

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

Nick Battaglia
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with
Stefania Amodeo (Cornell)
Mathew Madhavacheril (Princeton)
Simone Ferraro (LBL)
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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

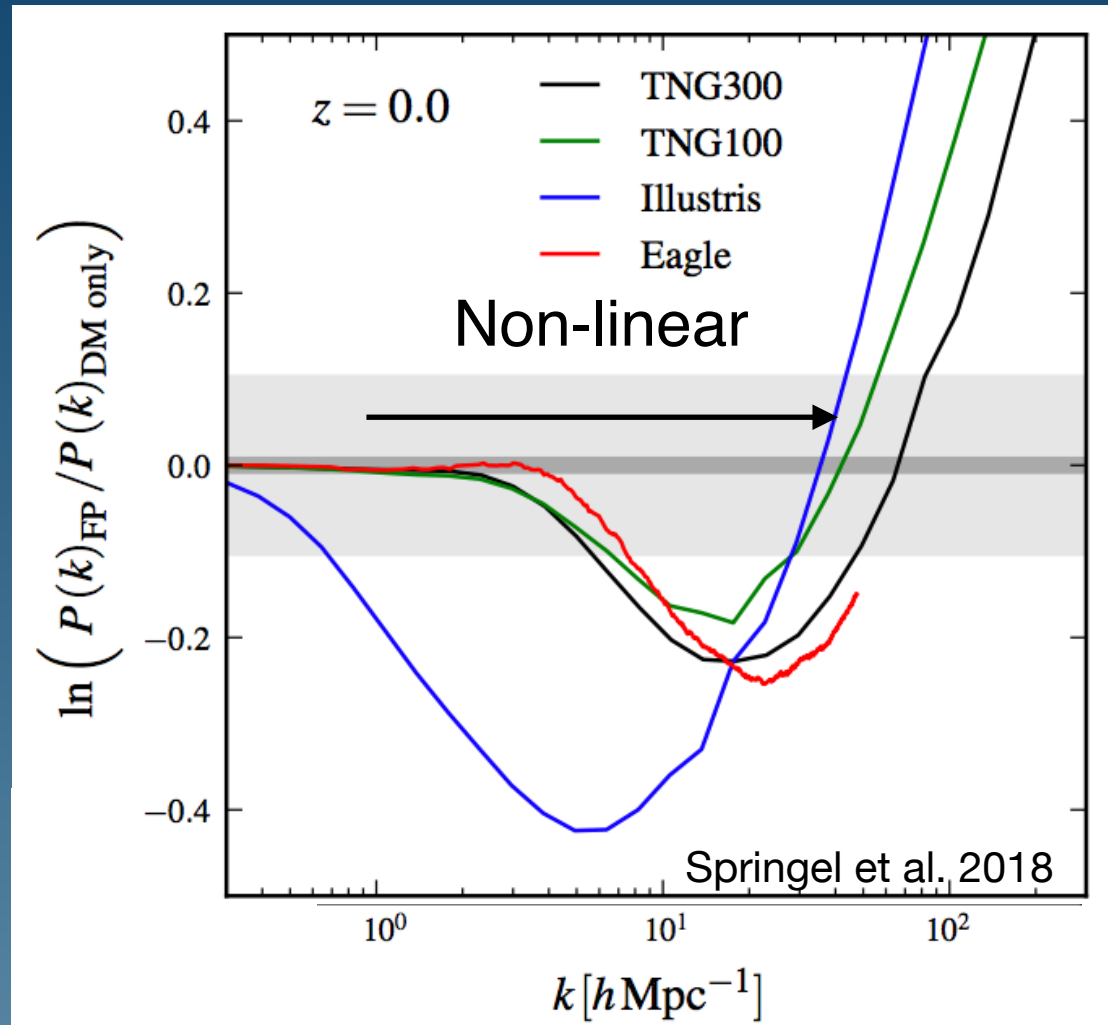
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BCCP Jan 15 2018

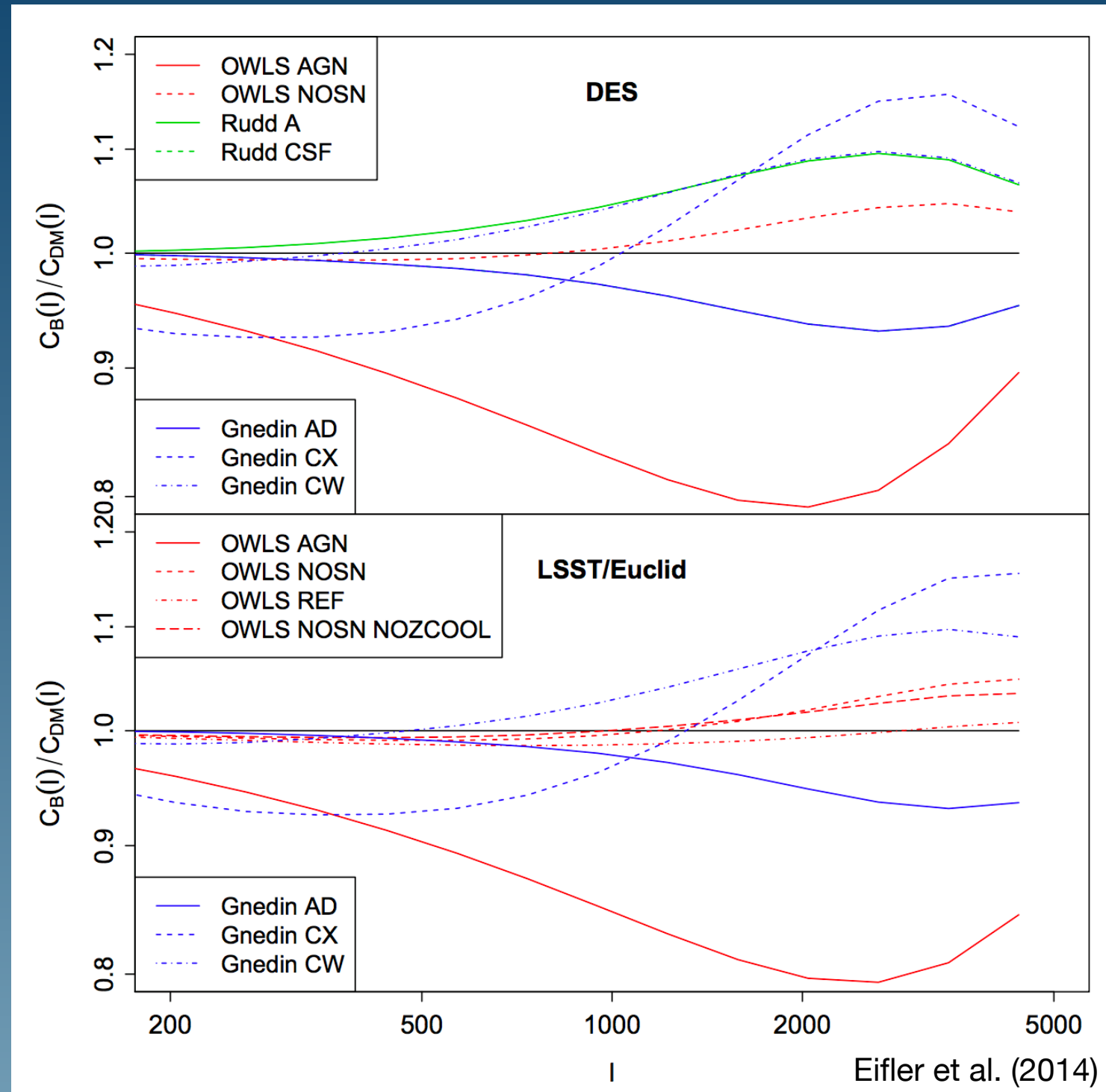
Baryonic Effects

Matter Power Spectrum



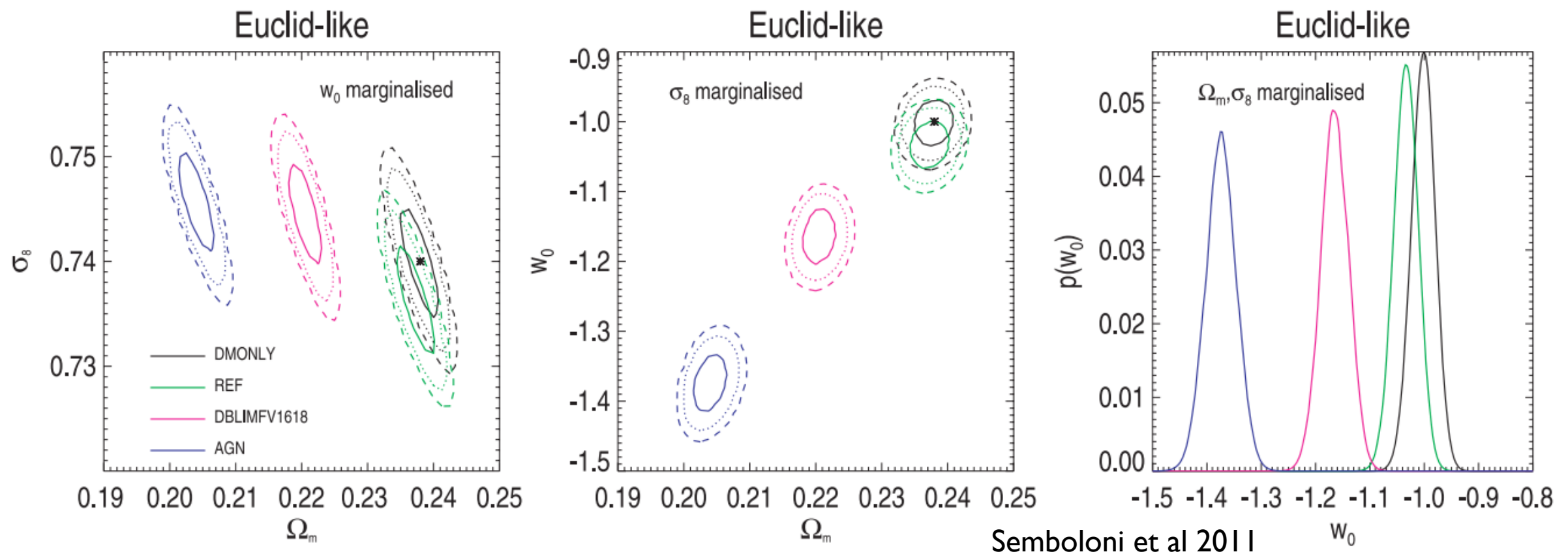
Or provides unique constraints on the main baryonic processes that govern growth of structure on these scales

