

Baryonic processes from thermal and kinetic SZ

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Motivation

Study the baryonic physics in galaxies and clusters to understand:

1. Late-time growth of structures (cosmology in the non-linear regime)
2. Galaxy evolution and star formation (in)efficiency

Use halo imprints on the CMB

Thermal SZ: Inverse Compton scattering of CMB photons

Kinetic: Doppler boosting of CMB photons

Gas thermodynamics from tSZ & kSZ

Thermal SZ

I.o.s. pressure

$$\frac{\Delta T^{tSZ}(\nu)}{T_{\text{CMB}}} = f(\nu)y$$

$$y = \frac{\sigma_T}{m_e c^2} \int_{los} P_e \, dl$$

Thermal Pressure

Kinetic SZ

I.o.s. momentum

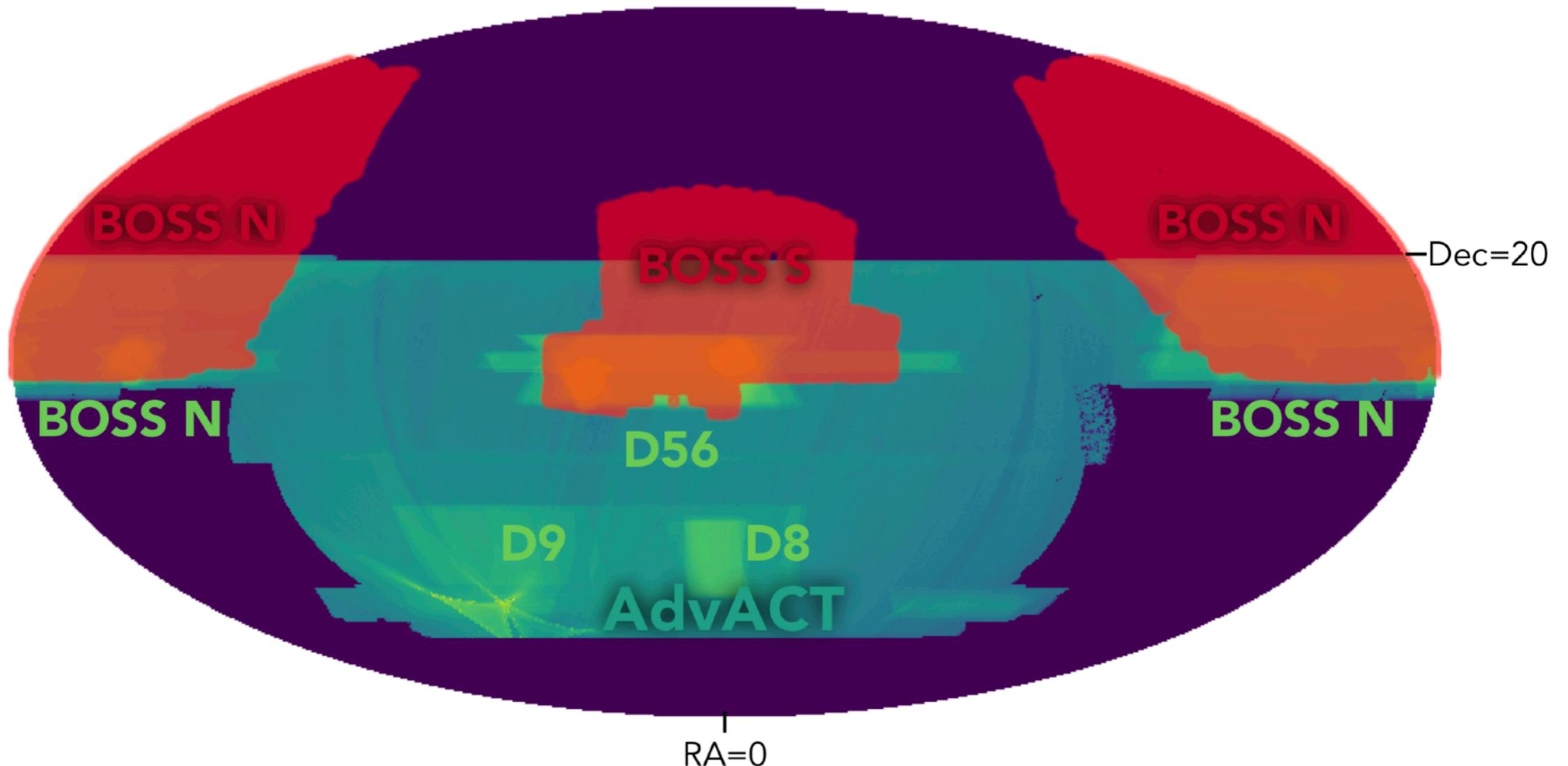
$$\frac{\Delta T^{kSZ}}{T_{\text{CMB}}} = \frac{\sigma_T}{c} \int_{los} e^{-\tau} n_e v_r \, dl$$

