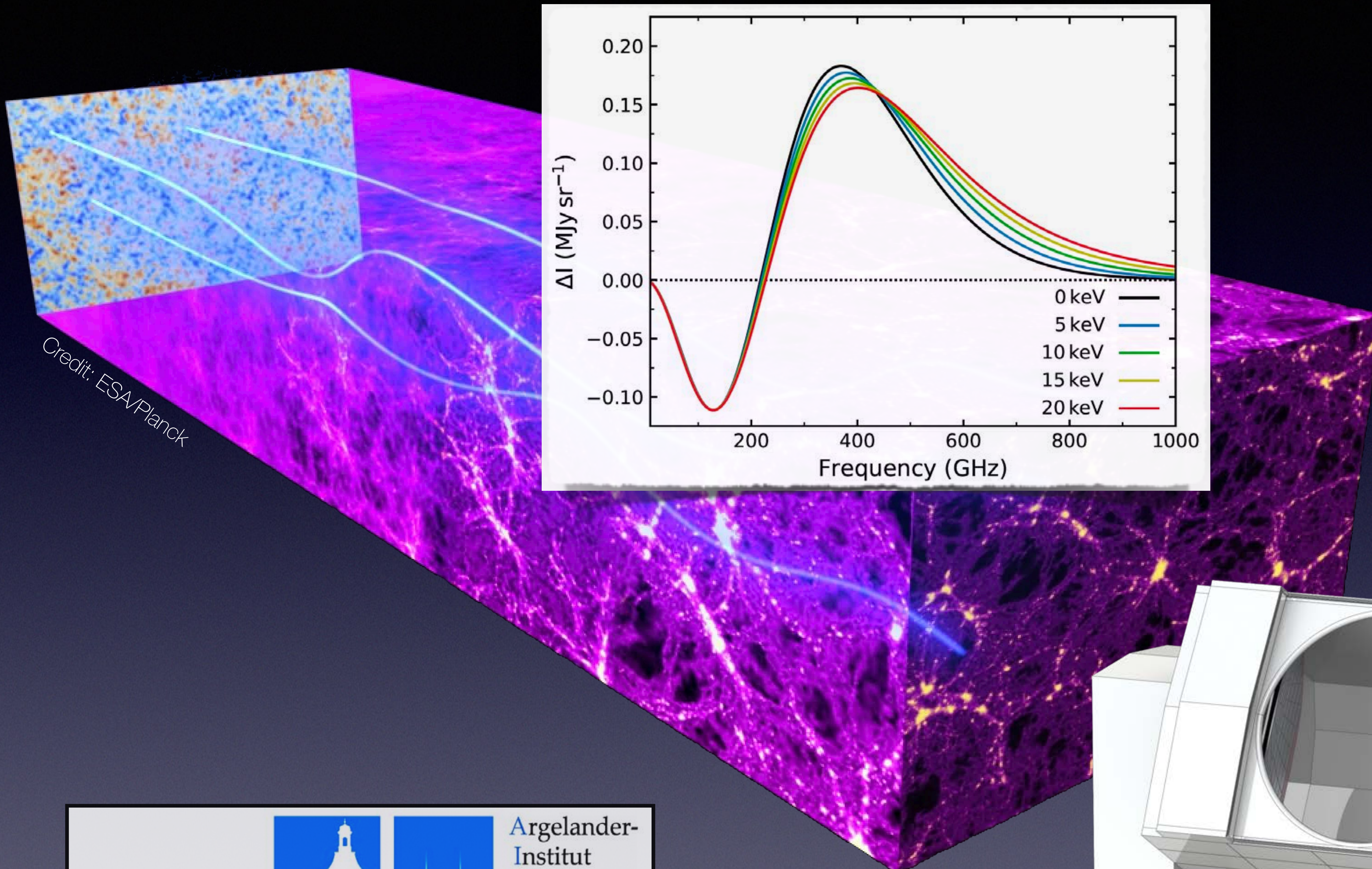
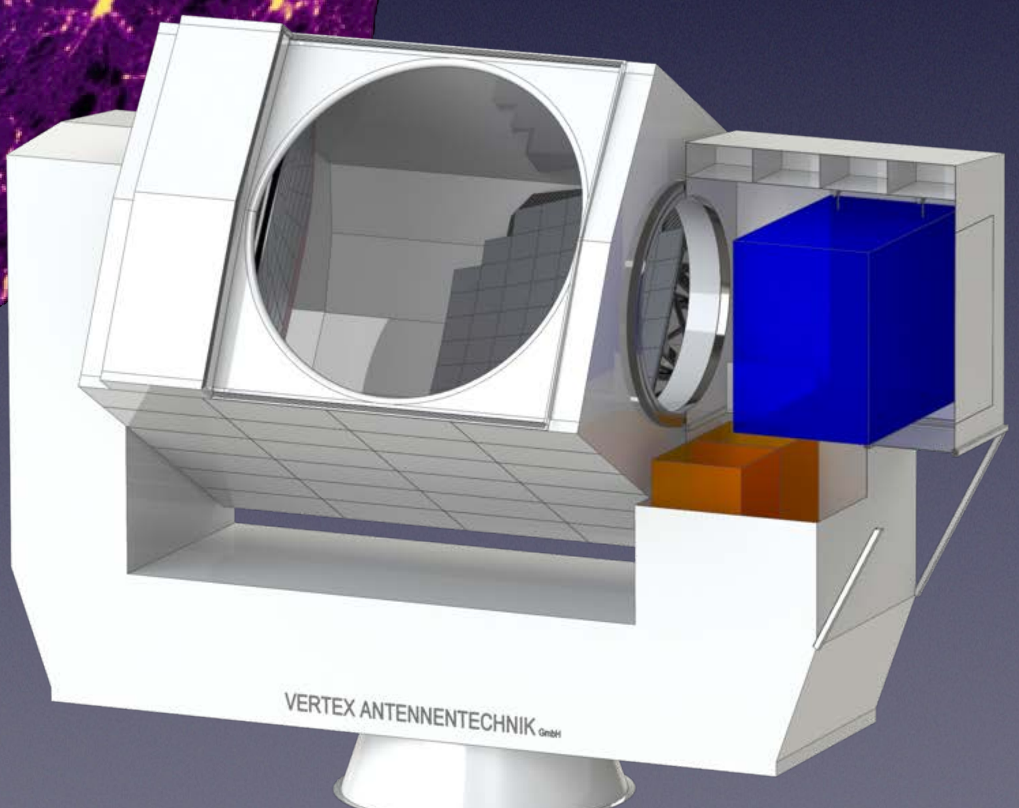
CCAT-prime & the quest for SZ Spectral Distortions





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Argelander-Institut für Astronomie

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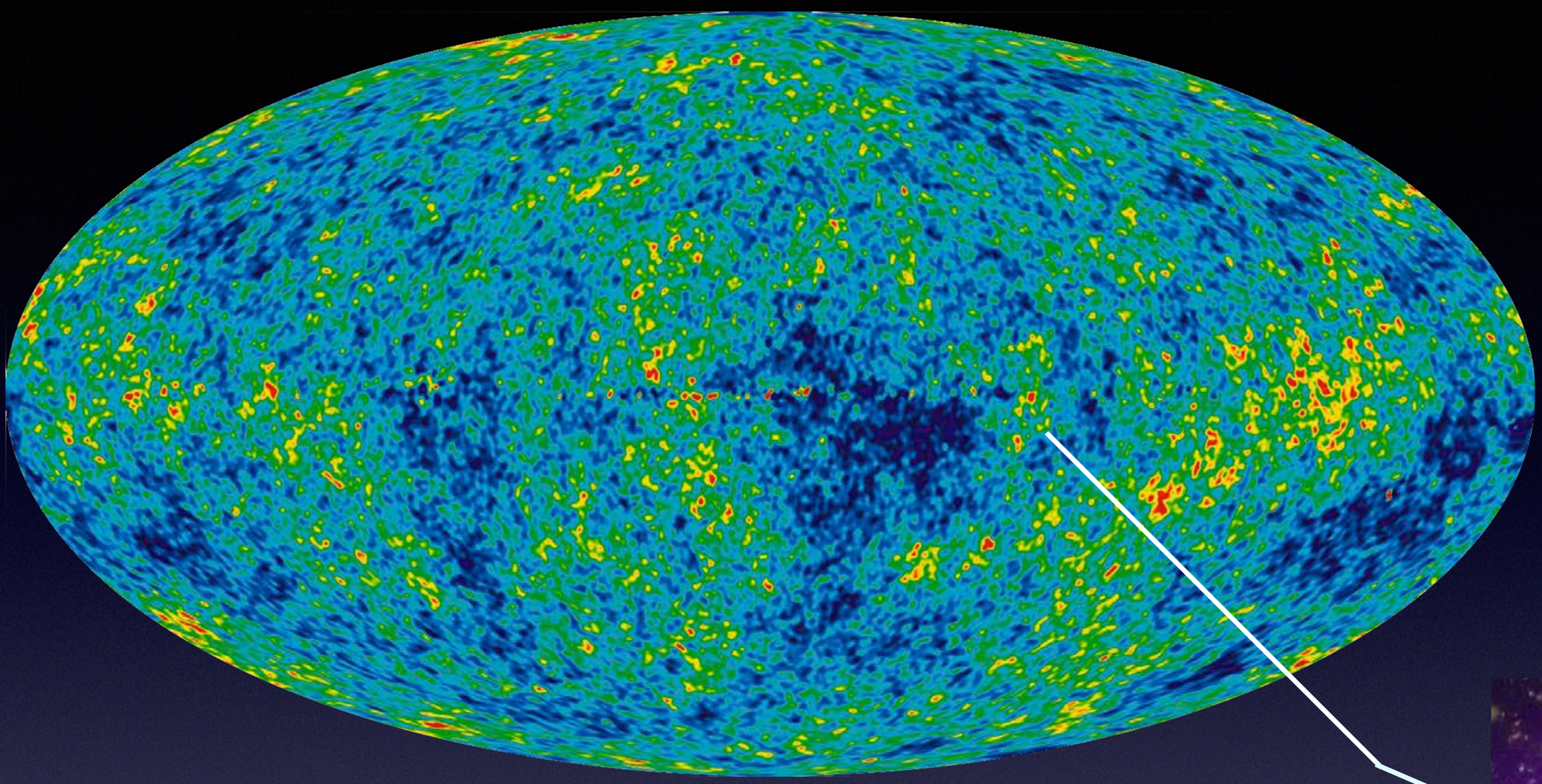
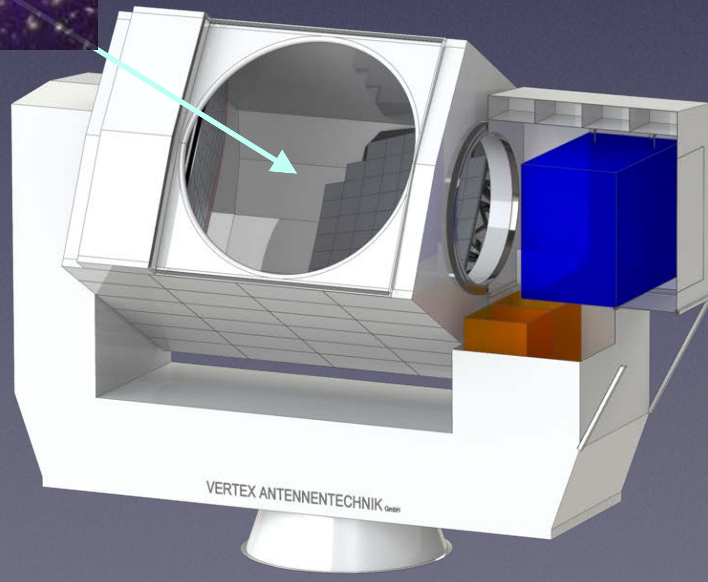
Maude Charmetant, Vyoma Muralidhara,
Rovina Pinto, Kevin Levy, Dominik Rhiem