Cosmic Shear



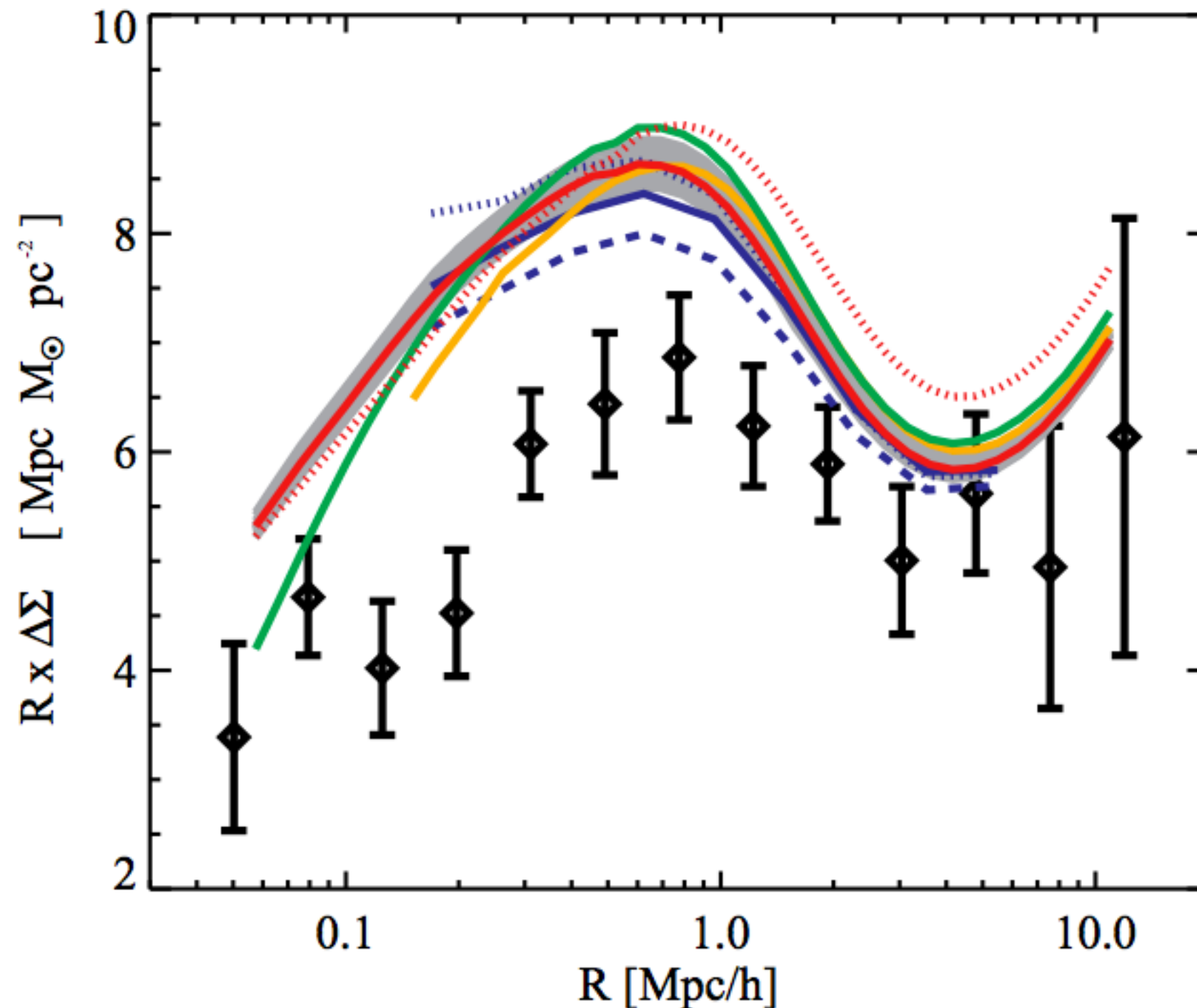
Cosmological & Astrophysical Implications

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



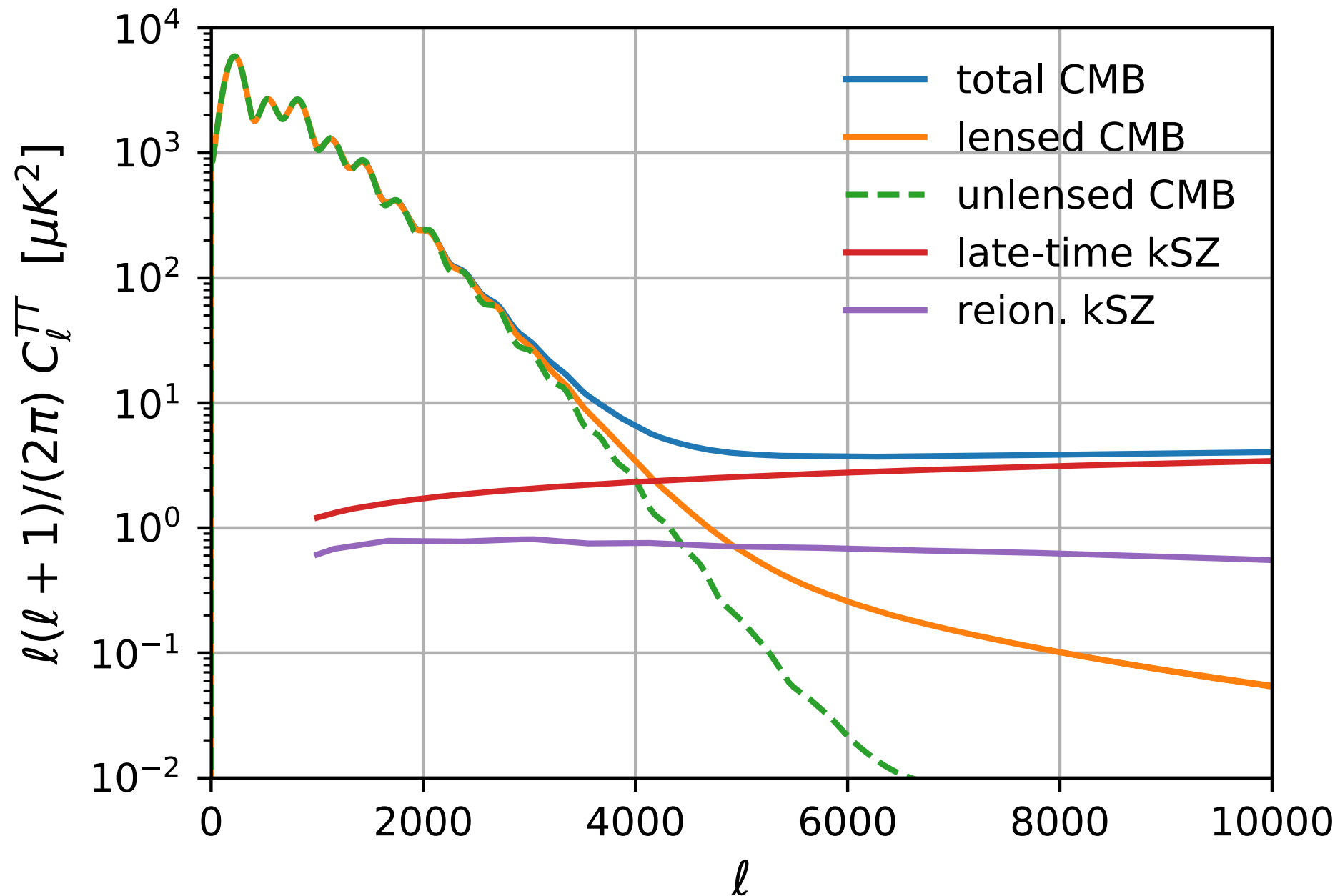
Lensing is Low: Cosmology, Galaxy Formation, or New Physics?

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)



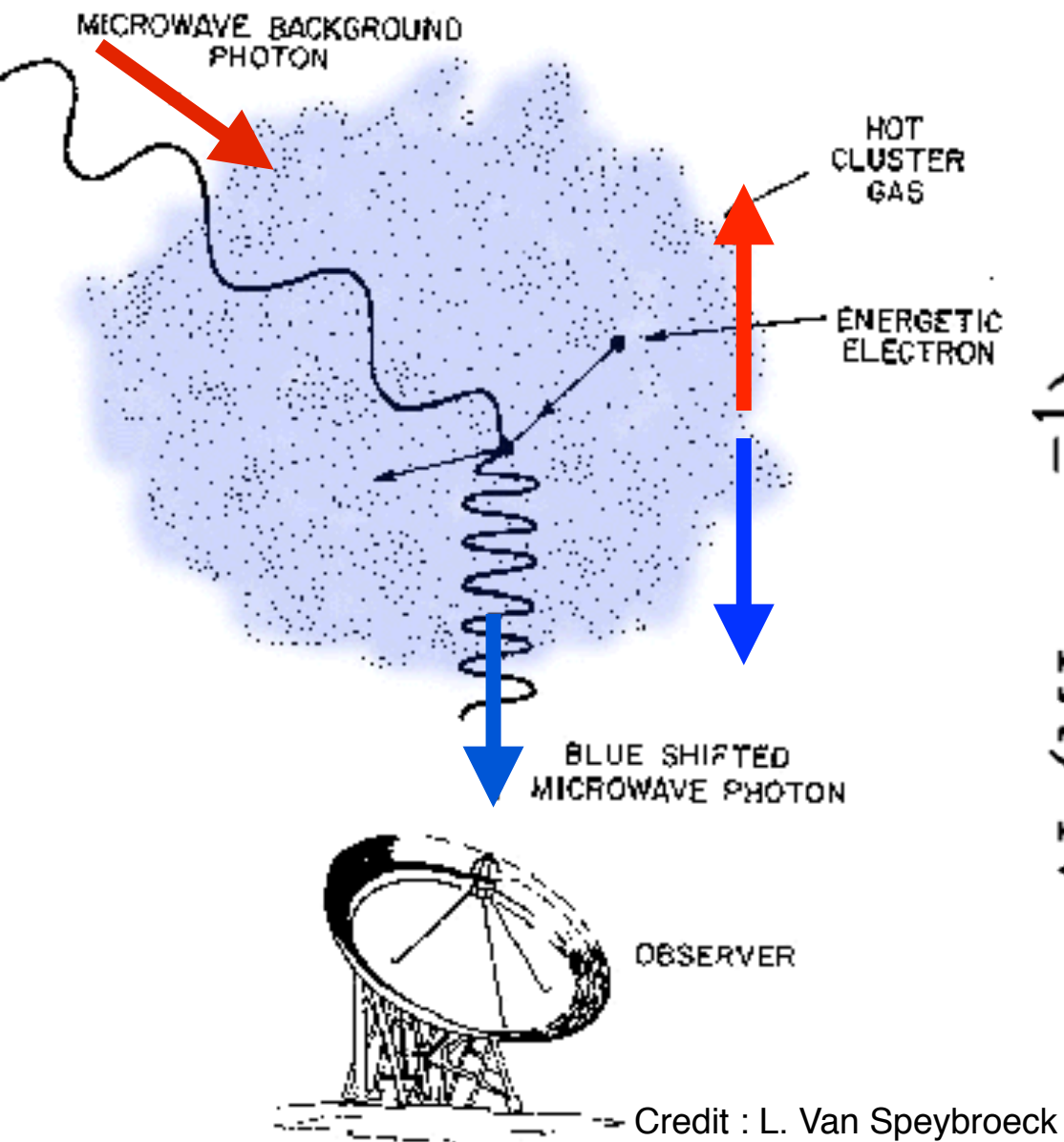
Smith et al. 2018

Ignoring effects from mis-centering & 2-halo contributions
Foregrounds are cleaned, but not correlated dusty sources