$$\tau = \sigma_T \int_{los} n_e \, dl$$

Gas Density

with independent
peculiar velocity estimates

Data: AdvACT + BOSS



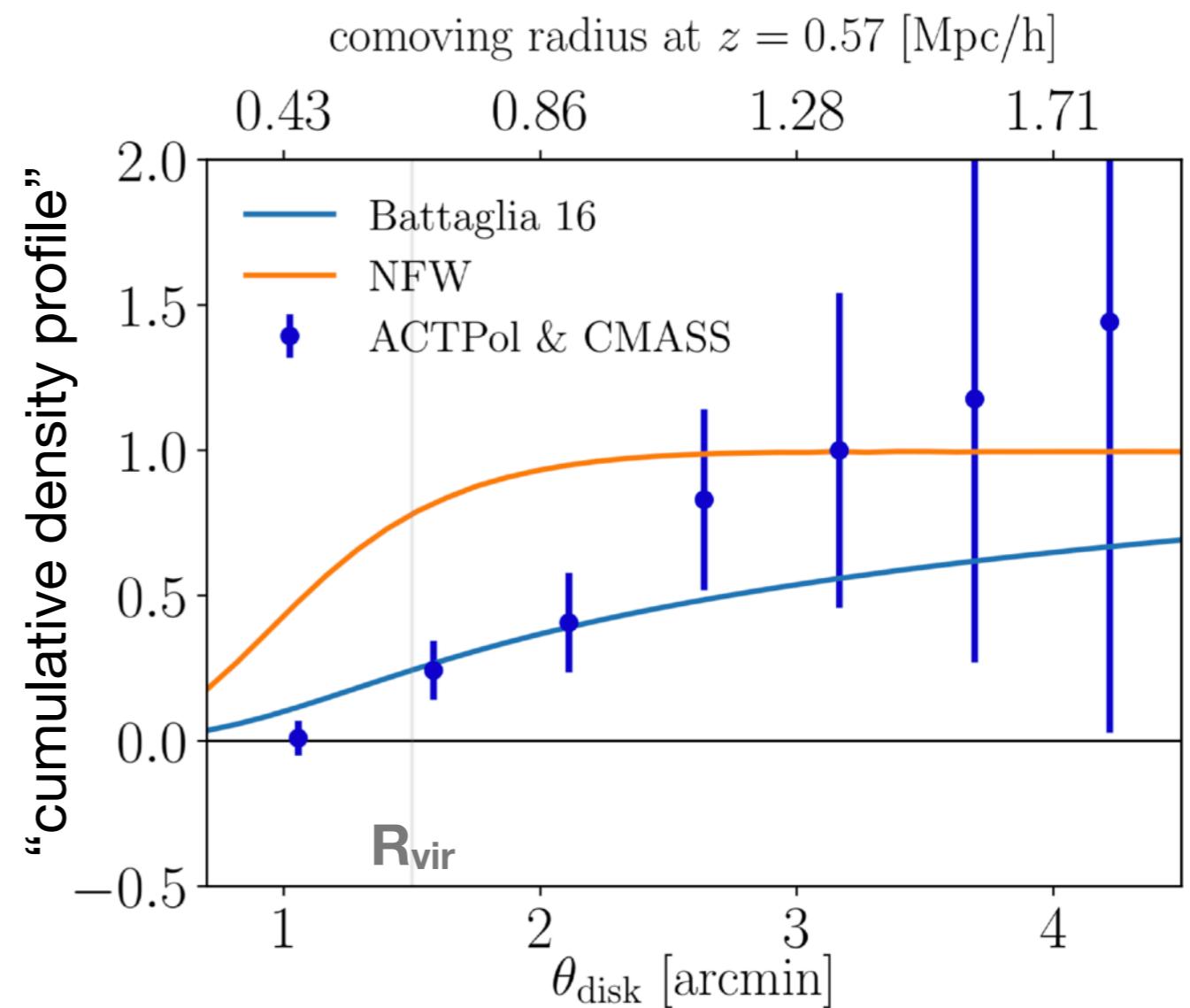
Slide credit E. Schaan

Previous kSZ detection

with ACTPol & BOSS (CMASS)

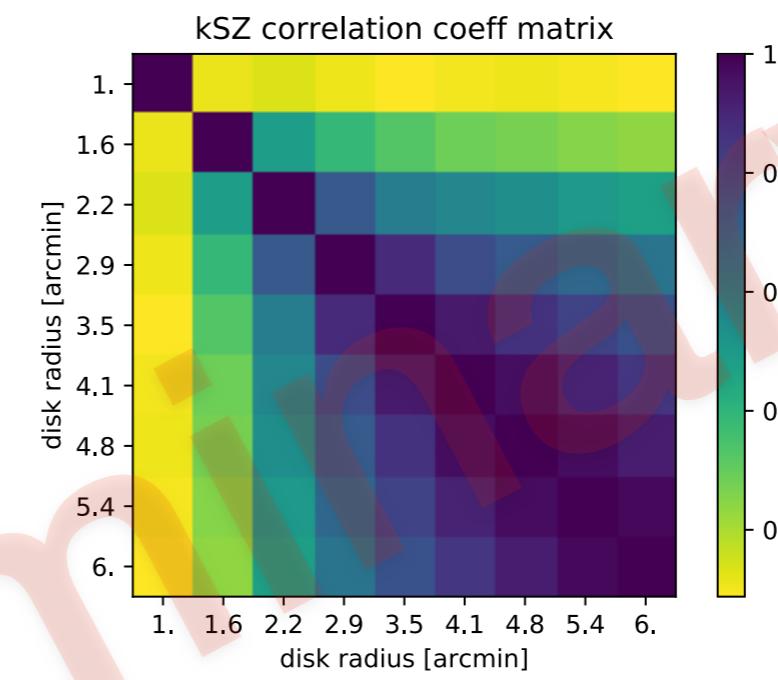
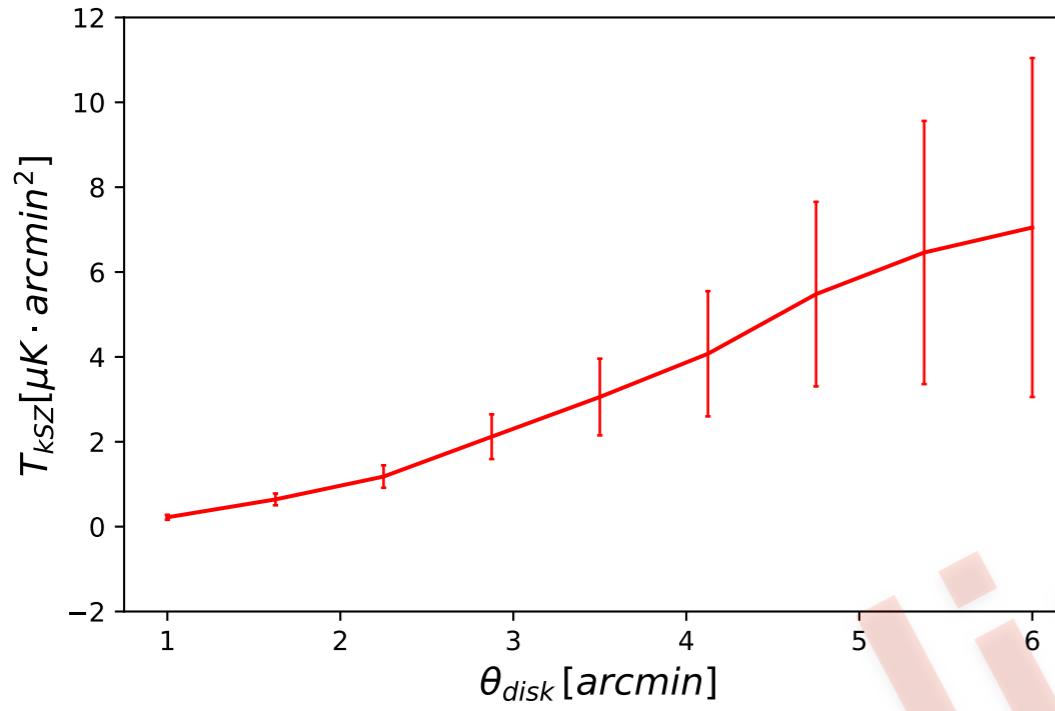
(Schaan, Ferraro et al. 2016)

