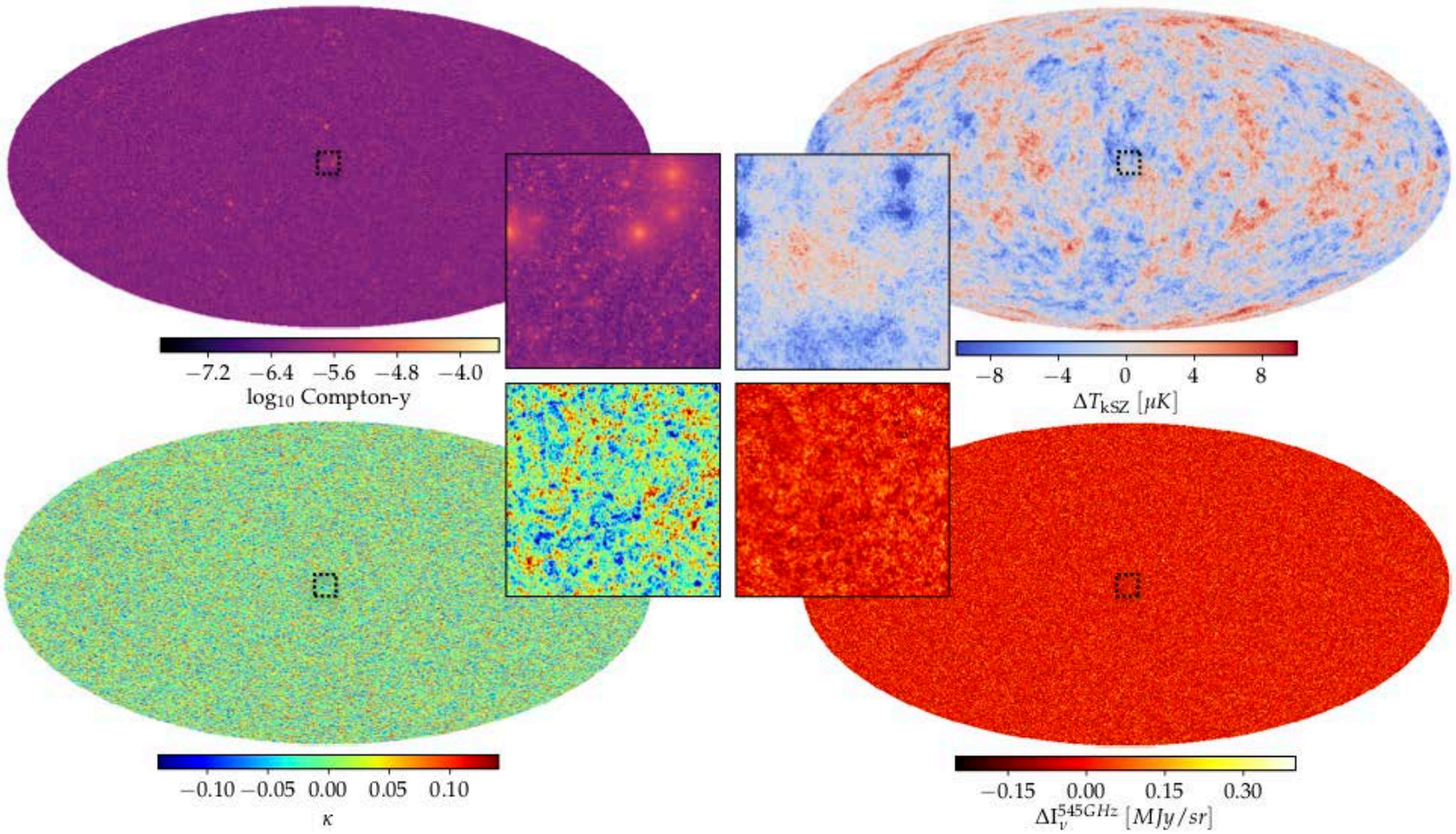
*Overview of*

# The Websky Extragalactic Simulations

arXiv 2001.08787

mocks.cita.utoronto.ca

George Stein, Marcelo Alvarez, Dick Bond, Alex van Engelen, Nick Battaglia

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*Ingredient # 1*

# Dark Matter Lightcone

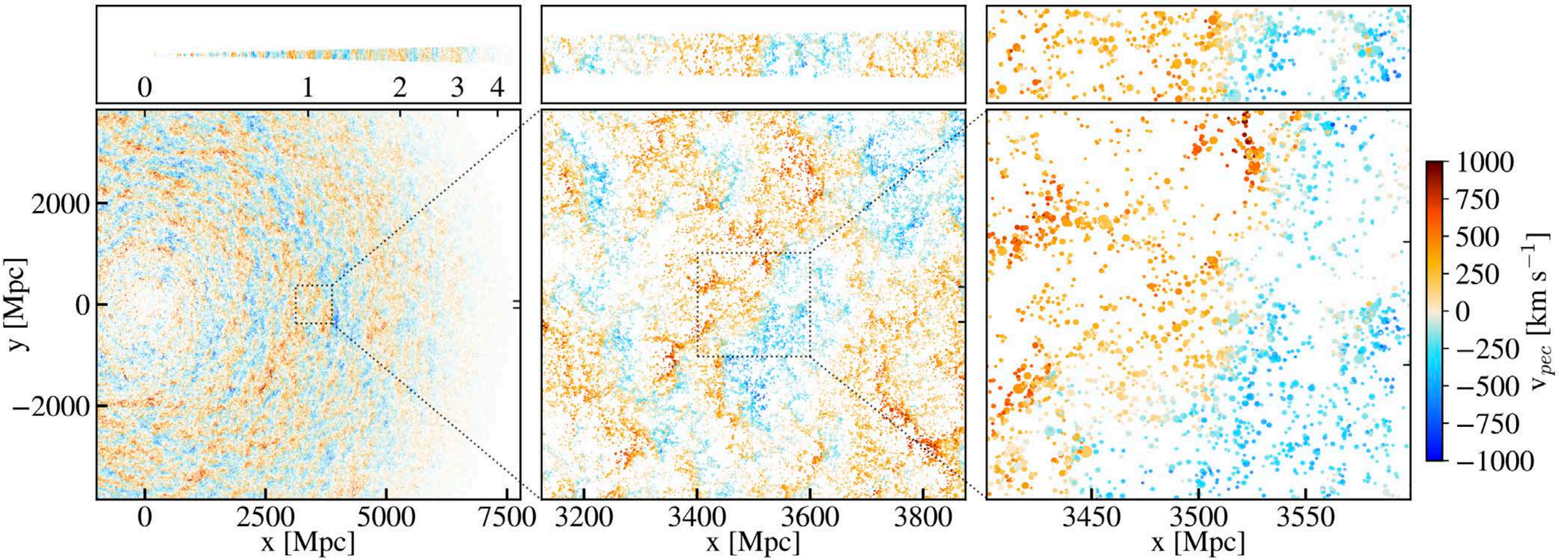
## Simulation details:

