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Prospects of the kSZ constraints on the baryonic effect

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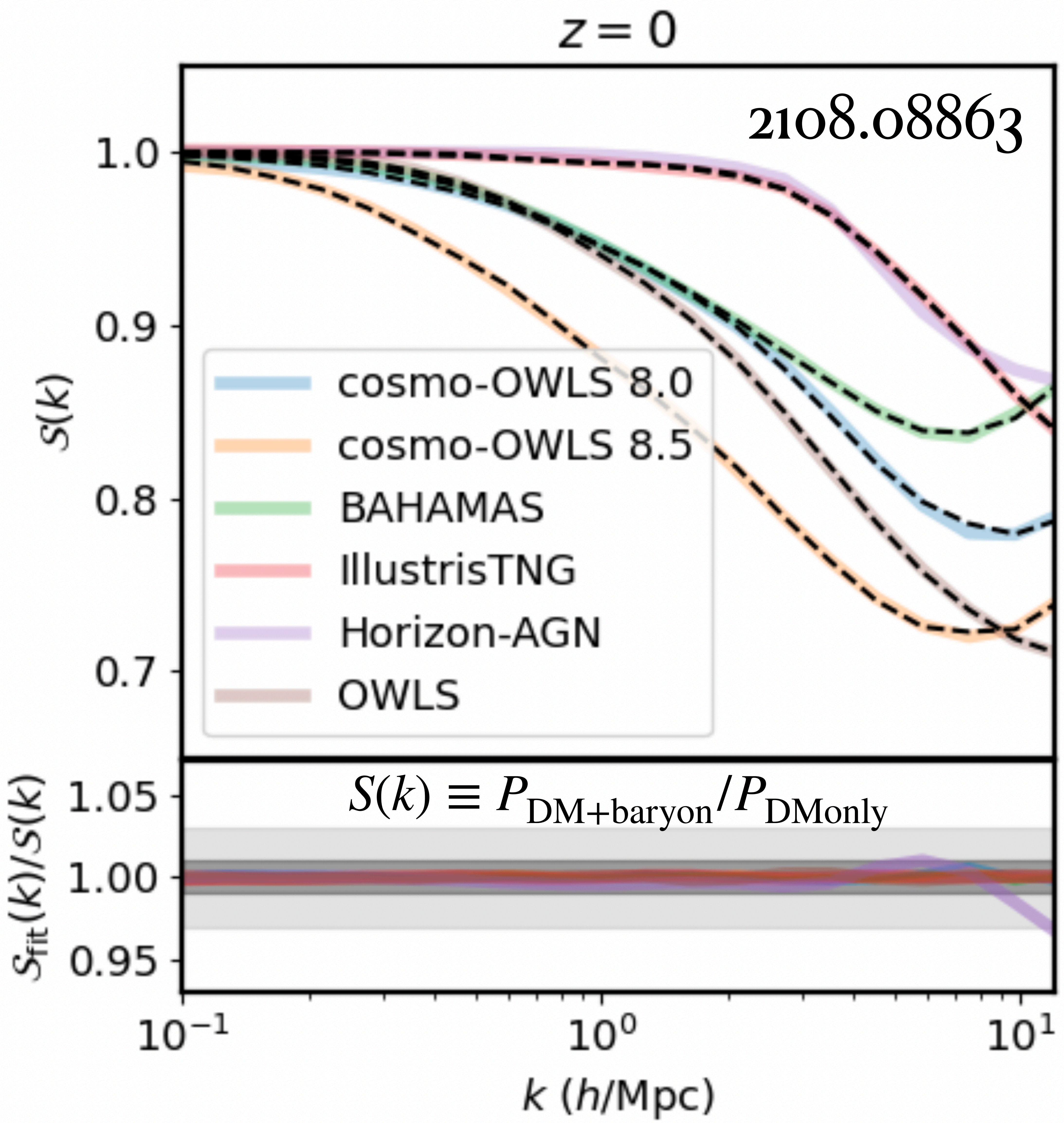
Motivation

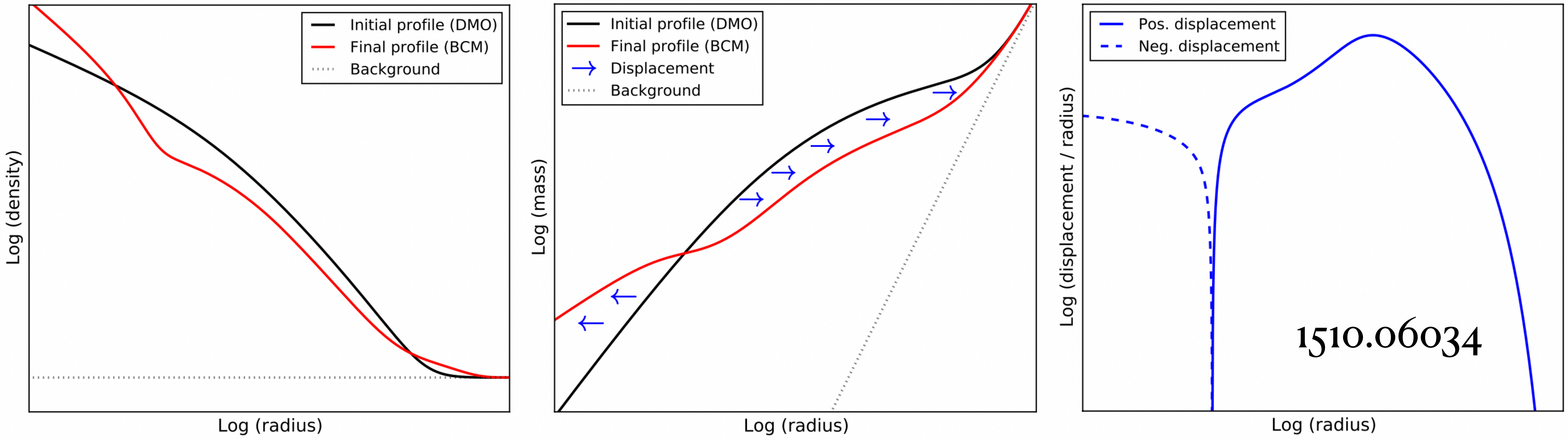
- Cosmological implications of weak lensing require accurate matter power spectrum prediction up to 5-10 h/Mpc.
- Baryonic (feedback) effect manifests itself at 1 h/Mpc, or even larger scales, leading systematic error
- First principle prediction from Hydro-sim, if not impossible, requires too many resources
- Emulators: HOW and WHAT to emulate?



