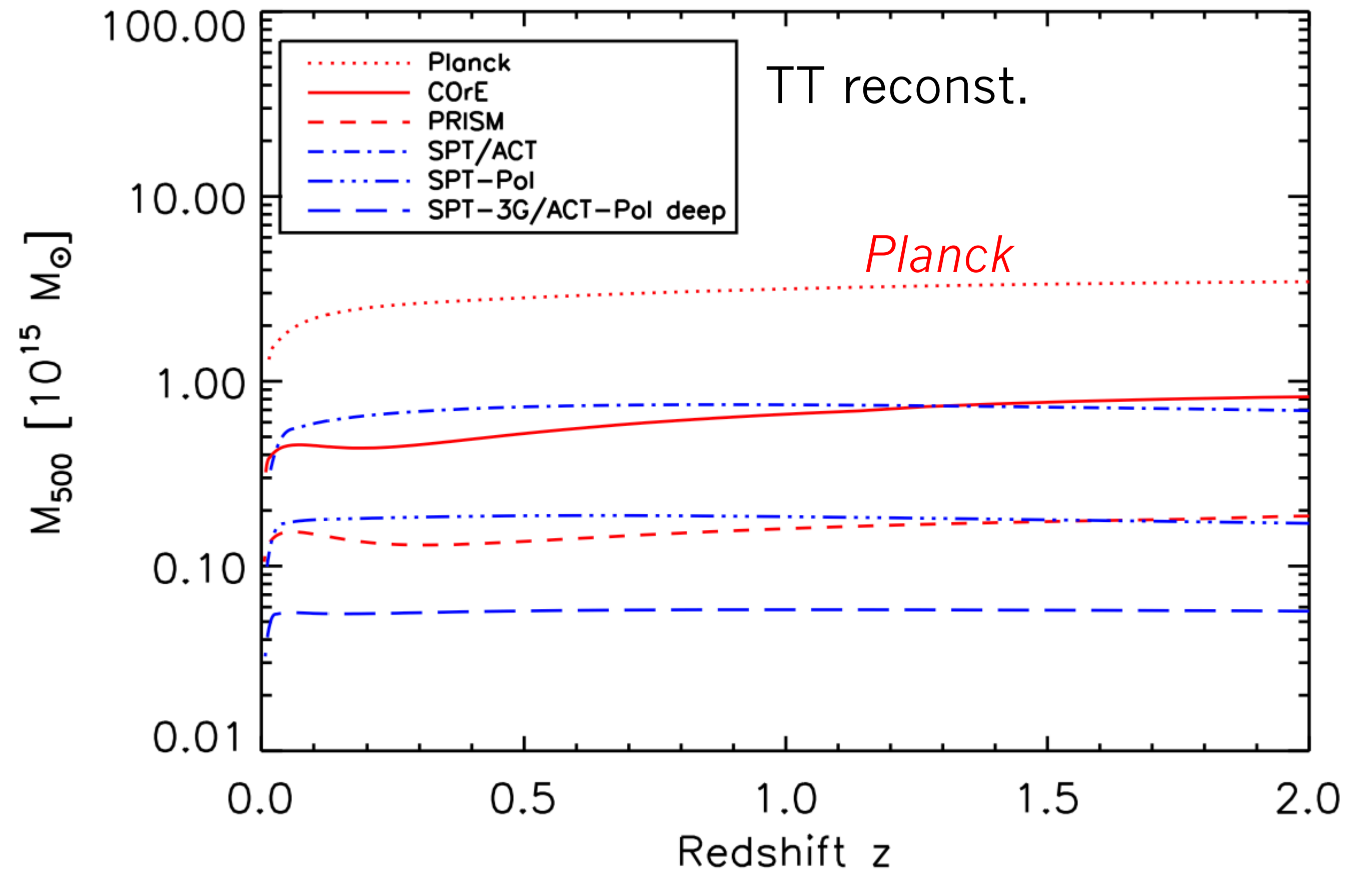
Akin to galaxy-galaxy lensing – studying objects:

- Clusters (Seljak & Zaldarriaga 2000)
- Galaxies (Dodelson & Starkman 2003)

Mass Sensitivity

Predictions for cluster mass detectable with S/N=1

Melin & Bartlett (2015)