Created using the mass-Peak Patch method *Stein, Alvarez, Bond - 1810.07727*

fullsky $z<4.6$, $9\times10^8$ halos,

effective 12,288 particles, 1900 $Gpc^3$ volume, from octants

4336 CPU hours, 7.67 TB

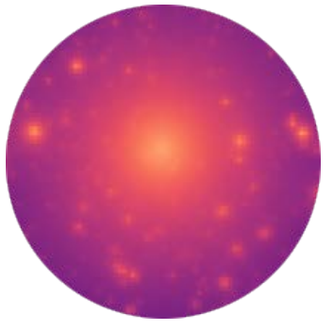


*Ingredient #2*

# Extragalactic Sky Models

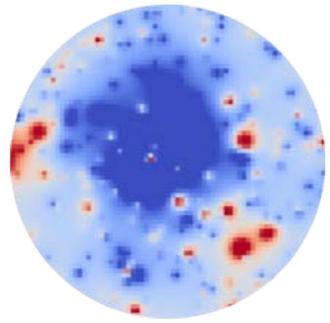
## thermal Sunyaev-Zel'dovich (tSZ)

$$\propto \frac{k_B \sigma_T}{m_e c^2} \int d\chi (1+z)^{-1} P_{th}(\chi \hat{n})$$



## kinetic Sunyaev-Zel'dovich (kSZ)

$$\propto \frac{\rho_{b,0} \sigma_T}{\mu_e m_p} \int d\chi (1+z)^2 \Delta_g(\chi \hat{n}) \mathbf{v}(\chi \hat{n}) \cdot \hat{n}$$