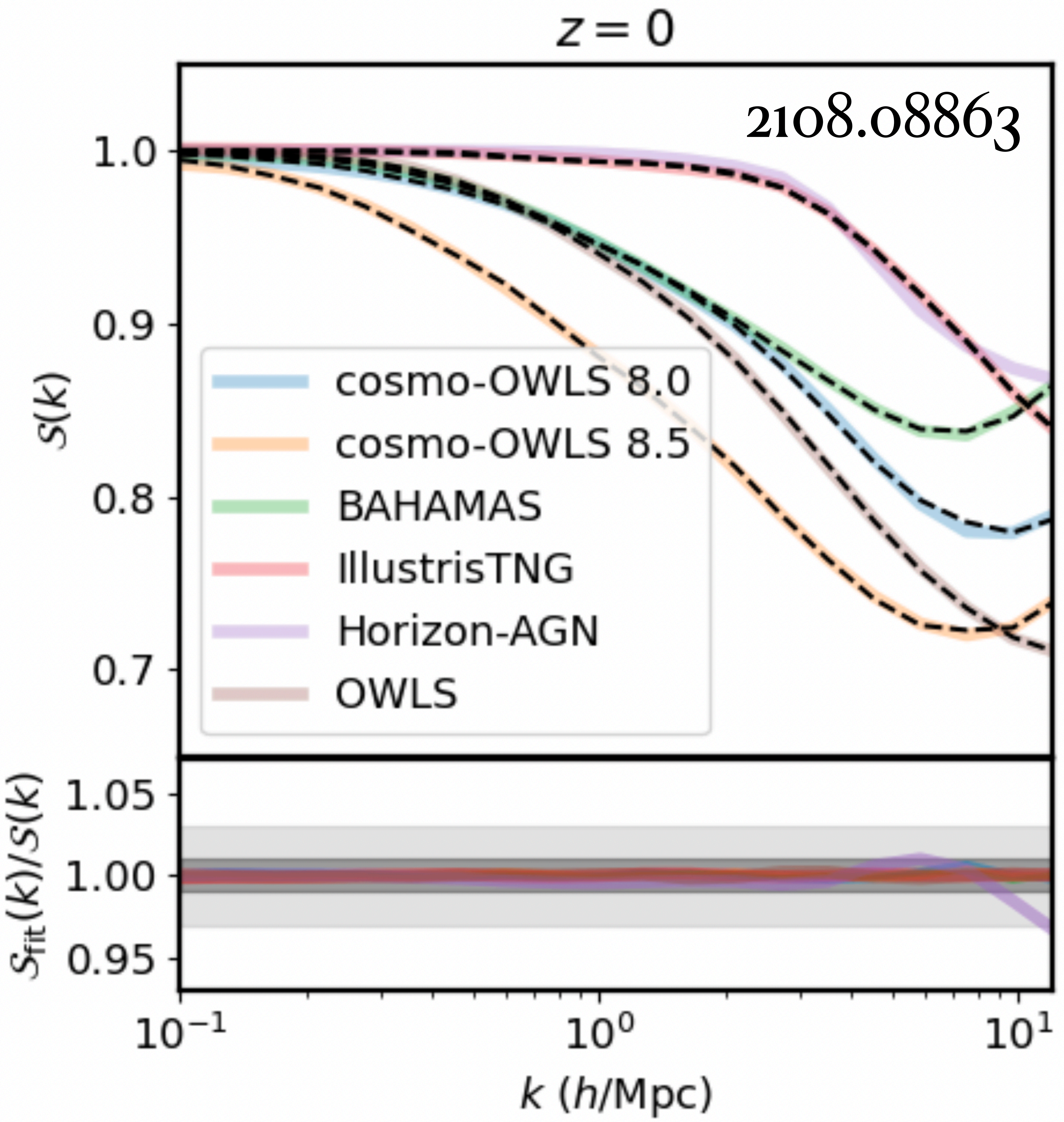
Baryonification

- 7 parameter phenomenological model (Baryon Correction Model, BCM) describing the modified gas and DM density profiles within and around halos.
- Originally proposed by Schneider&Teyssier (1510.06034); further developed in 1810.08629;2009.14225

$$\rho_{\rm nfw}(r) \quad \rightarrow \quad \rho_{\rm dmb}(r) = \rho_{\rm clm}(r) + \rho_{\rm gas}(r) + \rho_{\rm cga}(r),$$



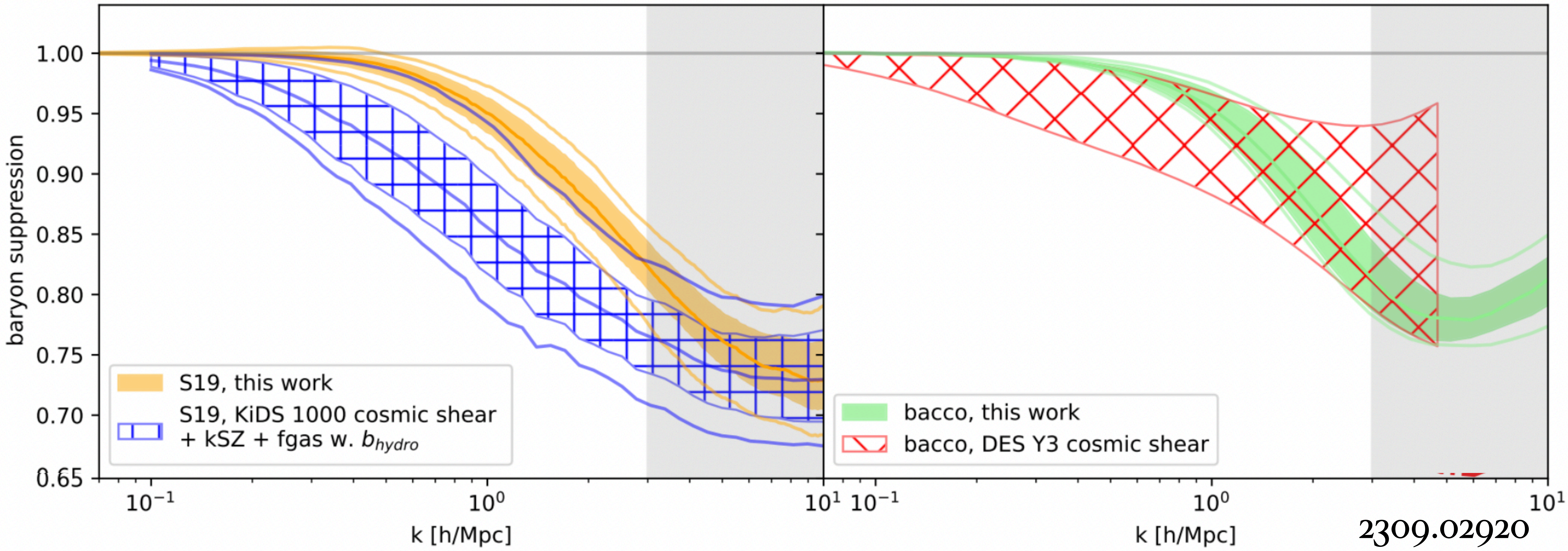
Baryonification emulators



- How to emulate? —— rescaling DM simulations to include baryonic effect
- What to emulate? —— mapping BCM parameters to S(k)
- BCemu emulator (2108.08863); BACCO emulator (2011.15018)
- Be Fed in WL analysis (2206.08591); Global fitting with WL, X ray, tSZ, kSZ observations (2110.02228; 2309.02920; et al.)
- [See 2305.09710 for a Hydro-sim based emulator SP(k)]

Current constraints

- Fitted to gas/halo and stellar/halo mass fractions from X-ray, optical and infrared observations
- Comparison between two emulators



2309.02920

Kinetic Sunyaev-Zel'dovich (kSZ) effect

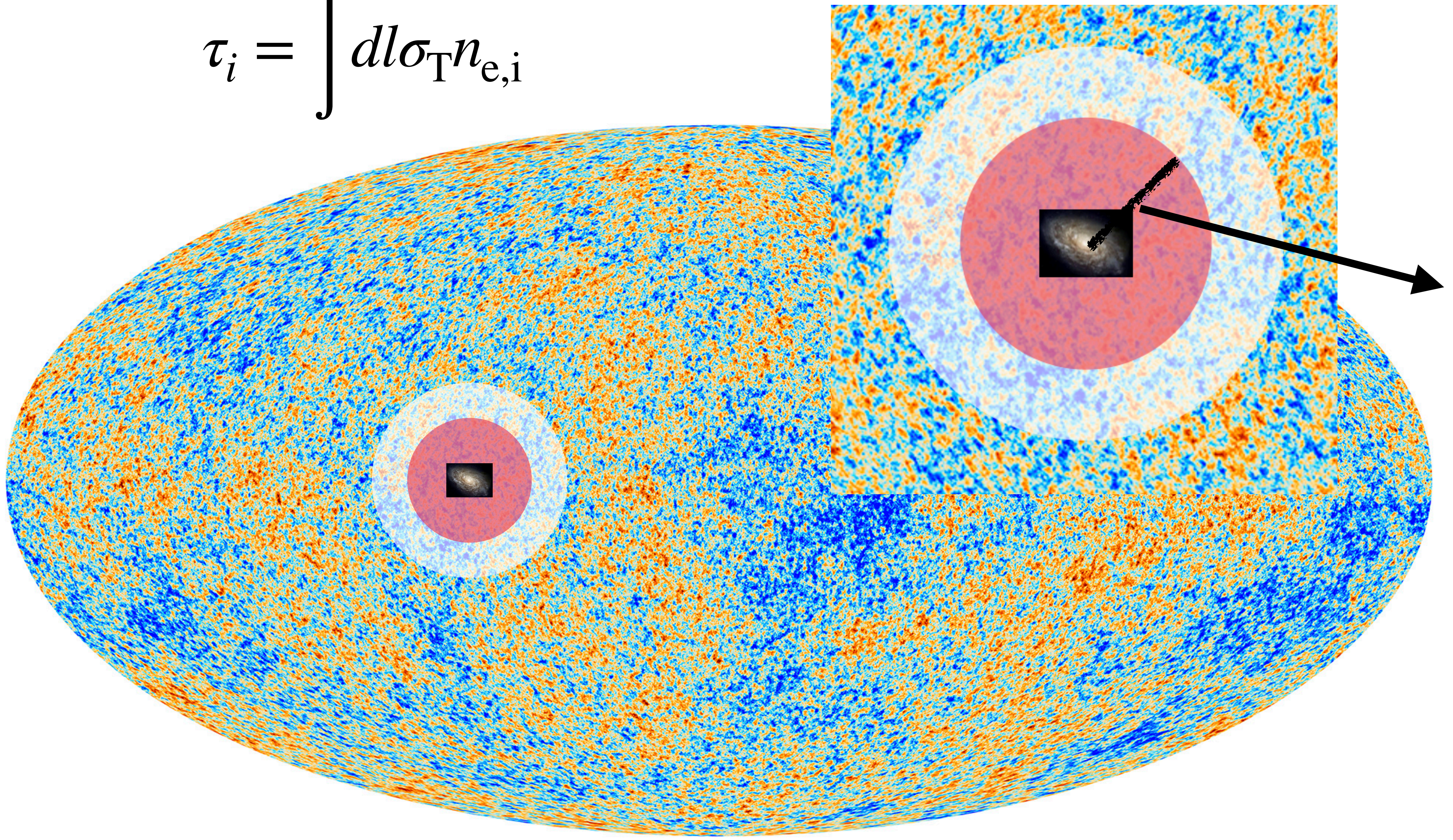
Sunyaev R. A., Zel'dovich Y. B., 1970, Ap&SS, 7, 3