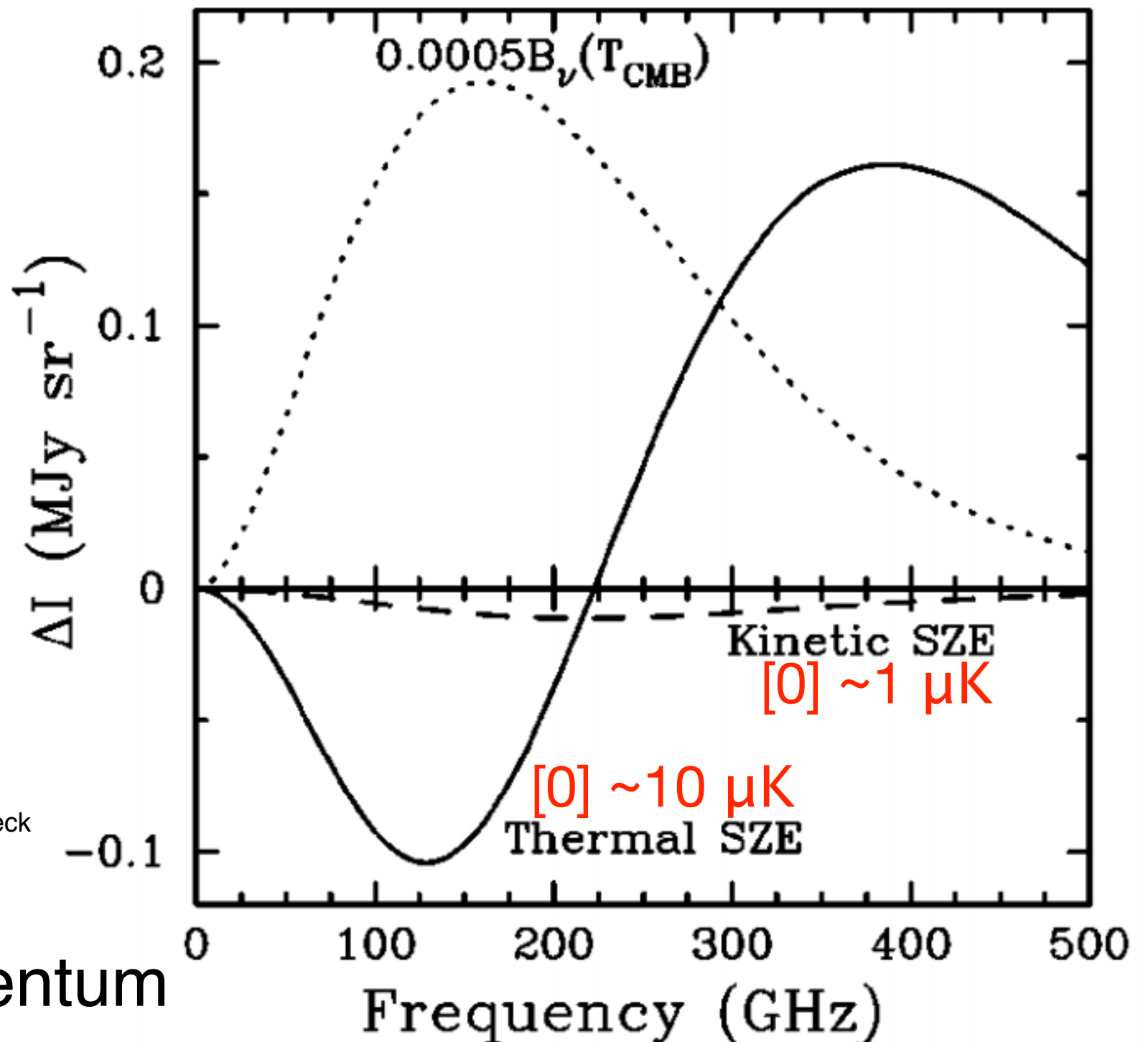
kSZ is more than just a CMB lensing foreground/bias

Sunyaev-Zeldovich Effects

Inverse Compton & Doppler boosting of CMB photons



LOS pressure & momentum



What is measured?

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

optical depth
(profile)

'bulk' radial velocity

θ aperture

r (lag)

\mathbf{x}

\mathbf{y}

Origin

Slide credit S. Ferraro

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

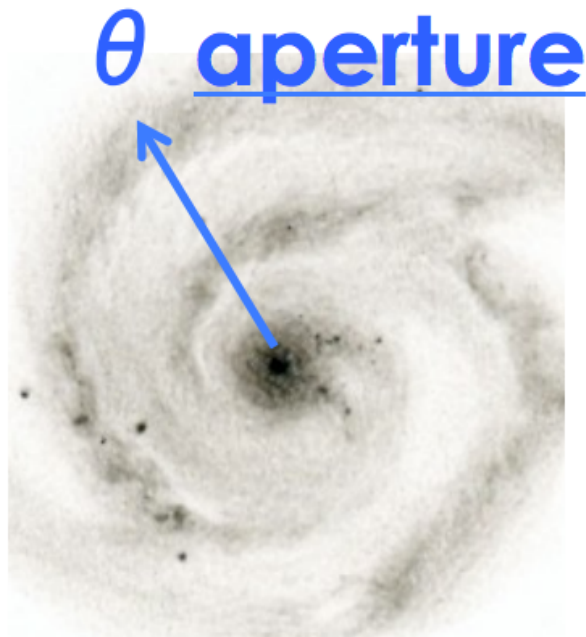
TWO different measurements!

Measuring the density profile

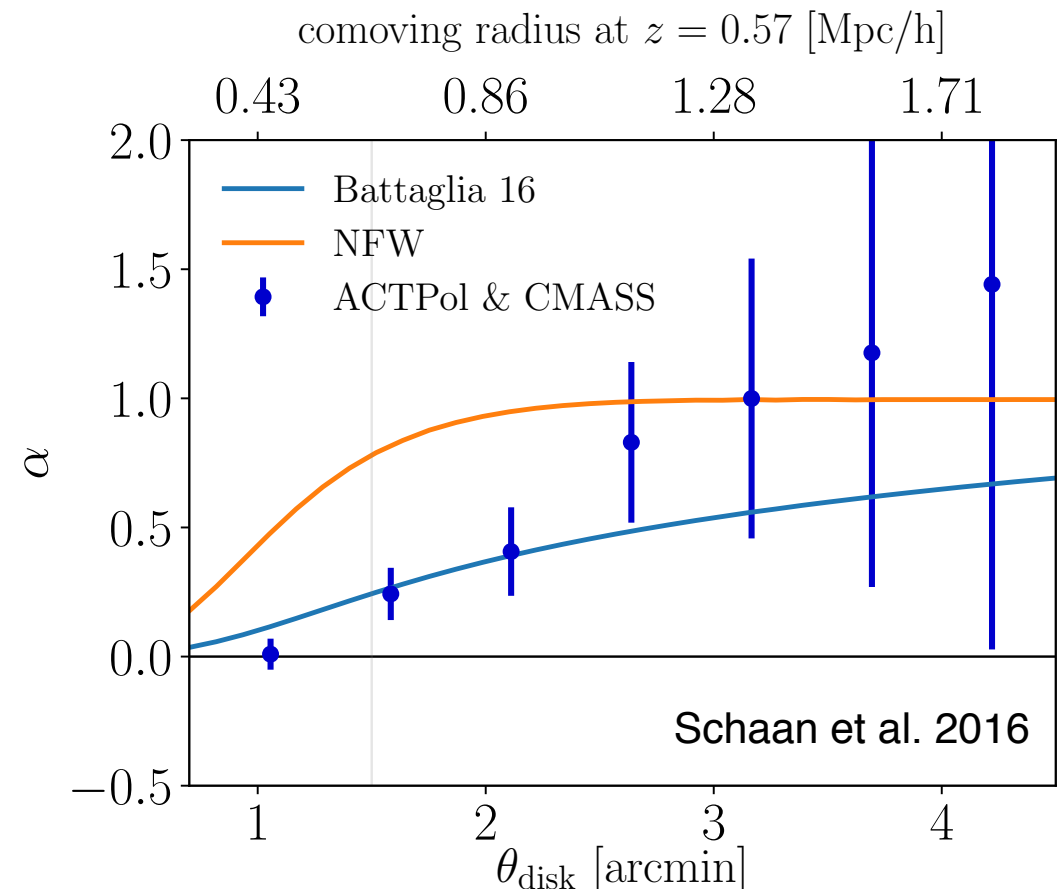
$$\left\langle \frac{\Delta T}{T}(\mathbf{x}) v_r^{\text{rec}}(\mathbf{x}) \right\rangle(\theta) = \sigma_{v_r}^2 \tau(\theta)$$

zero lag
 aperture
 cosmology (independent of θ)
 optical depth (profile)