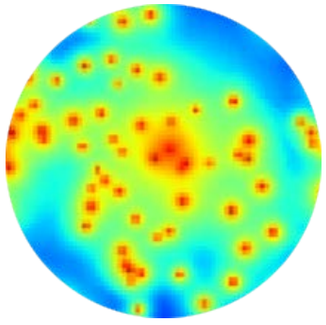


using gNFW profiles from
*Battaglia, Bond, Pfrommer, Sievers (2012)*

## Weak Lensing

$$= \int d\chi W_\kappa(\chi) \delta(\chi \hat{n})$$

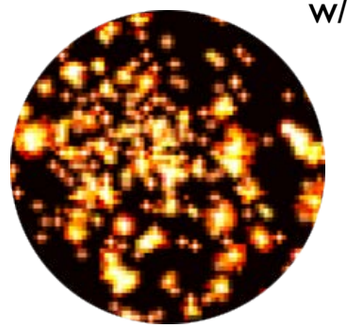
using NFW profile



## Cosmic Infrared Background (CIB)

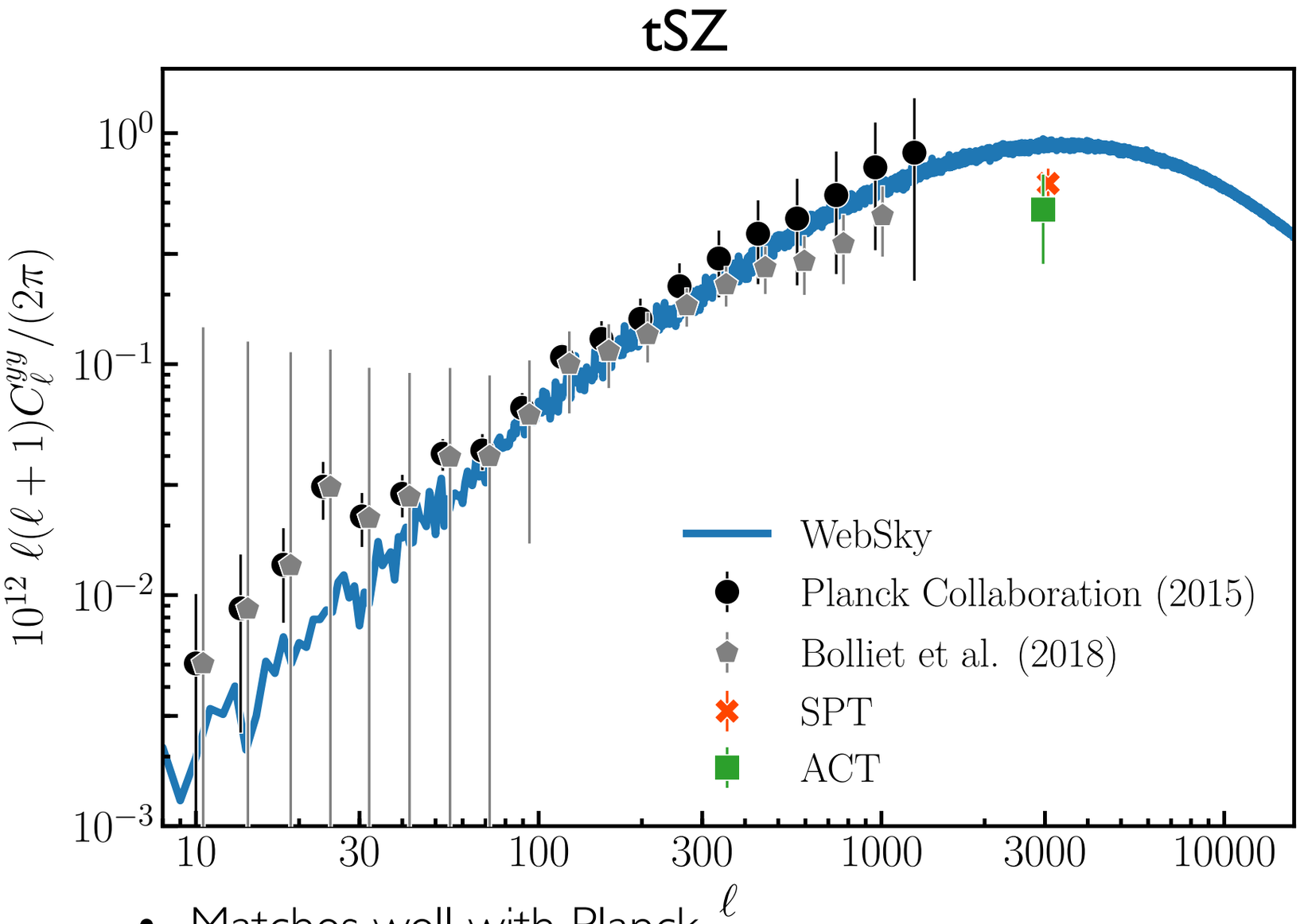
$$L_{(1+z)\nu}(M,z) = L_0 \Phi(z) \Sigma(M,z) \Theta[(1+z)\nu, T_d(z)]$$

using Planck 2013 model
w/ HerMES best fit params



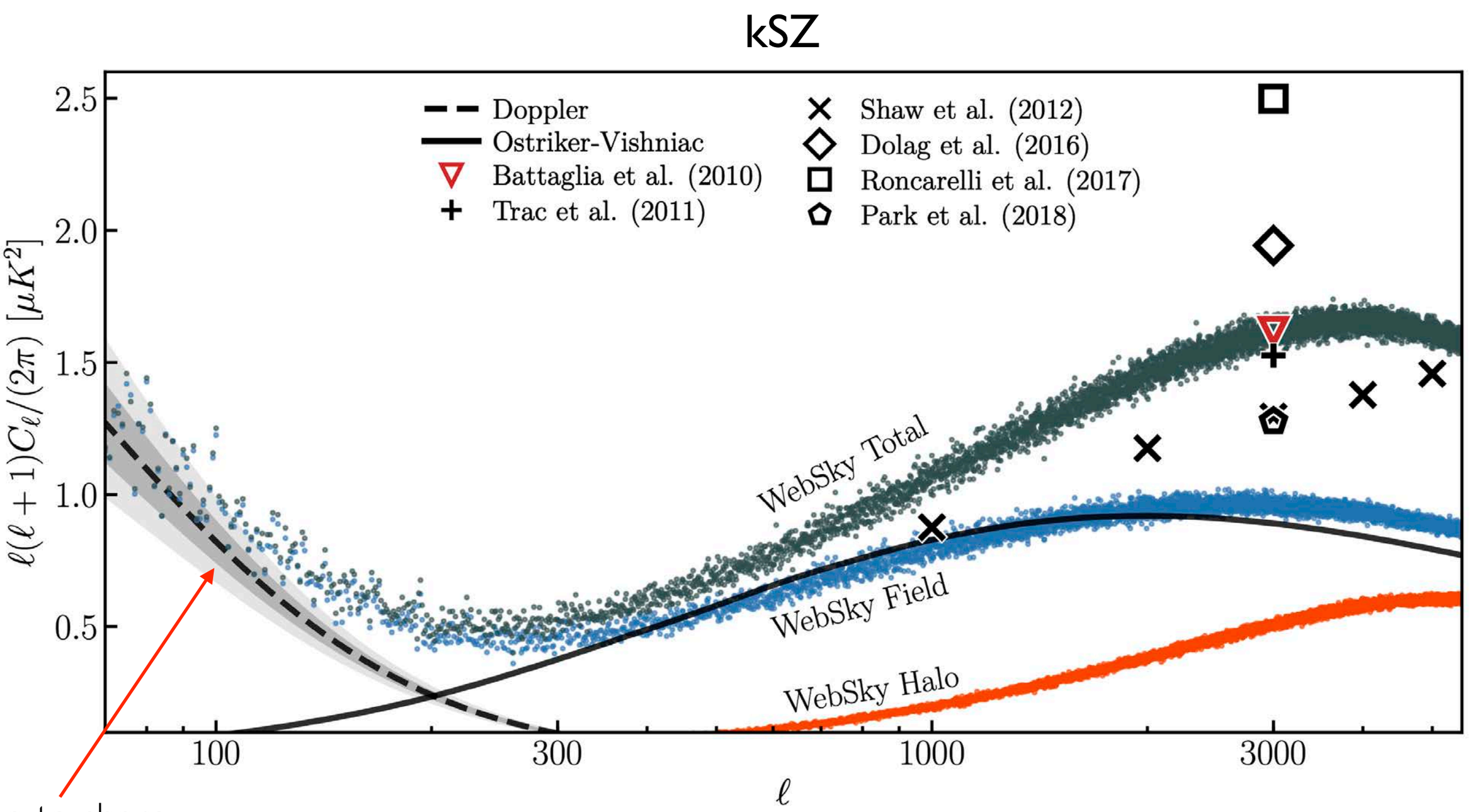
$\Phi(z)$ : normalization of the L-M relation
$\Sigma(M,z)$ : dependence of the luminosity on halo mass
$\Theta[(1+z)\nu, T_d(z)]$ : spectral energy distribution

# Validations: tSZ




- Matches well with Planck
- ~30% disagreement with ACT and SPT
  - small-scale suppression in the tSZ power?
  - systematic effects in the SPT and ACT measurements?
  - CIB fill in?