$$\delta T_i \simeq \left(-T_0 \frac{\tau_i}{c}\right) \vec{v}_i \cdot \hat{n}_i,$$

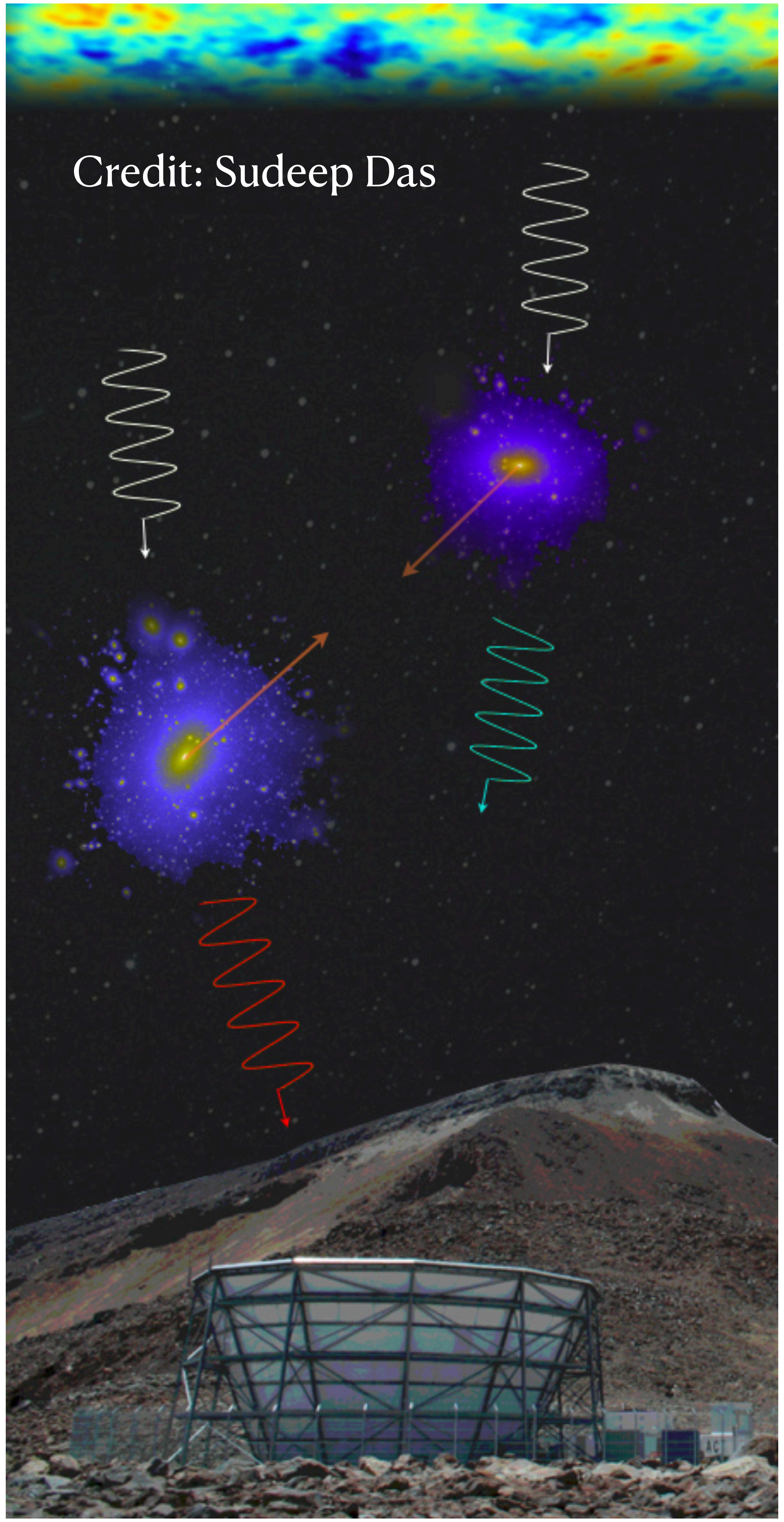
Optical depth

Peculiar velocity

$$\tau_i = \int dl \sigma_T n_{e,i}$$



θ_c



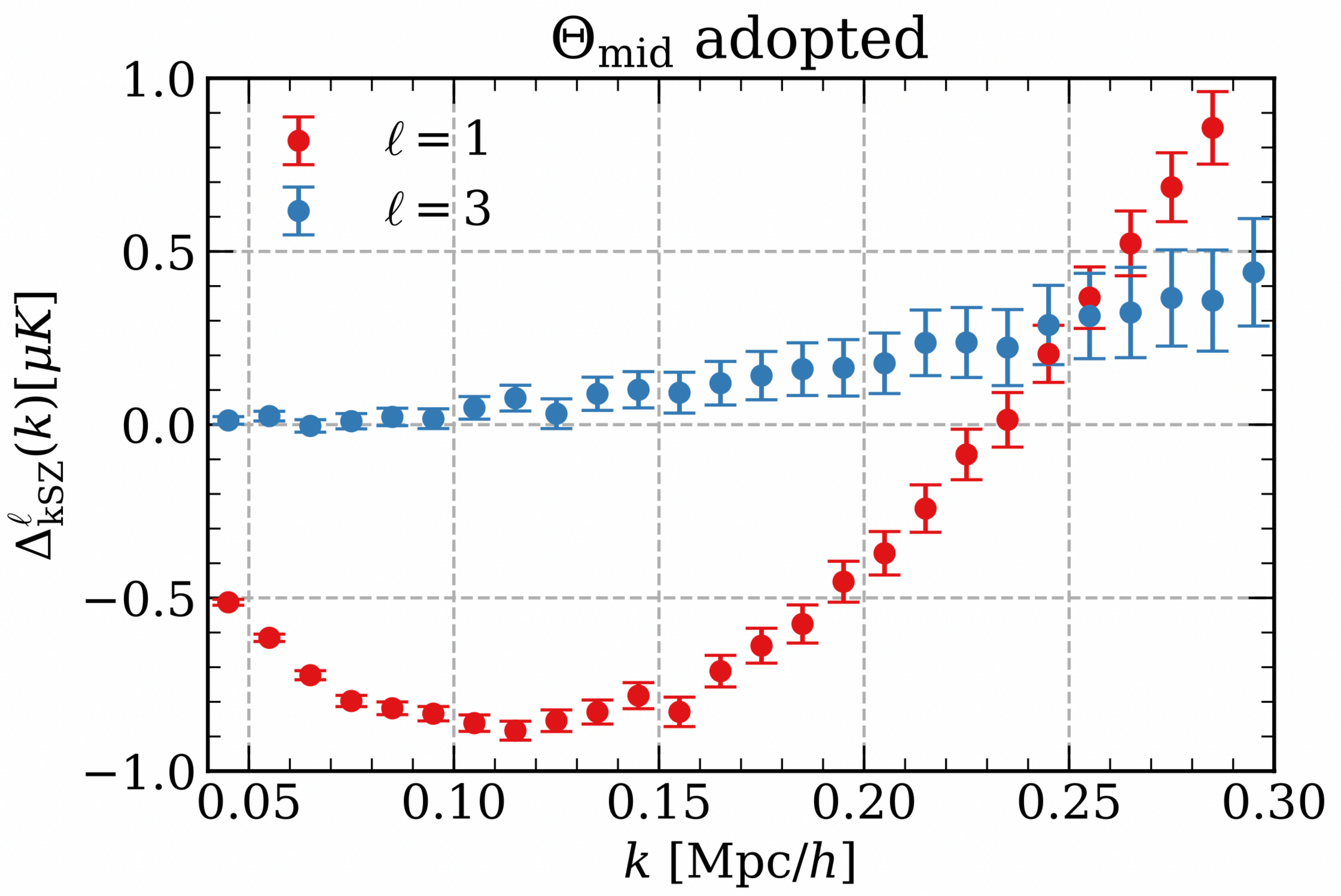
Zheng&Zhang, in prep.