- 148 GHz
- 660 deg²
- SNR \approx 3
- $\langle M_{\text{halo}} \rangle = 2 \times 10^{13} M_{\odot}$
- $\langle z \rangle = 0.57$

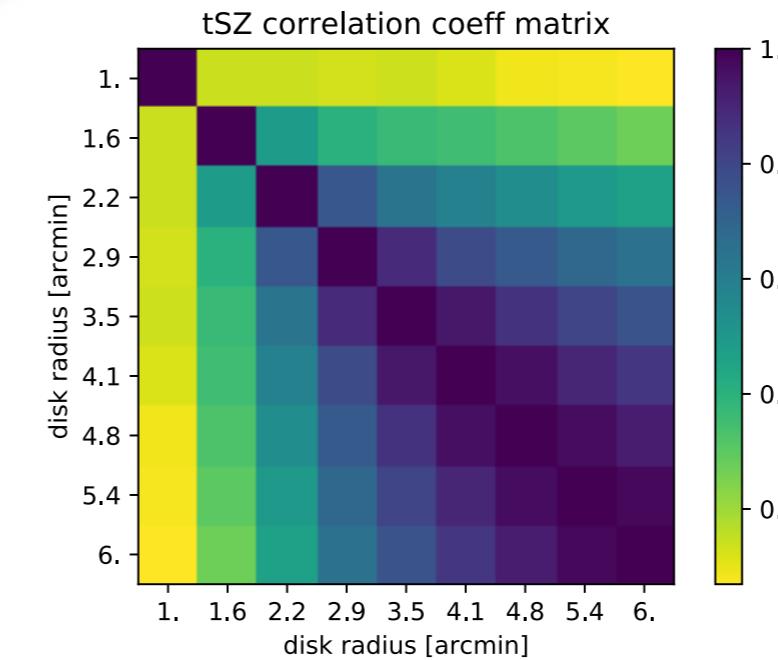
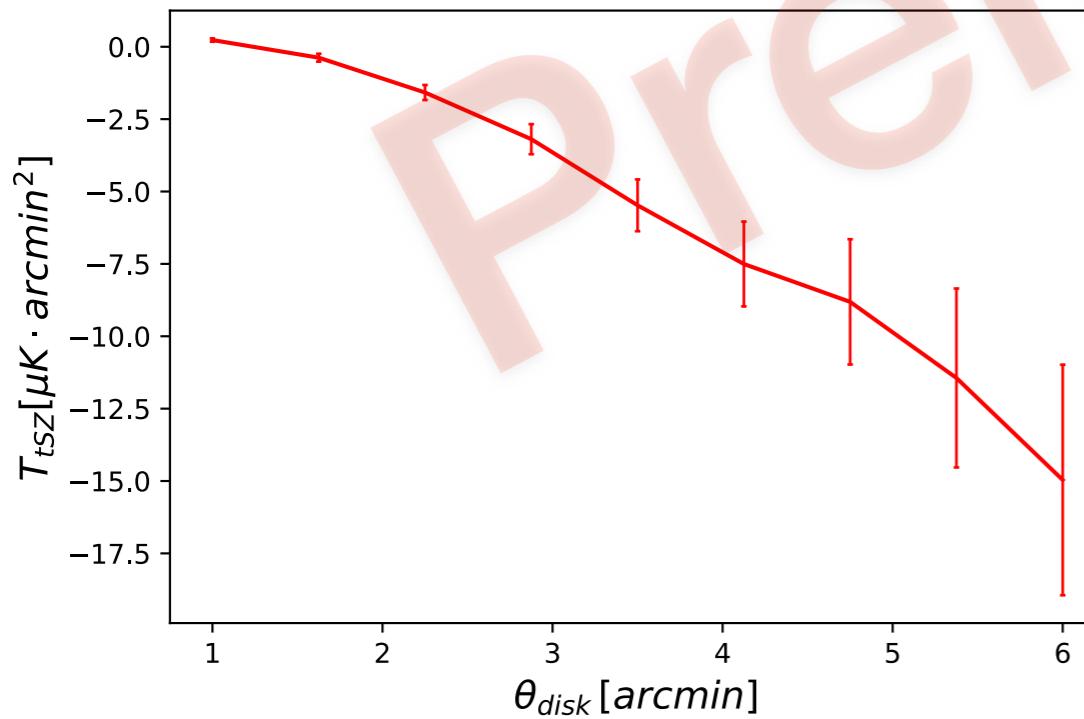