CMB as a backlight: SZ effect



I. Lensing

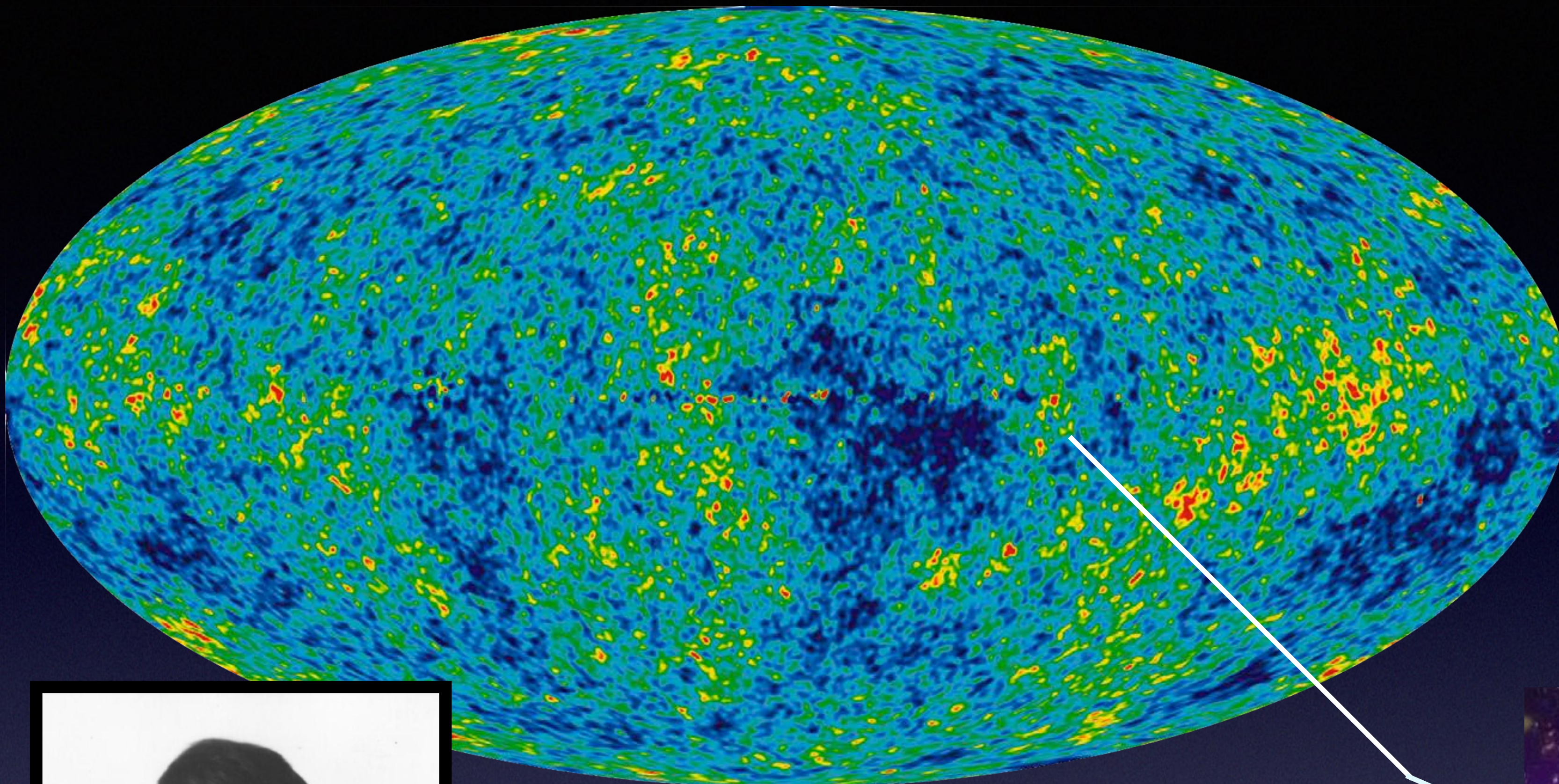
II. Scattering



CMB as a backlight: SZ effect

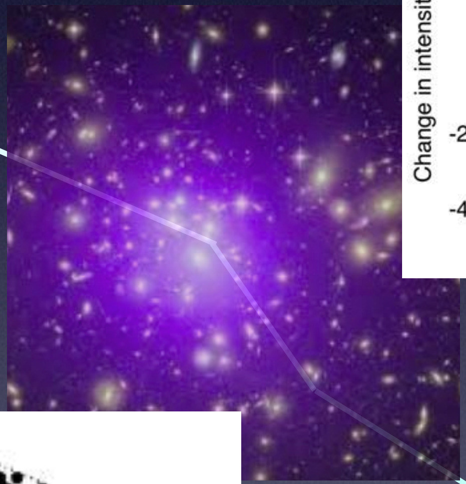
I. Lensing

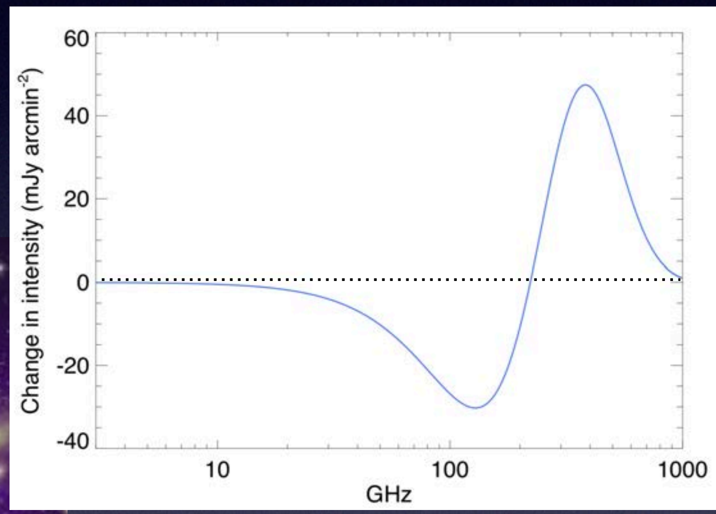
II. Scattering

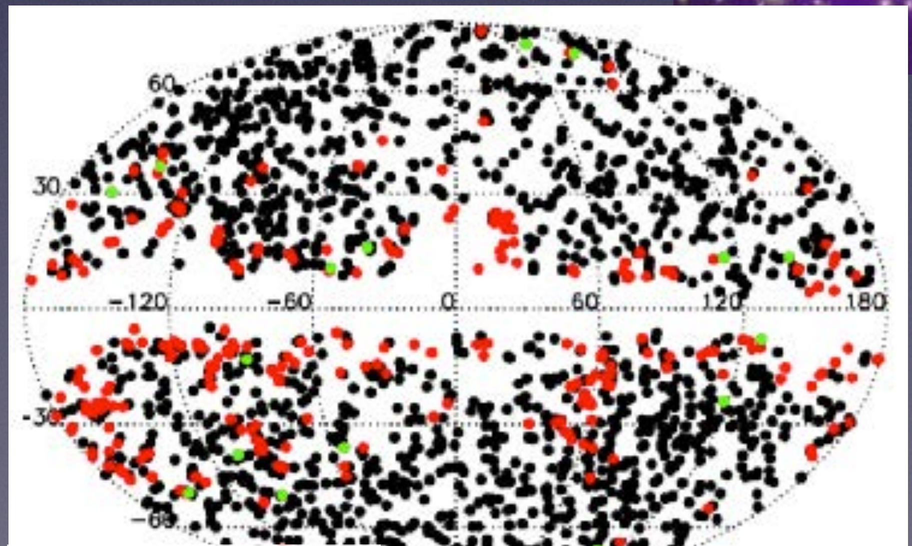


$$\frac{\Delta n}{n_0} = \frac{\Delta J}{J_0} = xy\,\frac{e^x}{e^x - 1}\left\{\frac{x}{\tanh(x/2)} - 4\right\}.$$