Mock pairwise kSZ observation

$\lg M_c, \delta, \gamma, \mu$: the slope of the gas profile

θ_{ej}: maximum radius of gas ejection

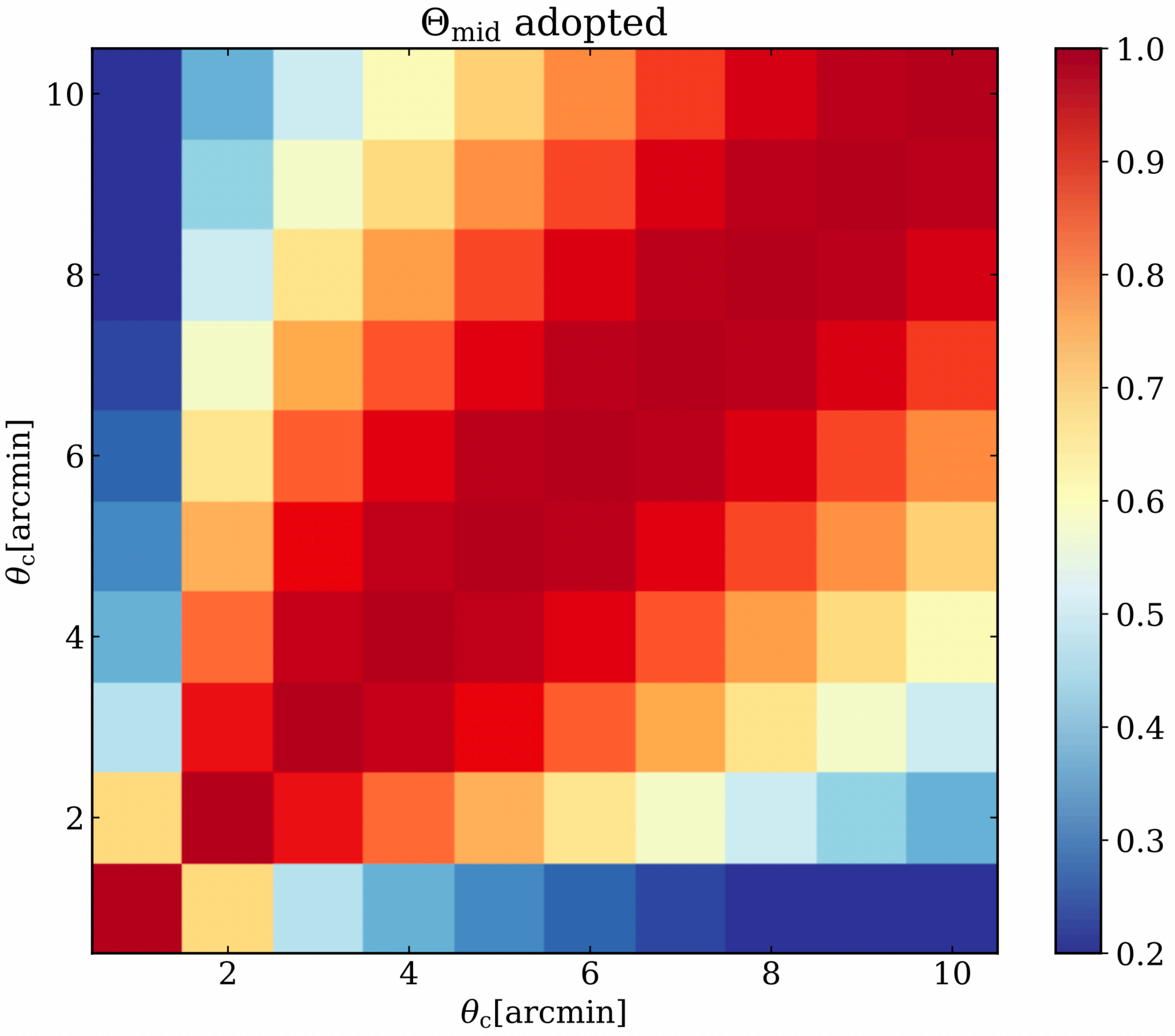
	Θ	Θ_{mid}	Θ_{S22}	Θ_{G23}	Prior
Gas	$\lg M_c$	13	13.2	14.53	[11,15]
	θ_{ej}	5	5	4.36	[2,8]
	δ	7	7	6	[3,11]
	γ	2.5	2.5	1.92	[1,4]
Star	η	0.225	0.24	0.23	[0.05,0.4]
Gas	μ	1	0.3	0.5	[0,2]

