

BARYONS, FEEDBACK, GG-LENSING, AND ALL THE GOOD STUFF

Nick Battaglia
Cornell University

with
Stefania Amodeo (Cornell)
Mathew Madhavacheril (Princeton)
Simone Ferraro (LBL)
Emanuel Schaan (LBL)
Colin Hill (IAS)
David Spergel (FI, Princeton)

BARYONS, FEEDBACK, GG-LENSING AND ALL THE GOOD STUFF

Simone Ferraro <sferraro@berkeley.edu>

to Nicholas ▾

Hey Nick,

We have more or less finalized the program for the BCCP workshop. Can you talk about baryons, feedback, gg lensing and all the good stuff?

Thanks!

Simo

Nick Battaglia
Cornell University

with

Stefania Amodeo (Cornell)

Mathew Madhavacheril (Princeton)

Simone Ferraro (LBL)

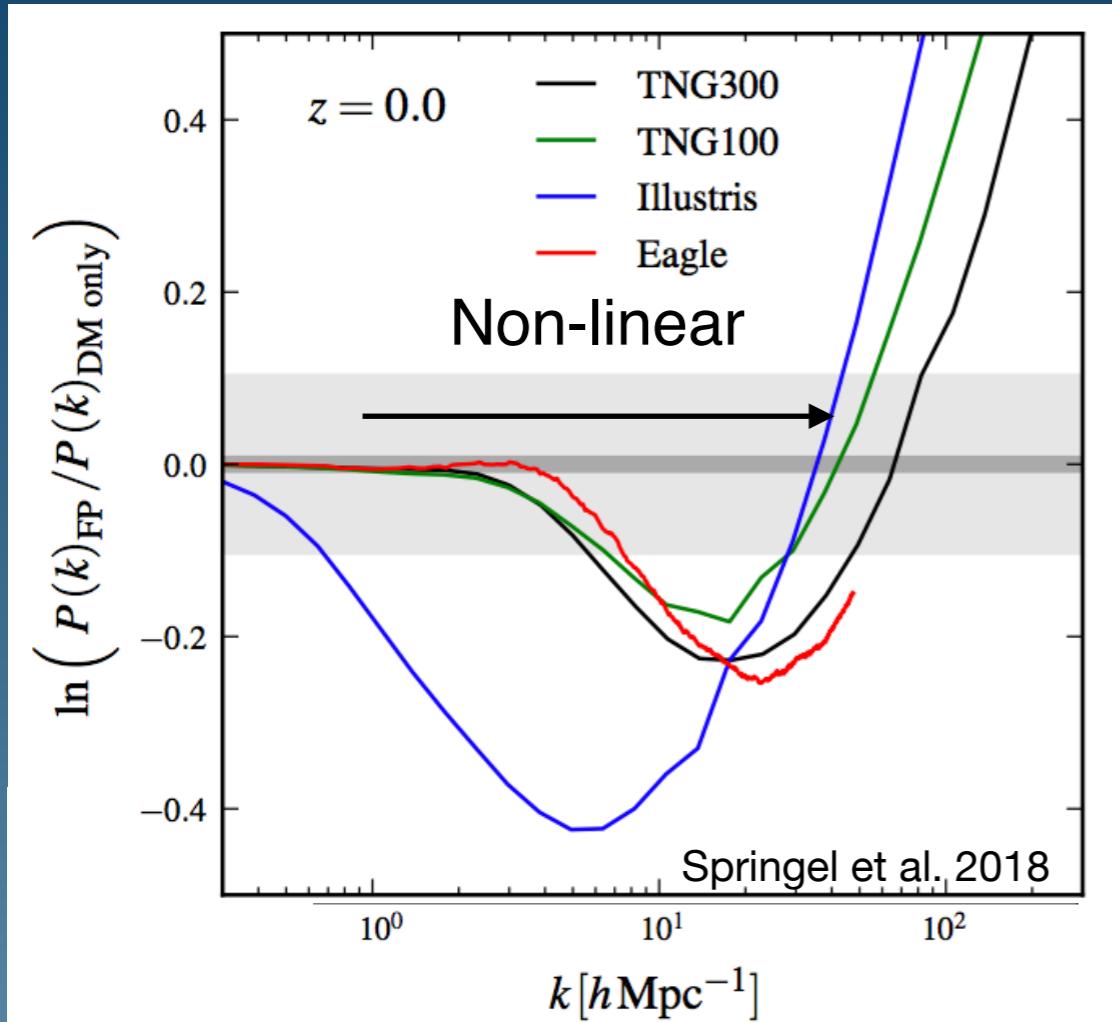
Emanuel Schaan (LBL)

Colin Hill (IAS)

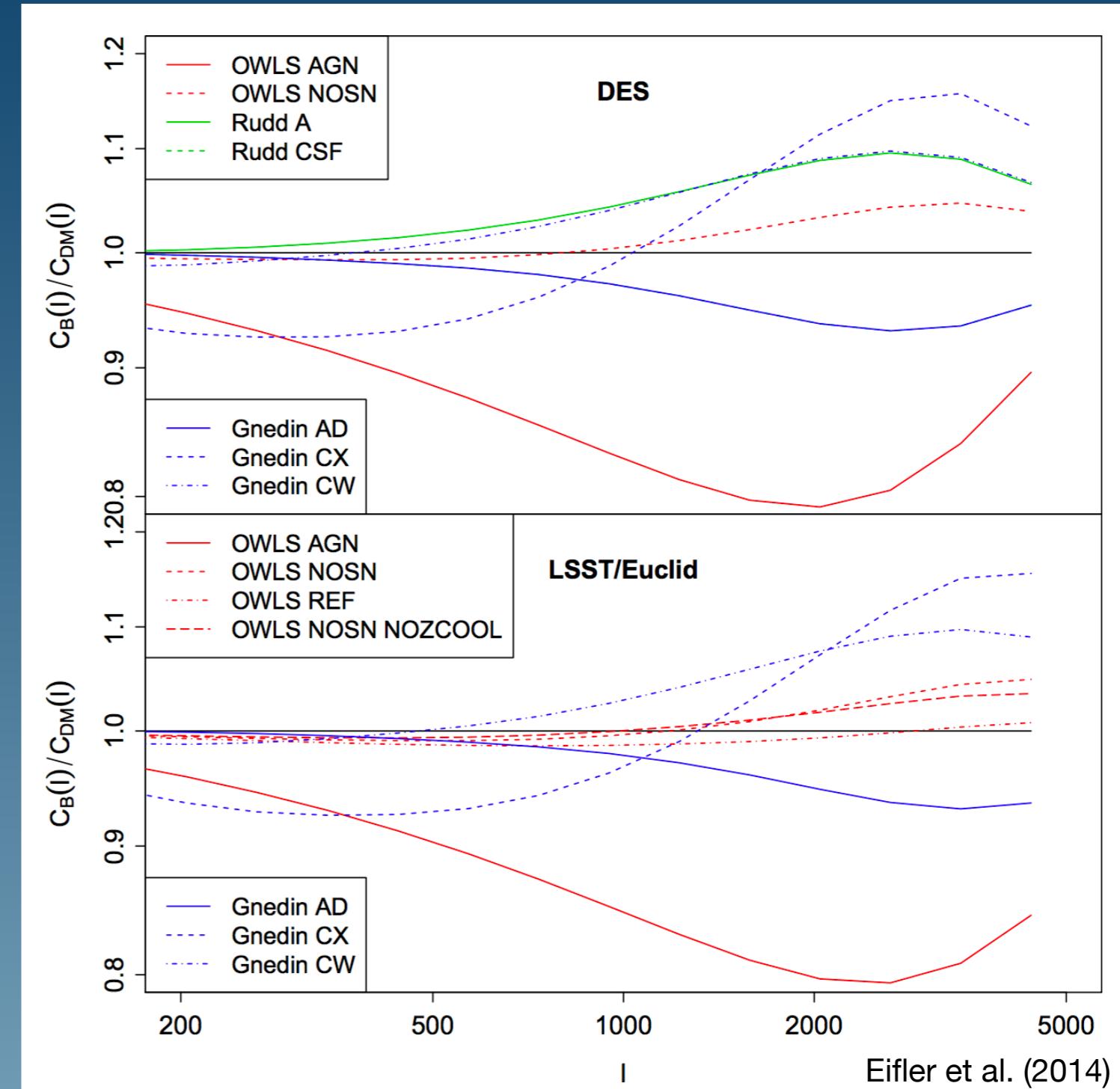
David Spergel (FI, Princeton)

Baryonic Effects

Matter Power Spectrum



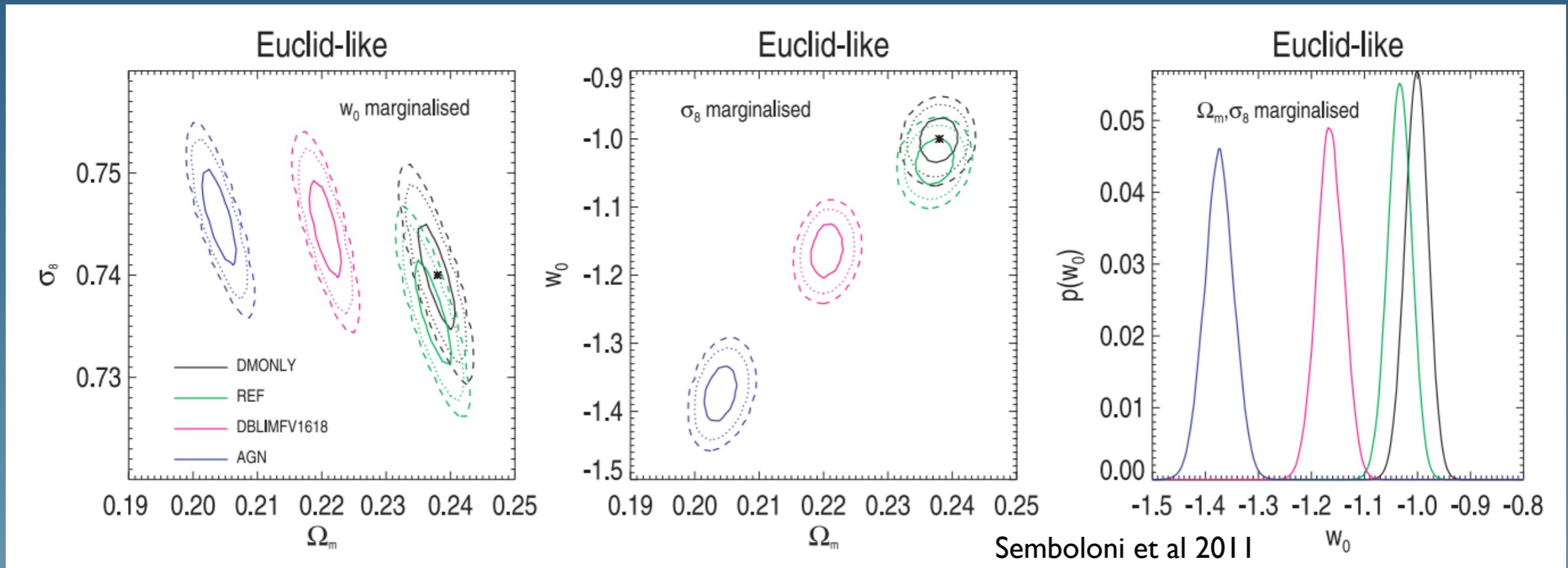
Cosmic Shear



Or provides unique constraints
on the main baryonic processes
that govern growth of structure
on these scales

