CMB Halo Lensing

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CMB Lensing

Planck Coll. XV (2015)

Analog of cosmic shear

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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
Cluster-CMB Lensing

439 Planck 2015 cosmology clusters:
Detection: $5\sigma$

Planck Collaboration XXIV (2015)

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Future Surveys 2016
3 ACTPol deep fields at 146 GHz
Convergence maps stacked on 12,000 CMASS galaxies
Detection: 3.2σ
Clean CMB map

Fit model using a pixel-pixel likelihood on CMB map

Study a number of systematics

Detection: $3.1\sigma$

$M_{200} \sim \text{few} \times 10^{14} \, M_{\odot}$
CMB Halo Lensing

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

1. TT gives highest sensitivity at $z > 0.1$
2. TT (4-5) X better than EB at $z > 0.5$
1. TT & EB equivalent at 3 arcmin and 1 microK-arcmin: but do not reach $10^{14} \, M_\odot$
2. Resolution not important for EB
3. TT gains quickly with resolution
CMB lensing needed for “high z” clusters

$M_{200} = 10^{14} M_\odot$

Euclid

CMB-S4

Close to LSS-noise floor
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)
Bins:
\[ \Delta \log M_{200} = 0.1 \]
\[ \Delta z = 0.1 \]

Survey area:
\[ \Omega = \pi \]