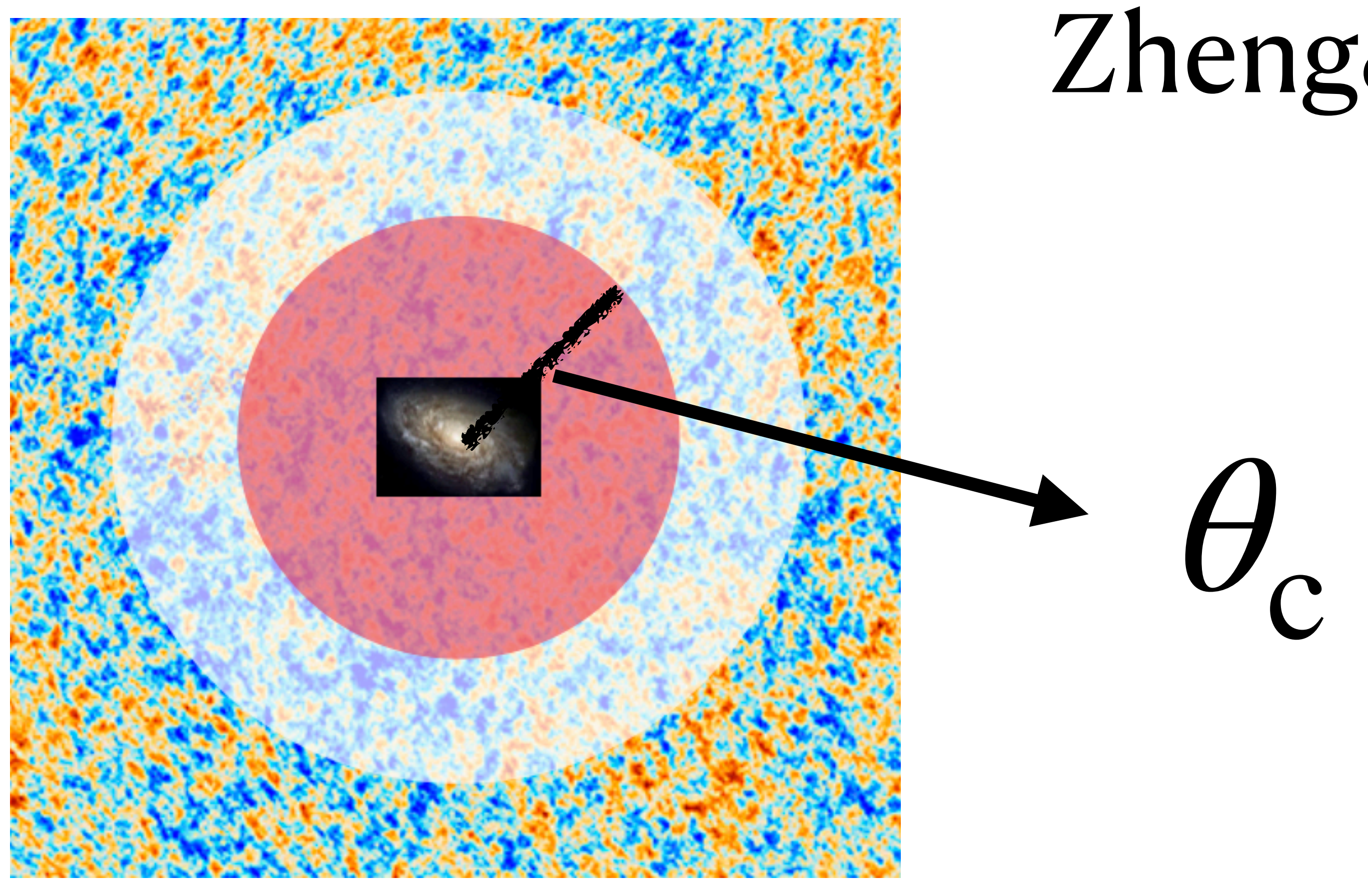


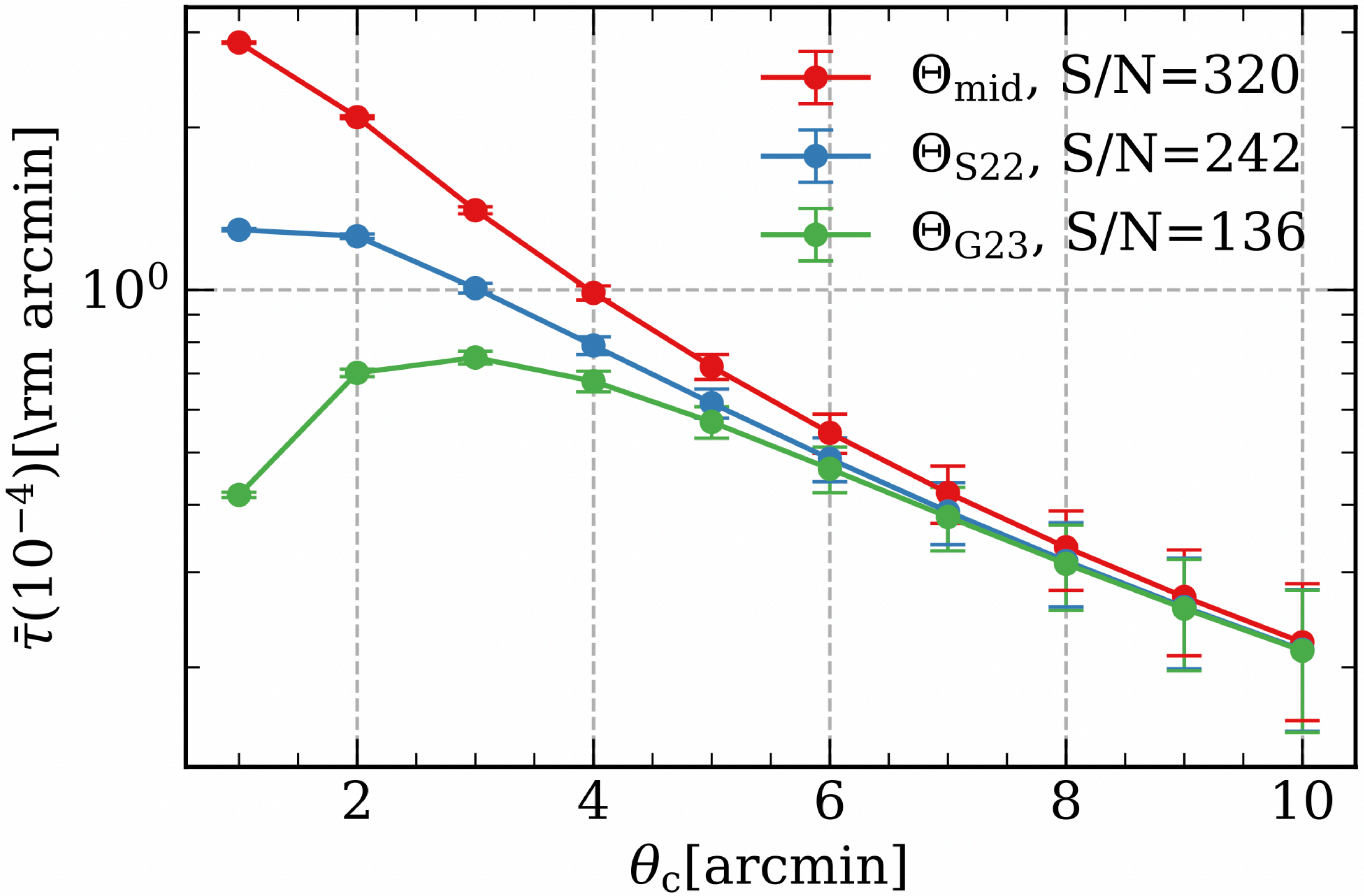
	FWHM [arcmin]	Noise [μK-arcmin]	Redshift	V	$\bar{n}_g$ [$(h^{-1}$ Gpc$)^3$]	$\bar{M}$ [$M_\odot/h$]	f_{sky}
CMB-S4-like + Next-LSS	1	2	0.8 $(0.6 < z < 1.0)$	37.8	2×10^{-4}	2.6×10^{13}	1

Mock optical depth profiles

Zheng&Zhang, in prep.