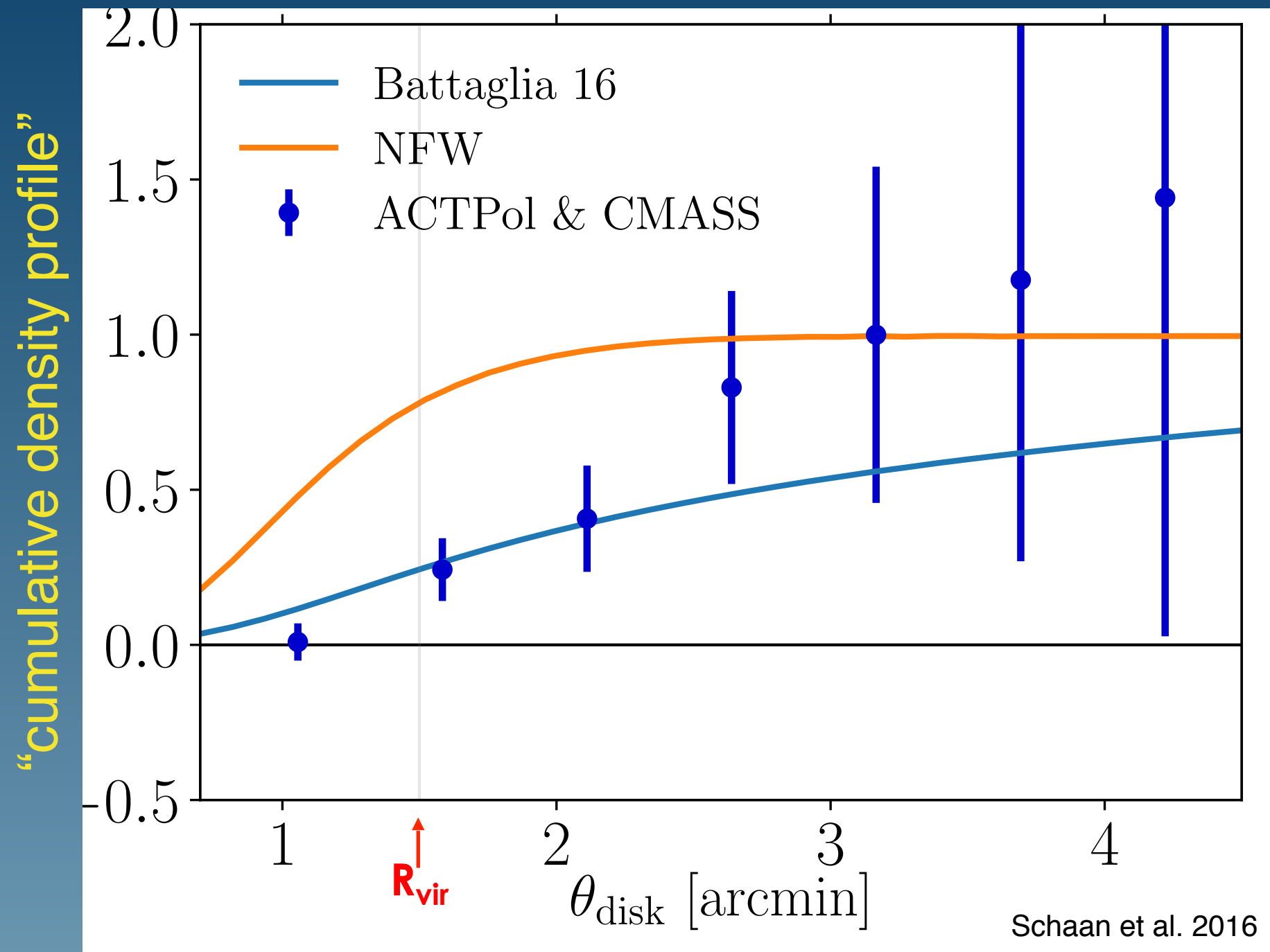
Ho et al. 2009
Li et al. 2014



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



Initial kSZ results



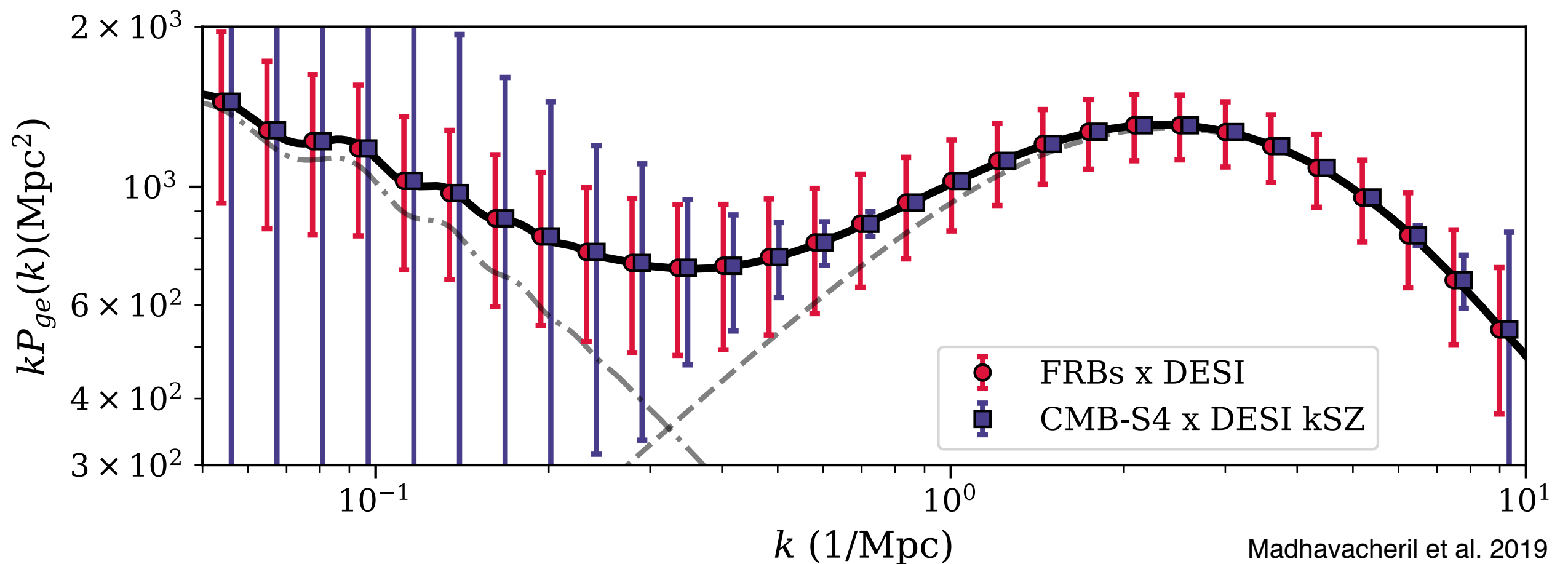
BOSS CMASS galaxies + ACTPol CMB data
 $z \sim 0.6$, $M \sim 2 \times 10^{13} M_{\text{sun}}$

Forecasted Constraints on the Density Profile

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

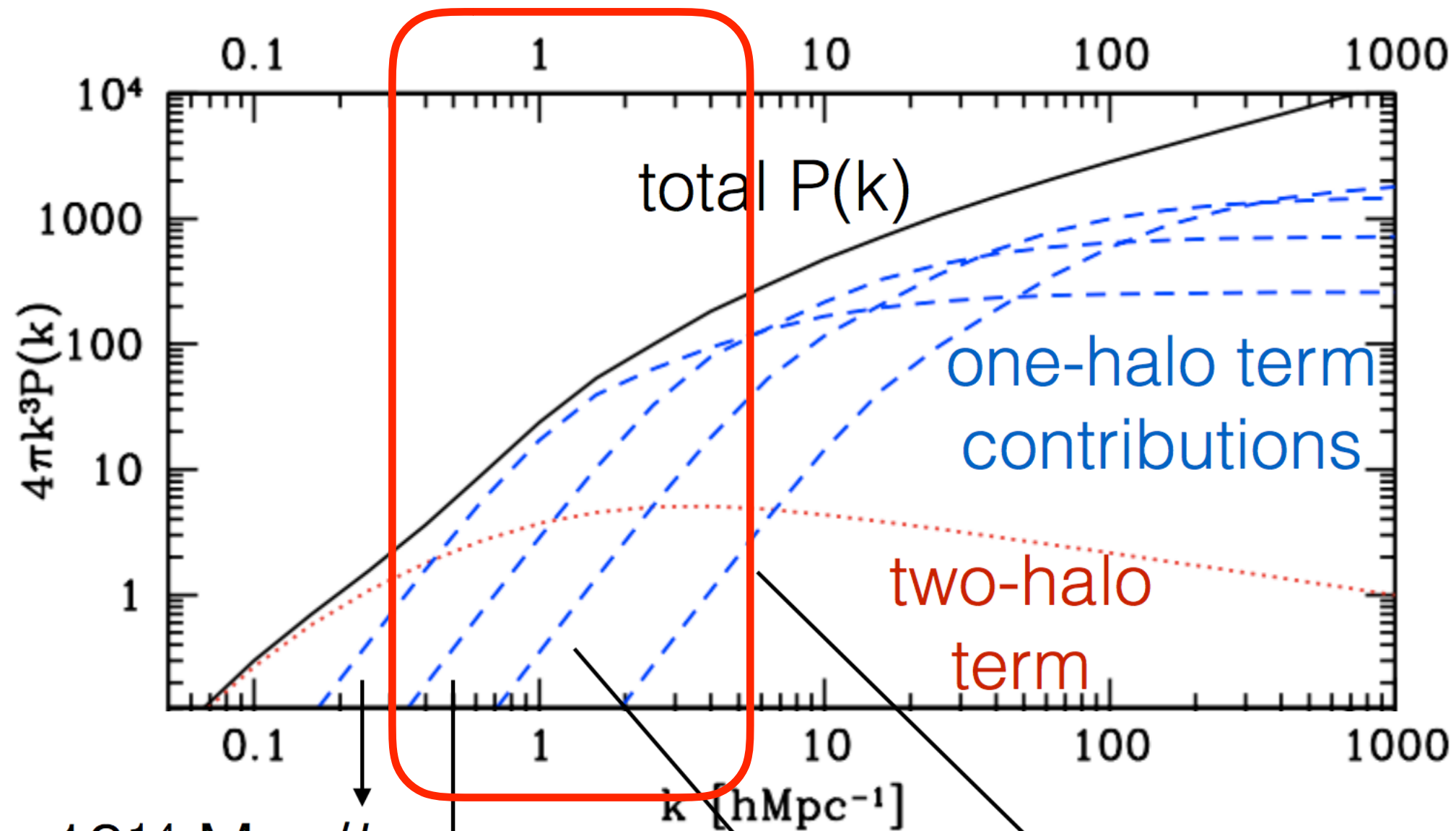
Forecasted kSZ detections are on the order of 100σ across multiple redshift ranges and mass ranges in the next 5-10 years.

Use kSZ as a tool to calibrate baryonic effects



Which halos do we need to measure?

dominated by group-scale halos over relevant wavenumbers



$M > 10^{14} M_{\text{sun}}/h$

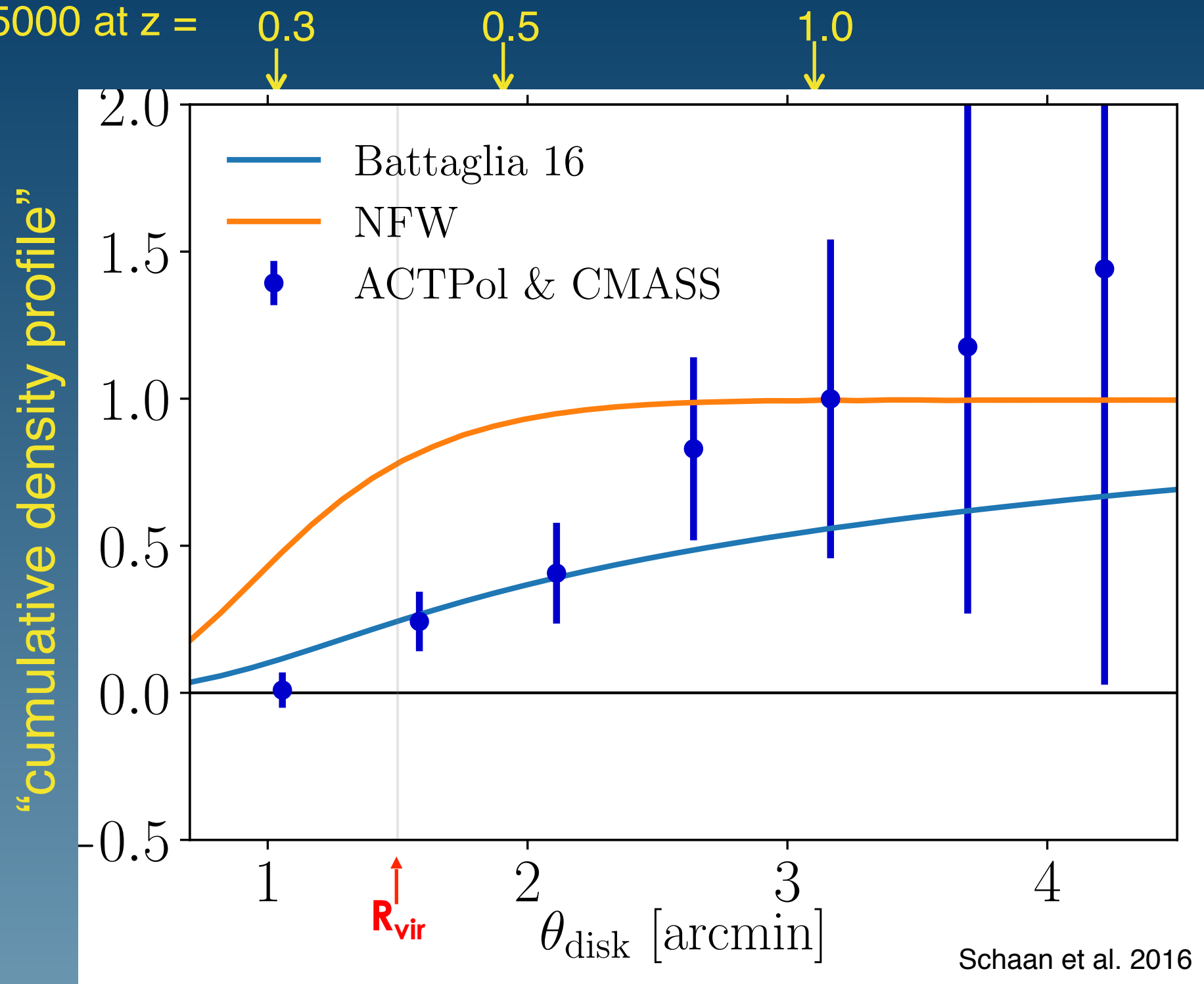
$10^{14} M_{\text{sun}}/h > M > 10^{13} M_{\text{sun}}/h$