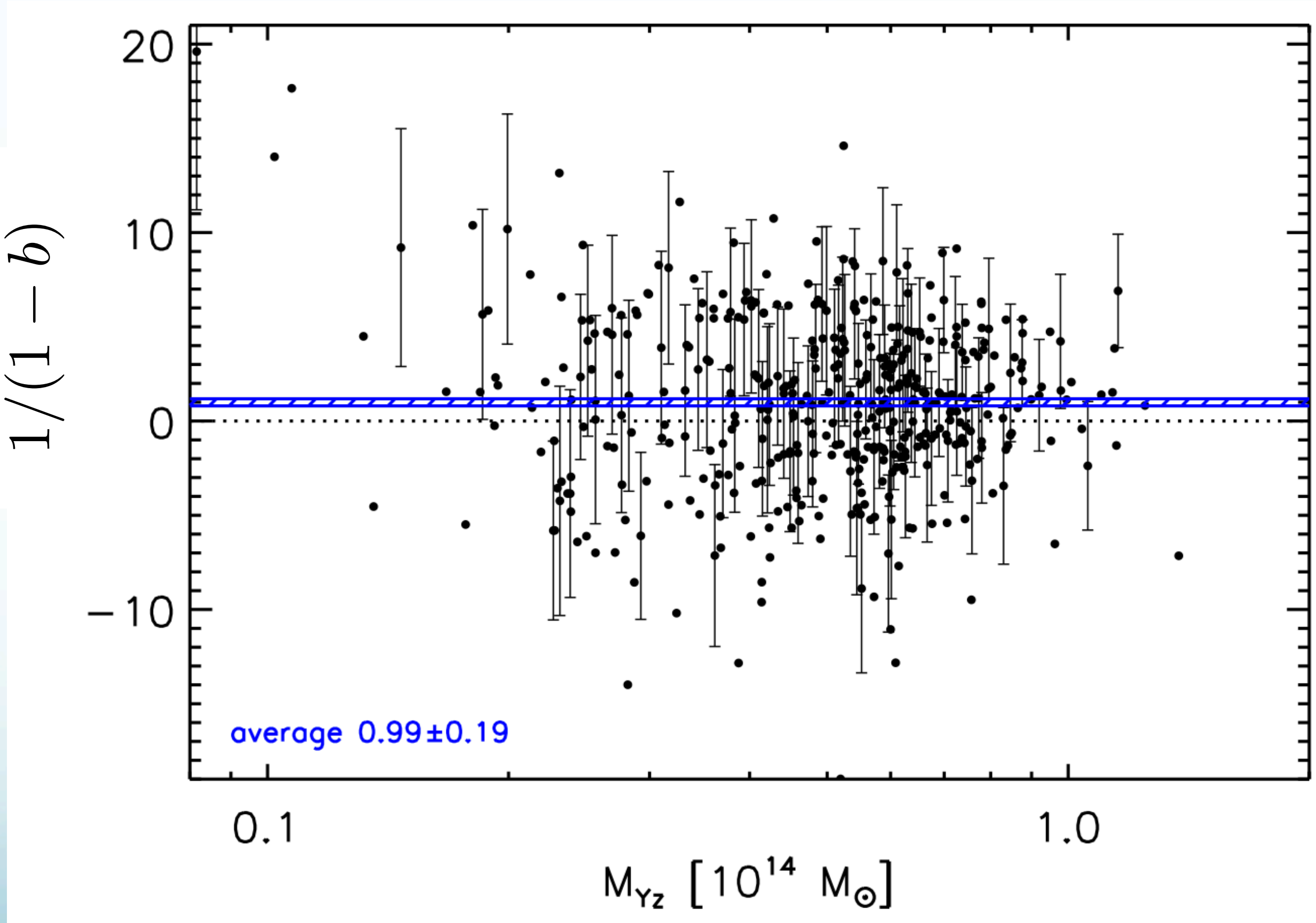


Cluster-CMB Lensing

439 *Planck* 2015 cosmology clusters:

Detection: $5\,\sigma$

Planck Collaboration XXIV (2015)