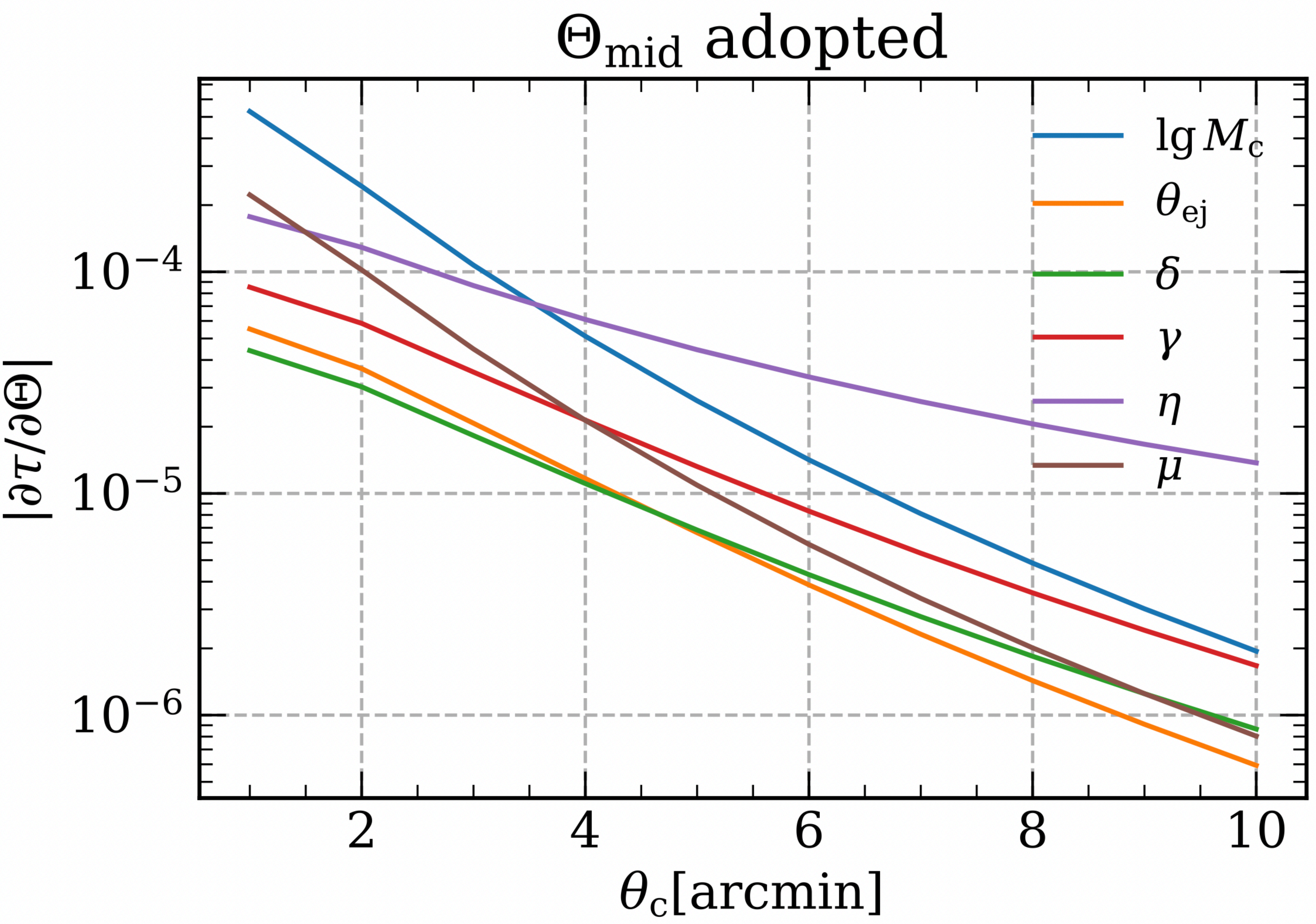


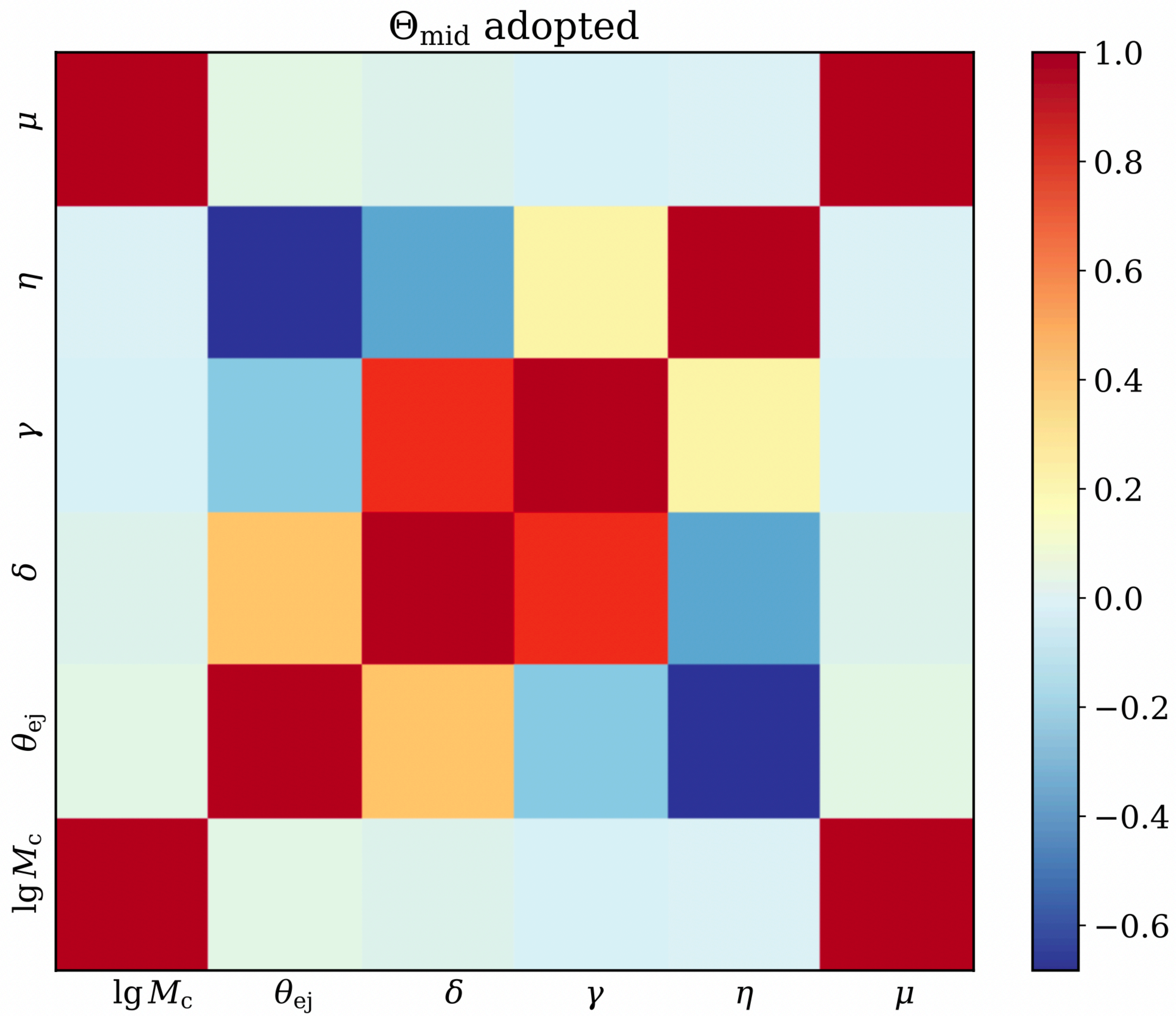


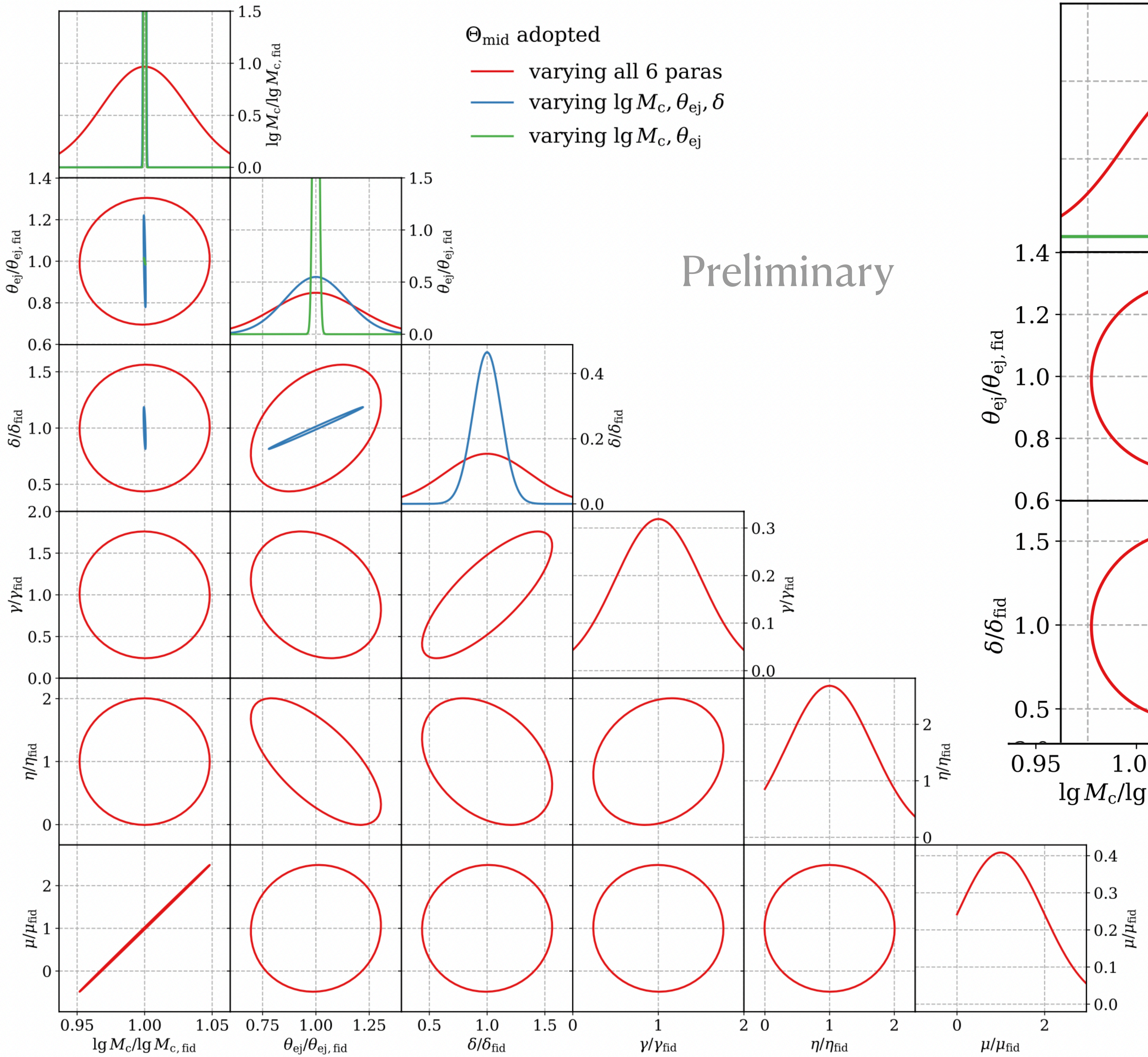


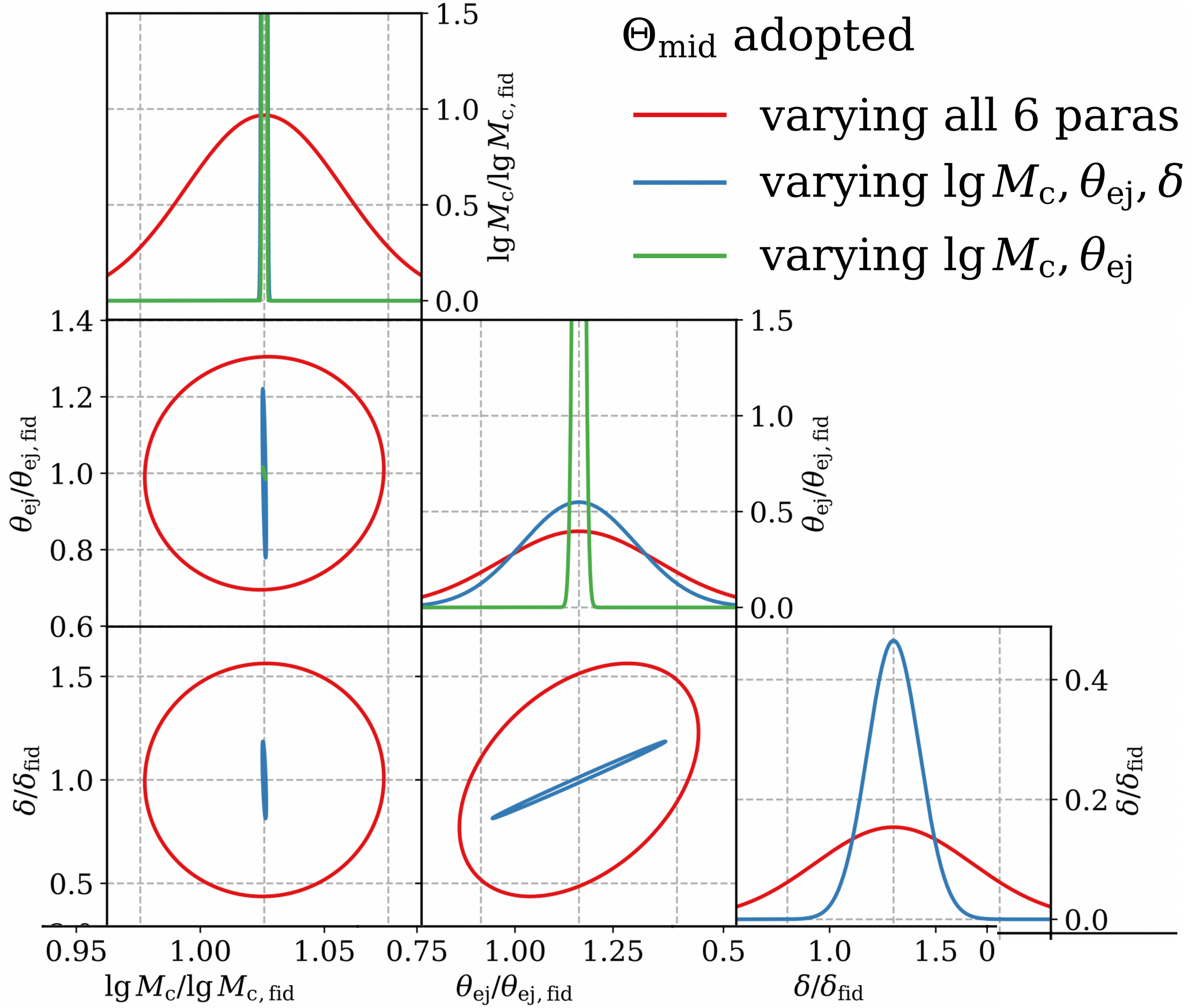