other ~3-4 σ detections by Hand+12, de Bernardis+16

New detections



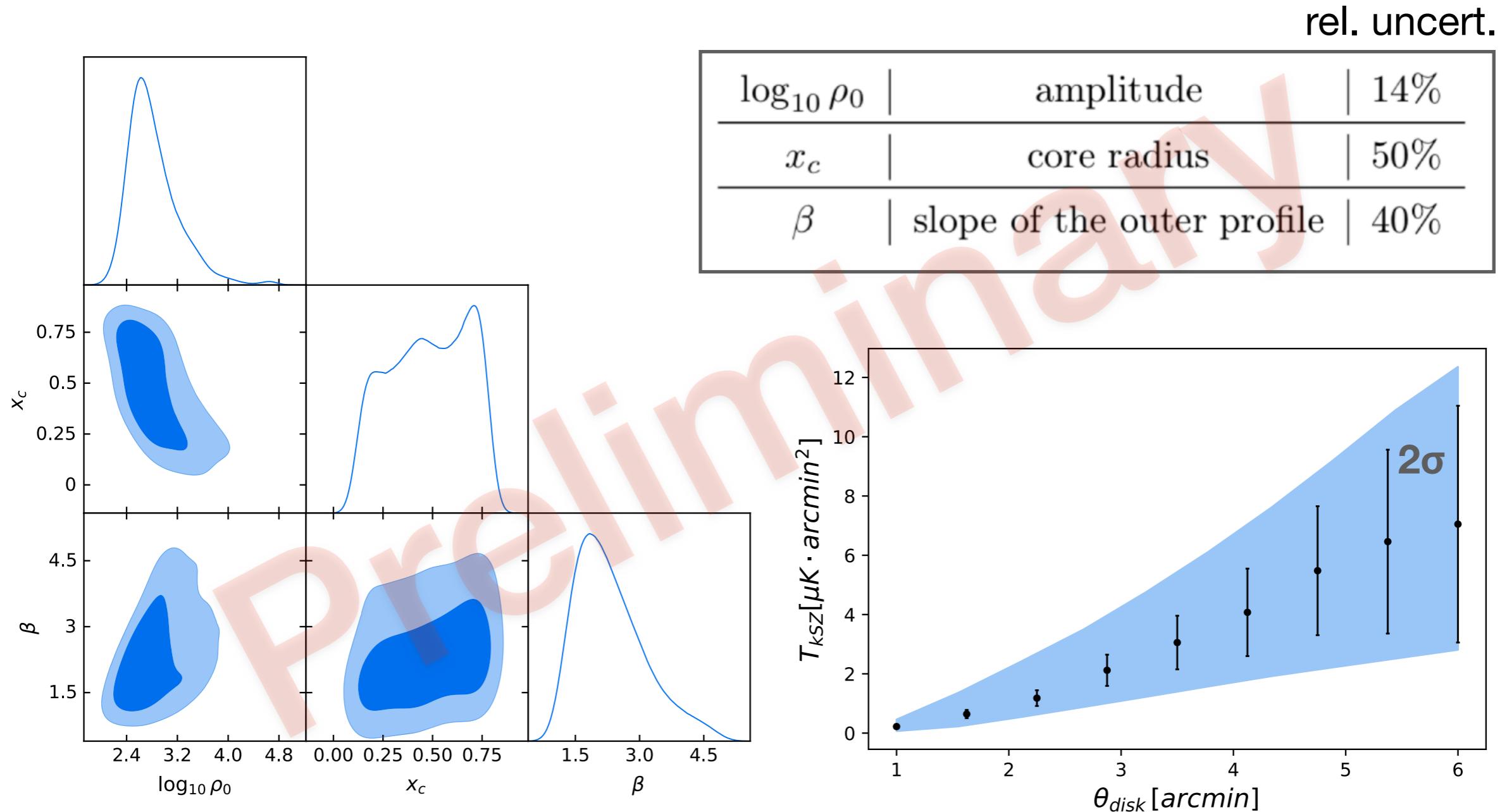
kSZ: SNR~6



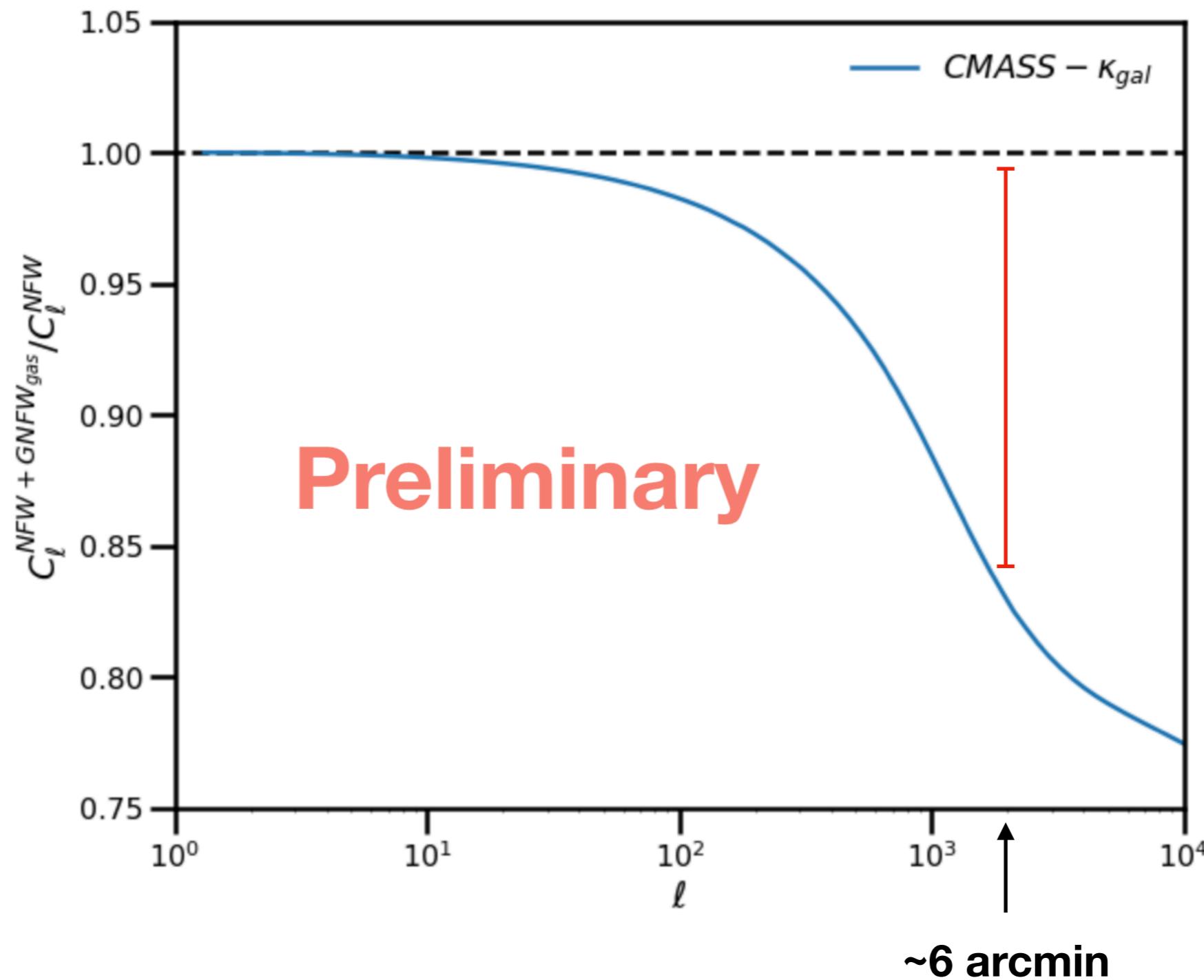
tSZ: SNR~9

Constraints on the IGM / ICM: GNFW density model