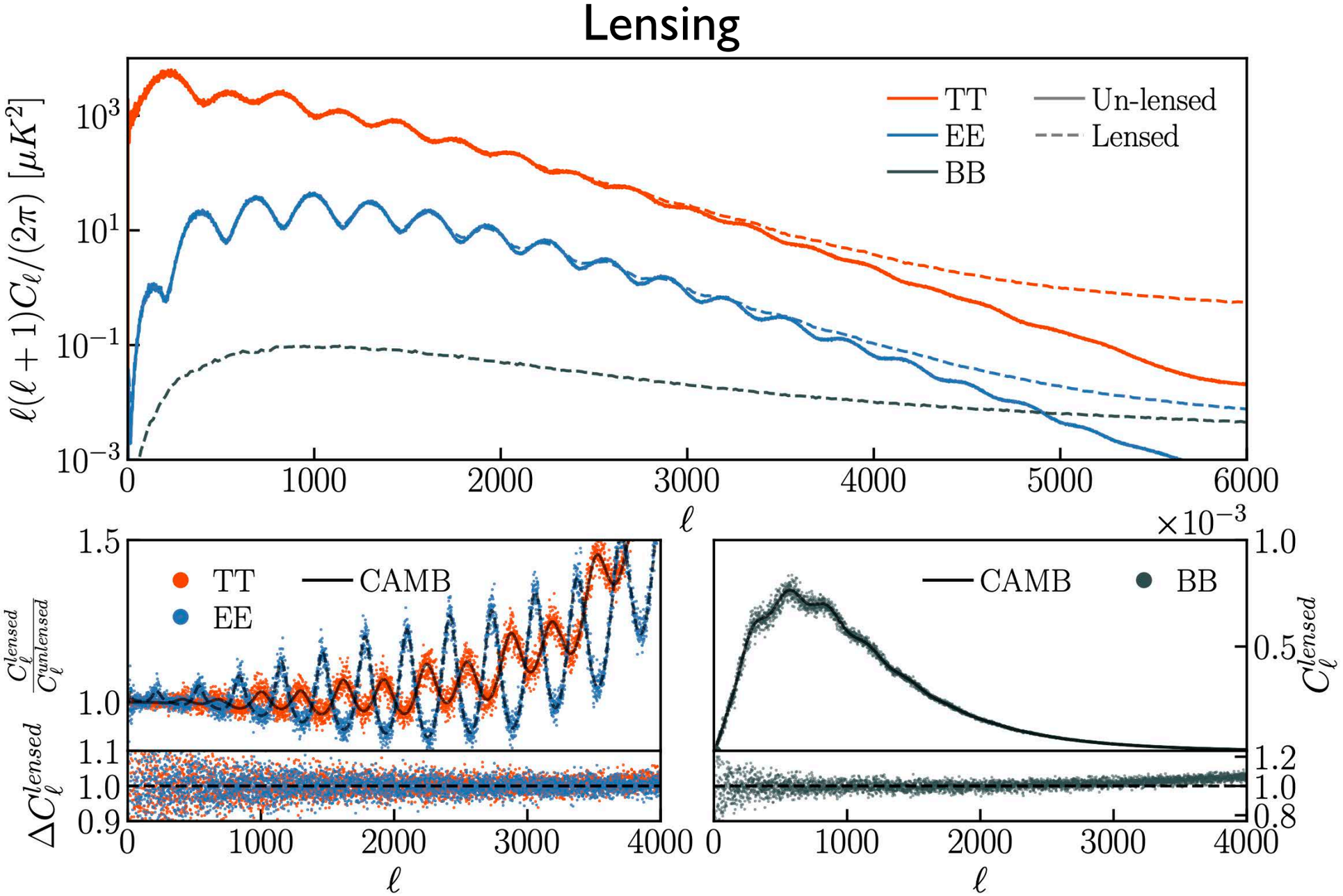
# Validations: kSZ




Due to sharp cutoff in structure at z=4.5

- Agrees with various hydrodynamical studies & theory
- Includes late-time contribution only. Early time kSZ can be added independently