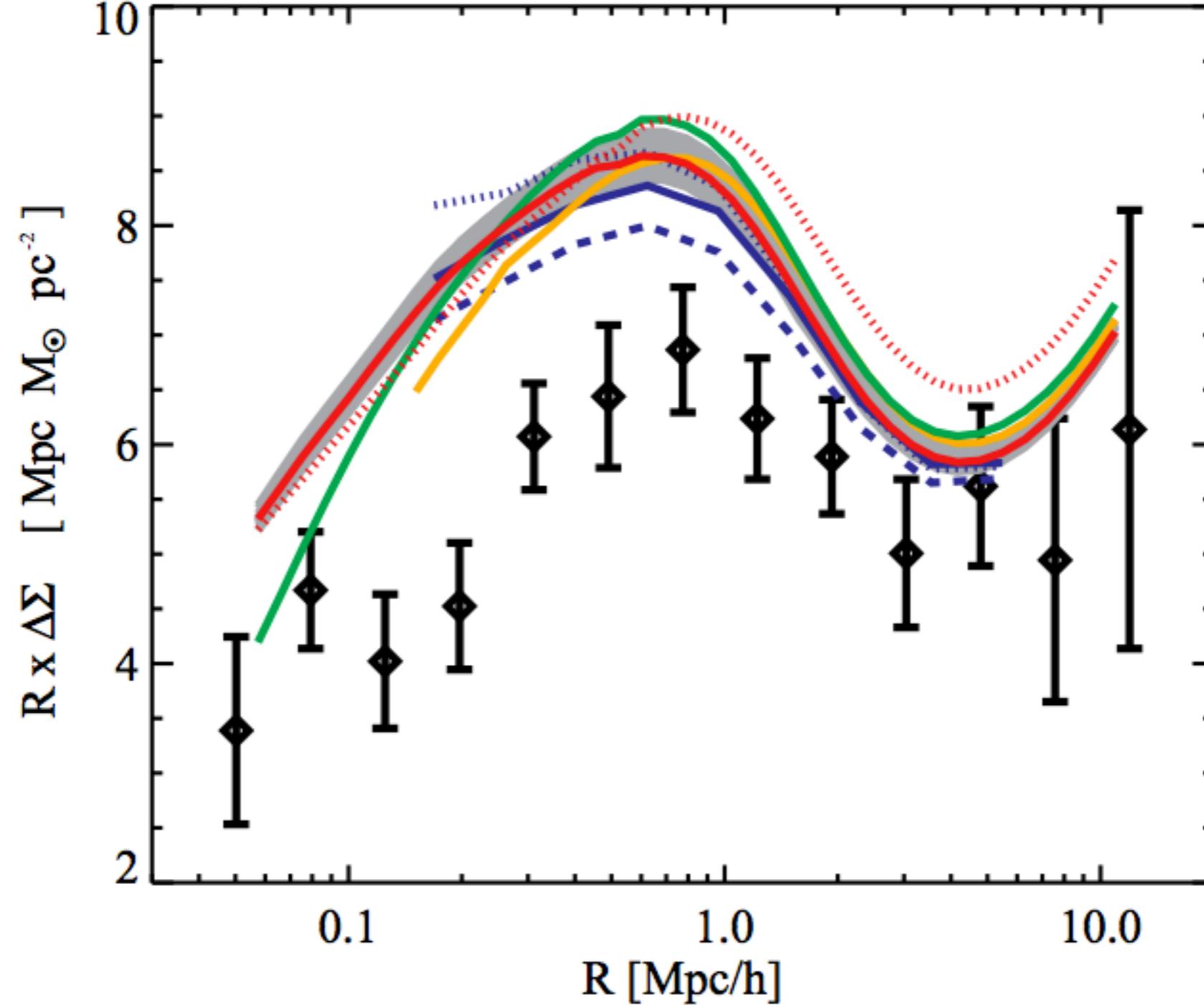
Cosmological & Astrophysical Implications

Pushing into the non-linear regime leads to increasing the uncertainties from baryons and potential biases in the inference of cosmological parameters



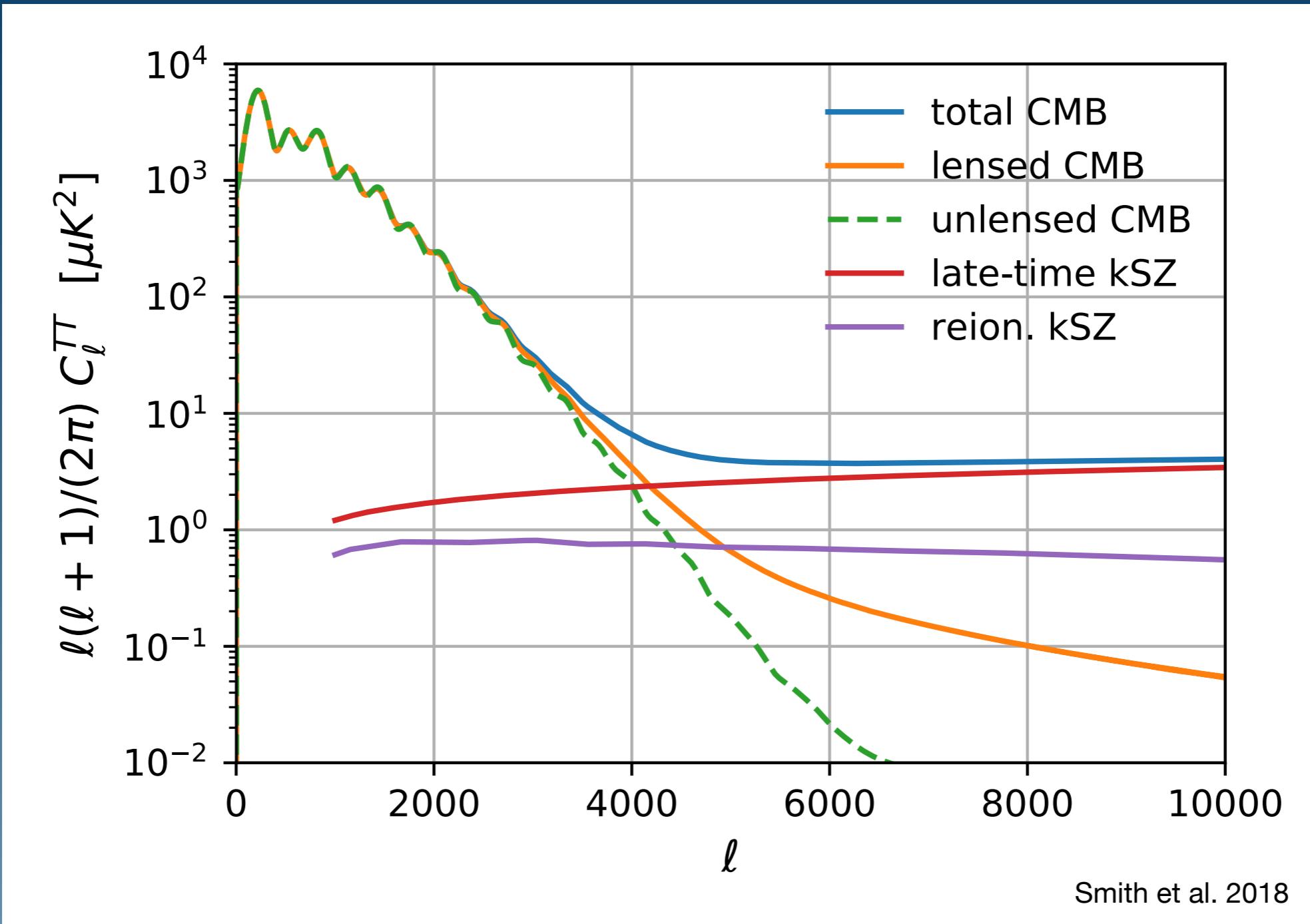
Lensing is Low: Cosmology, Galaxy Formation, or New Physics?

Alexie Leauthaud^{1,2}, Shun Saito³, Stefan Hilbert^{4,5}, Alexandre Barreira³, Surhud More², Martin White⁶, Shadab Alam^{7,8}, Peter Behroozi^{6,9}, Kevin Bundy^{1,2}, Jean Coupon¹⁰,



Kinetic Sunyaev-Zeldovich (kSZ)

CMB Intensity (Foreground Cleaned)