$$\rho_{\text{gas}} = \rho_0 (x/x_c)^\gamma [1 + (x/x_c)^\alpha]^{-\frac{\beta-\gamma}{\alpha}} \rho_{\text{cr}}(z) f_b$$



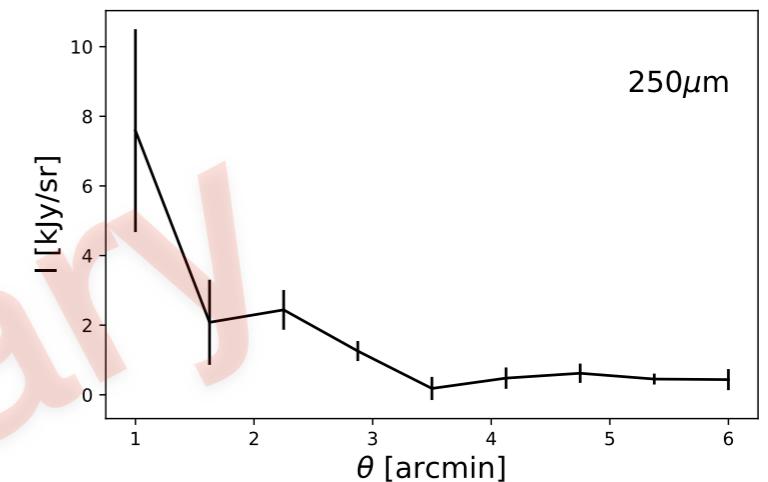
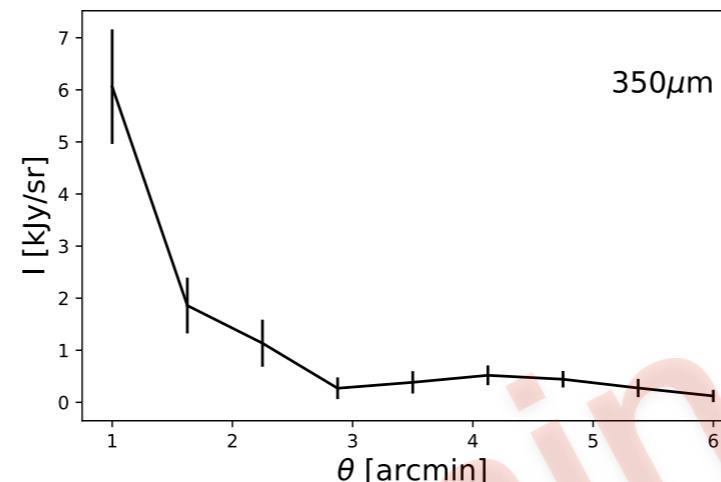
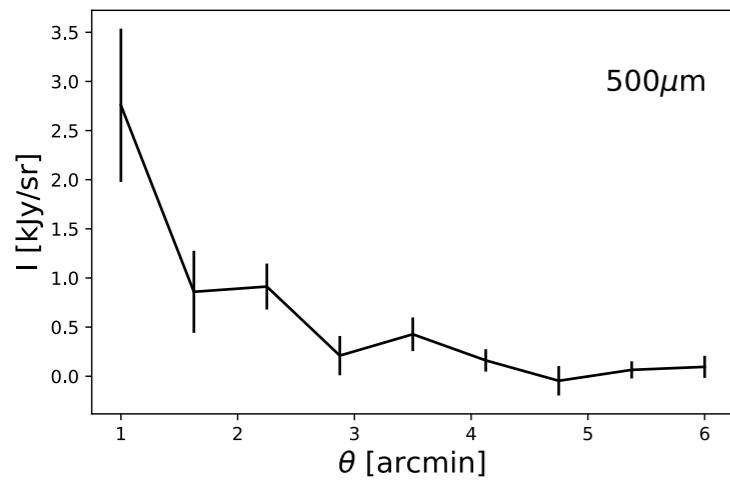
0th order modeling of the baryons in gg-lensing