$10^{13} M_{\text{sun}}/h > M > 10^{12} M_{\text{sun}}/h$

$10^{12} M_{\text{sun}}/h > M > 10^{11} M_{\text{sun}}/h$

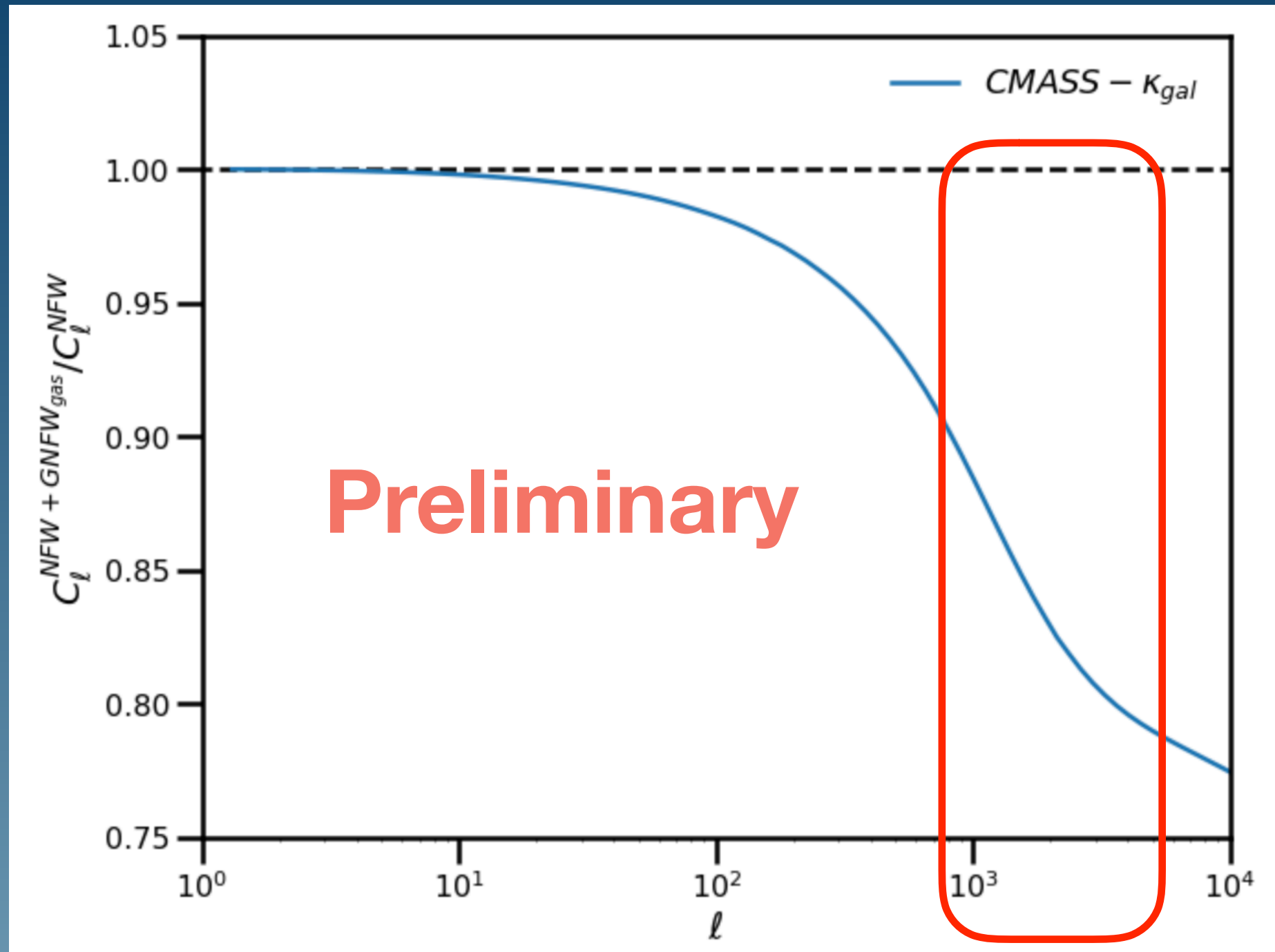
Cosmological Implications

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

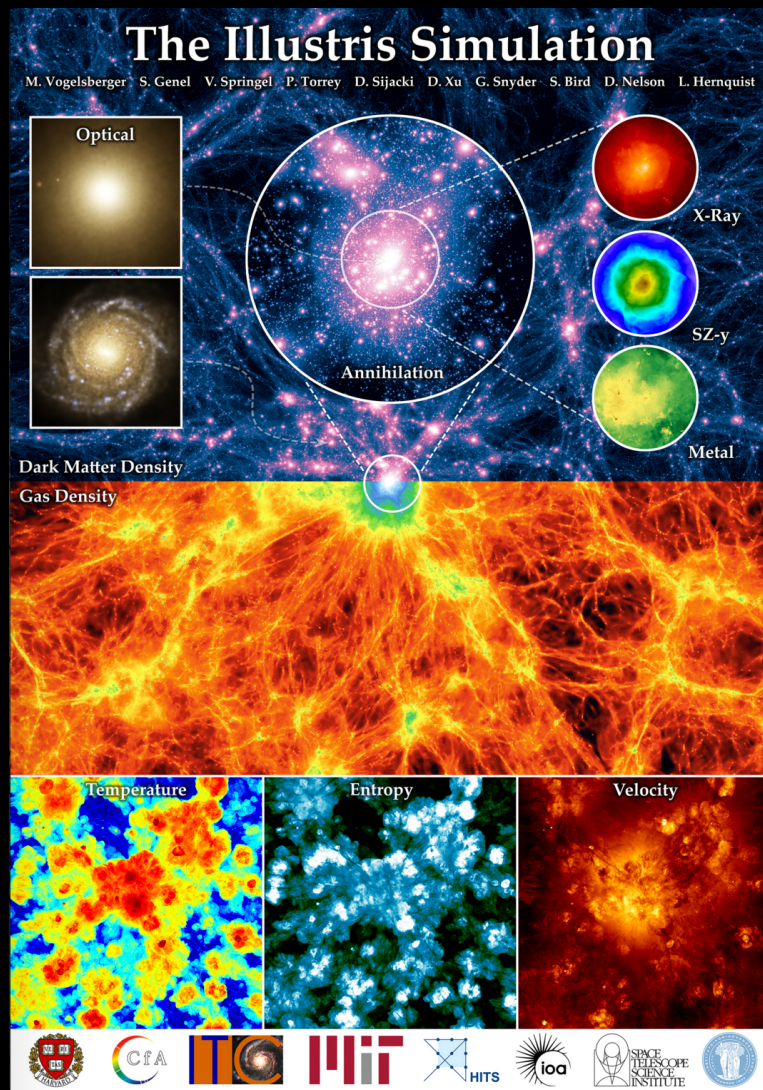


BOSS CMASS galaxies + ACTPol CMB data
 $z \sim 0.6$, $M \sim 2 \times 10^{13} M_{\text{sun}}$