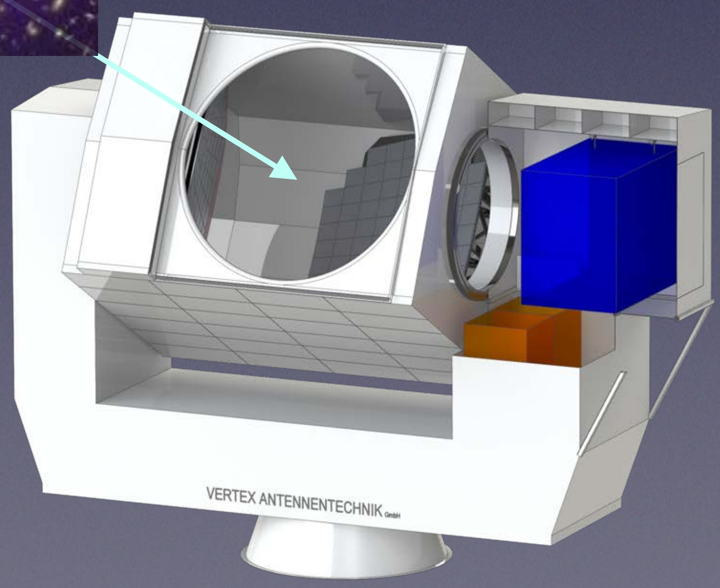
Sunyaev & Zeldovich, 1972







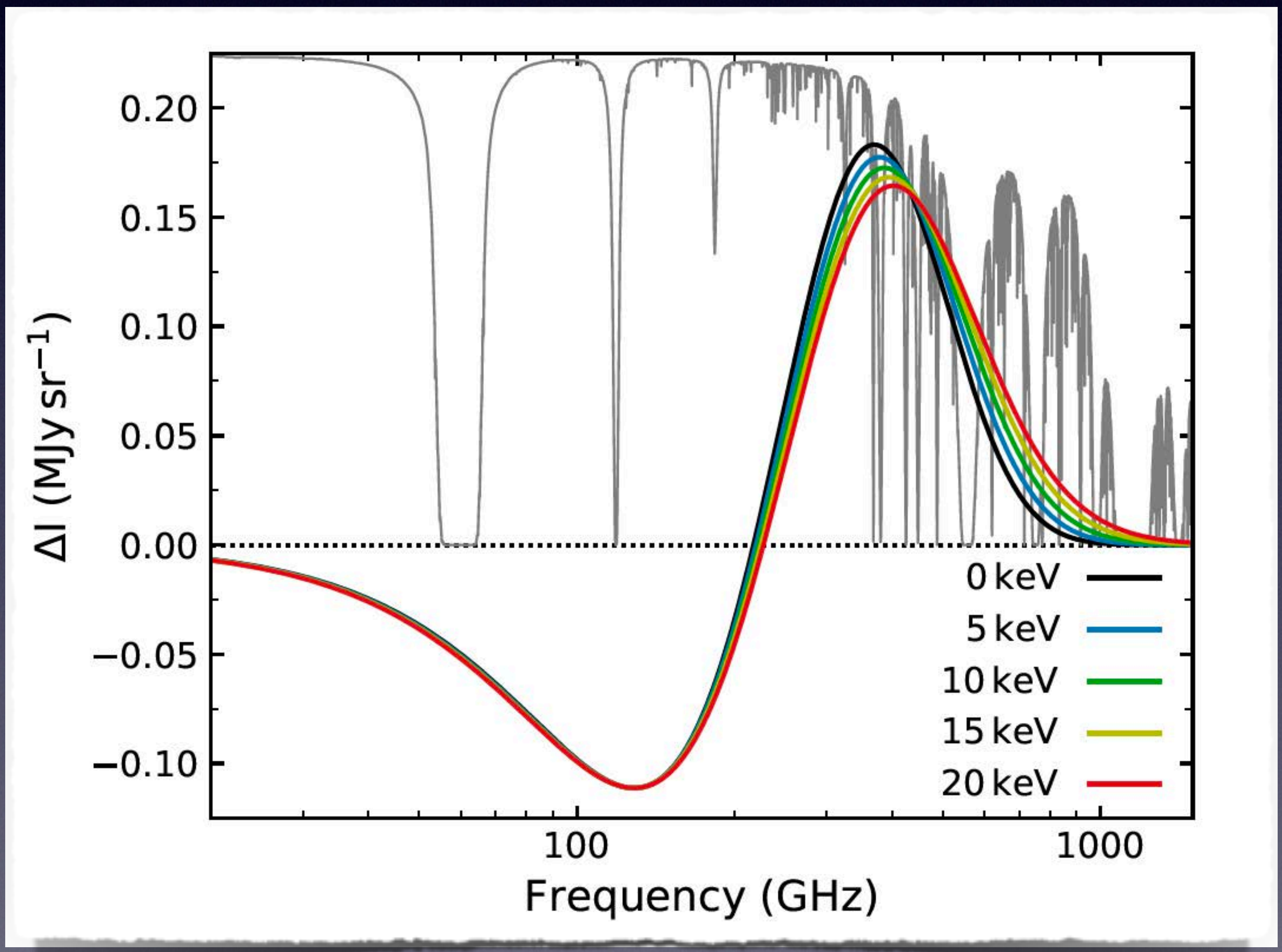
Planck/ESA

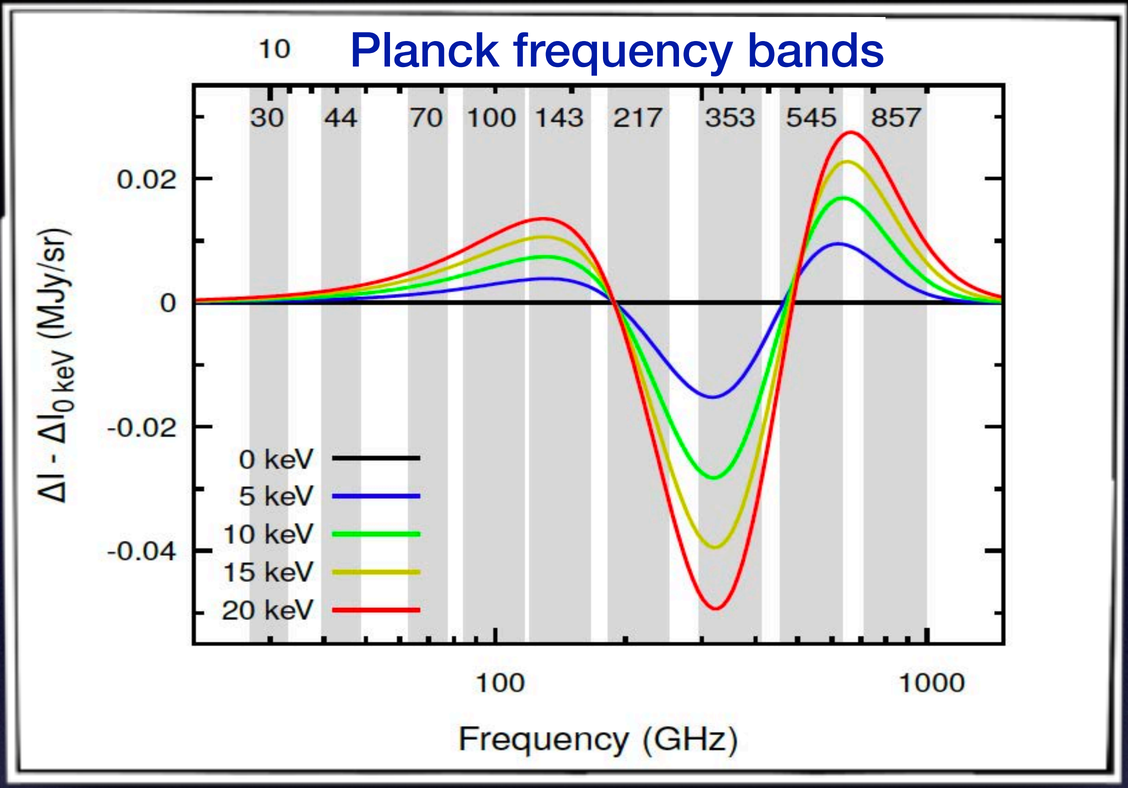


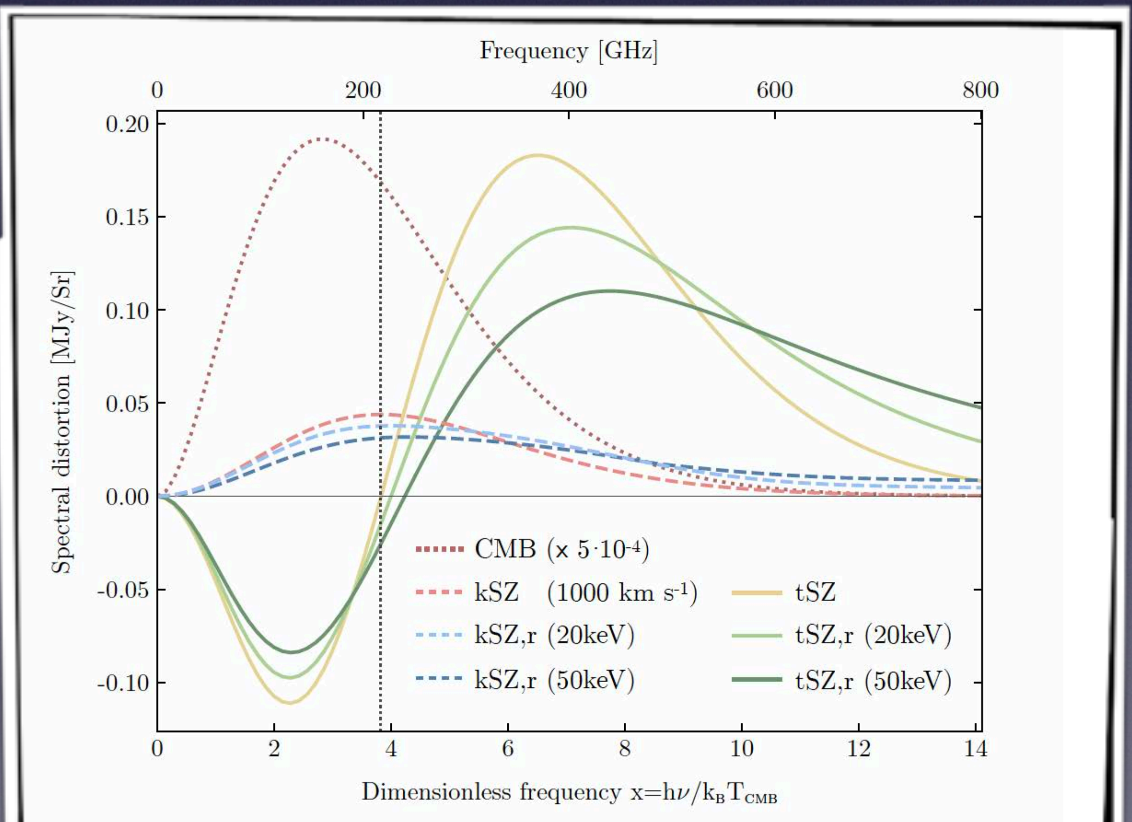
Relativistic SZ (rSZ) effect

For hot clusters with typical electron energy $kT_e \approx 5$ keV, the relativistic corrections to the SZ spectrum become significant.

$$f(x, T_e) = \left(x \frac{\exp(x)+1}{\exp(x)-1} - 4 \right) (1 + \delta_{SZE}(x, T_e))$$