Slide credit N. Battaglia

Modeling the tSZ: include dust?

Dust emission of BOSS (CMASS) galaxies from Herschel/SPIRE



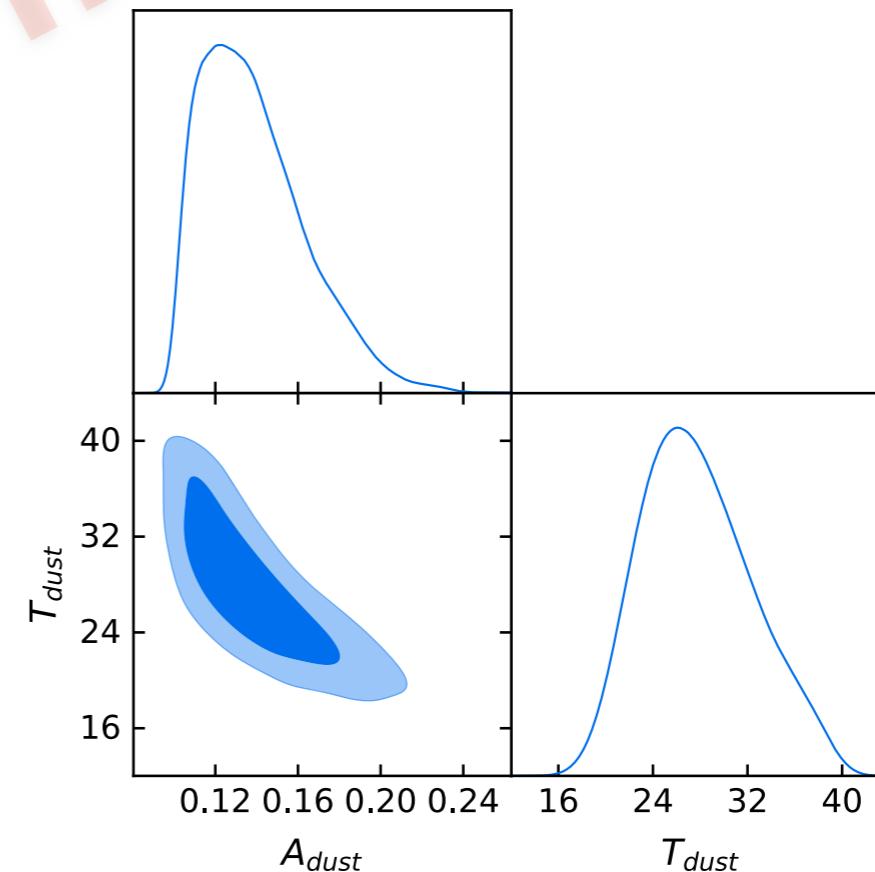
Dust model (modified BB, e.g. Erler+18)

$$I(\nu) = A_{dust} \left(\frac{\nu(1+z)}{\nu_0} \right)^{\beta_{dust}+3} \frac{e^{x_0} - 1}{e^x - 1}$$