# Validations: Weak Lensing

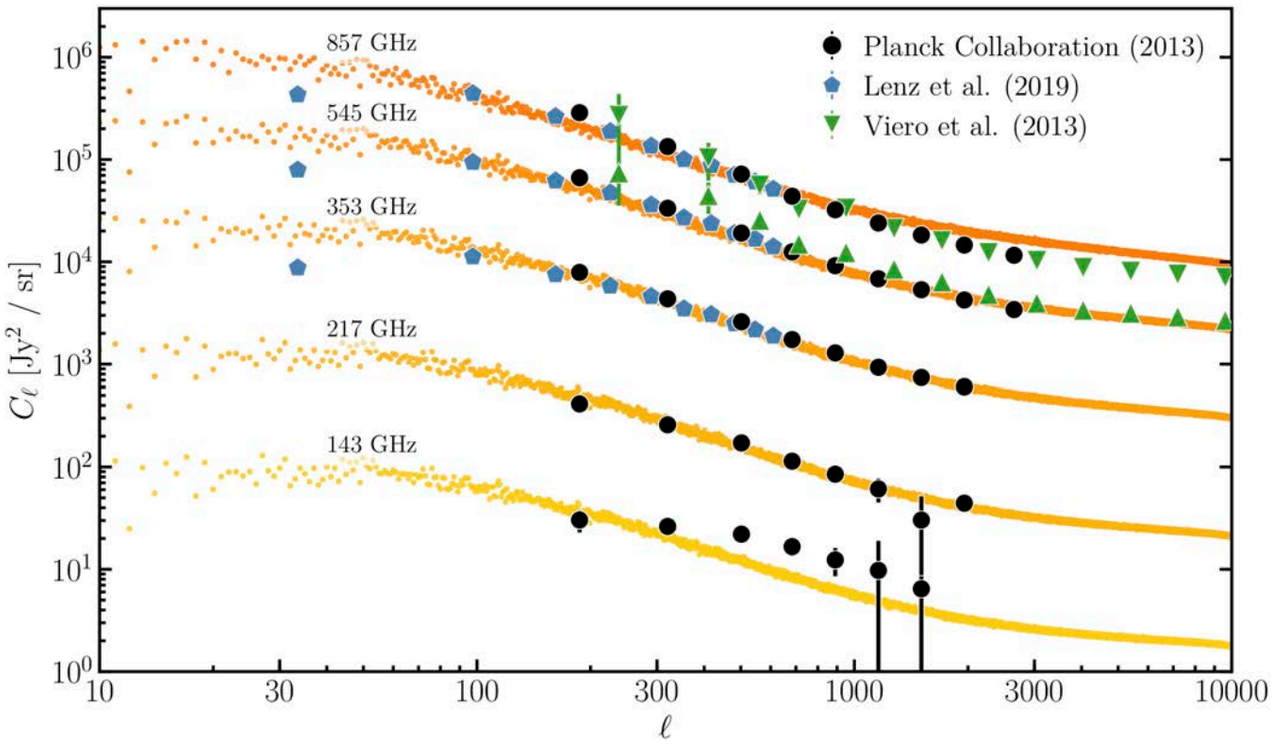



- Peak Smearing well reproduced
- r=0 in input CMB - feel free to lens your own with the convergence map provided

github.com/ajvanengelen/webskylensing

# Validations: CIB

## CIB Powerspectra




- Slight excess in small scale power at 857 GHz
  - $M_{h,min} \sim 1 \times 10^{12}\ M_\odot$

## CIB Decoherence

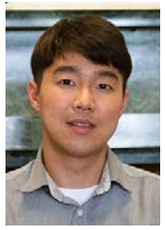
| | | 857 | 545 | 353 | 217 | 143 |
|---|---|---|---|---|---|---|
| 857 | *Websky* | 1 | $0.933 \pm 0.017$ | $0.882 \pm 0.021$ | $0.838 \pm 0.026$ | $0.802 \pm 0.032$ |
| | *Planck* | 1 | $0.949 \pm 0.005$ | $0.911 \pm 0.003$ | $0.85 \pm 0.05$ | |
| | *Lenz et al.* | 1 | $0.96 \pm 0.01$ | $0.91 \pm 0.01$ | $0.85 \pm 0.05$ | |
| 545 | *Websky* | ... | 1 | $0.960 \pm 0.014$ | $0.935 \pm 0.018$ | $0.9077 \pm 0.025$ |
| | *Planck* | ... | 1 | $0.983 \pm 0.007$ | $0.90 \pm 0.05$ | |
| | *Lenz et al.* | ... | 1 | $0.98 \pm 0.01$ | | |
| 353 | *Websky* | ... | ... | 1 | $0.968 \pm 0.014$ | $0.945 \pm 0.021$ |
| | *Planck* | ... | ... | 1 | $0.91 \pm 0.05$ | |
| | *Lenz et al.* | ... | ... | 1 | | |
| 217 | *Websky* | ... | ... | ... | 1 | $0.960 \pm 0.019$ |

**Table 1**. Frequency decoherence of the CIB measured by averaging $C_\ell^{\nu\nu'}/(C_\ell^{\nu\nu}C_\ell^{\nu'\nu'})^{1/2}$ over the range $150 < \ell < 1000$. Error bars correspond to the standard deviation in this range. We include the Planck measurements of [17] and the Lenz et al. measurements of [110].