0th order modeling of the Baryons in gg-lensing



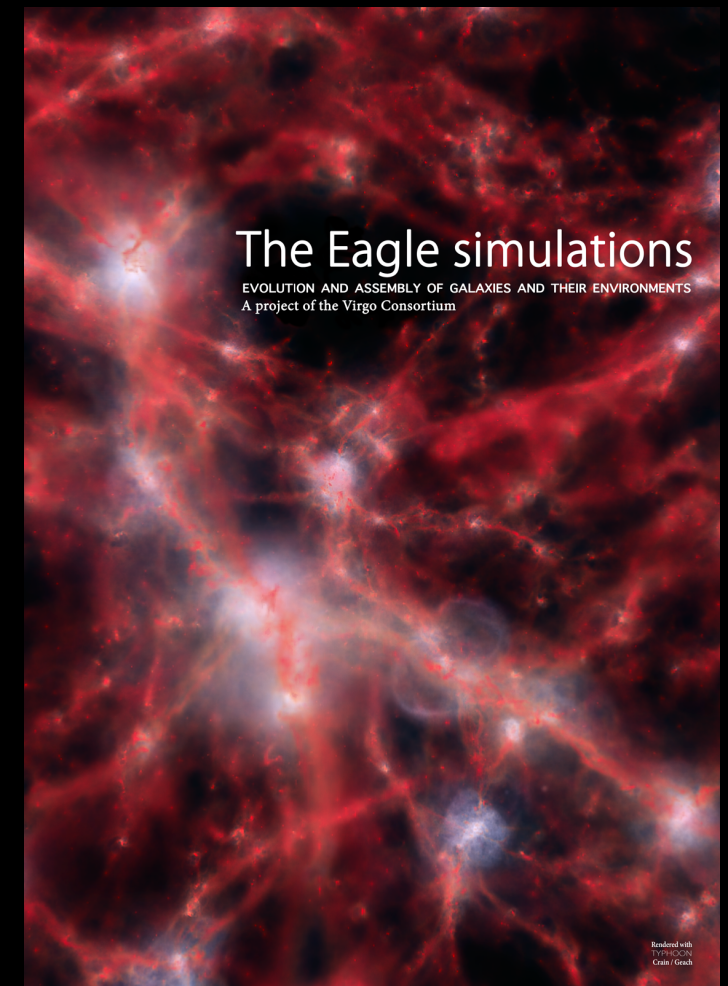
No baryon-DM back-reaction yet



Cosmological Simulations



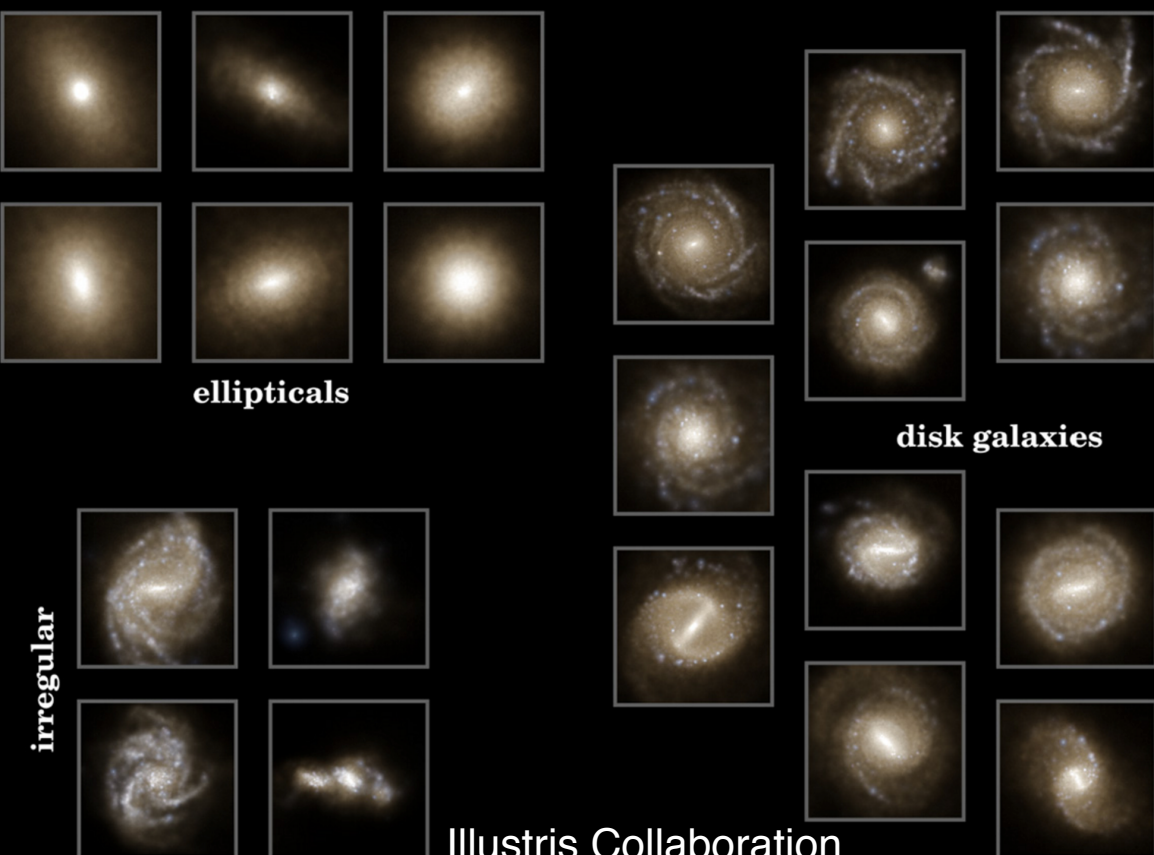
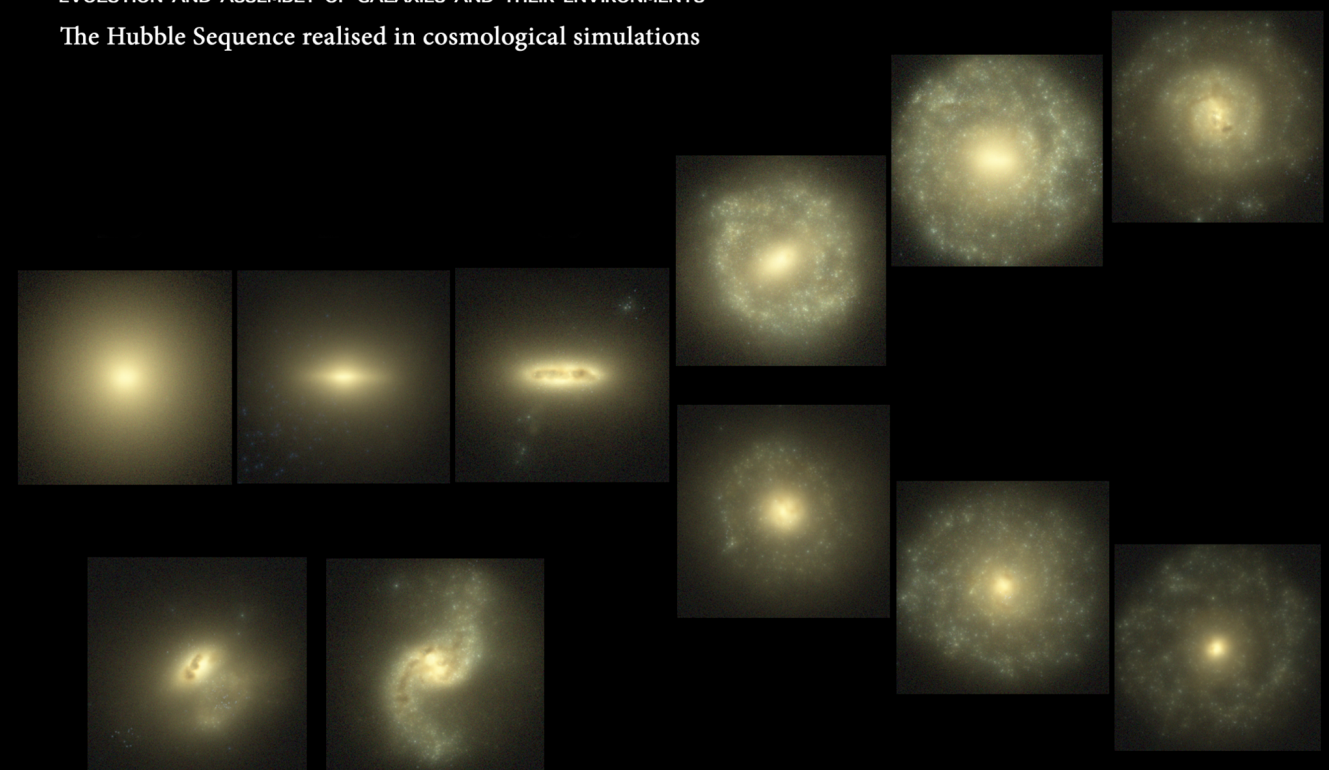
The Horizon Simulation



The Eagle Simulations

EVOLUTION AND ASSEMBLY OF GALAXIES AND THEIR ENVIRONMENTS

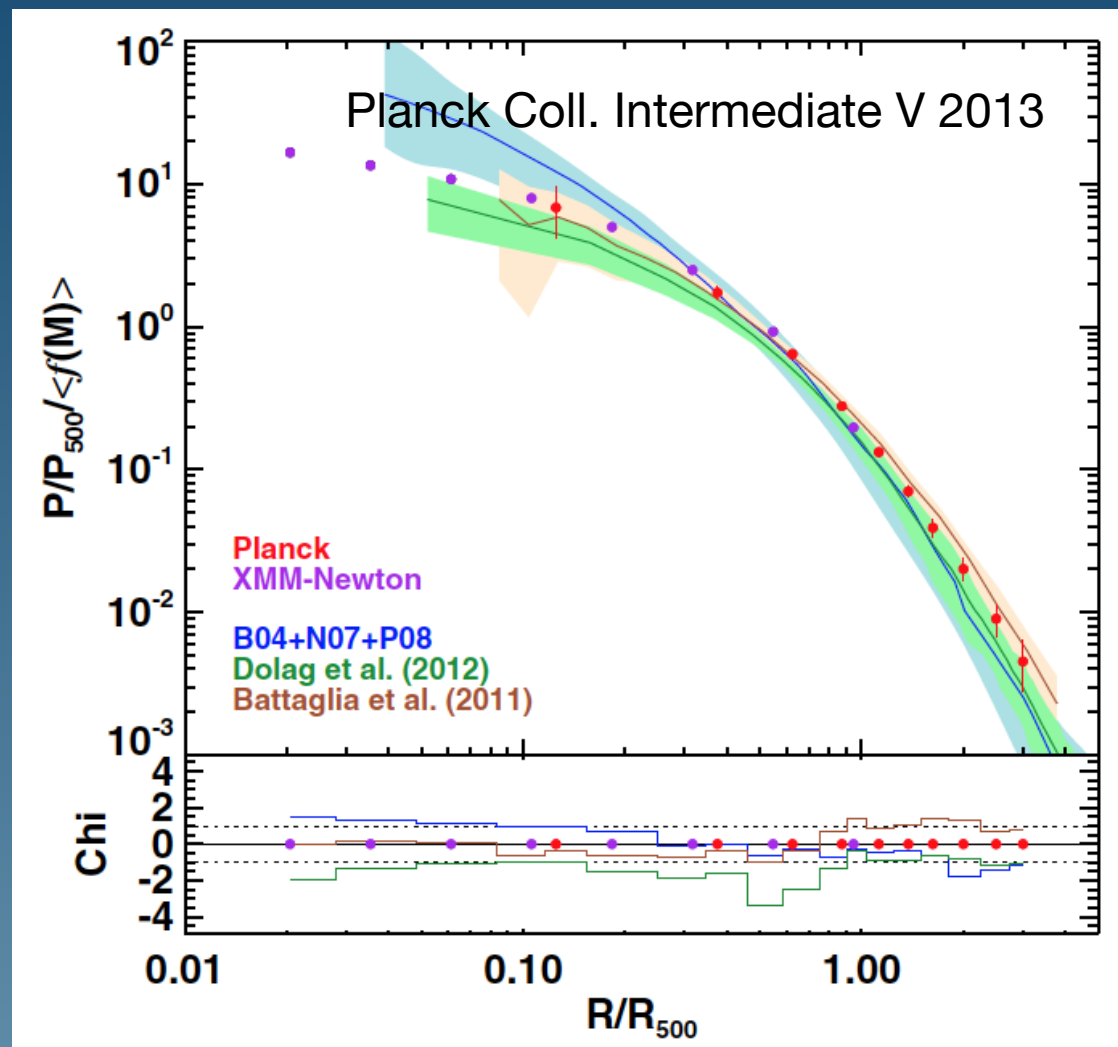
The Hubble Sequence realised in cosmological simulations