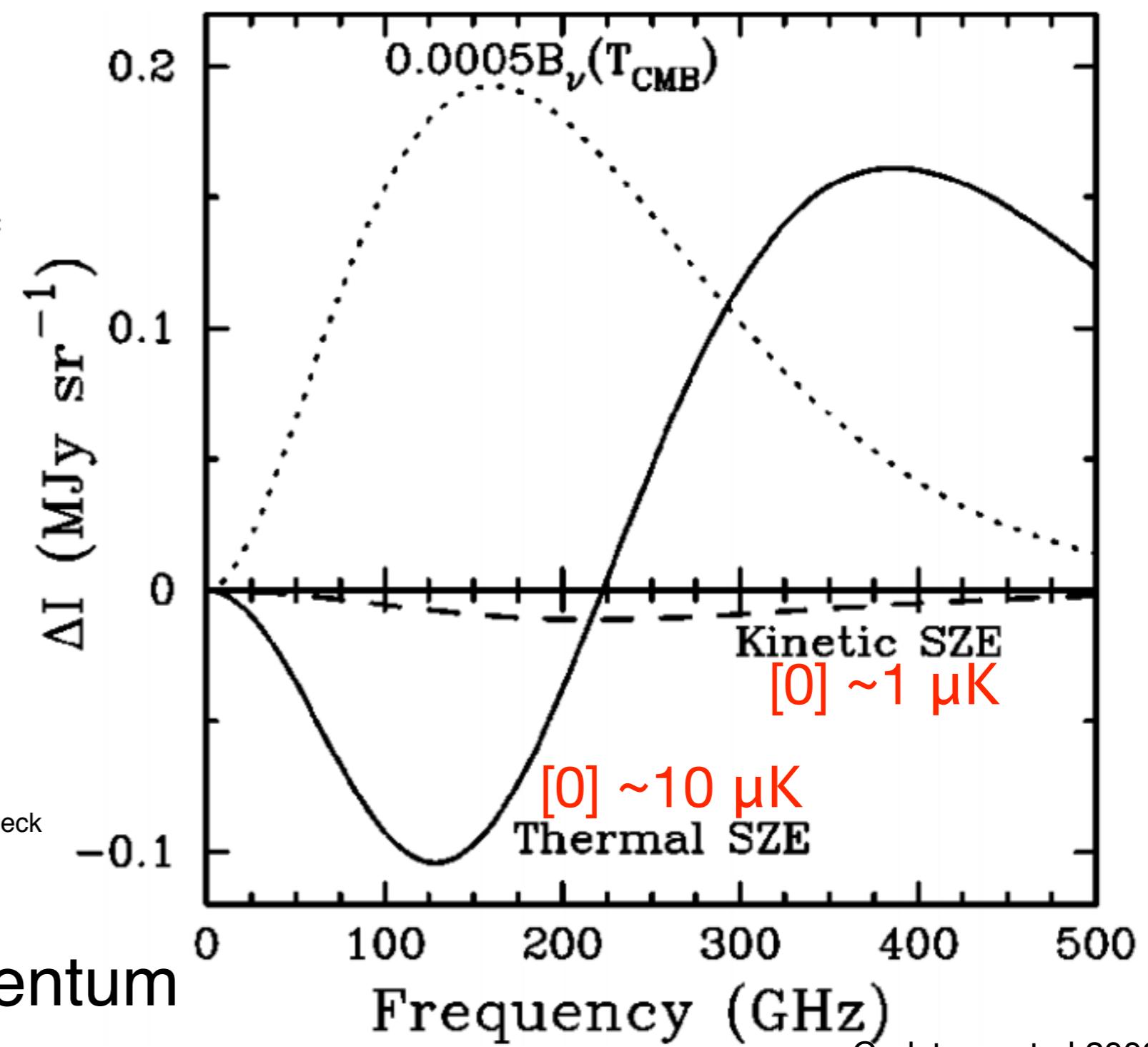
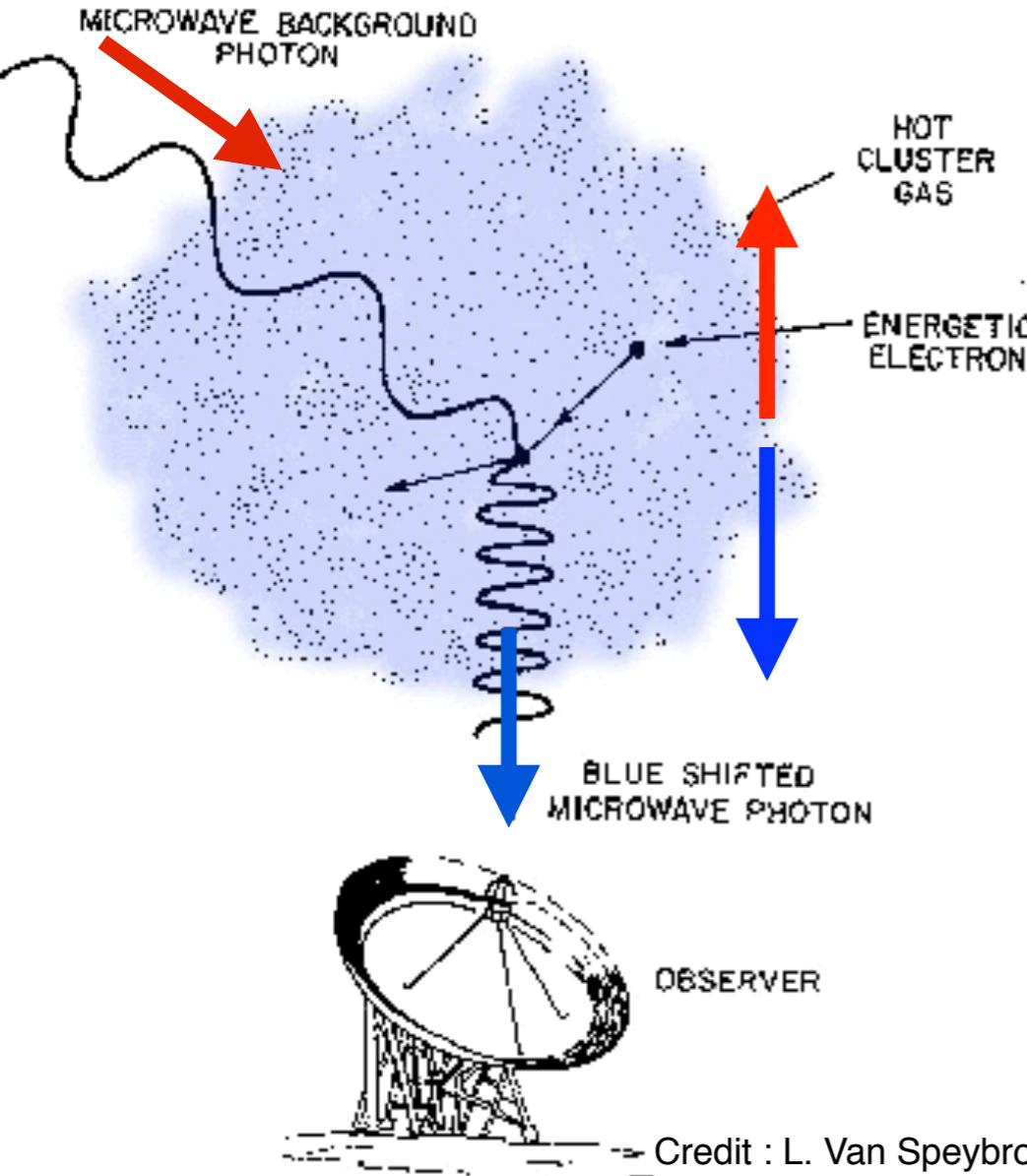
Ignoring effects from mis-centering & 2-halo contributions

Foregrounds are cleaned, but not correlated dusty sources

kSZ is more than just a CMB lensing foreground/bias

Sunyaev-Zeldovich Effects

Inverse Compton & Doppler boosting of CMB photons



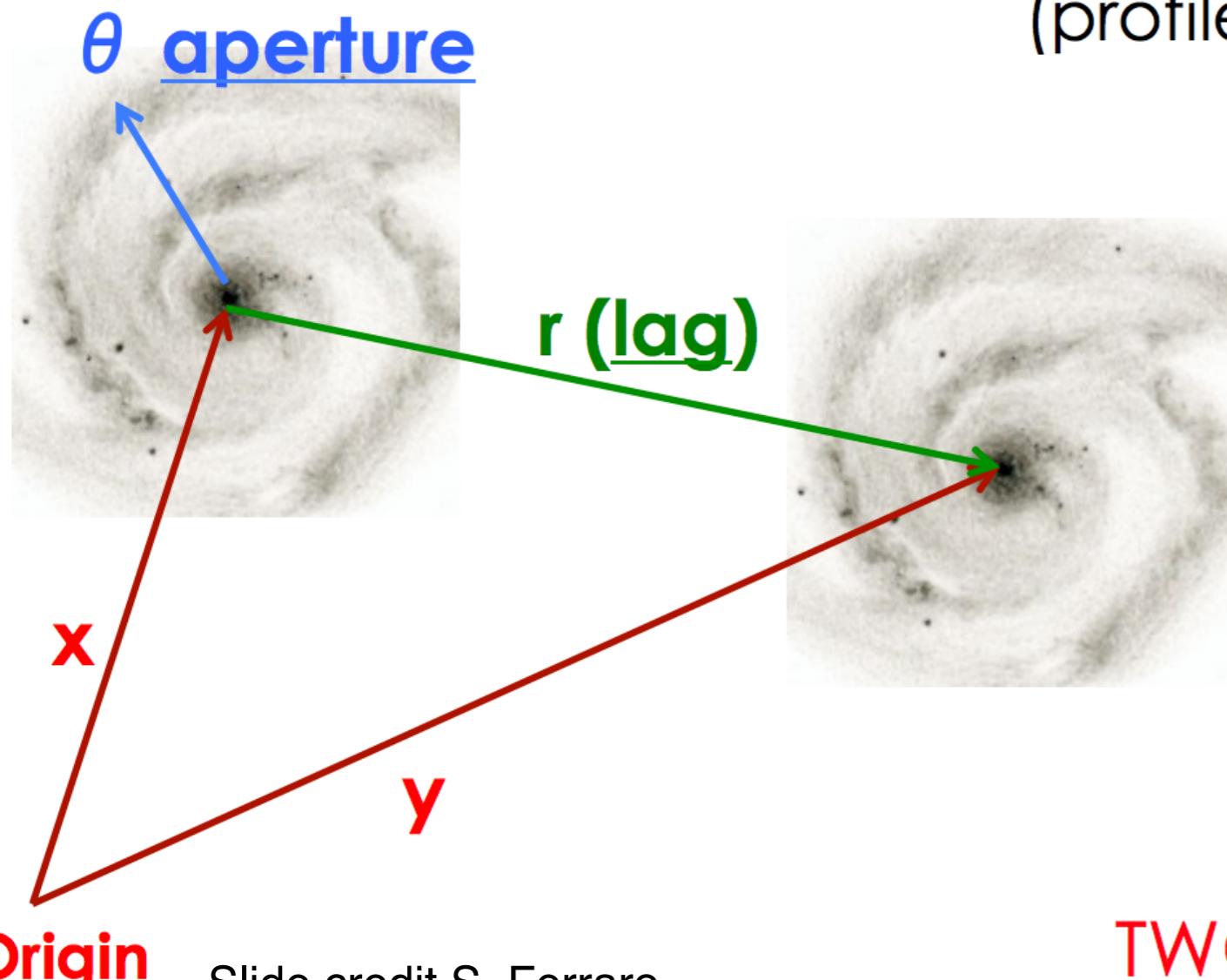
LOS pressure & momentum

Carlstrom et al 2002

What is measured?

$$\left(\frac{\Delta T}{T} \right)_{\text{kSZ}} (\mathbf{x} + \theta) = -\tau(\theta) v_r(\mathbf{x}) \quad (+ \text{2-halo})$$