- Frequency dependence not just an amplitude scaling

# non-Gaussianity of the CIB

Preliminary



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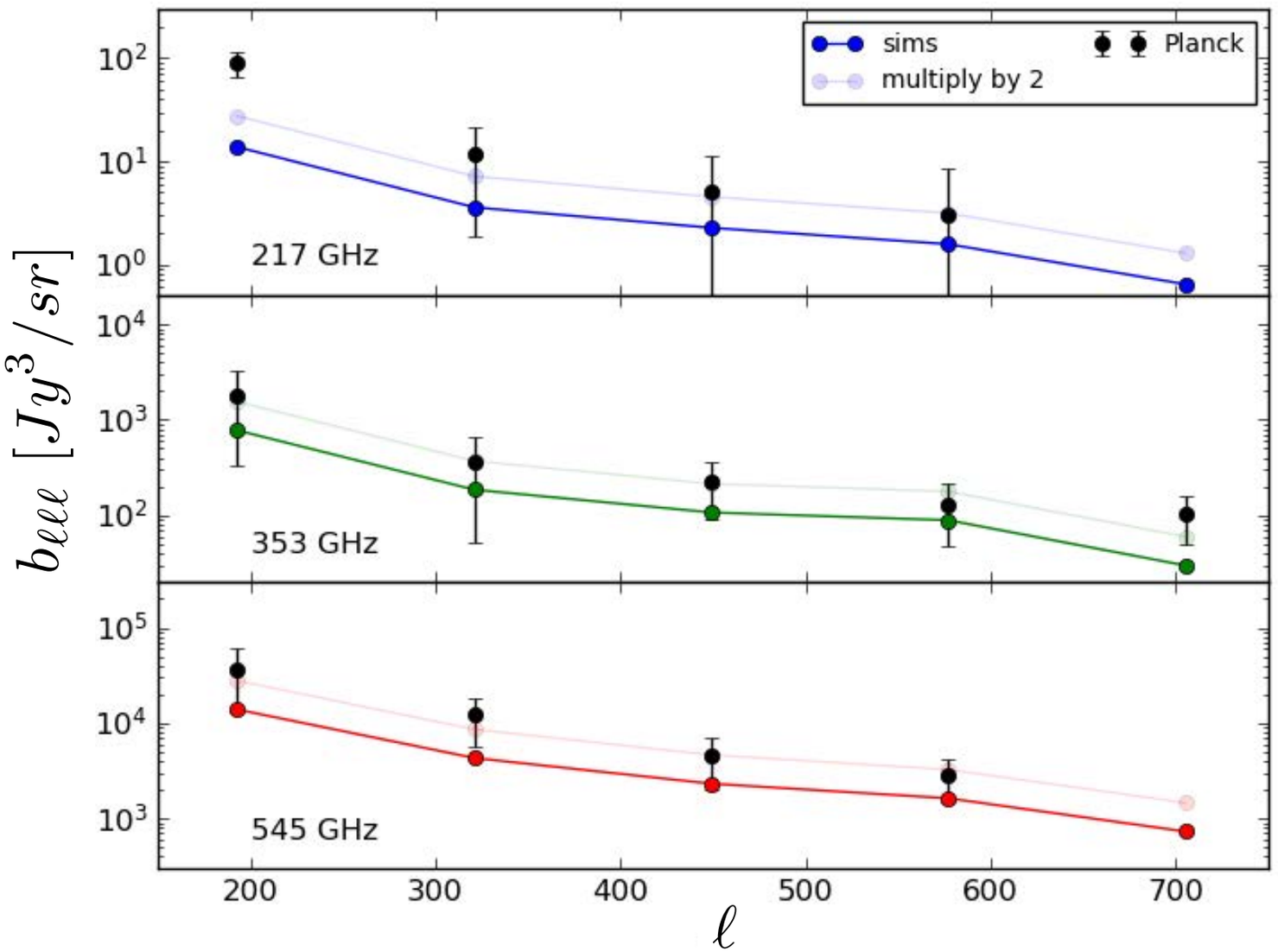
& the Webskiers



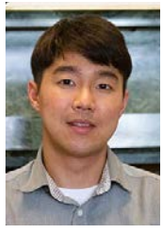

**Factor of 1.5-2** bispectrum discrepancy between Planck and Websky.

- **Stochasticity of CIB sources?**
- **Gravitational lensing of the CIB?**
- **Minimum halo mass of the simulations?**

# non-Gaussianity of the CIB

*Stochasticity*

Preliminary



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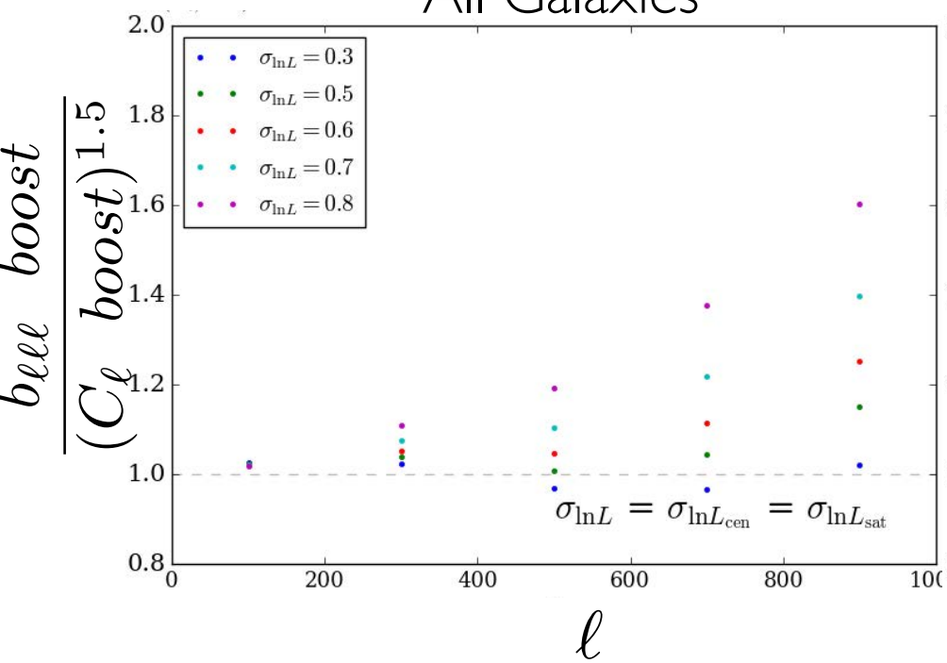
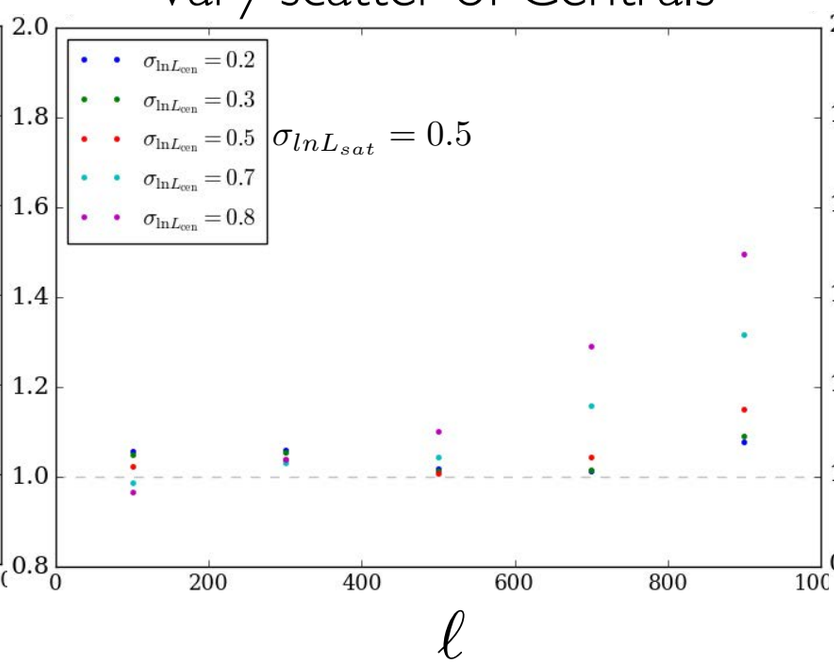
$L_0$: single free model parameter to scale all frequency maps by,
so no overall factor to change bispectrum without messing up power spectrum
$\rightarrow$ **Stochasticity of CIB sources?**
Physically motivated, L(M, z) $\rightarrow$ L(M, z, ….)