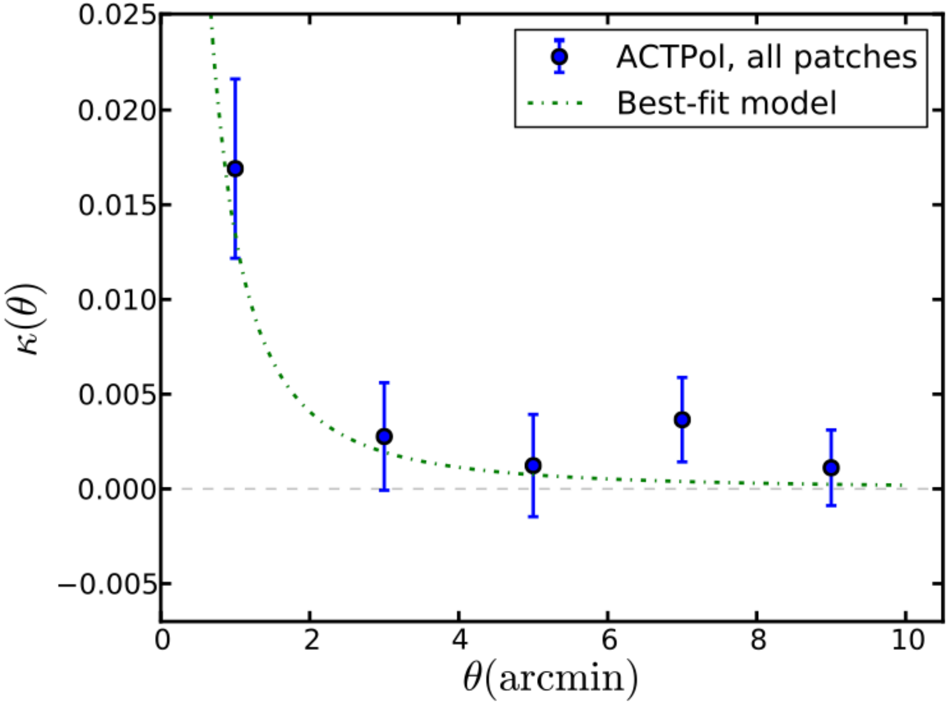


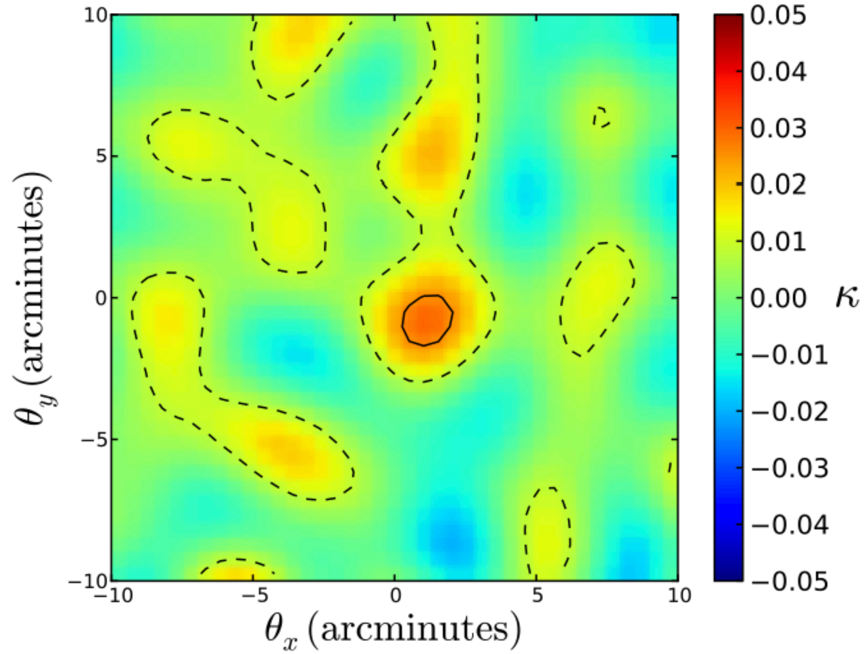
Atacama Cosmology Telescope

Madhavacheril et al. (2015)