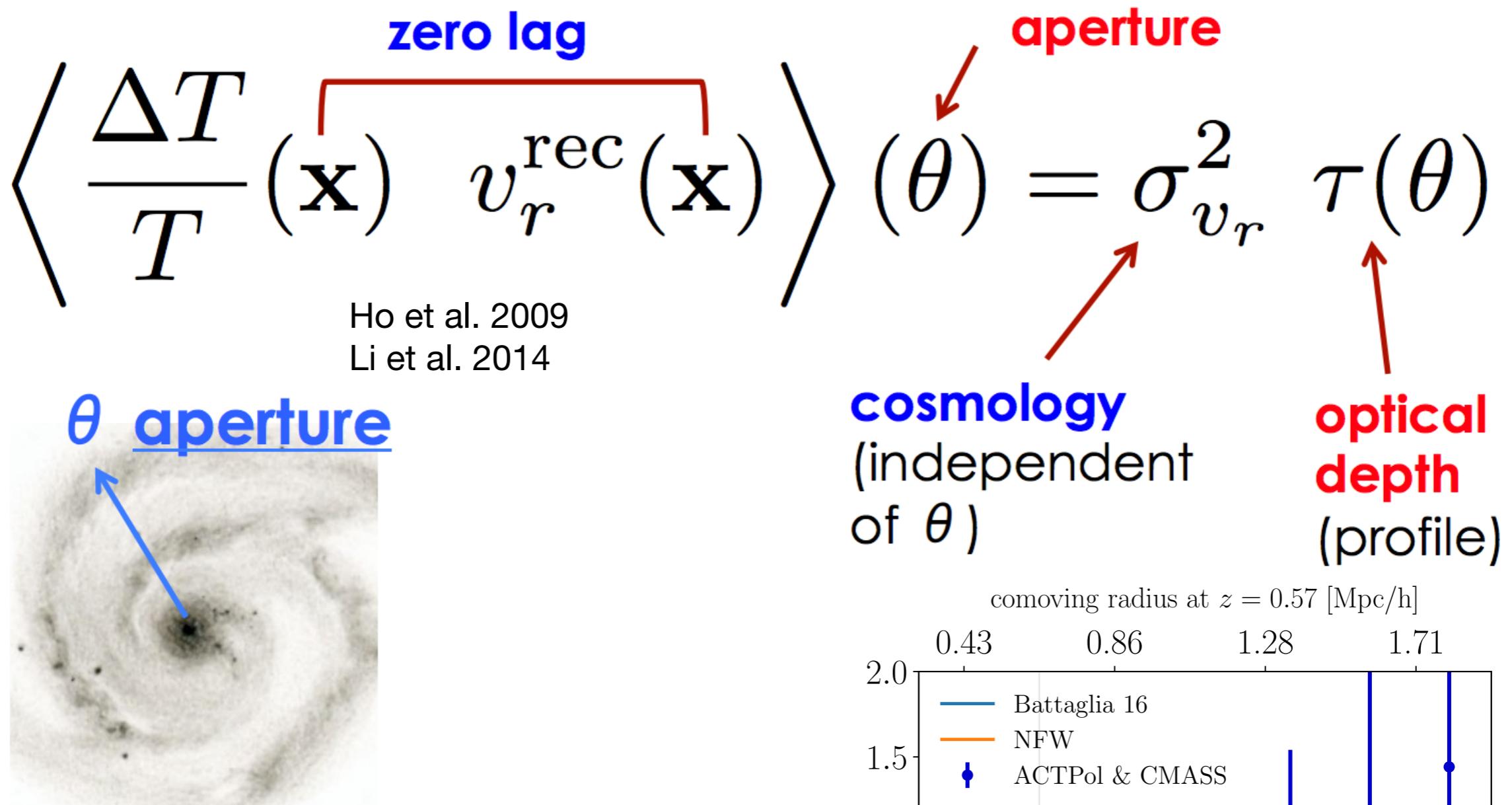
optical depth
(profile) 'bulk' radial velocity



- Vary \mathbf{r} at fixed $\theta \rightarrow$ velocity field on large scales
- Vary θ at fixed $\mathbf{x} \rightarrow$ gas profile and abundance.

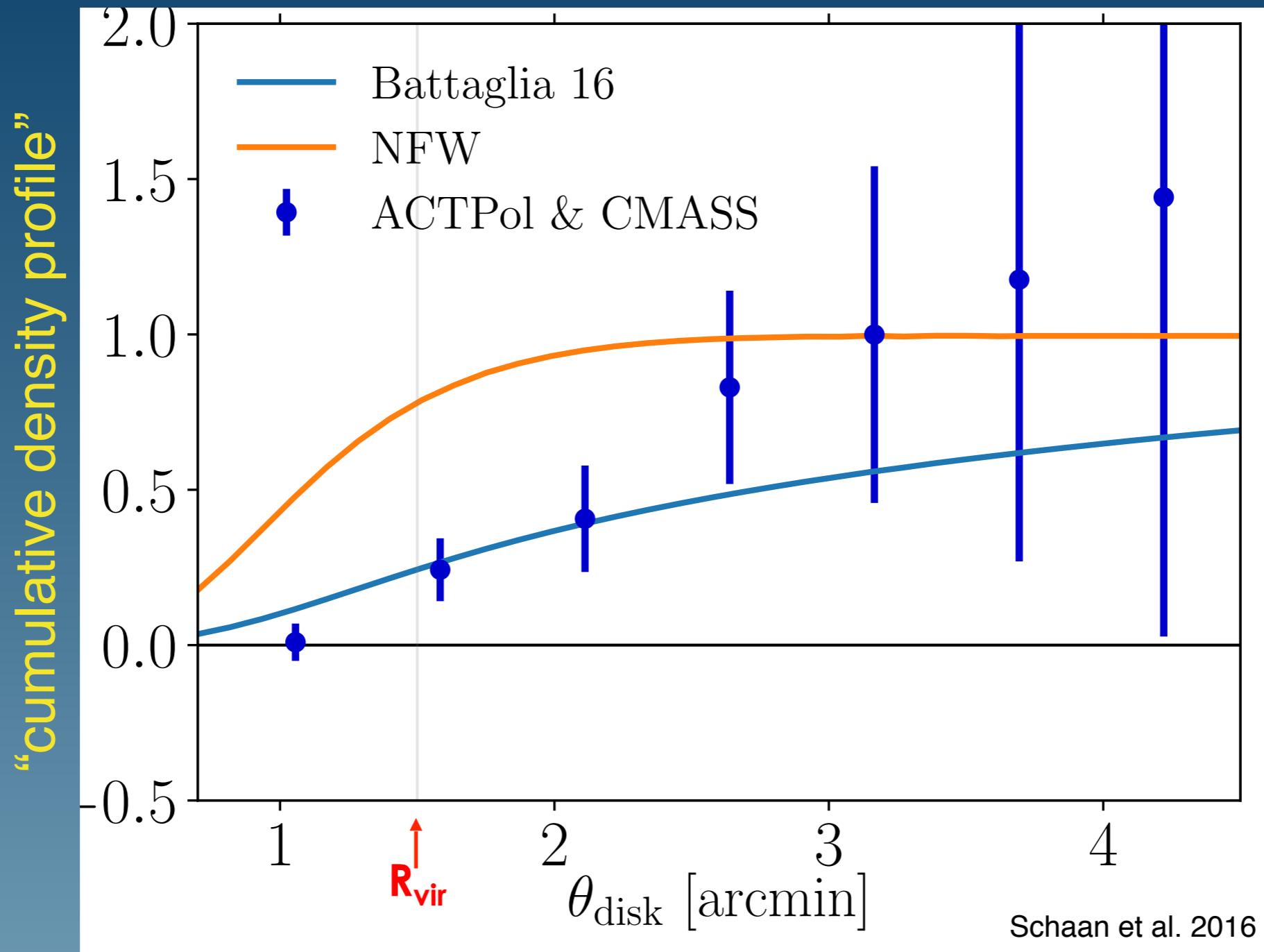
TWO different measurements!

Measuring the density profile



The kSZ measurements
with SO & CMB-S4 will
be spectacular

Initial kSZ results



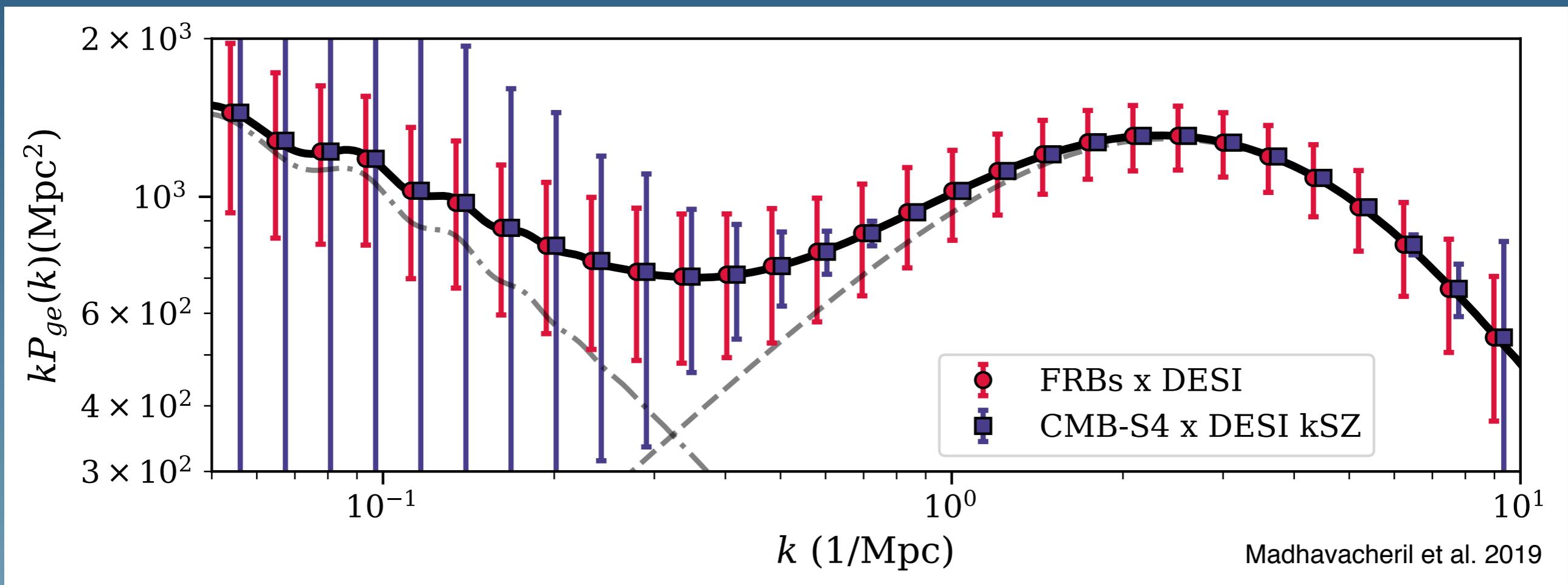
BOSS CMASS galaxies + ACTPol CMB data
 $z \sim 0.6, M \sim 2 \times 10^{13} M_{\text{sun}}$

Forecasted Constraints on the Density Profile

Emergence of kSZ detections ($\sim 4\sigma$)