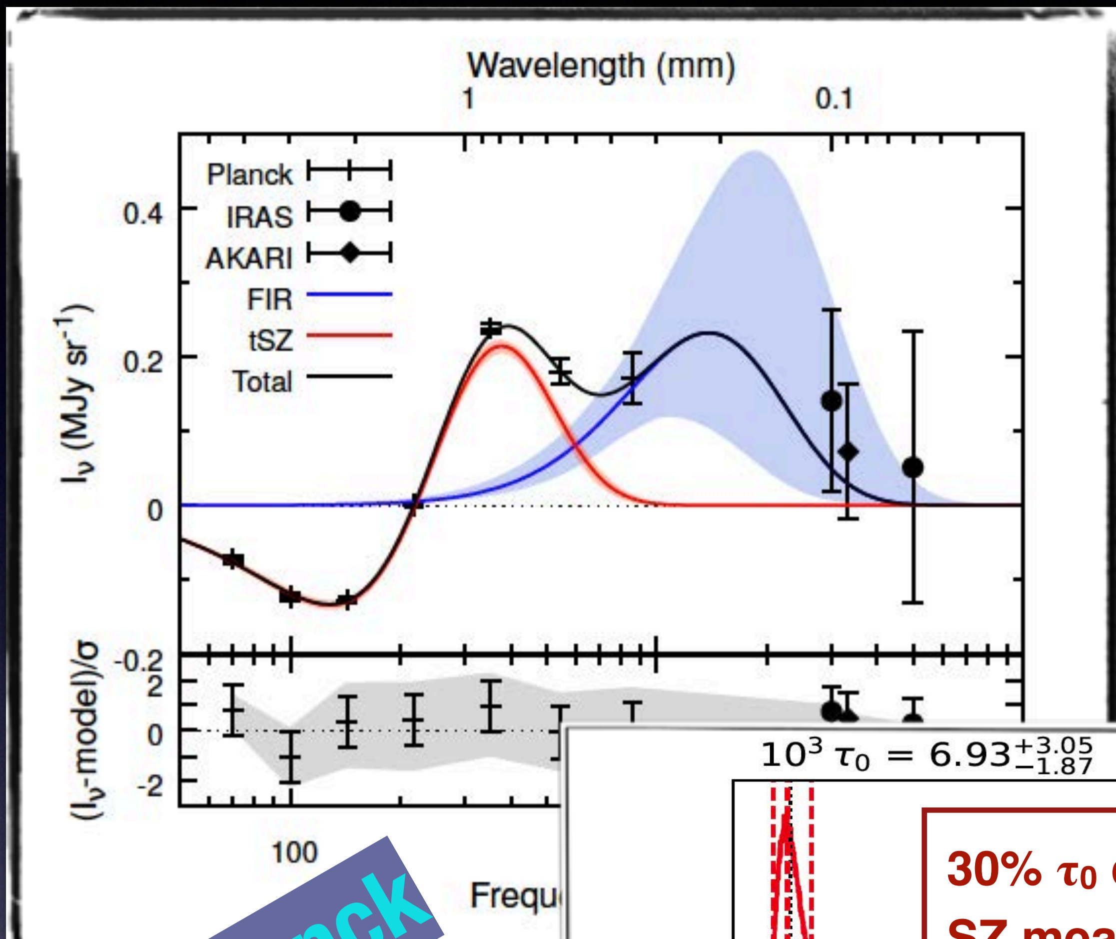


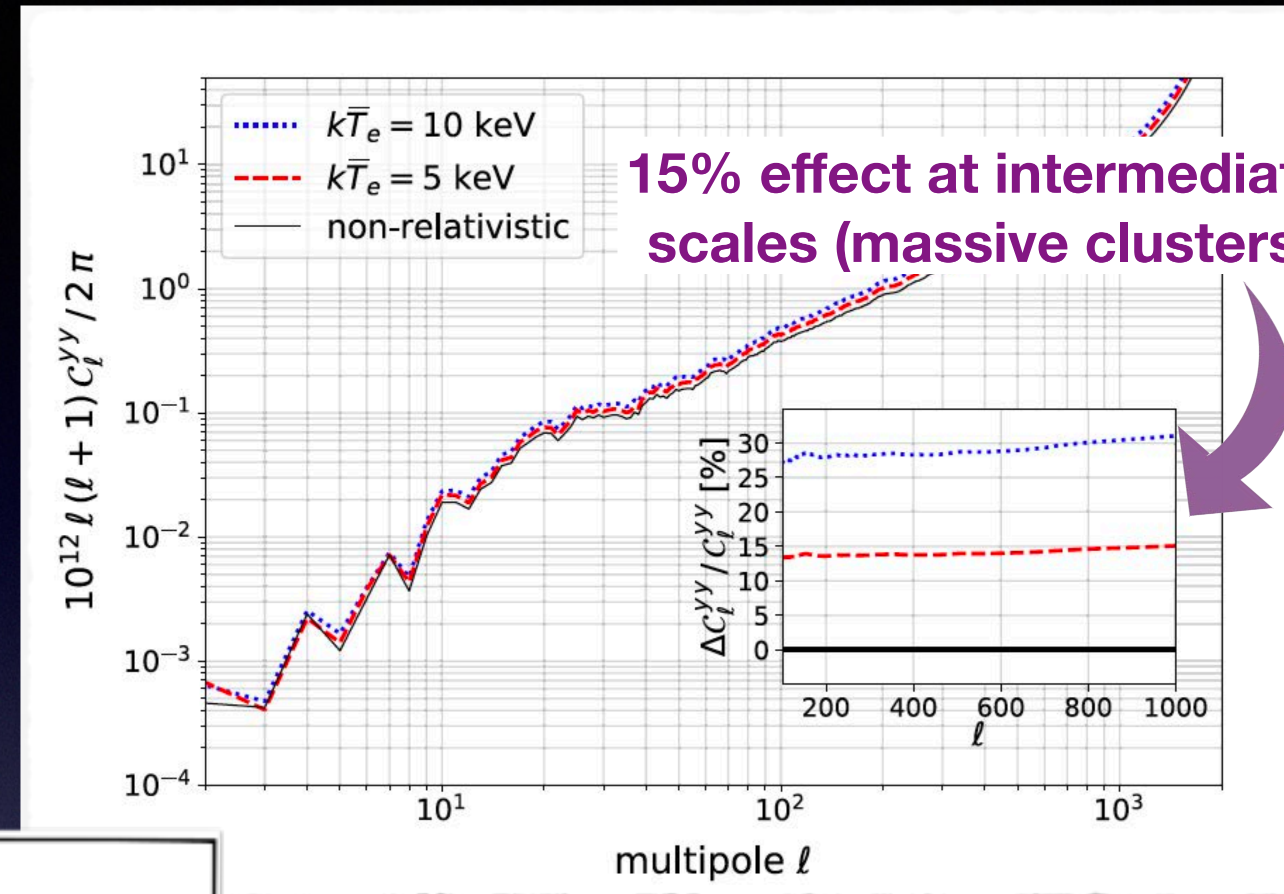




rSZ effect applications

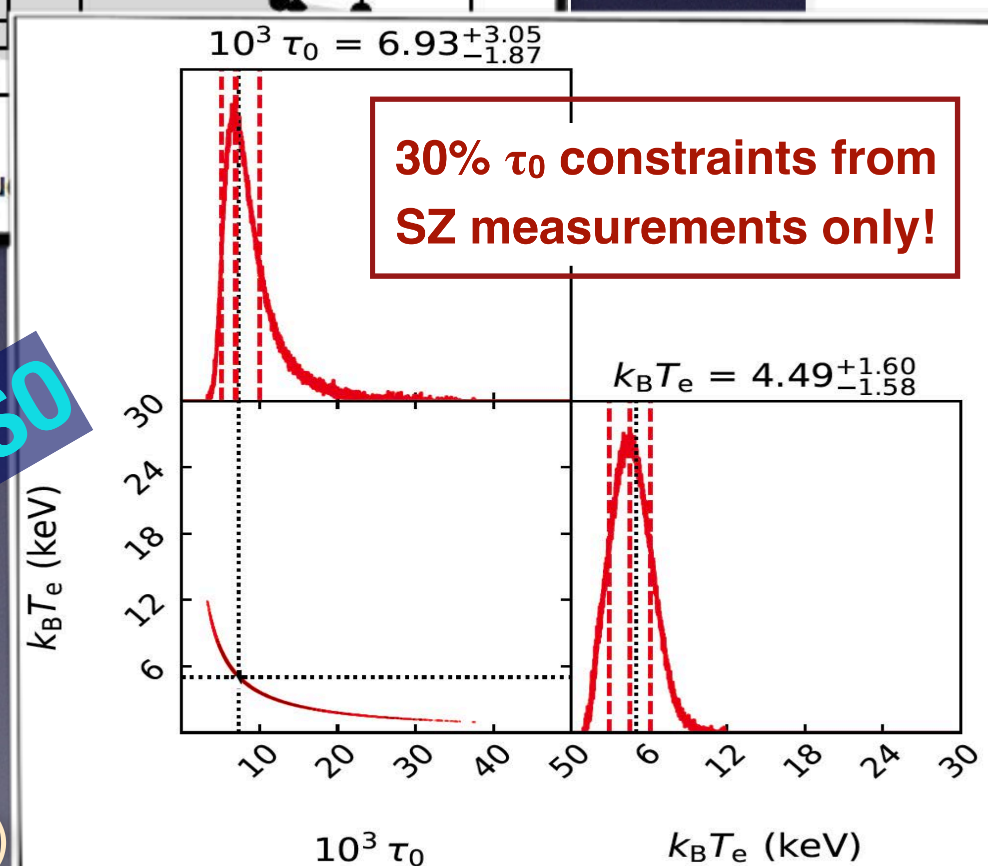
Erler et al. (2018) $k_B \langle T_{SZ} \rangle = 4.4^{+2.1}_{-2.0}$ keV





15% effect at intermediate scales (massive clusters)

rSZ corrections on the tSZ power spectrum (Remazeilles et al. 2019)