3 ACTPol deep fields at 146 GHz
Convergence maps stacked on 12,000 CMASS galaxies
Detection: 3.2σ

$M_{200\rho_0} \sim 2 \times 10^{13}\,\mathrm{M}_\odot$





South Pole Telescope

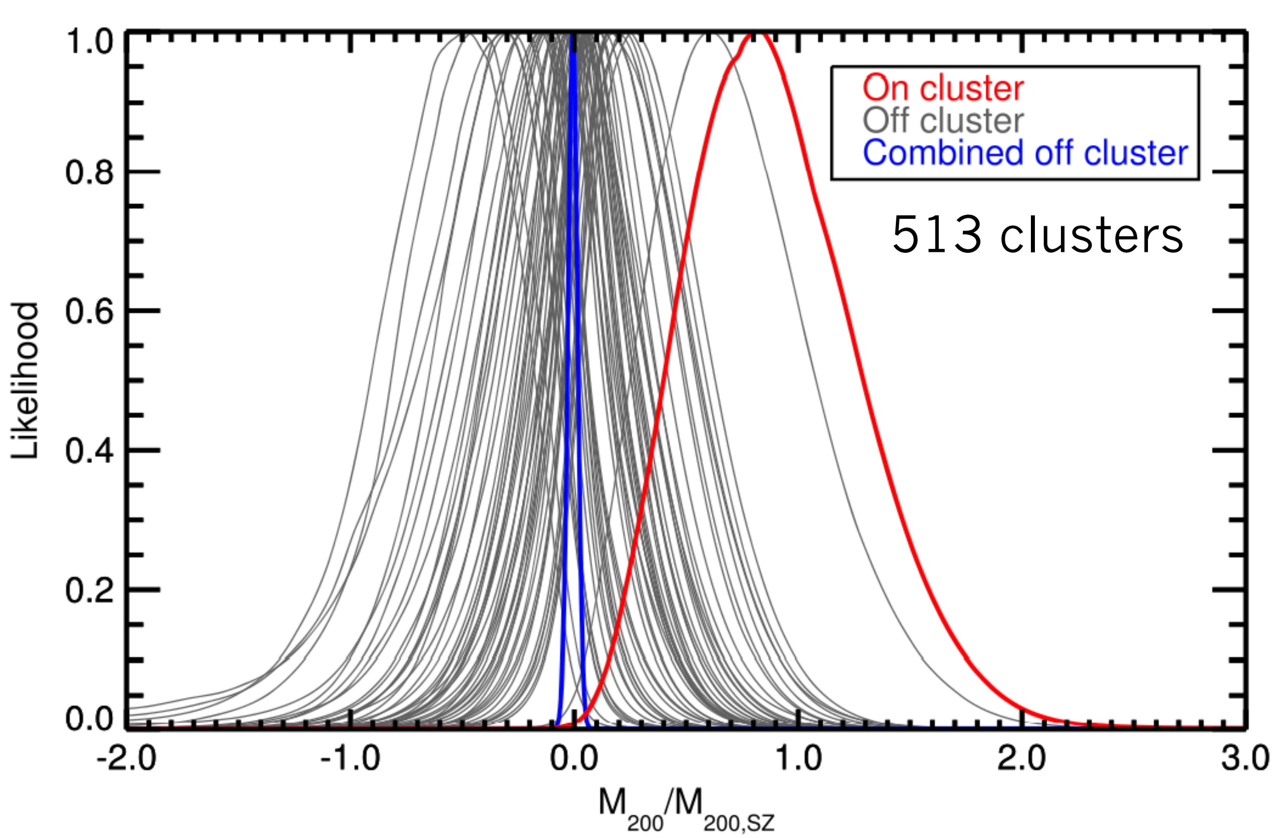
Baxter et al. (2015)