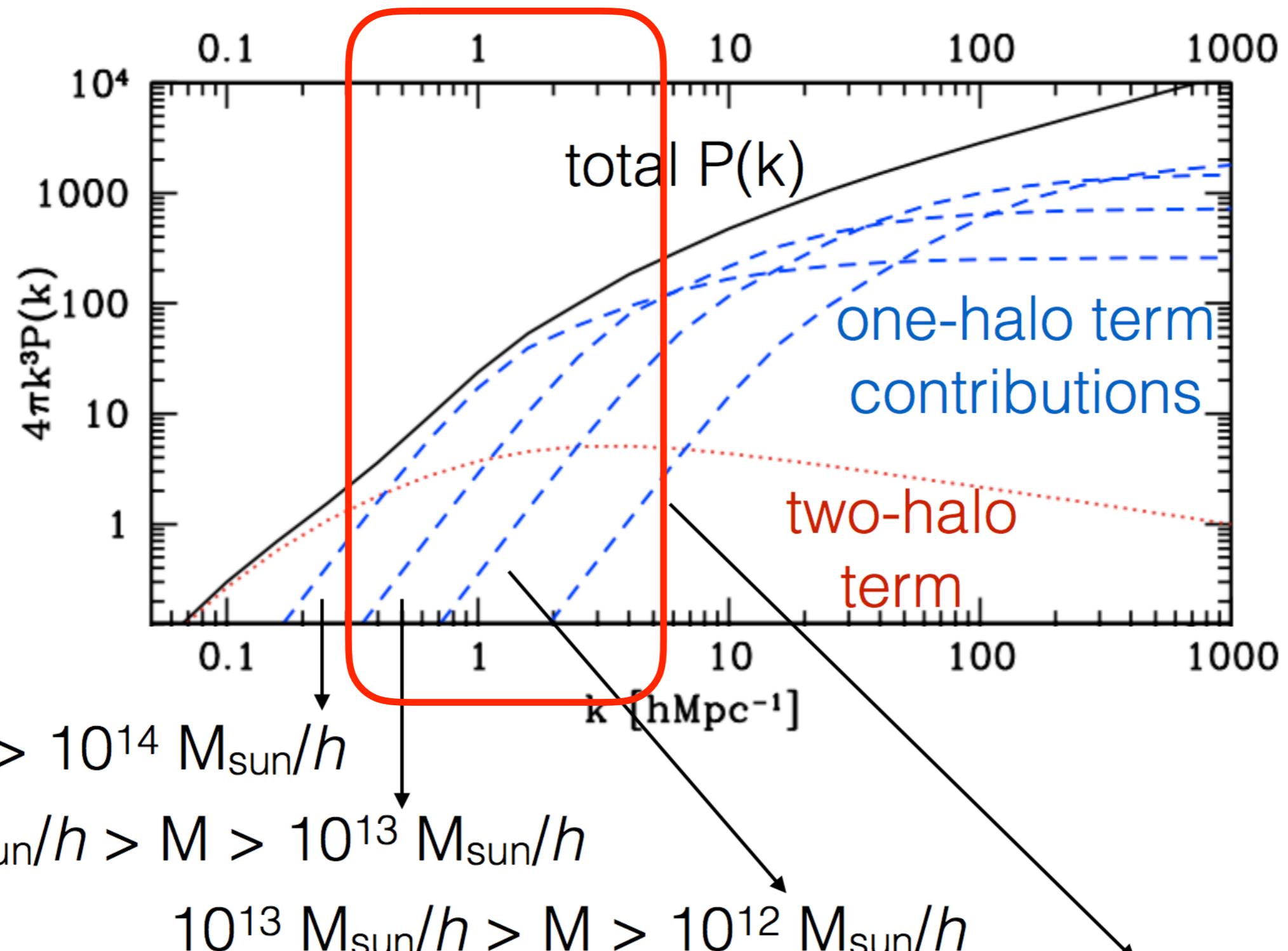
Forecasted kSZ detections are on the order of 100σ across multiple redshift ranges and mass ranges in the next 5-10 years.

Use kSZ as a tool to calibrate baryonic effects



Which halos do we need to measure?