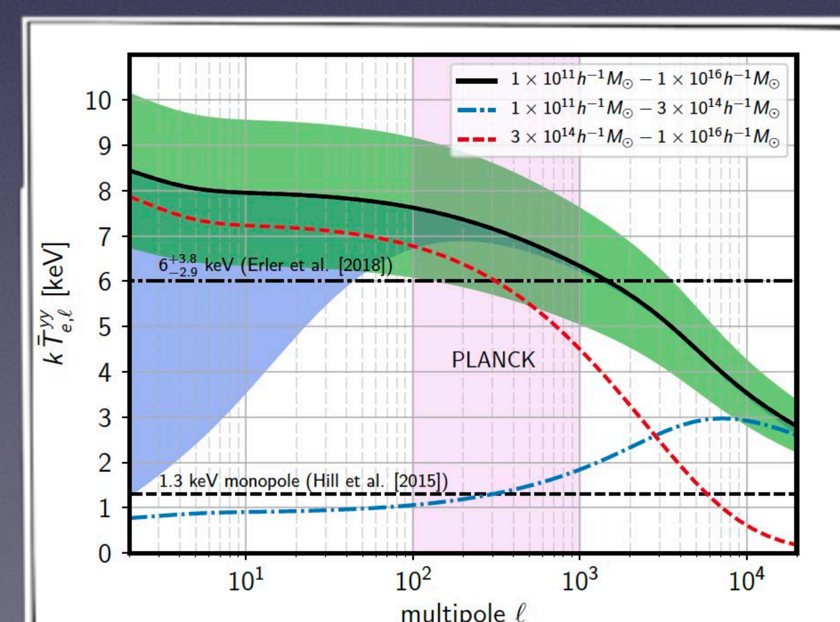


30% τ_0 constraints from SZ measurements only!

From Planck

From CCAT-p + SO

Erler et al. (in prep)

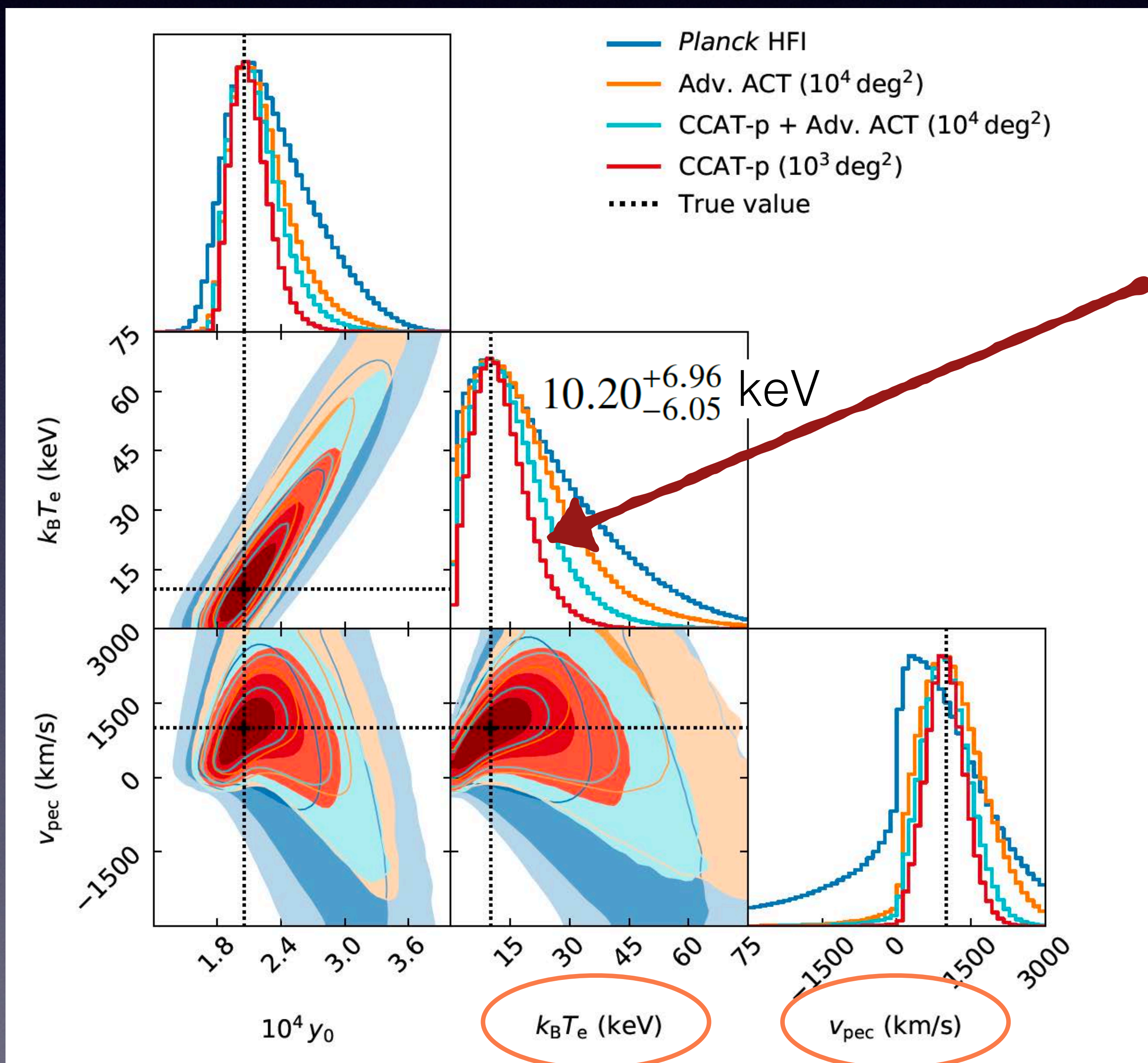


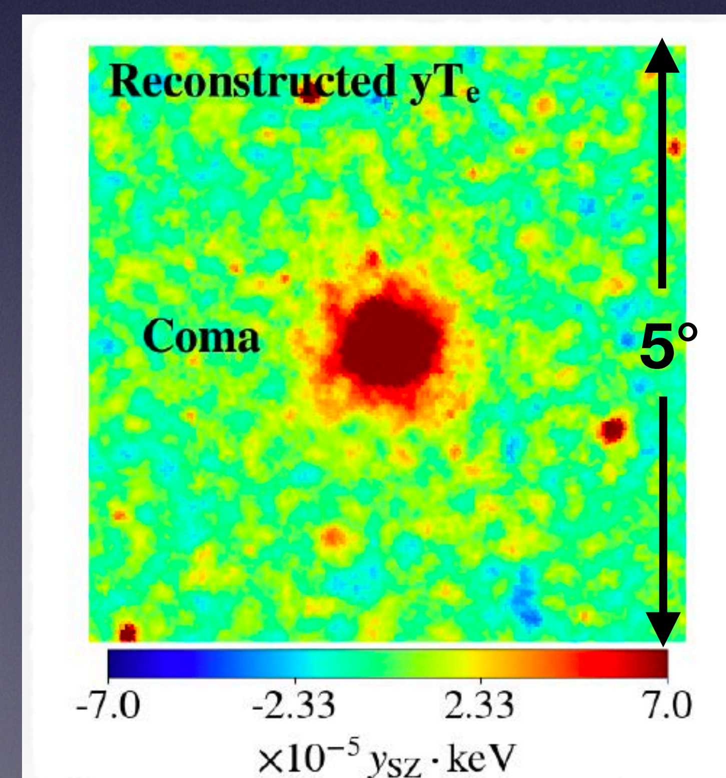
rSZ for CCAT-prime First-Light

We stand a very good chance to measure the rSZ-derived temperature in a single cluster for the first time!