Clean CMB map

Fit model using a pixel-pixel likelihood on CMB map

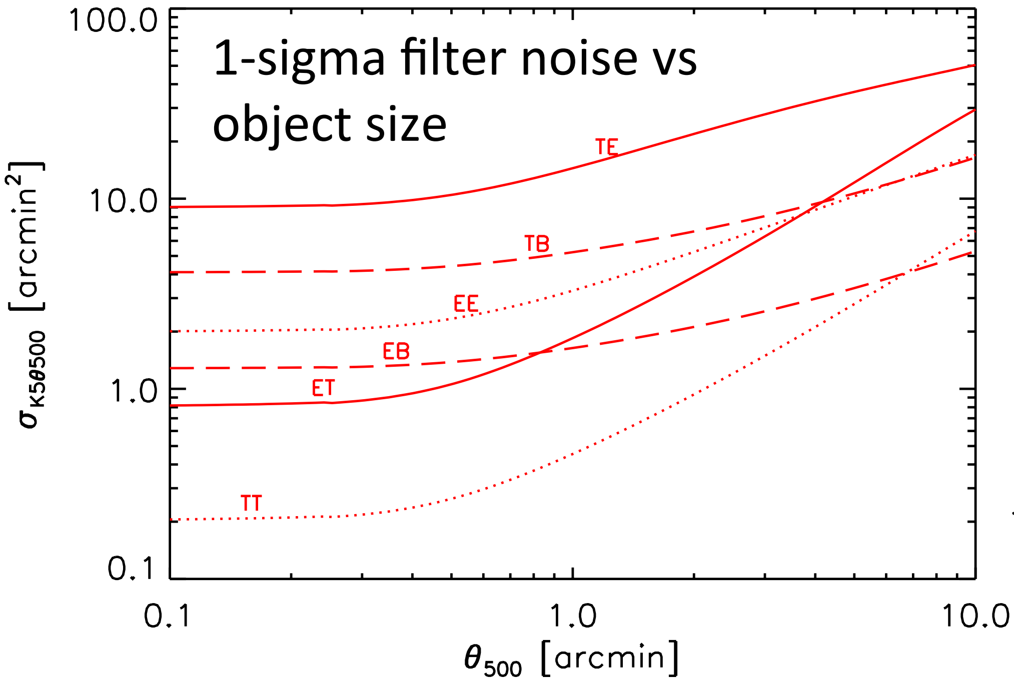
Study a number of systematics

Detection: 3.1σ



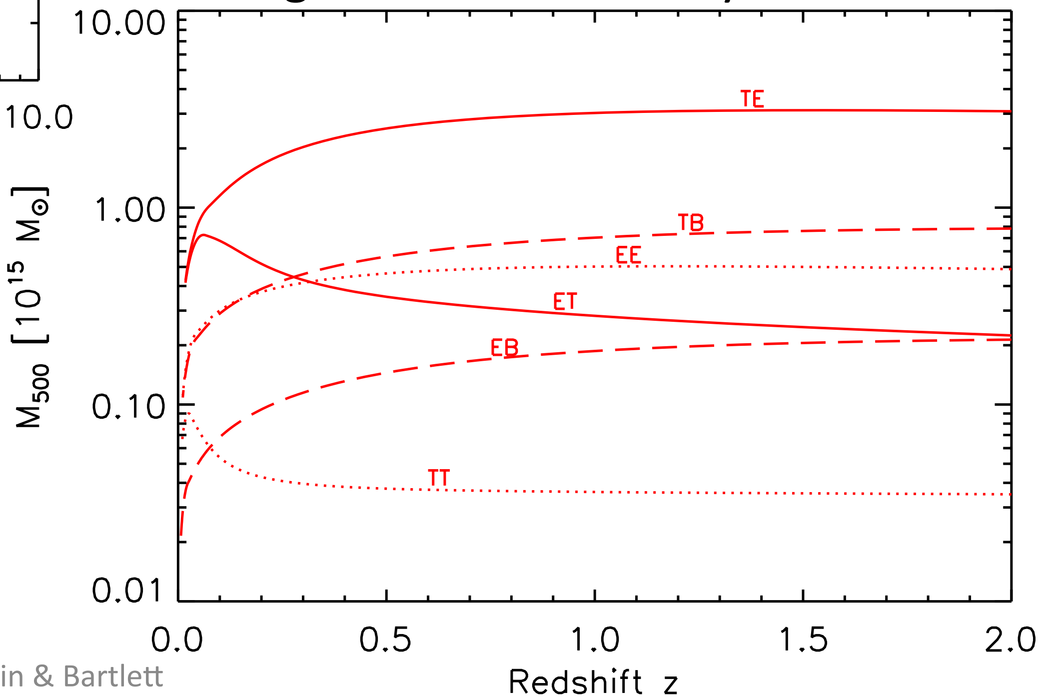
$M_{200} \sim \text{few} \times 10^{14}\,\mathrm{M}_{\odot}$