dominated by group-scale halos over relevant wavenumbers



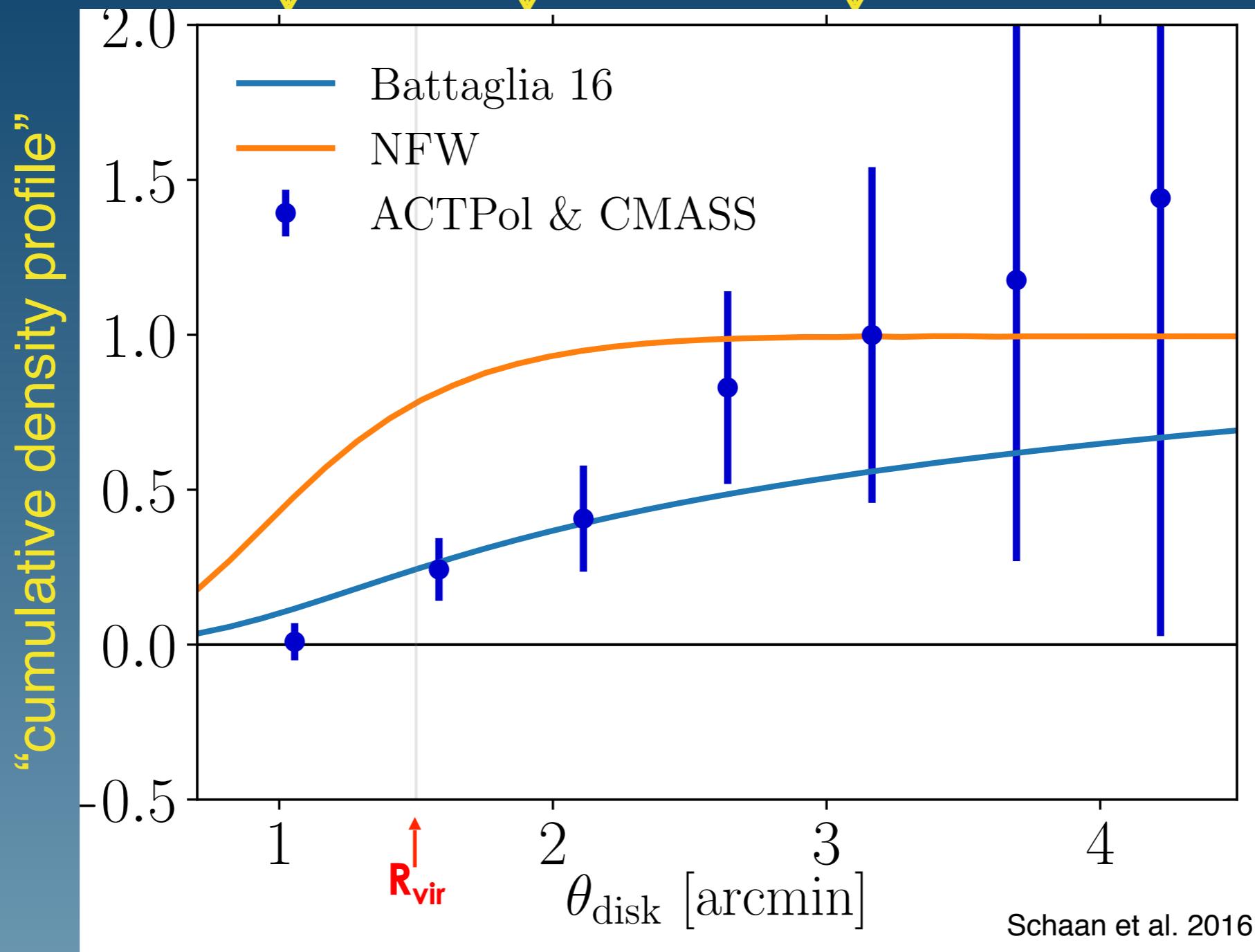
Cosmological Implications

LSST $L_{\max} = 5000$ at $z =$

0.3

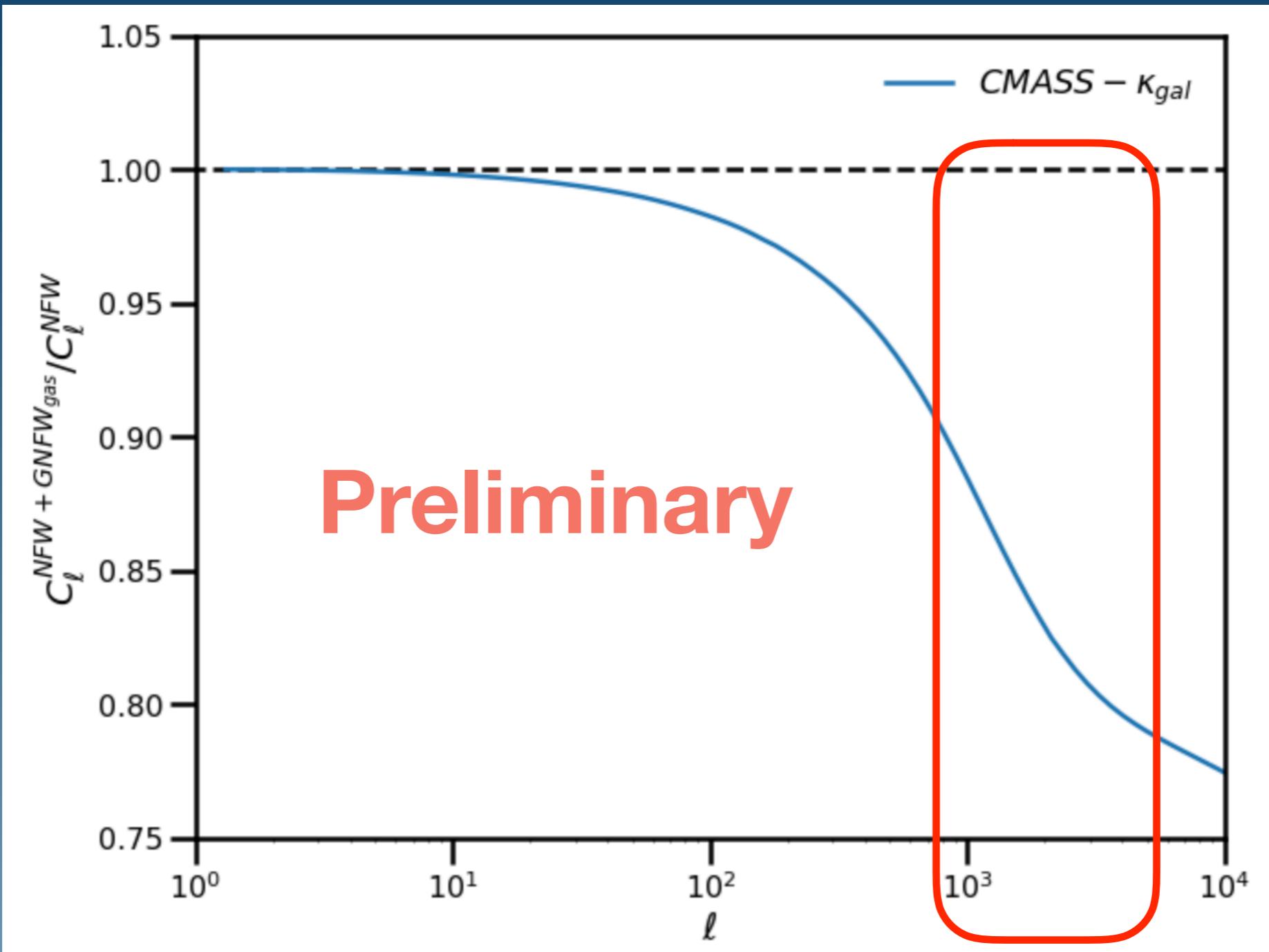
0.5

1.0

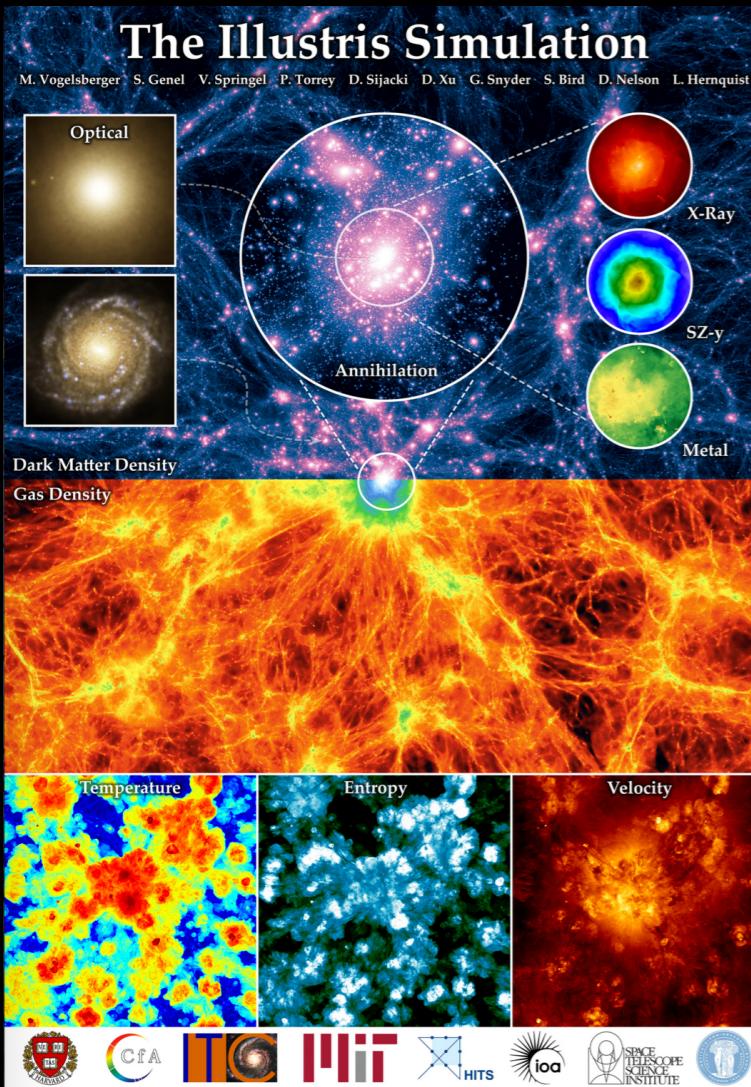


BOSS CMASS galaxies + ACTPol CMB data
 $z \sim 0.6, M \sim 2 \times 10^{13} M_{\text{sun}}$