$$x \equiv h\nu(1+z)/(k_B T_{dust})$$

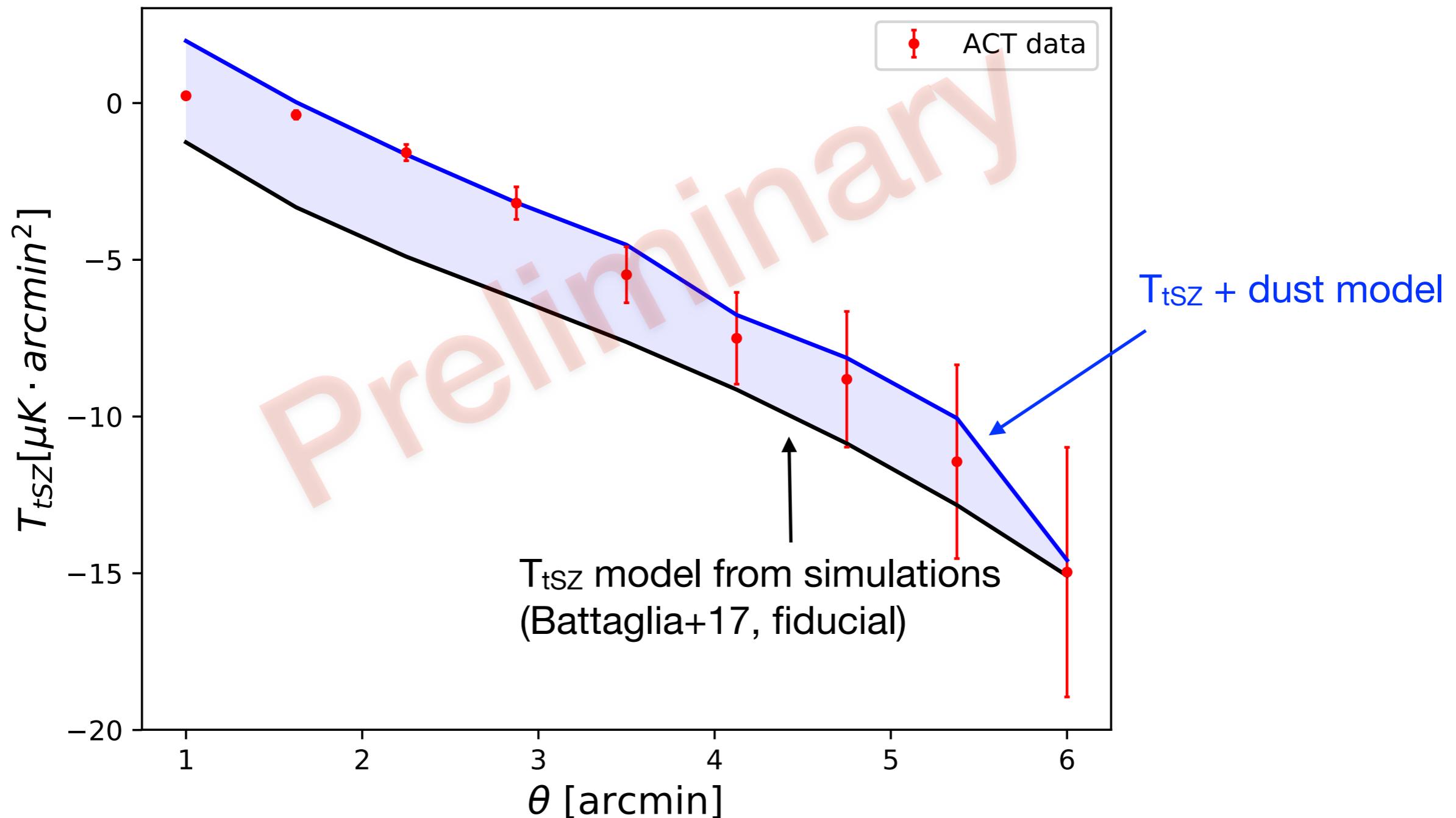
$$\beta_{DUST} = 1.5$$

$$\nu_0 = 857 \text{ GHz}$$



Modeling the tSZ: include dust!