CMB Halo Lensing



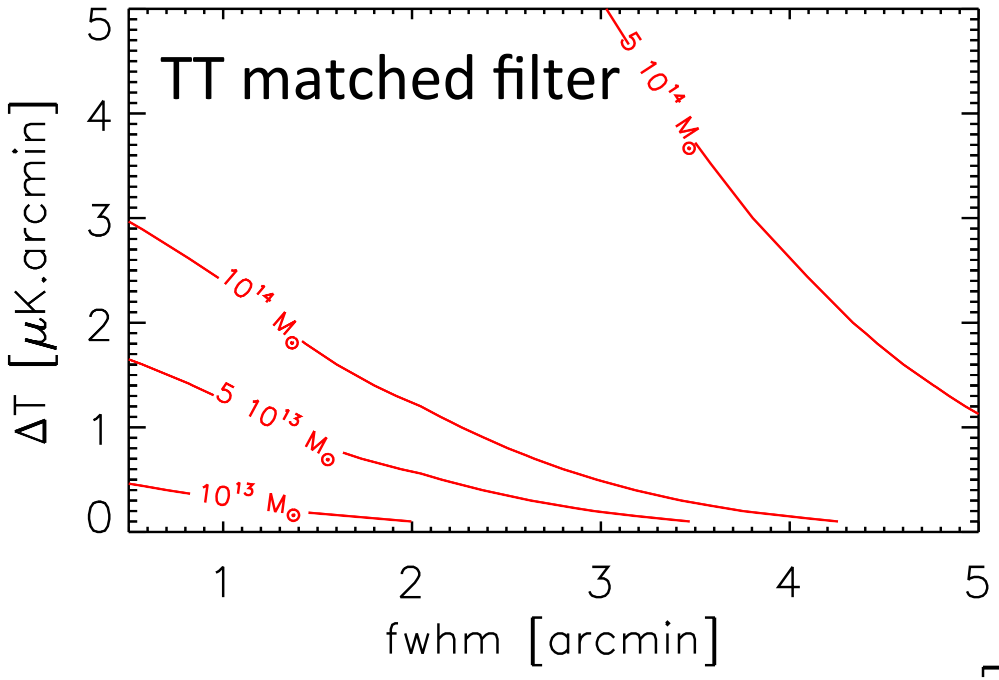
Matched filter for different estimators – case study:
- 1 micro-K map sensitivity
- 1 arcmin resolution

1-sigma mass sensitivity vs redshift



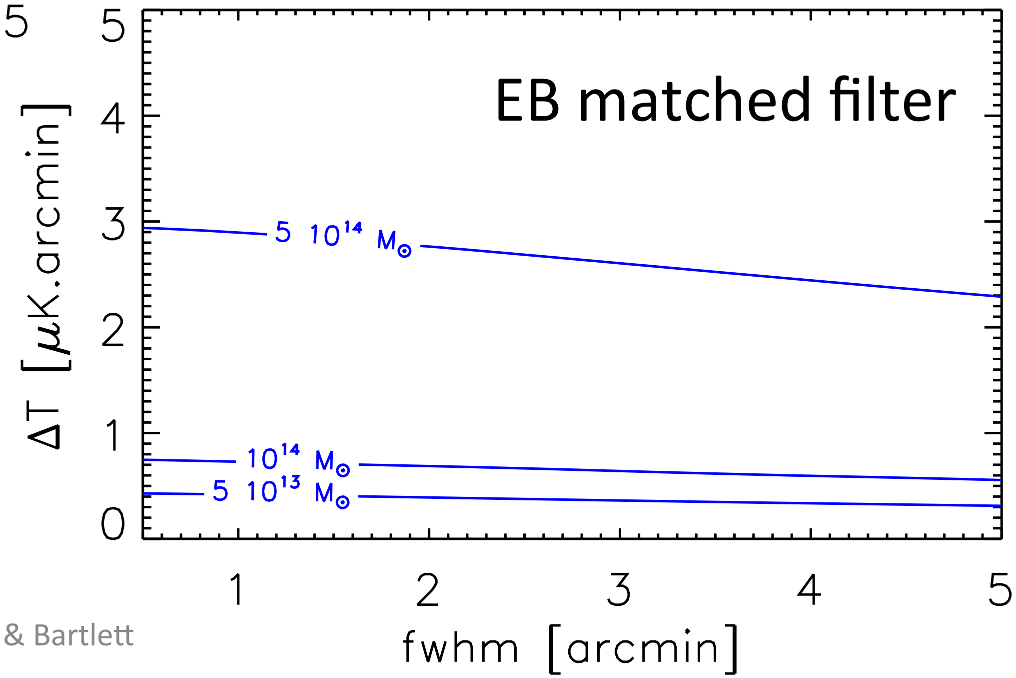
1. TT gives highest sensitivity at z>0.1
2. TT (4-5) X better than EB at z>0.5