Add lognormal scatter: $L_{gal} \rightarrow L_{gal} \times \mathrm{e}^{\sigma_{lnL} \times \mathcal{N}(0,1)}$

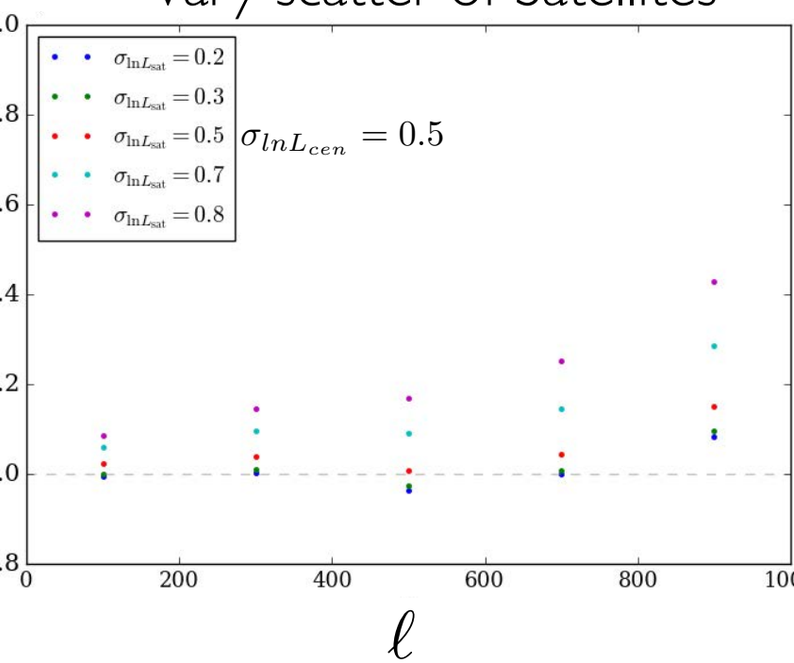
All Galaxies




Vary scatter of Centrals




Vary scatter of Satellites



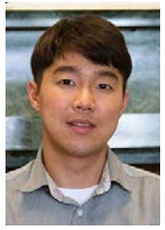

Can explain some of the difference between Planck and Websky., but not all

- mass dependent scatter?