This was prediction for CCAT-p-only 1k sq deg survey, for 4000 hours
= 25 sq deg in 100 hours

Ideal for imaging one massive cluster



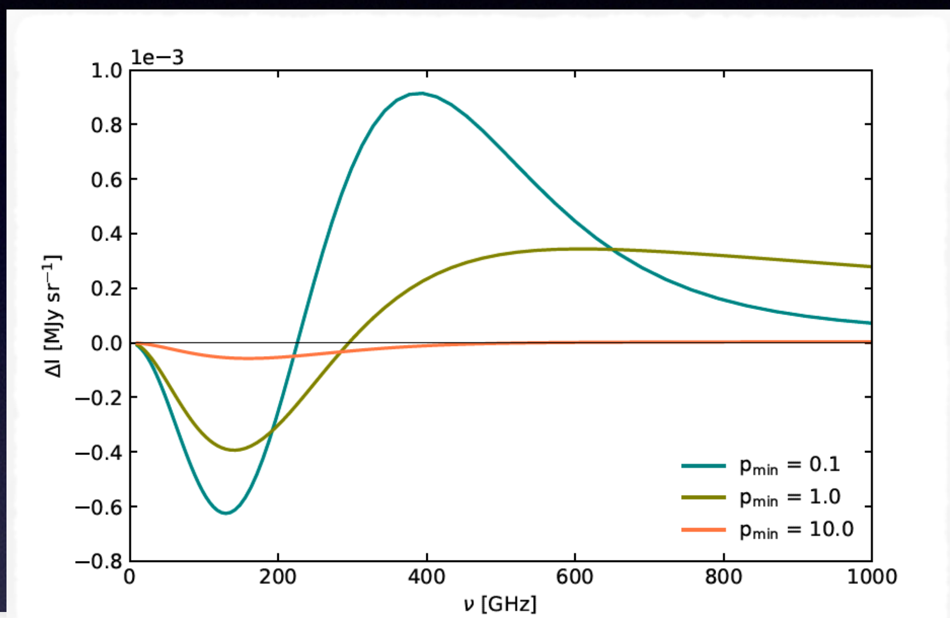


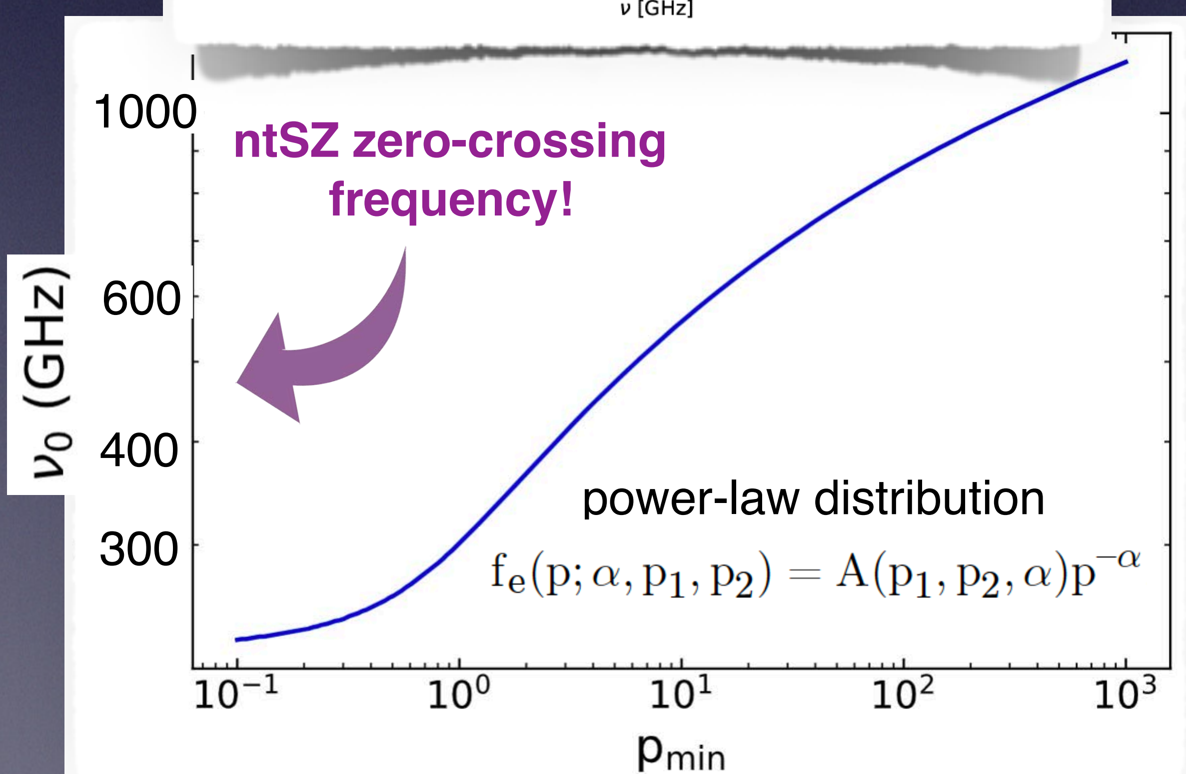
Prediction for Coma cluster temperature reconstruction with future PICO data (Remazeilles & Chluba 2019)

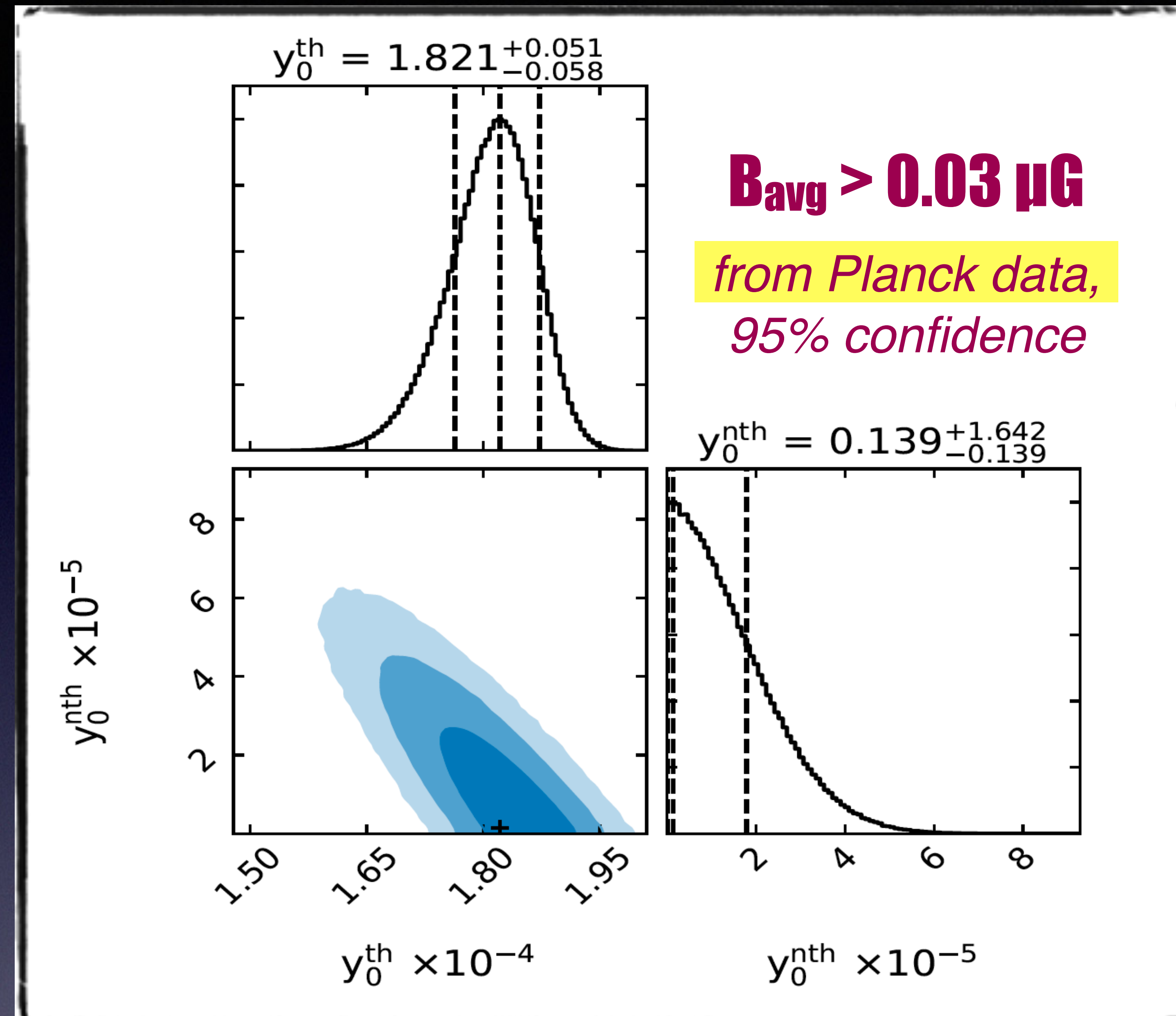
Nonthermal (ntSZ) effect: A new frontier