Resolution – Sensitivity Play



1-sigma mass contours at z=0.5 for TT et EB estimators

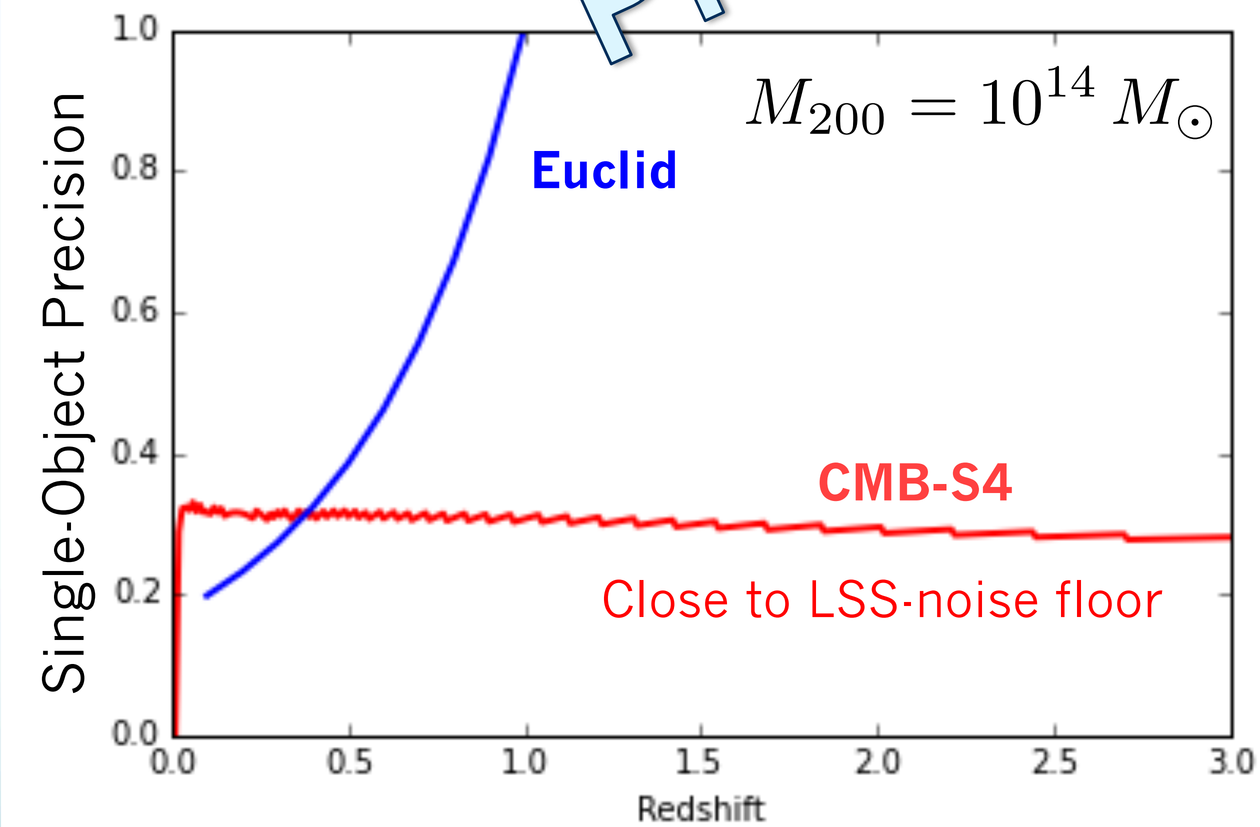
1. TT & EB equivalent at 3 arcmin and 1 microK-arcmin: but do not reach 10^{14} Msol
2. Resolution not important for EB
3. TT gains quickly with resolution