0th order modeling of the Baryons in gg-lensing



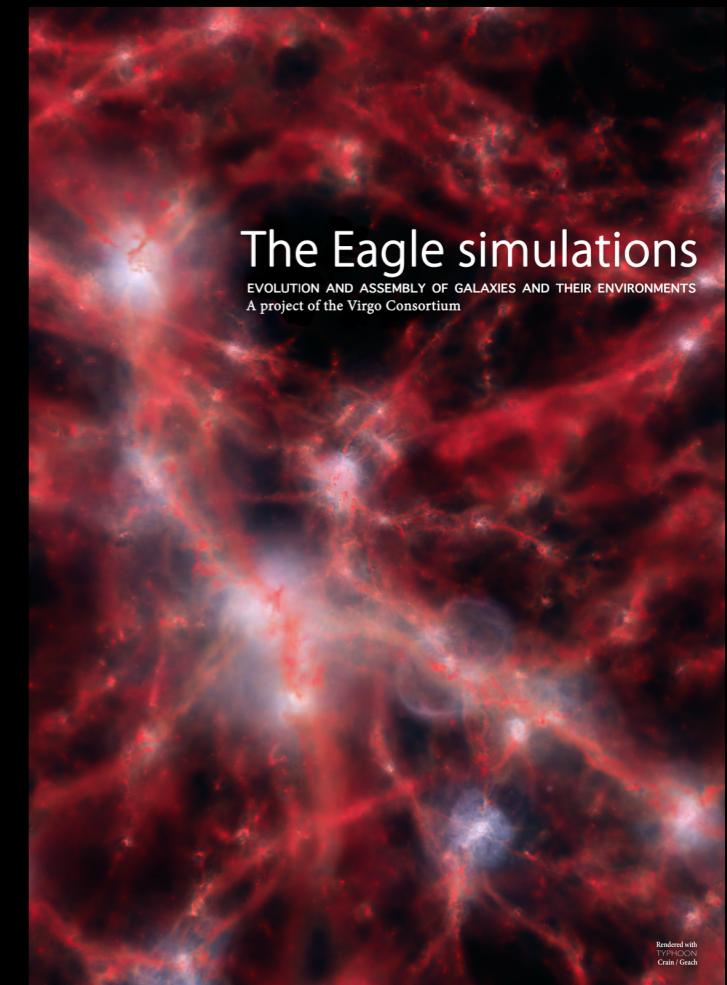
No baryon-DM back-reaction yet



Cosmological Simulations



The Horizon Simulation



The Eagle Simulations

EVOLUTION AND ASSEMBLY OF GALAXIES AND THEIR ENVIRONMENTS

The Hubble Sequence realised in cosmological simulations



irregular

ellipticals

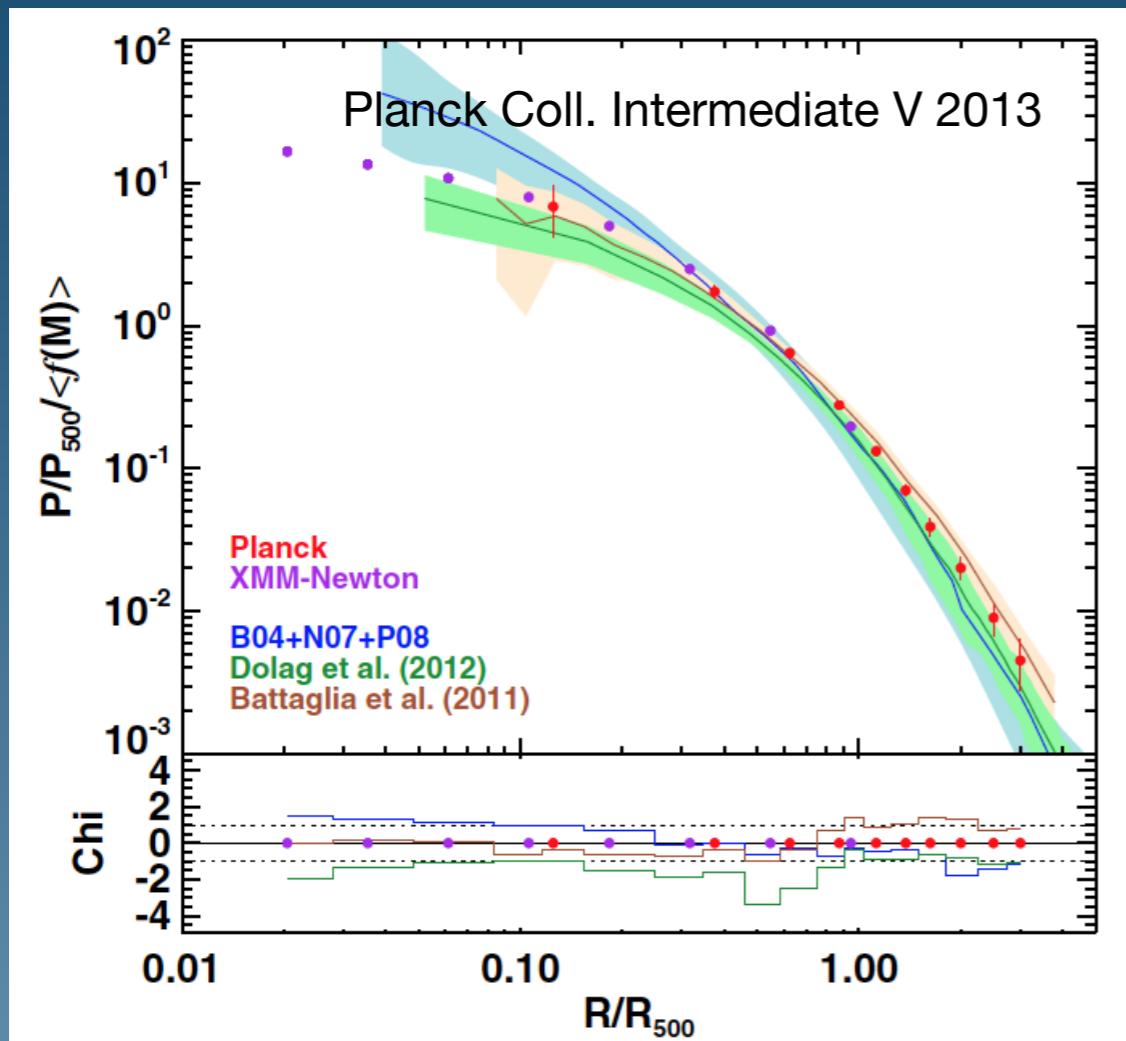
disk galaxies

Illustris Collaboration

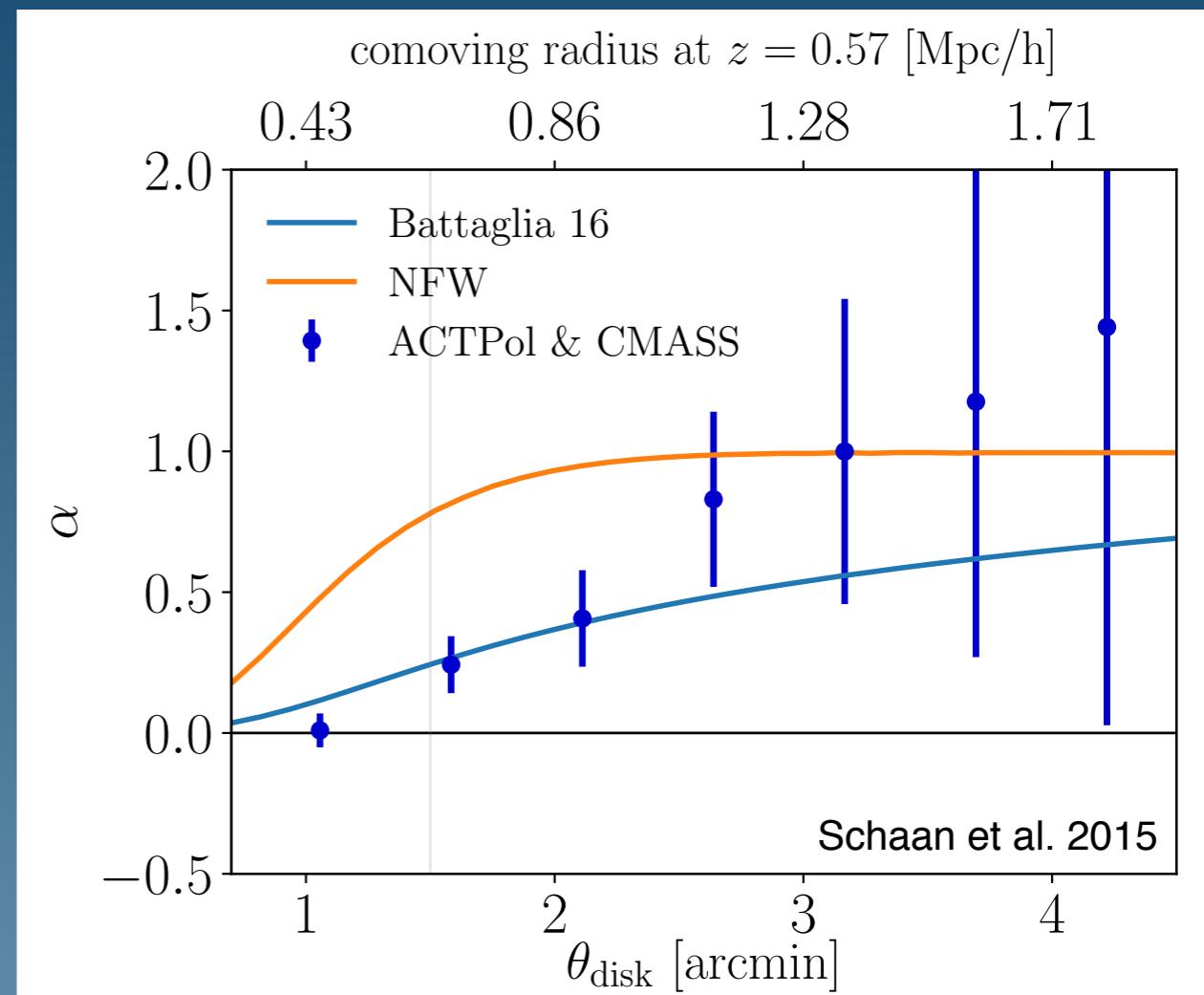
Combining tSZ & kSZ measurements

Previously, Knox+2004, Sehgal+2005 proposed to constrain T , τ & v_{pec}

Also see Erler et al 2017 & Mittal et al. 2018



+

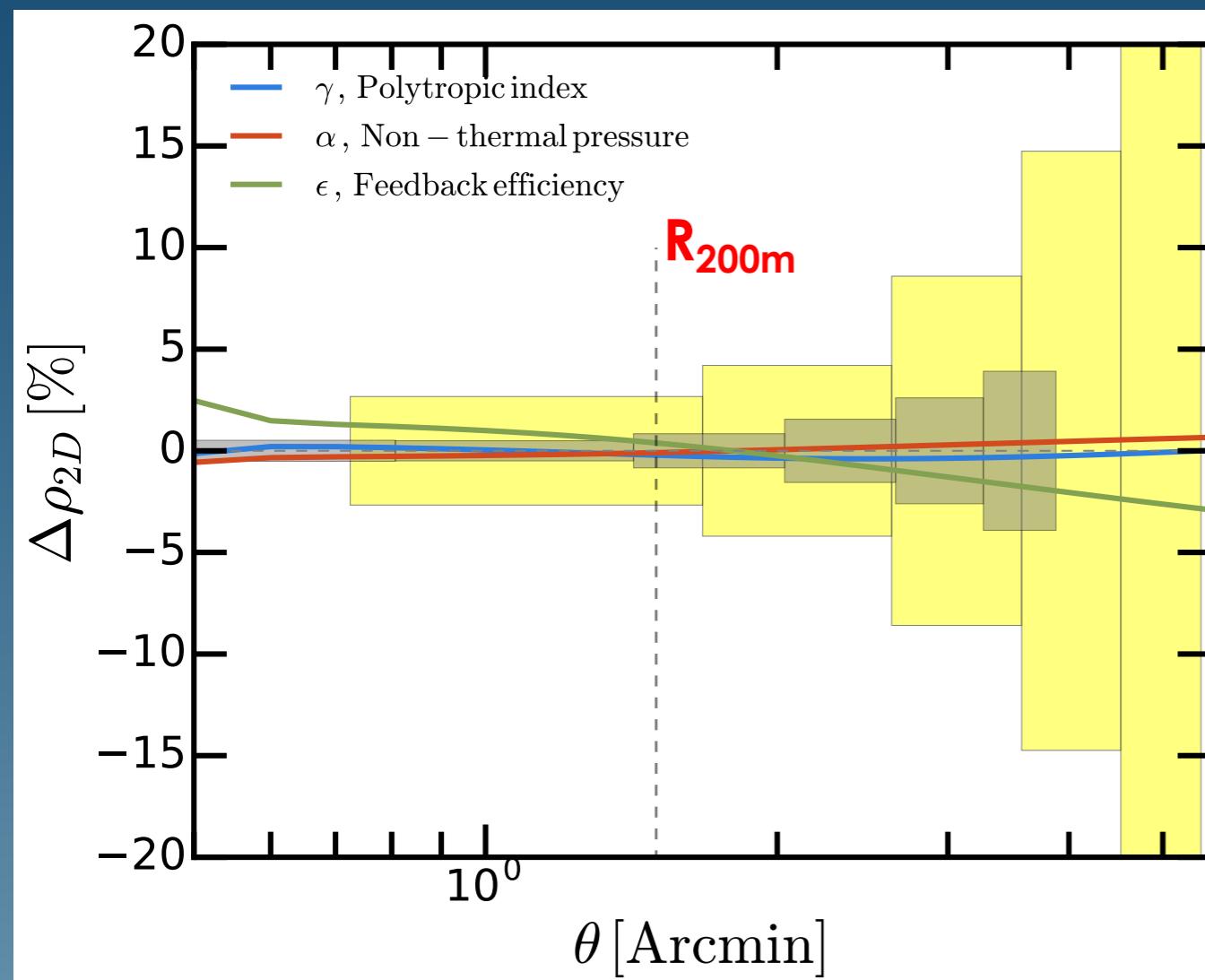


$$\underbrace{\frac{1}{3} \Phi_{\text{gas}}}_{\text{from kSZ & mass profile}} + \underbrace{\int P_{\text{th}} dV}_{\text{from tSZ}} + \underbrace{\int P_{\text{Nth}} dV}_{\rightarrow \text{inferred}} \propto P_{\text{Surface}}$$

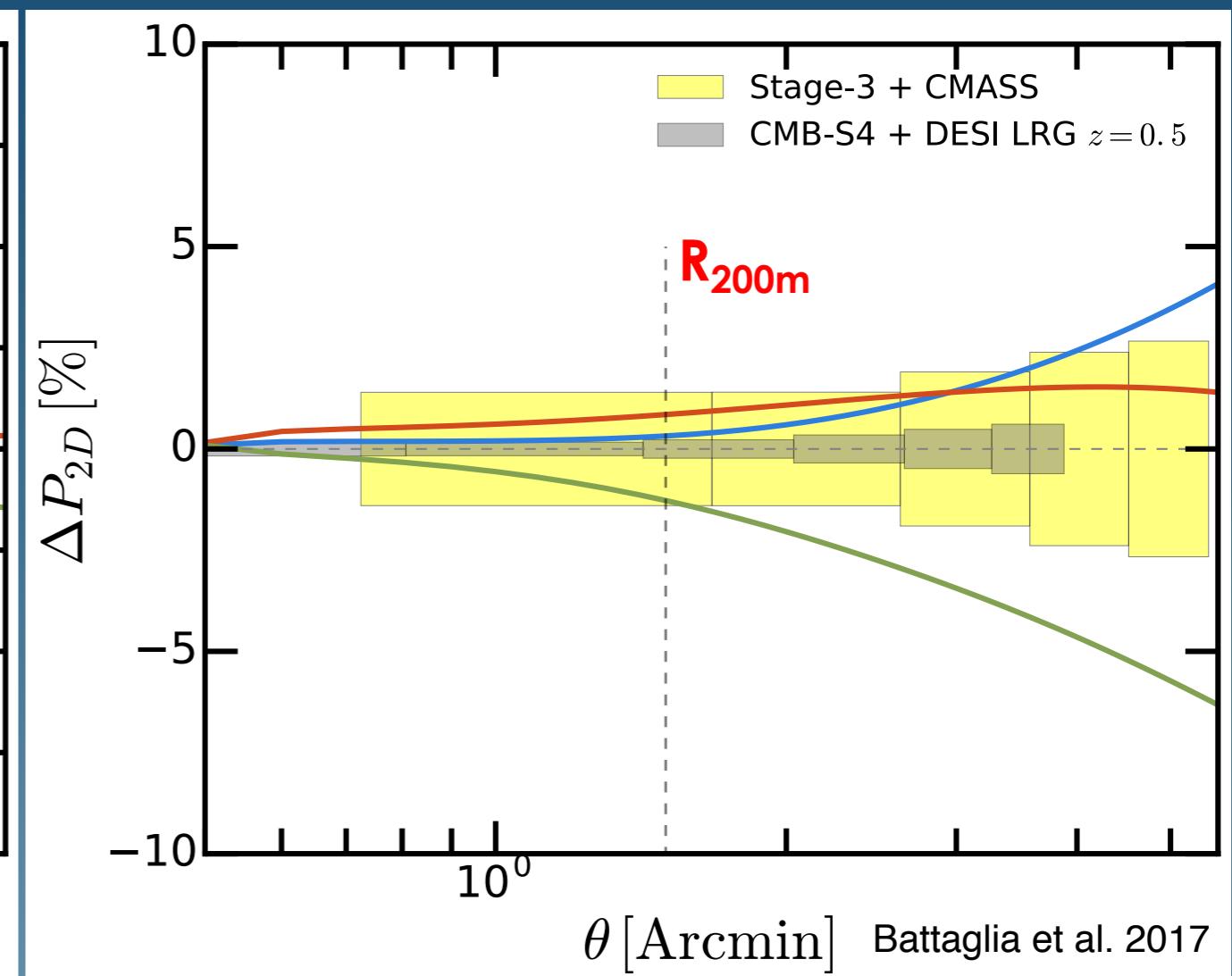
Constraint non-thermal pressure in halos