Zheng&Zhang, in prep.

Parameter degeneracy









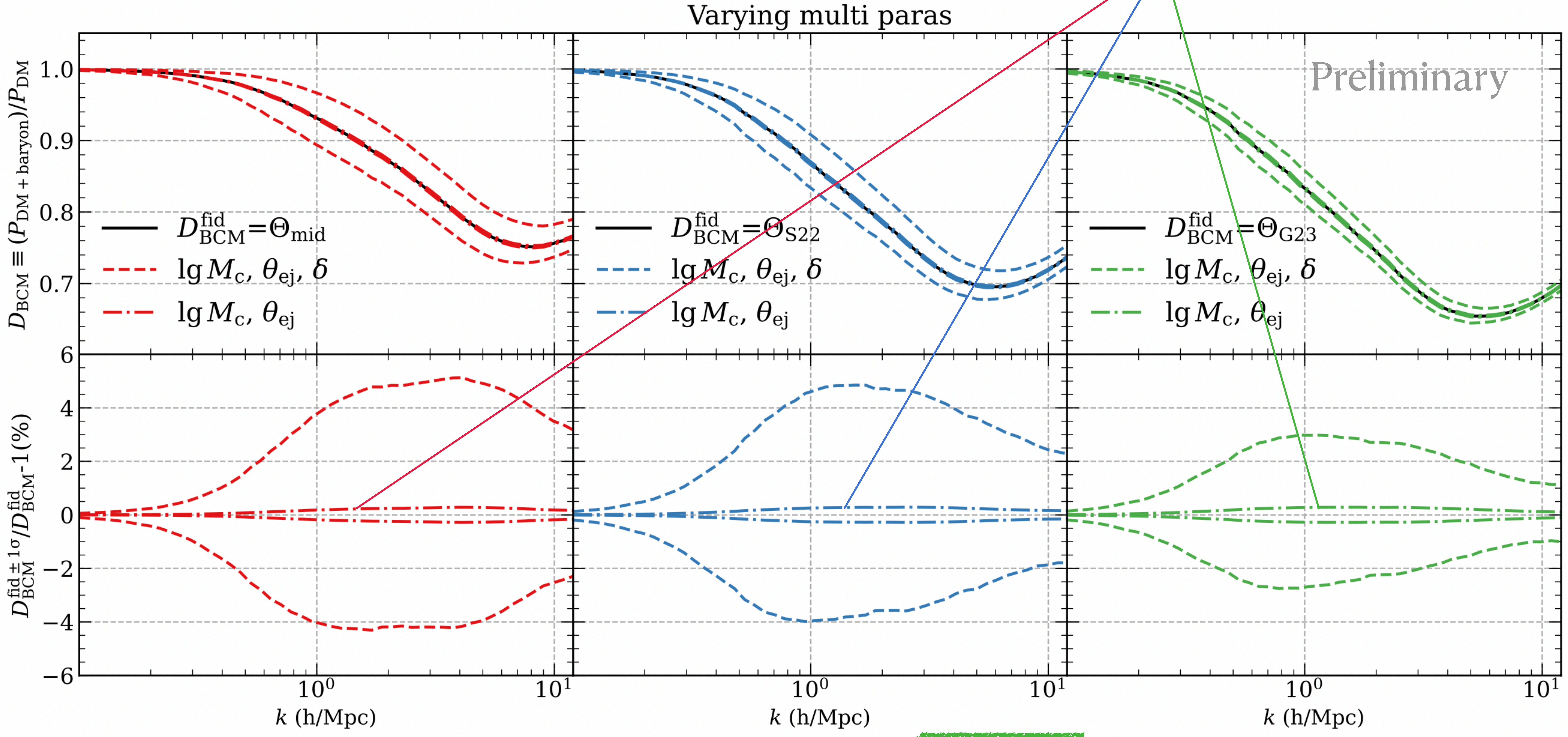
Fisher matrix contours

Zheng&Zhang, in prep.