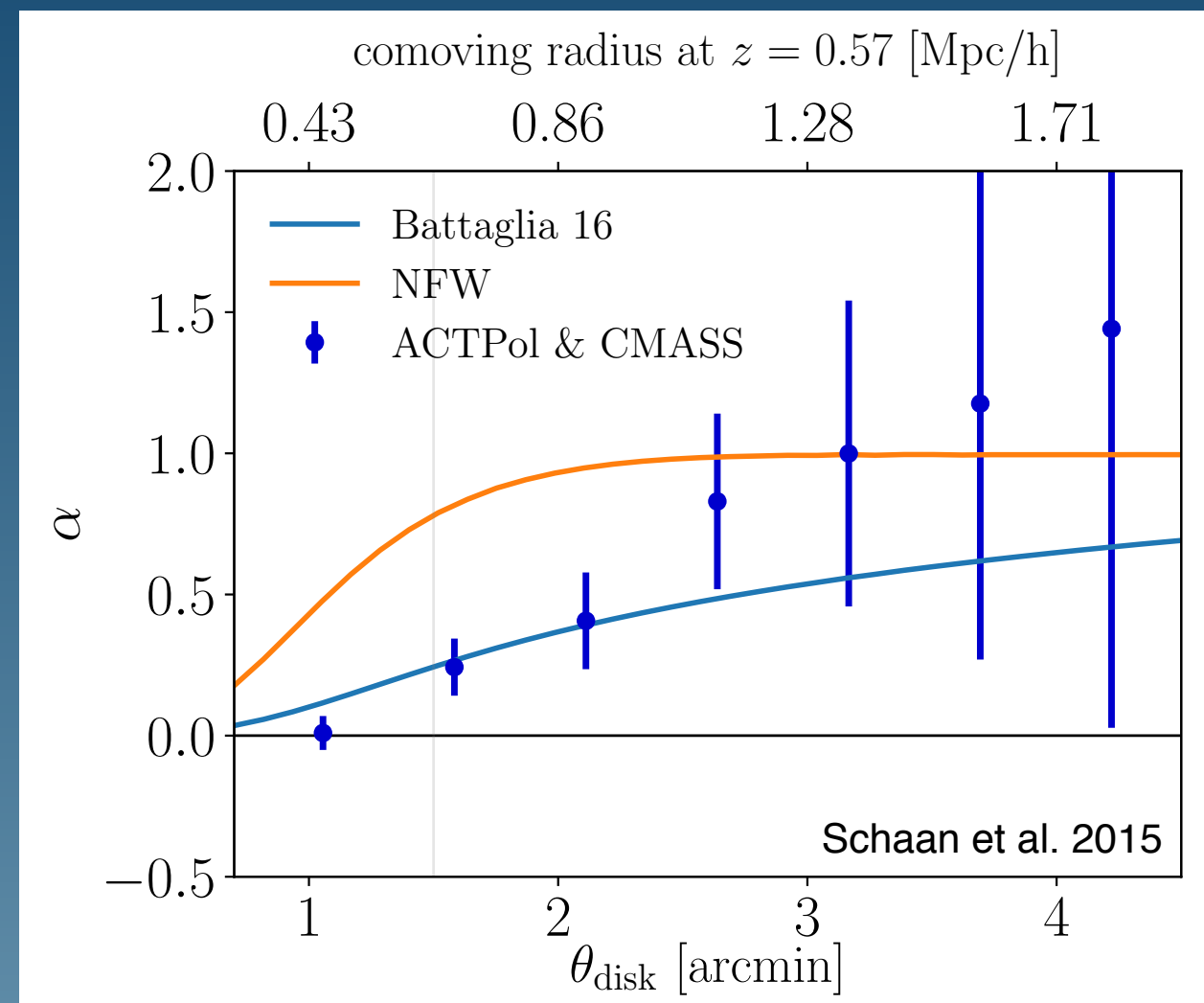
Combining tSZ & kSZ measurements

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

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



+

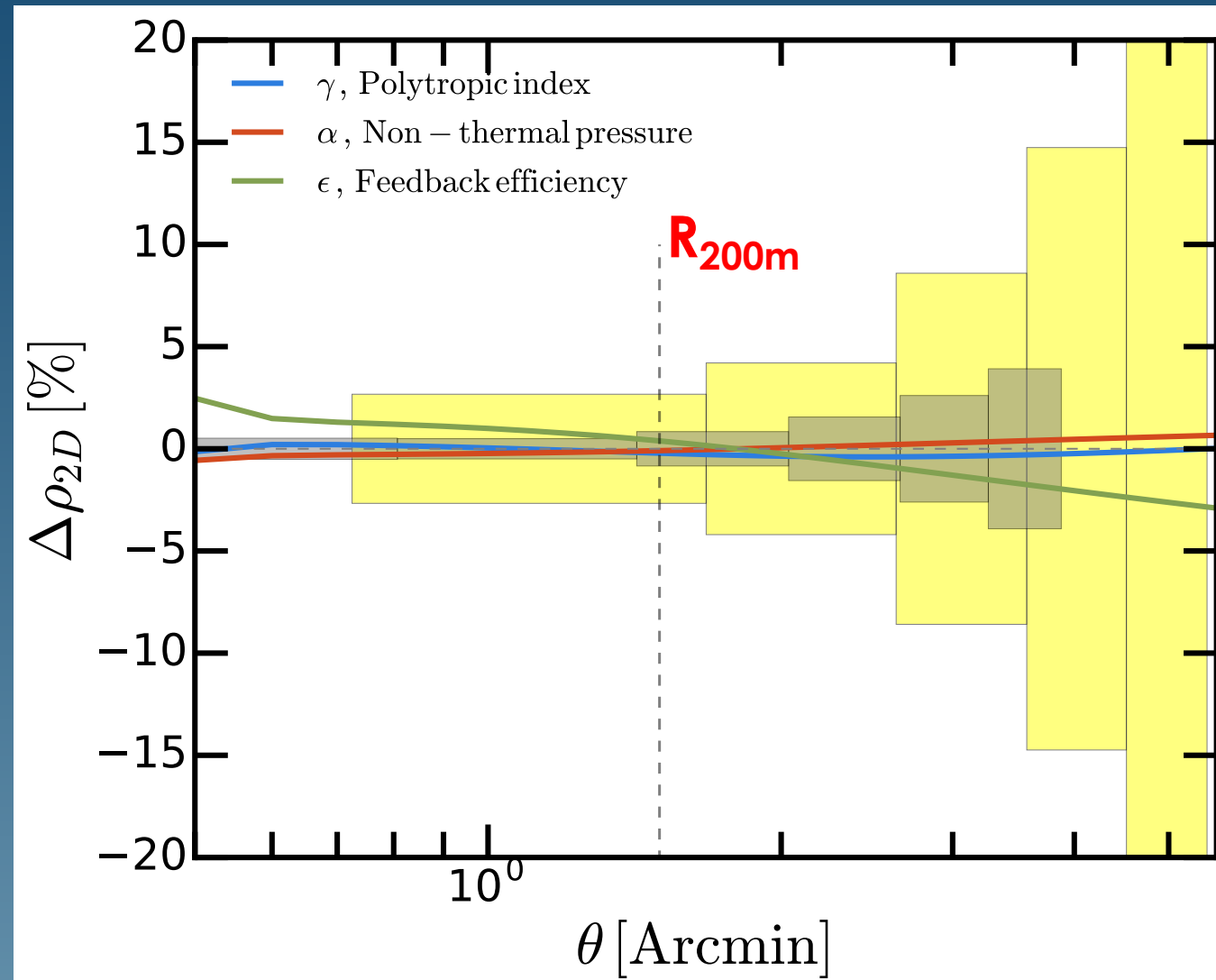


$$\underbrace{\frac{1}{3}\Phi_{\text{gas}}}_{\text{from kSZ \& mass profile}} + \underbrace{\int P_{\text{th}} dV}_{\text{from tSZ}} + \underbrace{\int P_{\text{Nth}} dV}_{\rightarrow \text{inferred}} \propto P_{\text{Surface}}$$

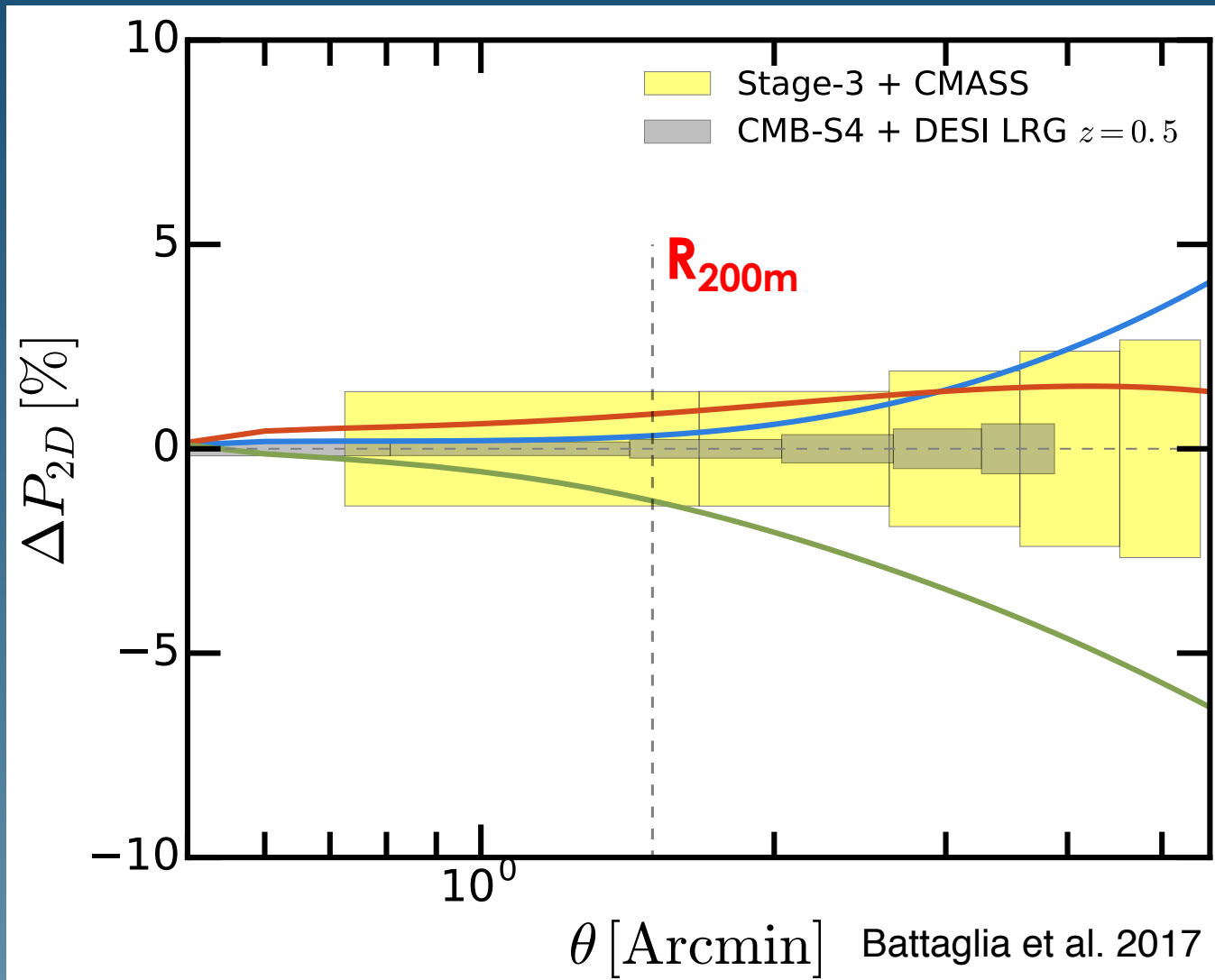
Constraint non-thermal pressure in halos