# non-Gaussianity of the CIB

*Gravitational Lensing of the CIB*

Work in Progress



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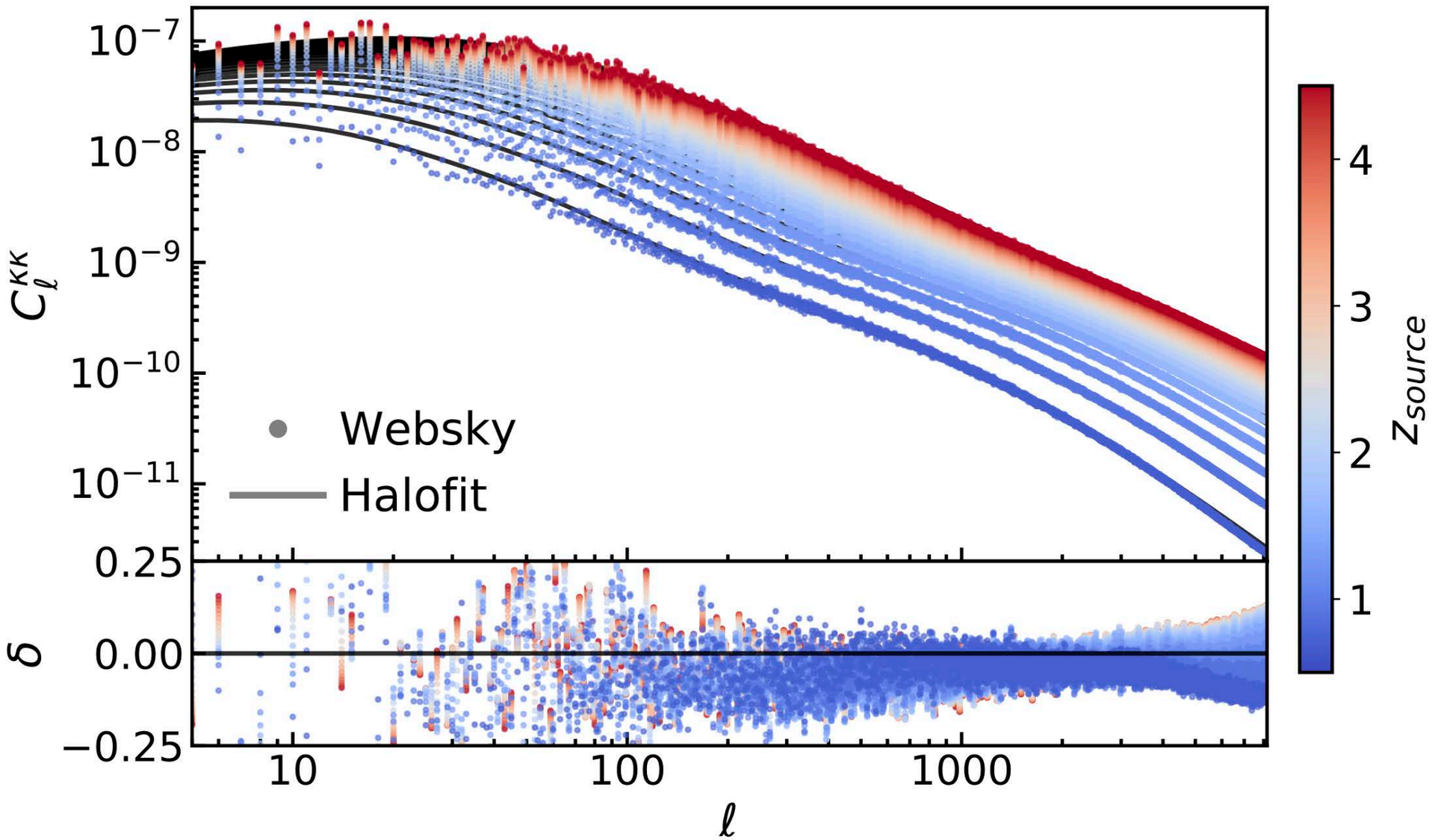
Are the Websky sims accurate enough to lens the CIB?



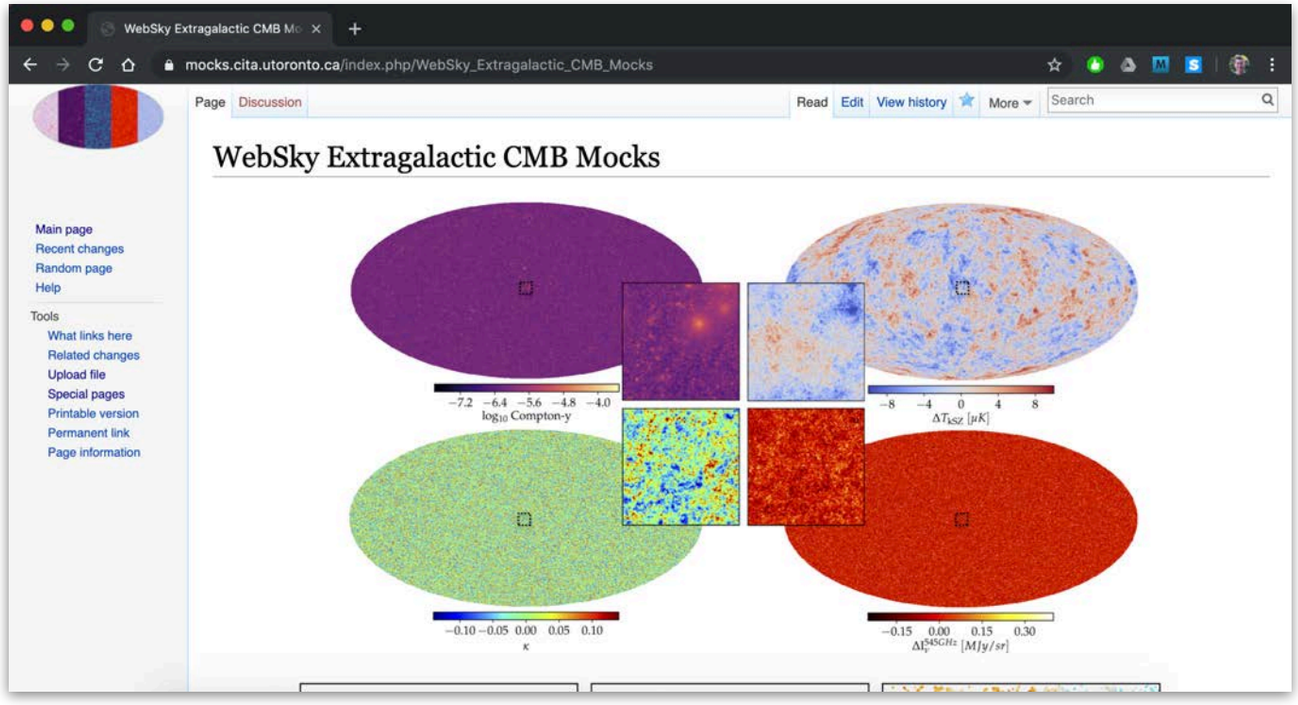

ongoing work, no CIB lensing to show yet

Post paper desires:

- Radio Galaxies
  - Zack Li github.com/xzackli/XGPaint.jl
- Galaxy (CIB) catalogues?
  - On disk at NERSC, available very soon
- Additional Realizations or cosmologies
  - In talk with Will & Daan about putting these together
- Nside > 4096
- anything else desired … ?

All data publicly available @

**mocks.cita.utoronto.ca**




or on NERSC @

**project/cmb/so_pysm_models_data/websky/0.3/**

Find the paper @

***2001.08787***

**The Websky Extragalactic CMB Simulations**

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Ask away @

***websky-cmb***