CMB photons will also scatter off other sources of free electrons, e.g. power-law distribution with a high-energy tail

but in clusters it is ≲1% of the tSZ signal 🙁





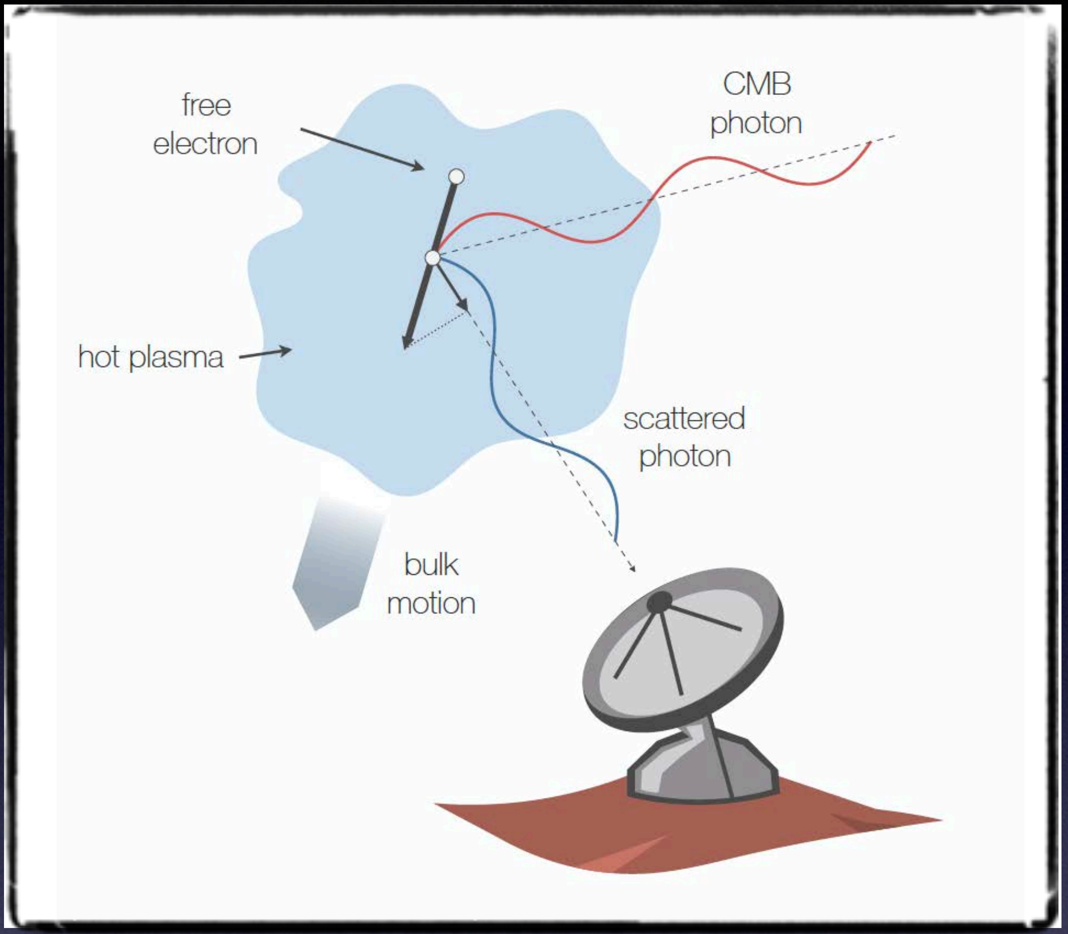


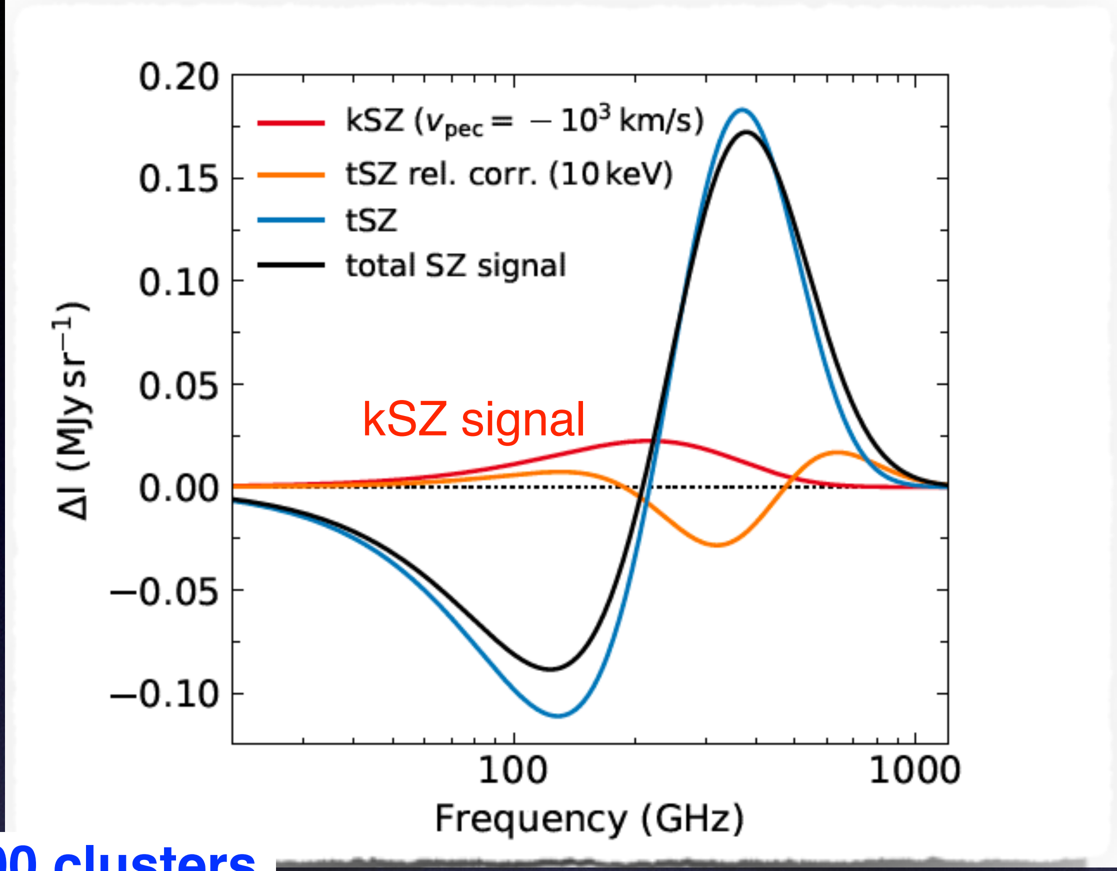
Muralidhara et al. (in prep)

With CCAT-prime and SO, order-of-magnitude better constraints on ntSZ-based B-field limits can be expected in the next ~5 years

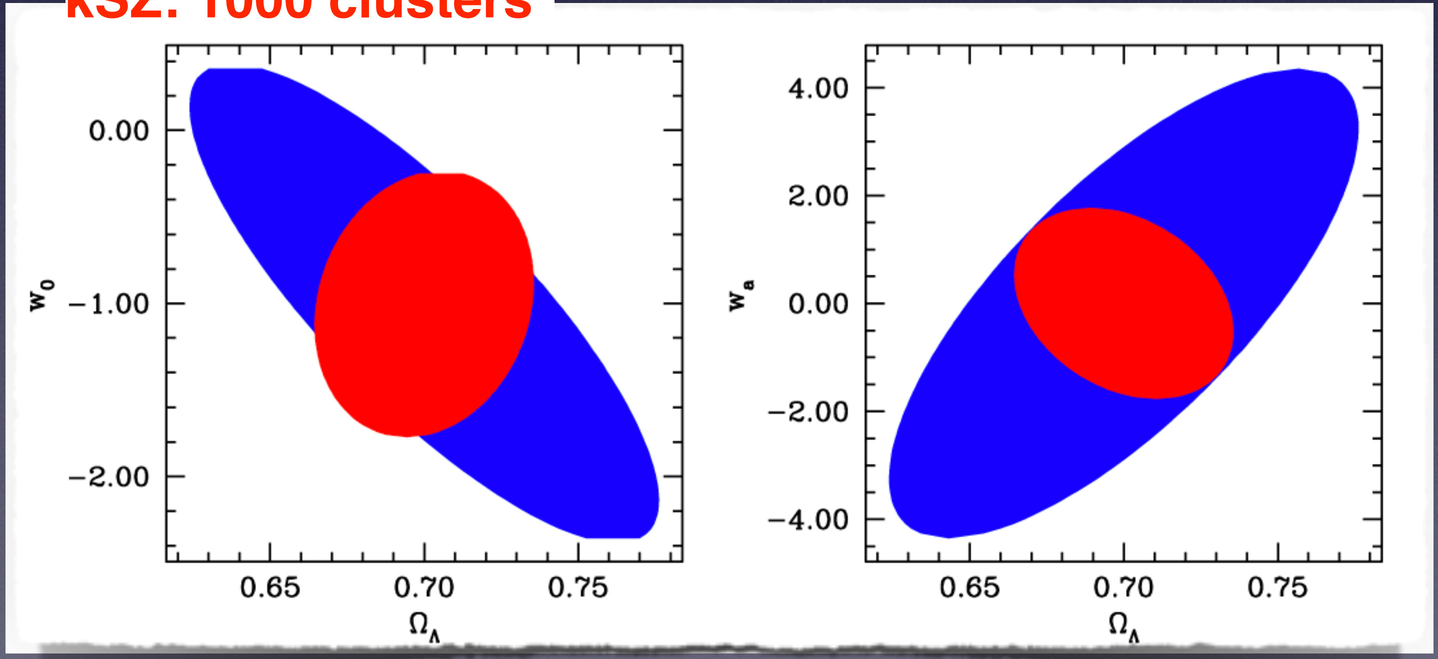
The kinematic SZ (kSZ) effect

Mroczkowski et al. (2019)