Combining tSZ & kSZ measurements forecasts

Density



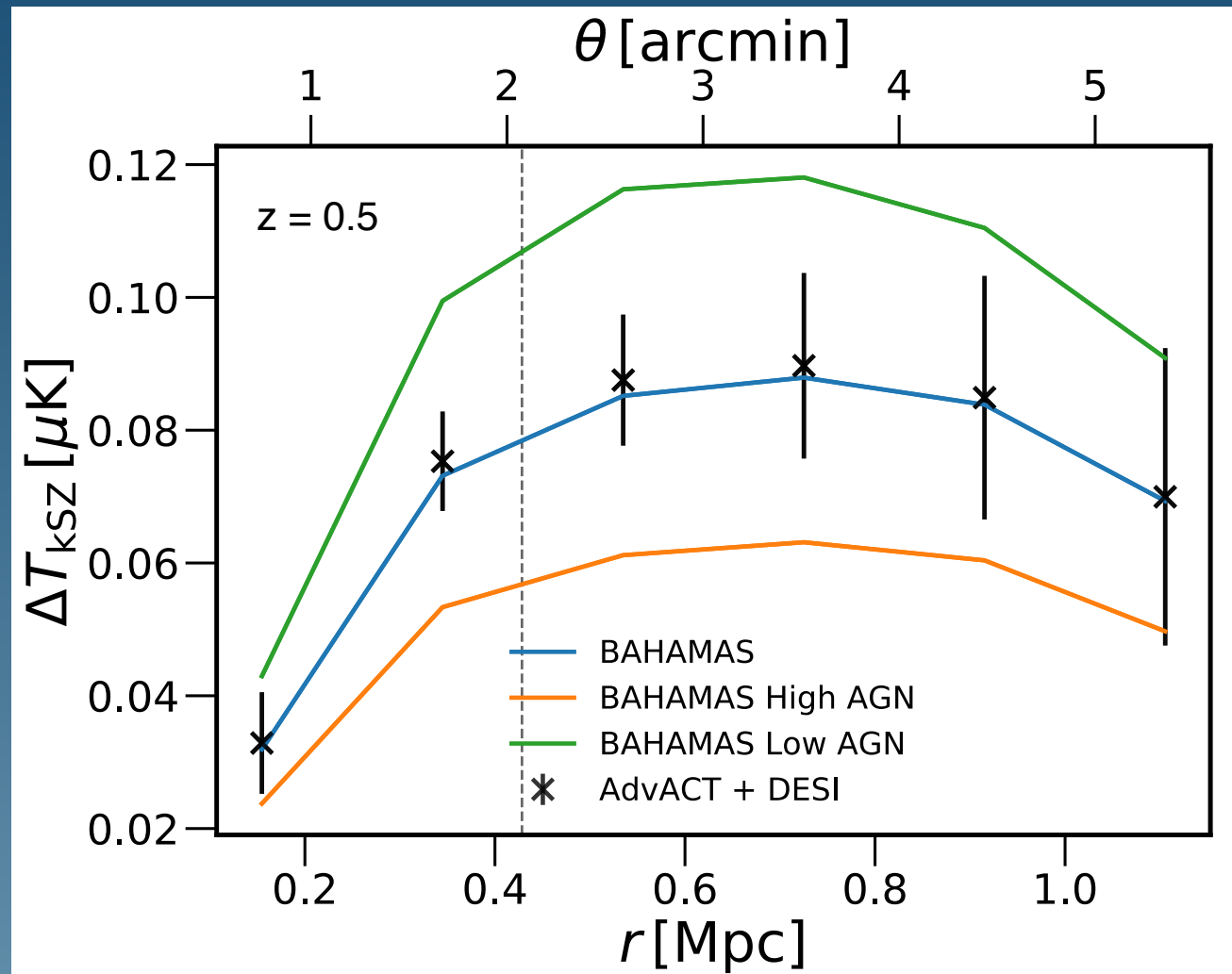
Pressure



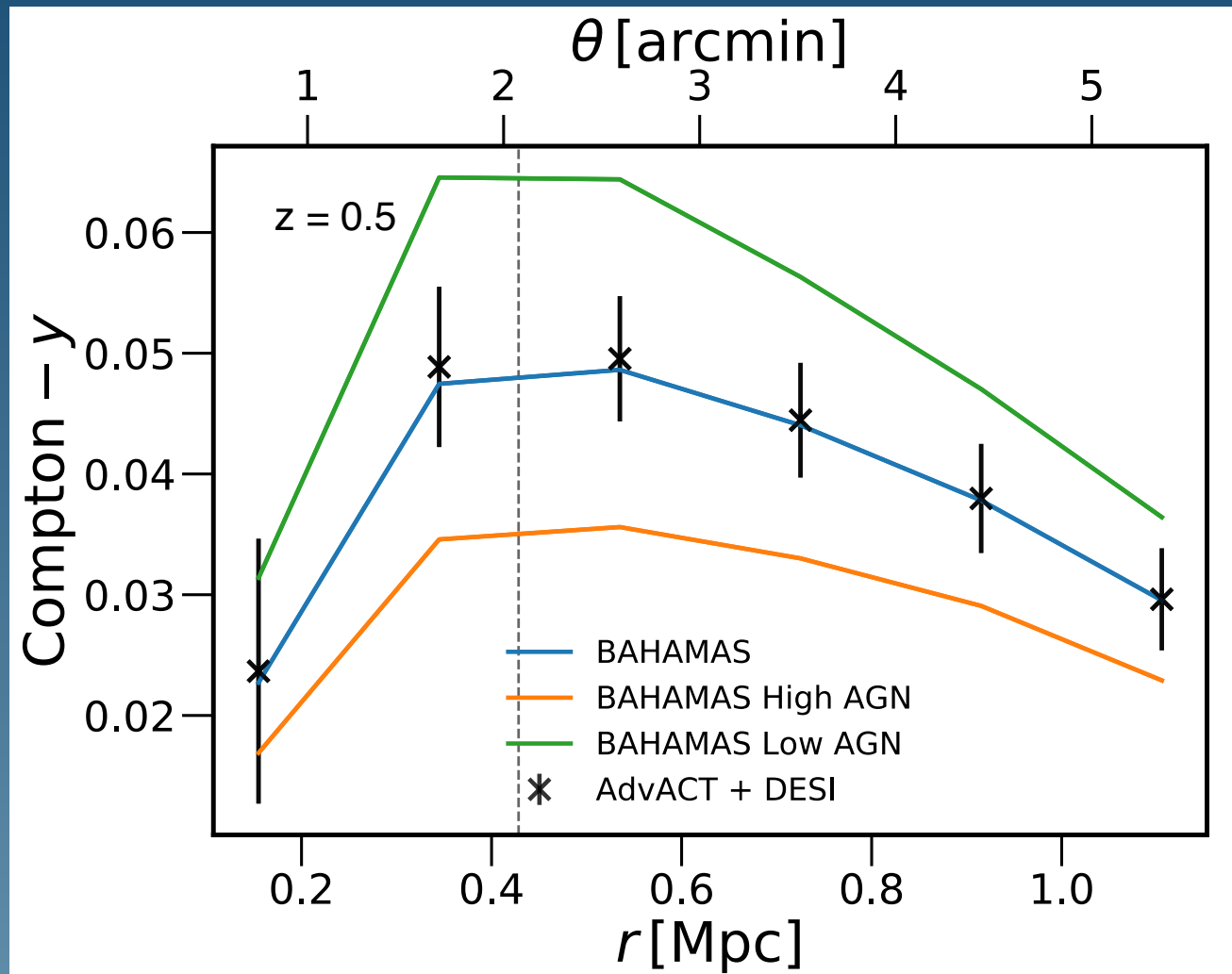
The improvement seen here is coming from:
Higher resolution, lower noise, and a larger sample

Combining tSZ & kSZ Measurements Forecasts

Density

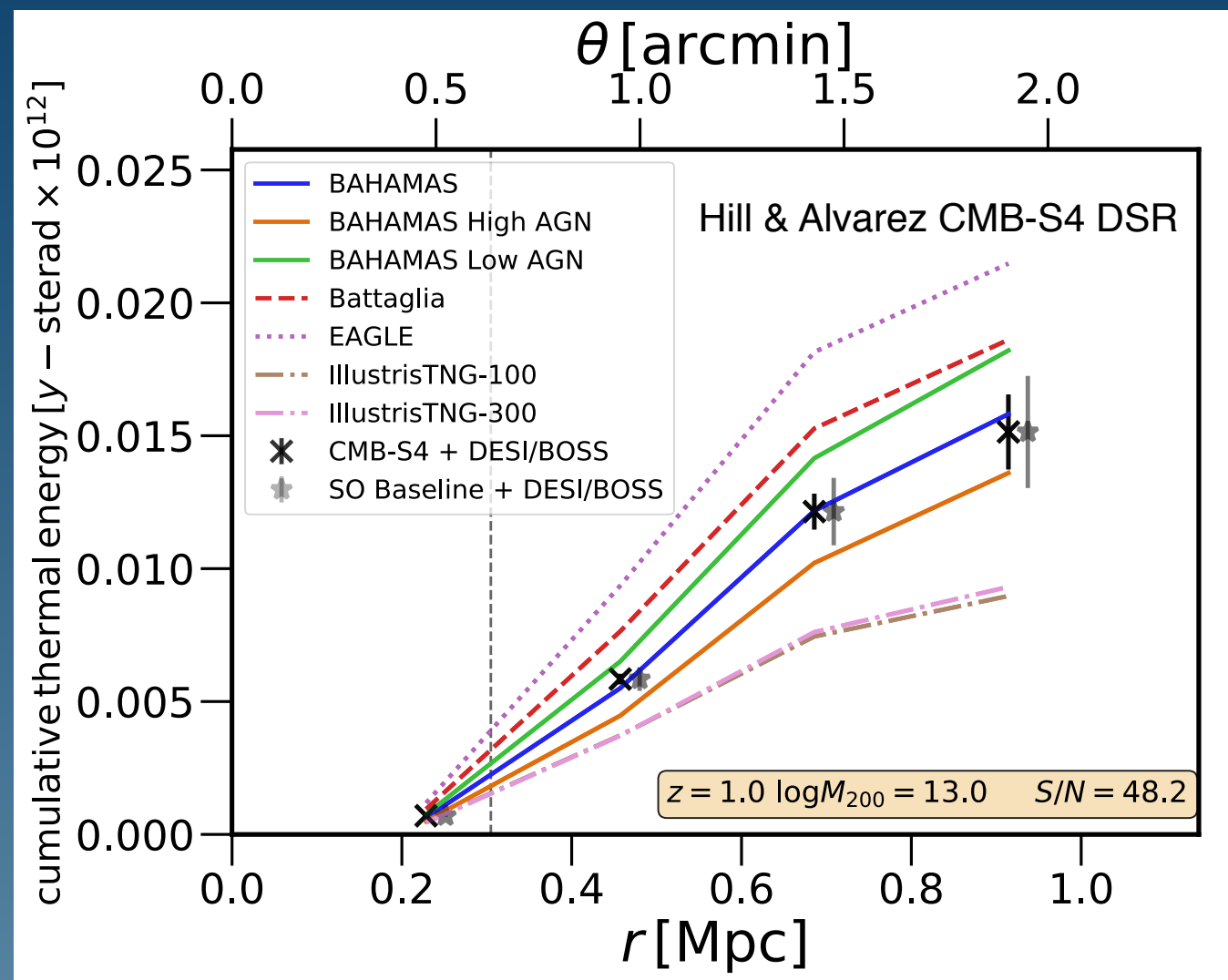
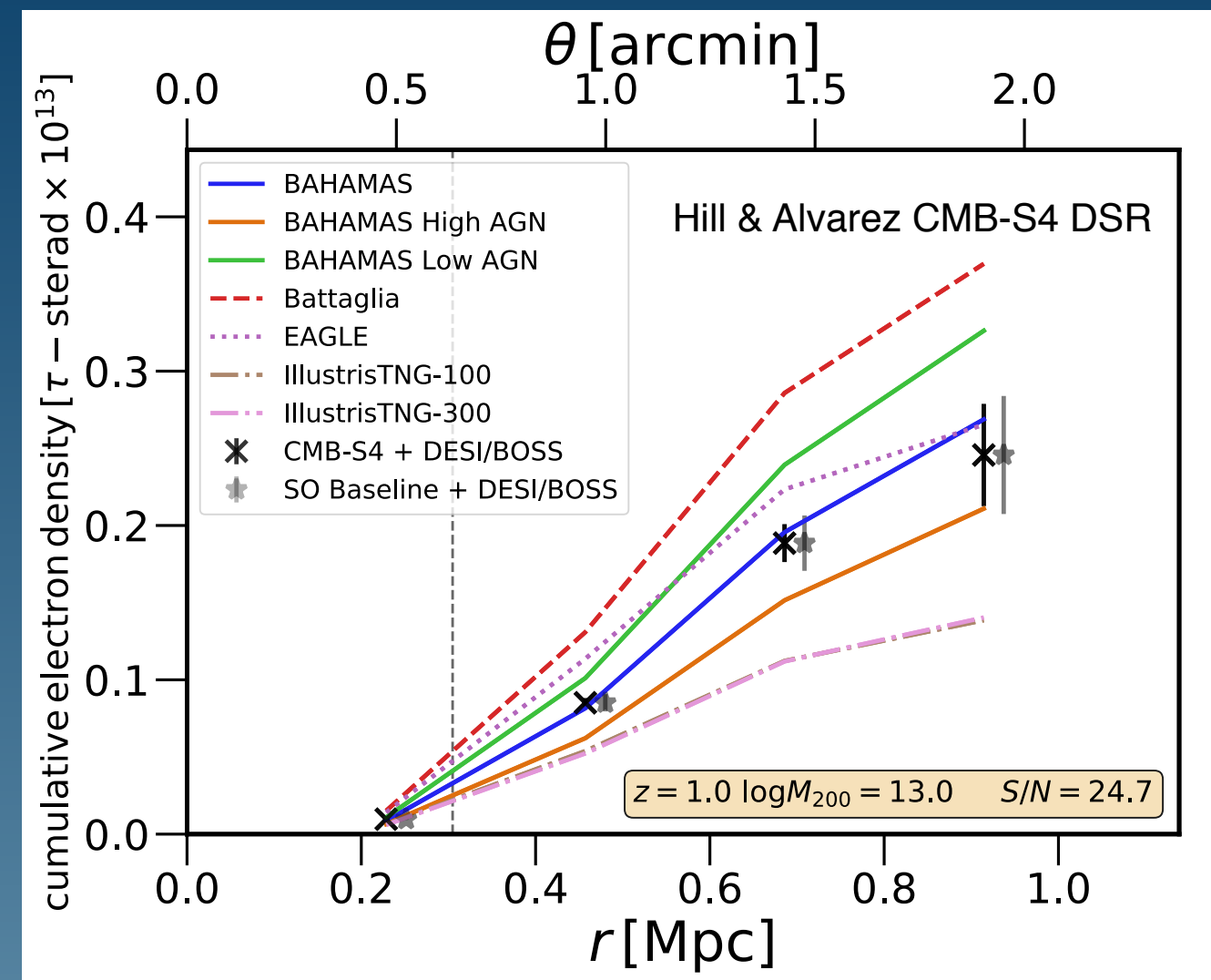


Pressure



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