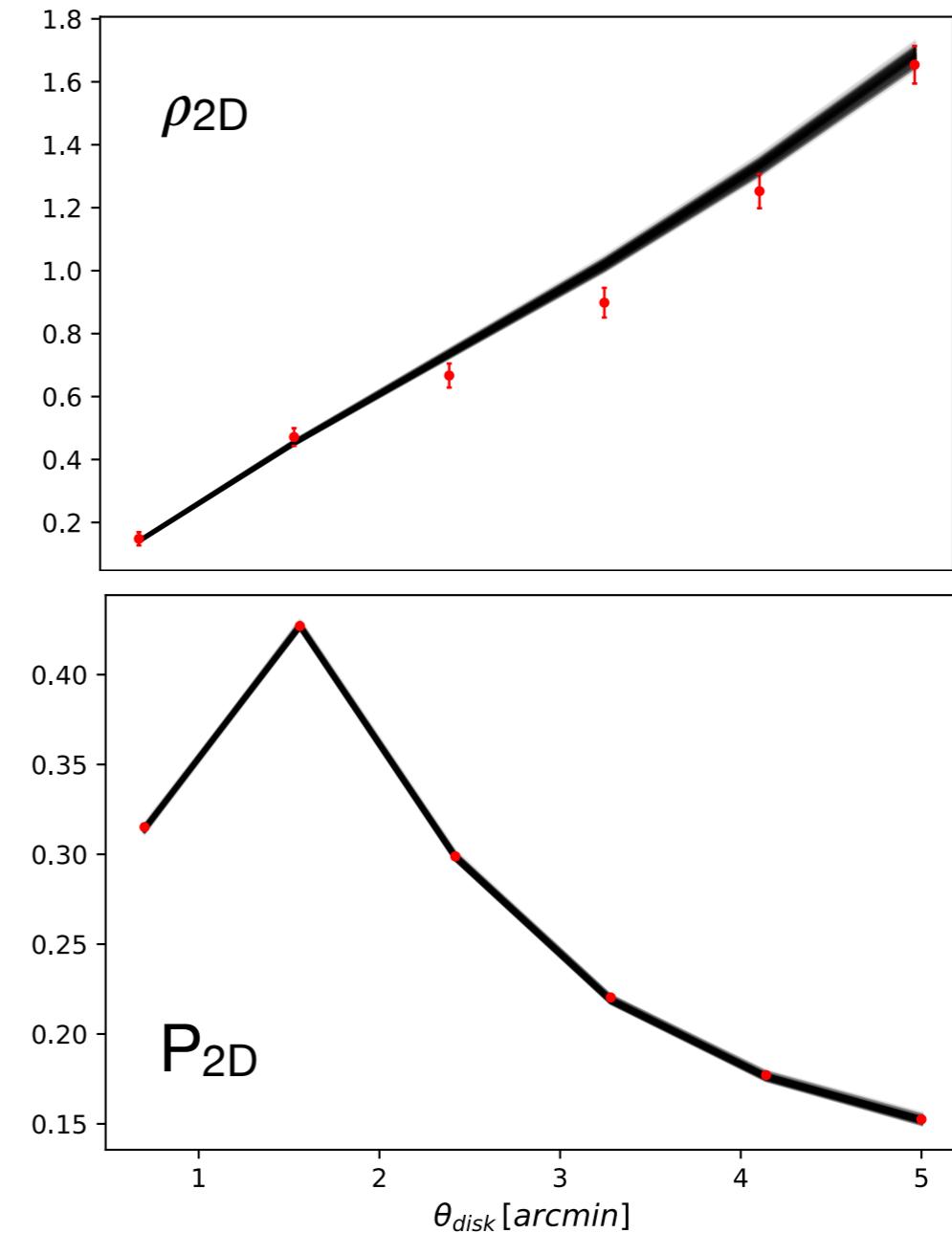
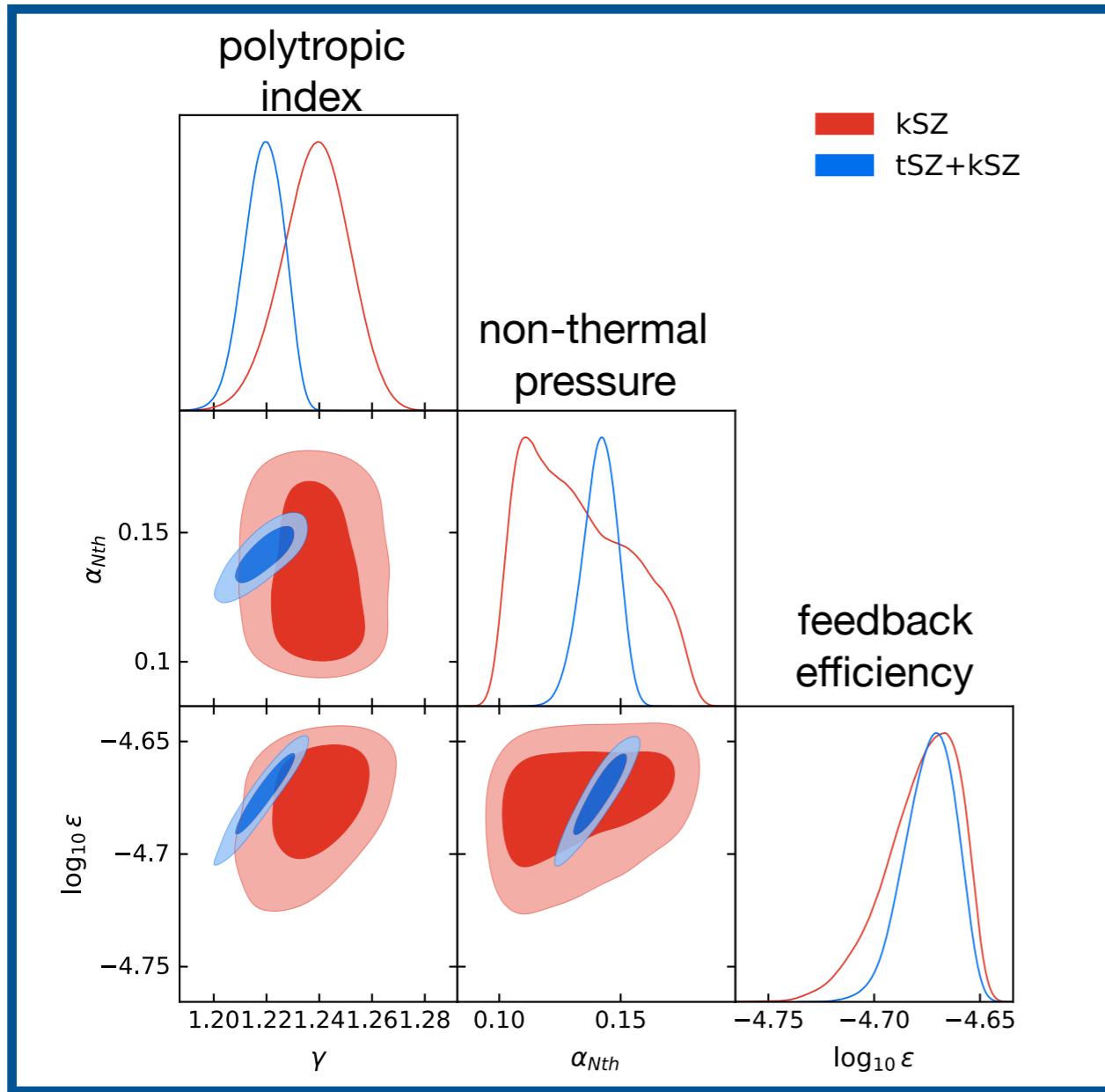
Dust emission of BOSS (CMASS) galaxies at 150 GHz



Combining tSZ & kSZ: Forecasts

Polytropic gas model (Ostriker+05, Bode+09, Shawn+10)

CMB-S4 + DESI-like survey, SNR ~ 200 (kSZ), ~ 500 (tSZ)



Constraints of few% on feedback and non-thermal pressure

Summary

- Cross-correlation of CMB observations with galaxy catalogs from LSS surveys allows to extract tSZ and kSZ signals
- tSZ and kSZ directly probe the spatial distribution of baryons in the IGM/ICM
- The combination of kSZ and tSZ measurements constrains the baryonic processes like feedback and non-thermal pressure support in the IGM/ICM
- These measurements can be used to constrain baryonic effects on the lensing spectra and matter power spectrum