The damping ($D_{\rm BCM}$ or $S(k)$) constraints

$D_{\rm BCM} = S(k) \equiv P_{\rm DM+baryon}/P_{\rm DMonly}$

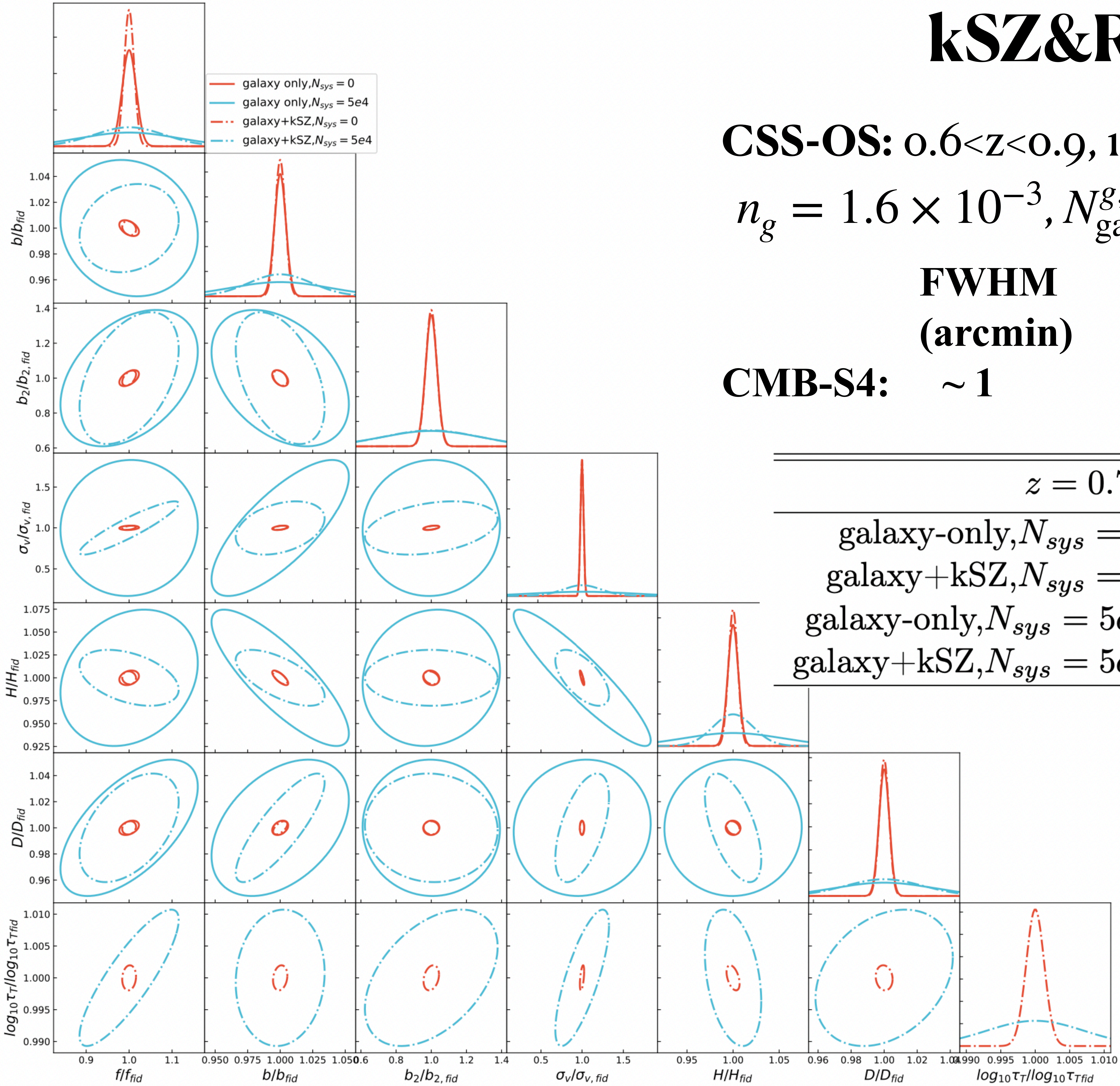
$< 0.3\% \sqrt{37.8 {\rm Gpc}^3 h^{-3}/V},$



MCMC?

Zheng&Zhang, in prep.

kSZ&RSD synergy, CSST+CMB-S4

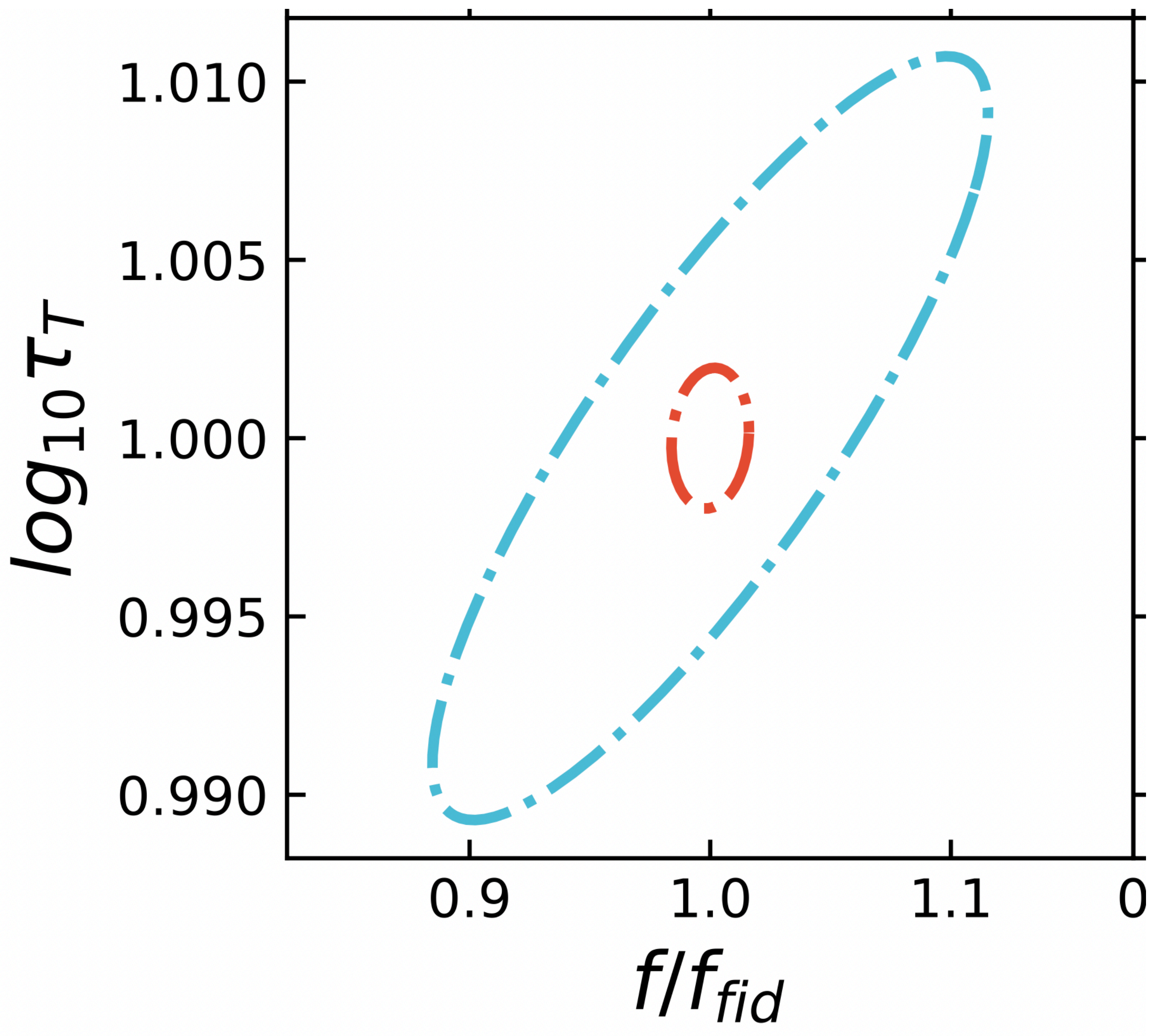


CSS-OS: 0.6<z<0.9, 17500 deg^2, $\sigma_z^0 = 0.005$

$n_g = 1.6 \times 10^{-3}, N_{\rm gas}^{g,i} = 5 \times 10^4, k \leq 0.2h/\mathrm{Mpc}$

	FWHM (arcmin)	Detector noise (μK-arcmin)	overlapping area (deg^2)
CMB-S4:	~1	~1	8000

$z = 0.75$	$\frac{\sigma_{log_{10}\tau_T}}{\lvert log_{10}\tau_T \rvert}\%$
galaxy-only,$N_{sys} = 0$	-
galaxy+kSZ,$N_{sys} = 0$	0.13
galaxy-only,$N_{sys} = 5e4$	-
galaxy+kSZ,$N_{sys} = 5e4$	0.70



Li&Zheng, in prep.

Summary

- Baryonificatoin methodology based on the Baryon Correction Model (BCM) is promising to quantify and constrain the baryonic (feedback) effects in a Bayesian paradigm. It is crucial for small scale cosmological tests such as for neutrino, Modified gravity, et al. (1911.08494) and to solve tensions like the S_8 tension (partly, 2110.02228, 2206.08591, 2309.02920,).
- BCM parameters are highly degenerated with each other in its design. Synergy between different observations from WL, Xray, SZ et al. are necessary.
- S/N of the kSZ detection will be ~100 in a CMB-S4 era. It is an amazing probe sensitive to both large and small cosmological scales. It definitely will play its role in constraining the baryon distribution in and around halos in the future.
- If CMB-S4 is too far away for you, please consider ACTpole and Simon.
- If you are interested in the kSZ detection from real observations, please check Shaohong Li's talk tomorrow.

Thanks!