Combining tSZ & kSZ measurements forecasts

Density



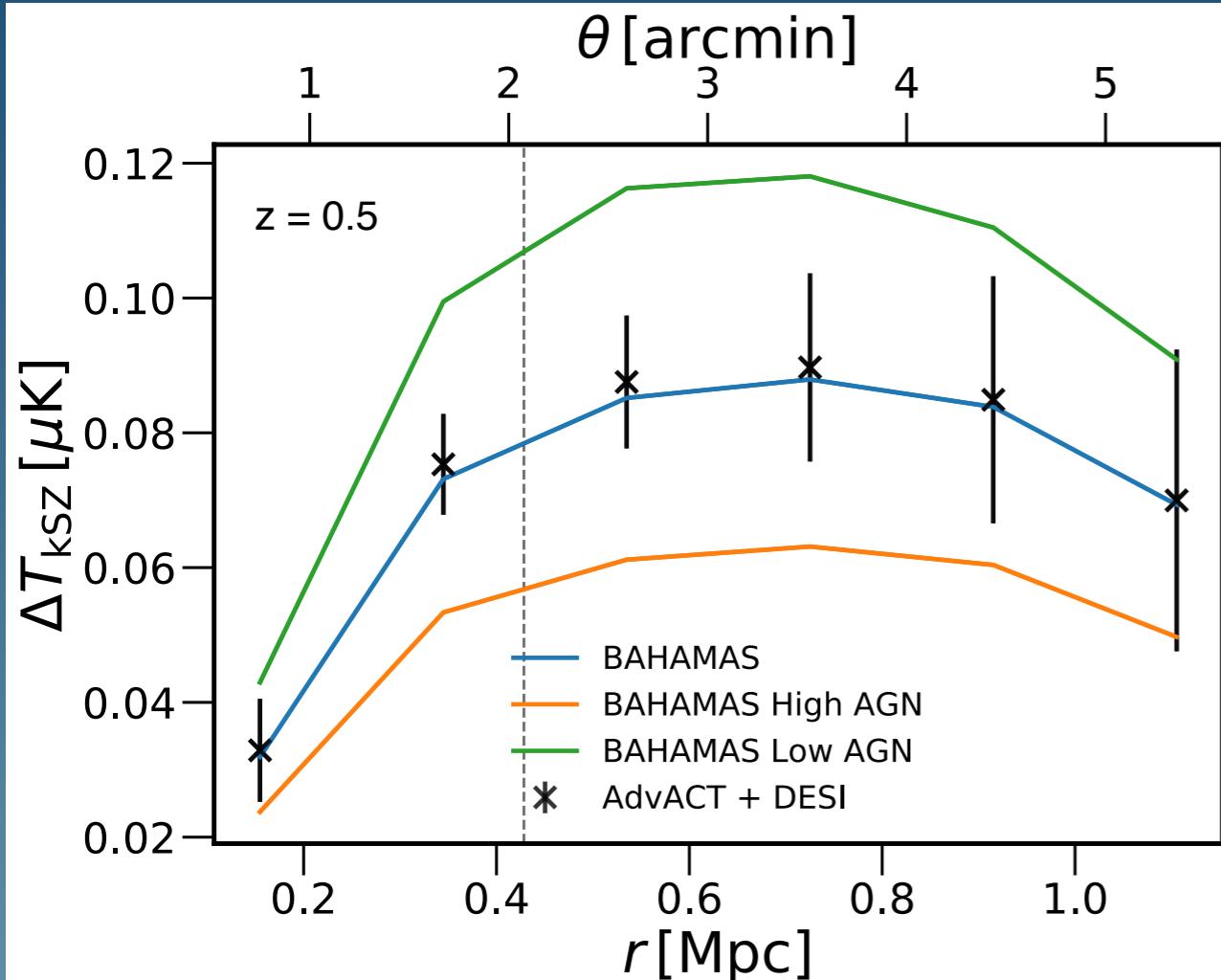
Pressure



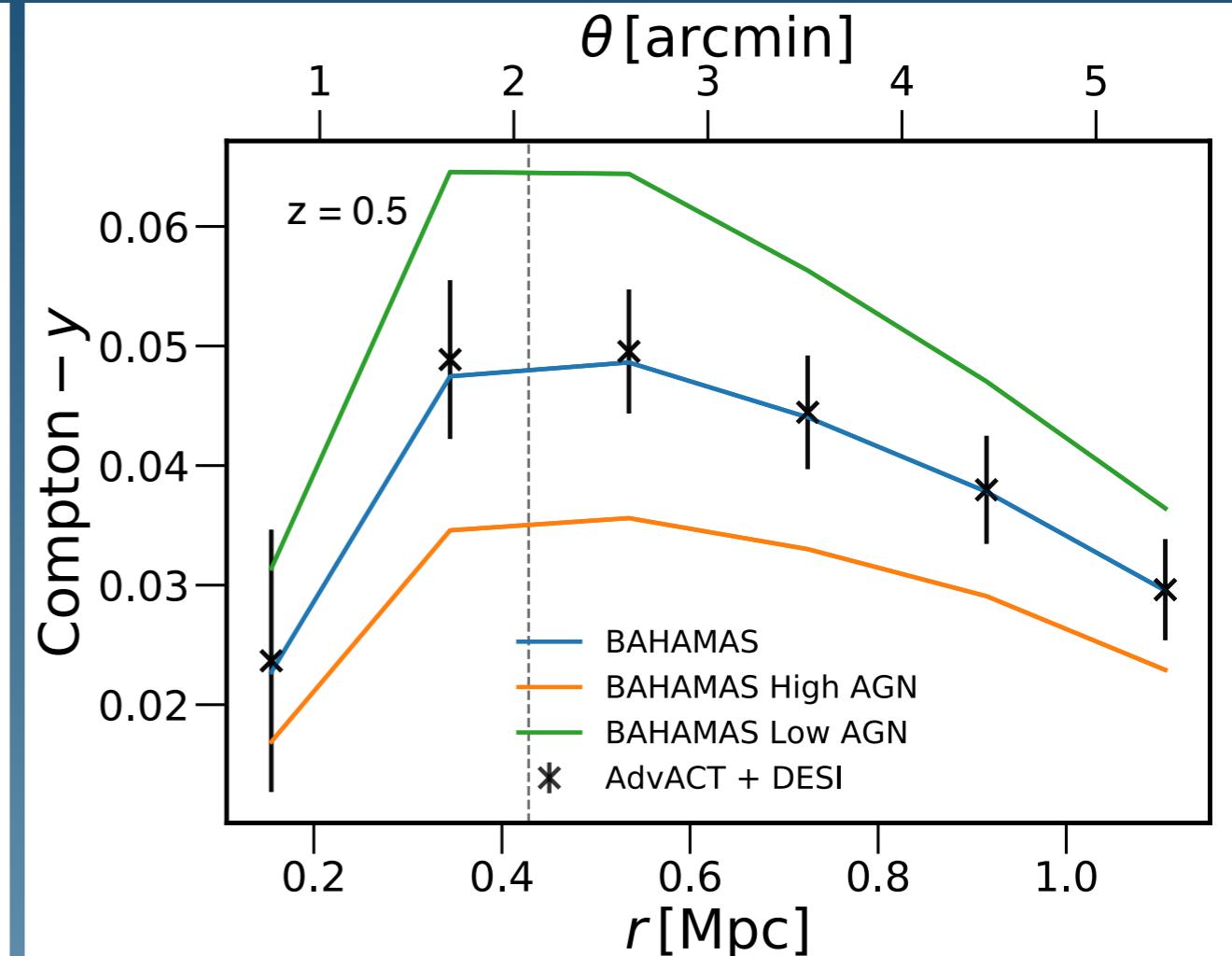
The improvement seen here is coming from:
Higher resolution, lower noise, and a larger sample

Combining tSZ & kSZ Measurements Forecasts

Density

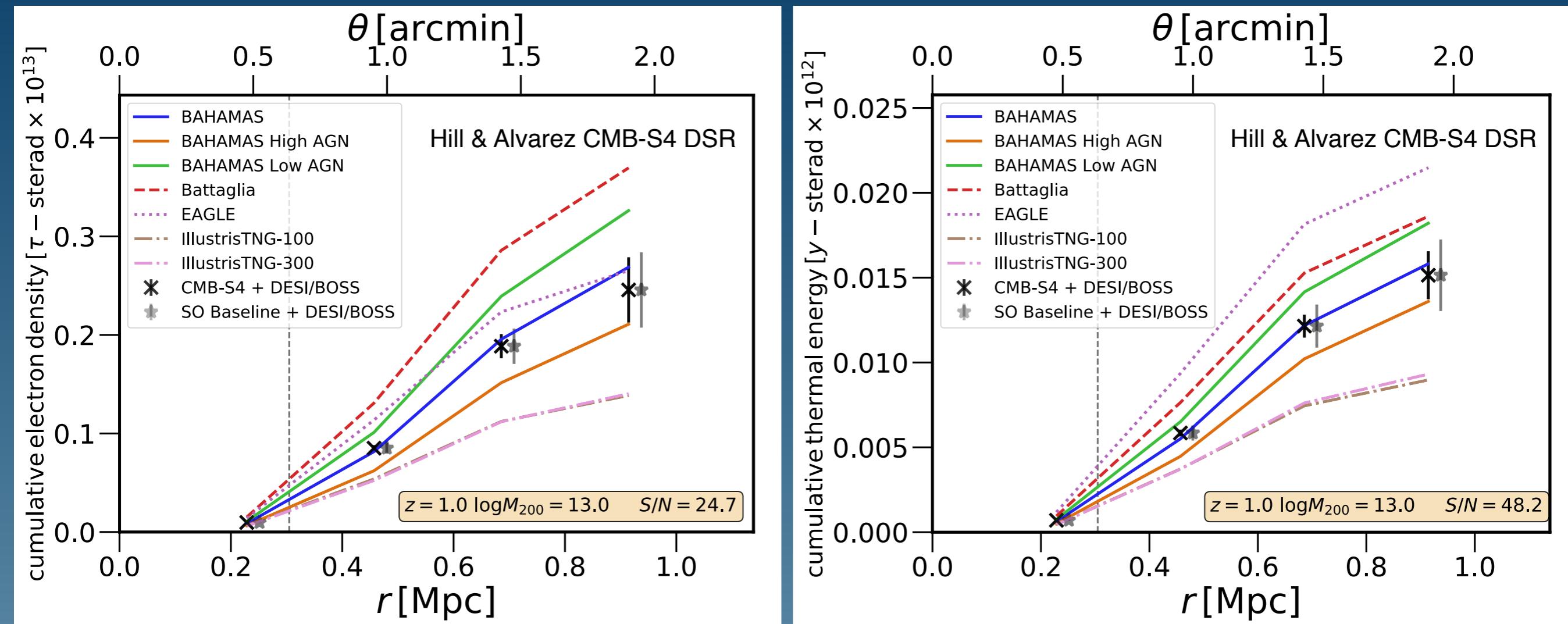


Pressure



Example of simulations that bracket the parameter space allowed by X-ray observations of cluster.

Forecasted Constraints and Comparison to Hydro-Sims



CMB-S4 will “rule out” all current galaxy formation models

Summary

Soon, measure the ionized gas profiles in galaxies with $M > 10^{12} M_{\odot}$, out to high- z (depends on spectroscopic survey)

Use these measurements to constrain baryonic effects on the lensing spectra and matter power spectrum

Effects are not small, they are roughly 10s of percent

Already a possible solution to the small-scale lensing problem pointed out in Leauthaud et al.

Learn about the physical processes in galaxy formation. Constrain feedback and sub-grid models in cosmological simulations. Current constraints are minimal.

Thank you