Euclid vs CMB-S4

Preliminary

CMB lensing needed for "high z" clusters



Summary/Comments

- Measure the masses of objects at higher z than shear
  - **NOT JUST cluster calibration!**
  - Astrophysics & galaxy formation: e.g., host halos for forming galaxies at z=2, of QSOs, or..., with stacks
- Combine with tSZ and kSZ to trace gas at same time (with stacks):
  - Most baryons don't make it into stars
  - Follow the baryons to understand galaxy formation!
  - Follow the mass
  - Get at feedback
  - At the peak epoch of star formation (z~2)

tSZ Stacks

Preliminary

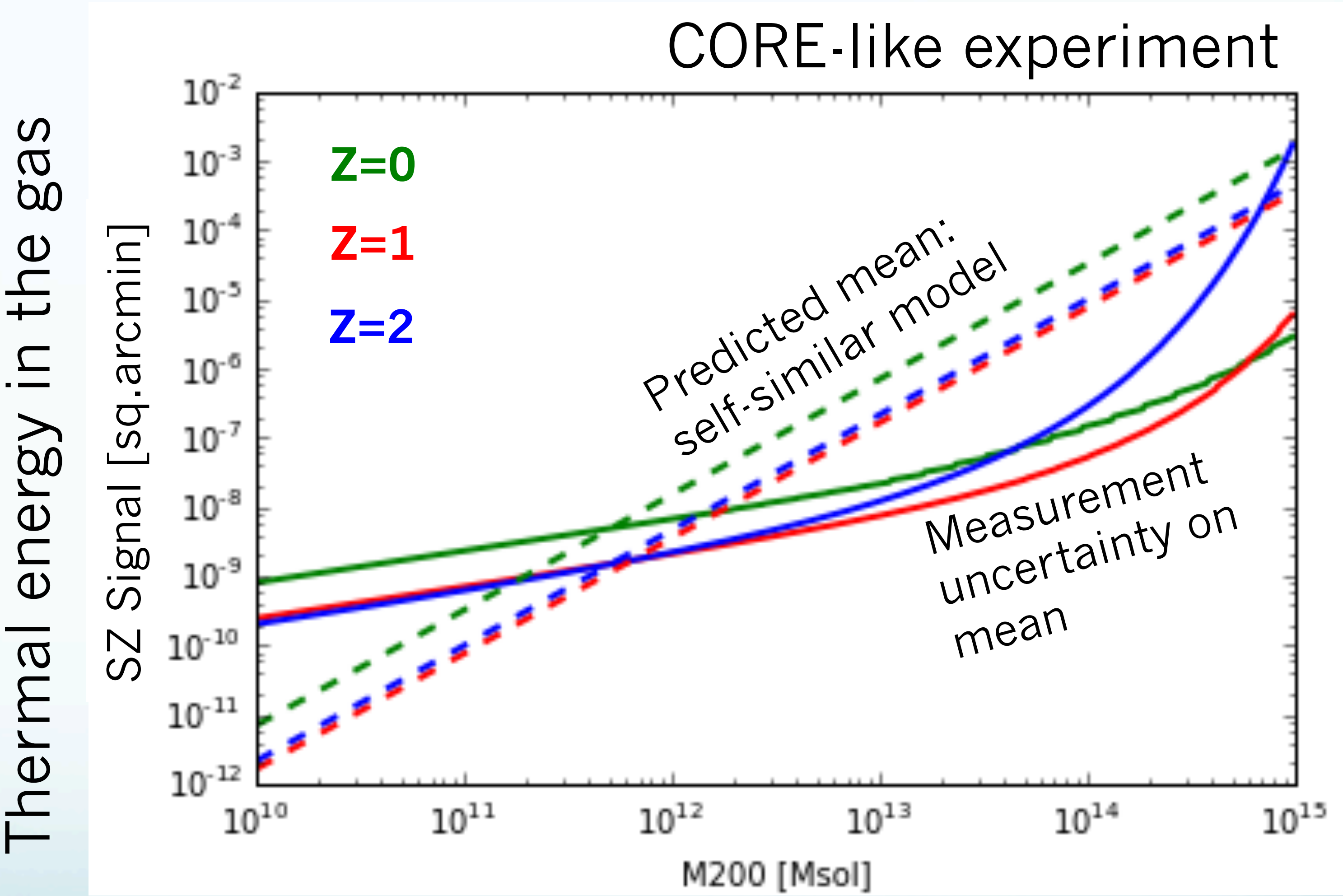
Bins:

$\Delta \log M_{200} = 0.1$

$\Delta z = 0.1$

Survey area:

$\Omega = \pi$



Where star formation is happening!