tSZ : 4000 clusters
kSZ: 1000 clusters

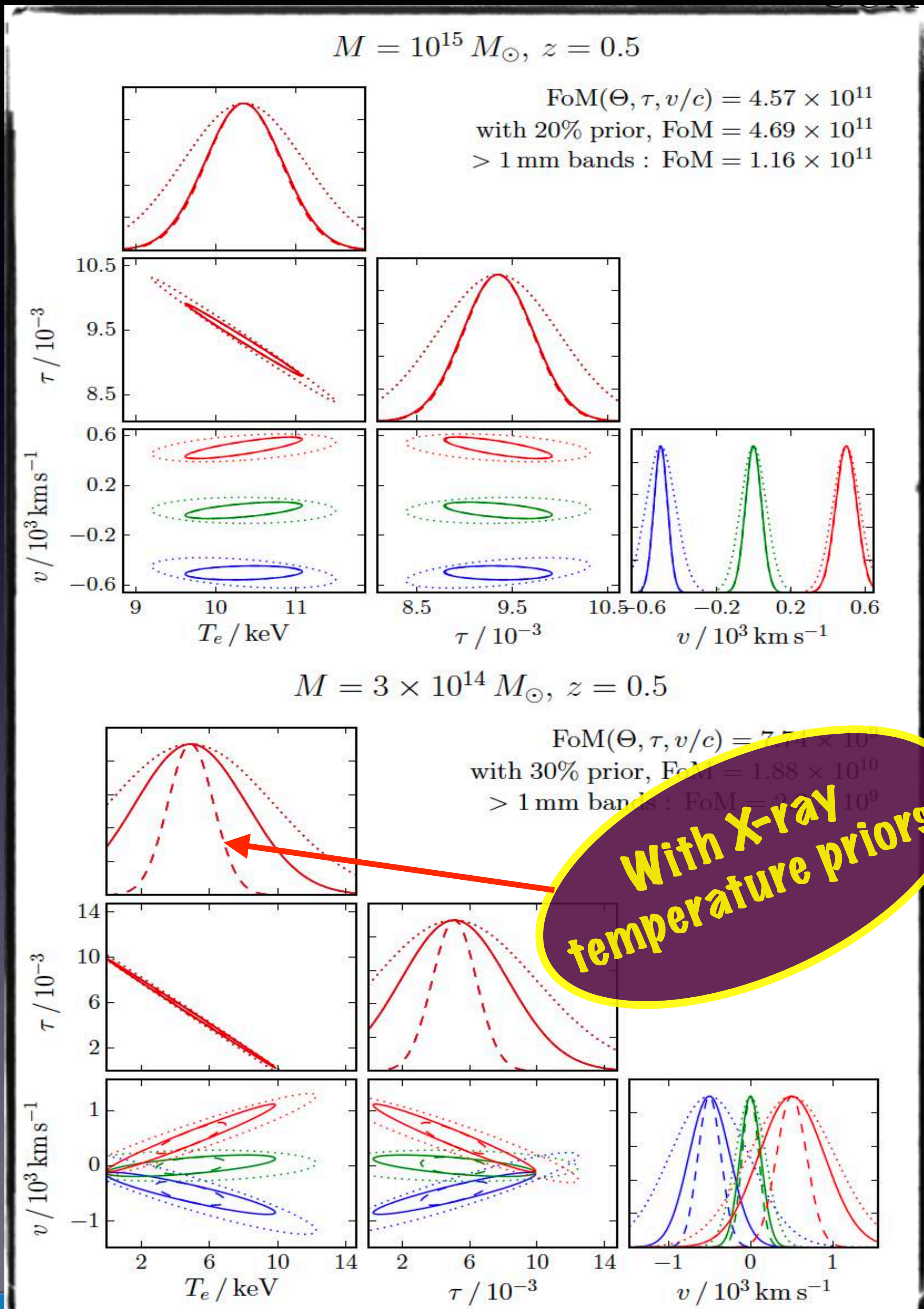


kSZ provides estimates for the **peculiar velocities**, and in the limit of the linear perturbation theory, directly the **growth rate**

$$\vec{v}(\vec{k}) = i \frac{d \ln D}{d \ln a} \frac{aH\delta(\vec{k})\vec{k}}{k^2}$$

Dark energy parameter constraints from a CCAT 25m-like survey, with σ_v=100 km/s (adapted from Bhattacharya & Kosowsky 2008)

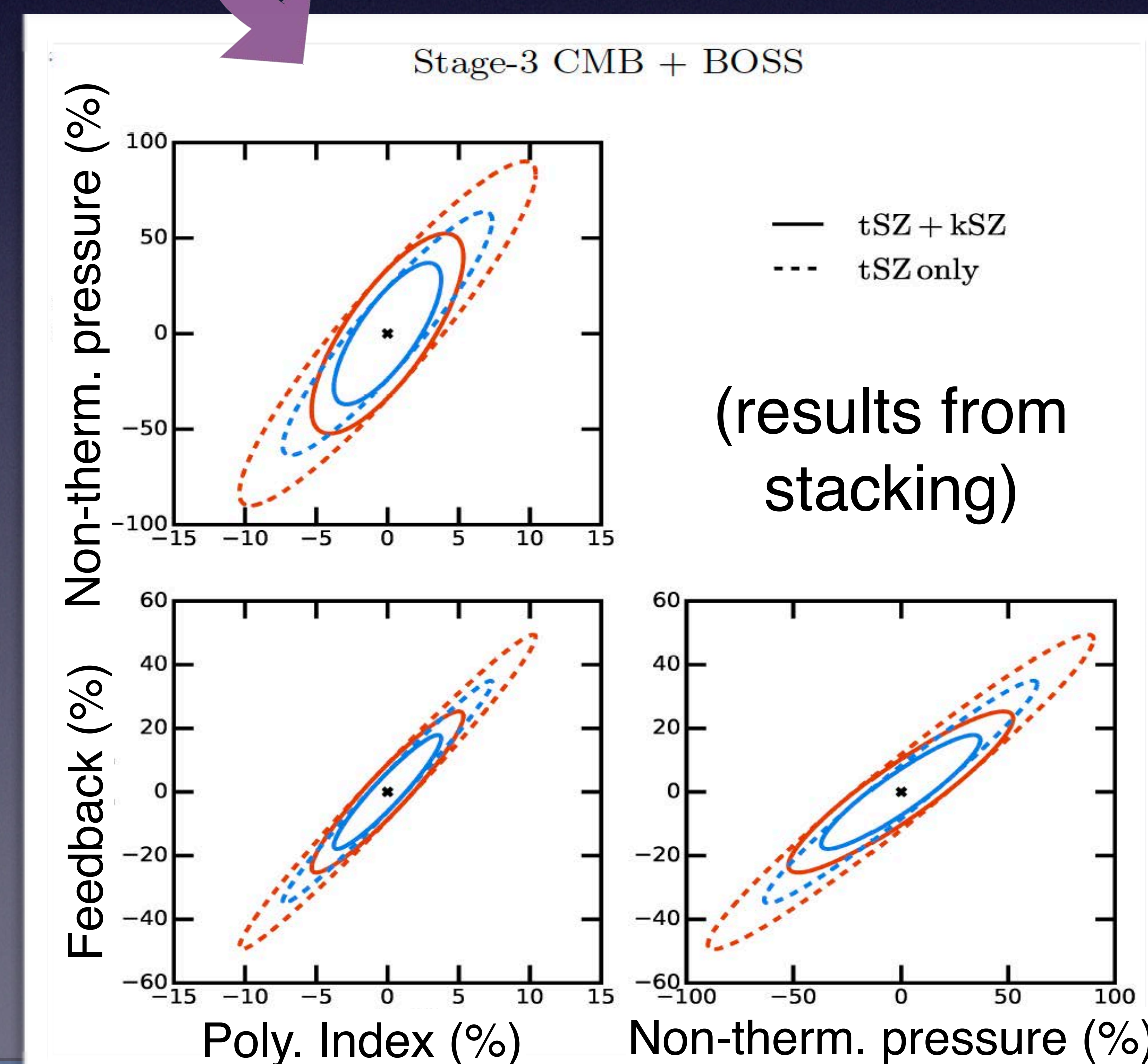
kSZ with CCAT-prime



CCAT-prime predictions by **Mittal et al. (2018)**

kSZ measurements in the near future will not only constrain cosmology, but also **search for the missing baryons (Maude's talk)**, and inform about feedback processes in galaxy evolution

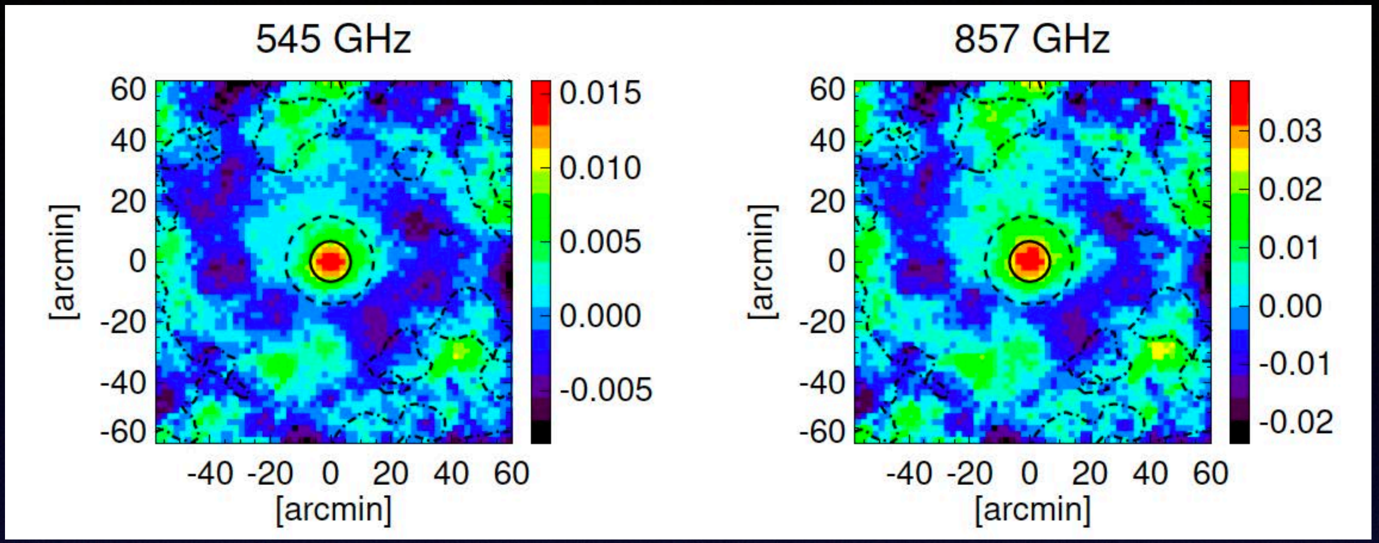
Battaglia et al. (2017)



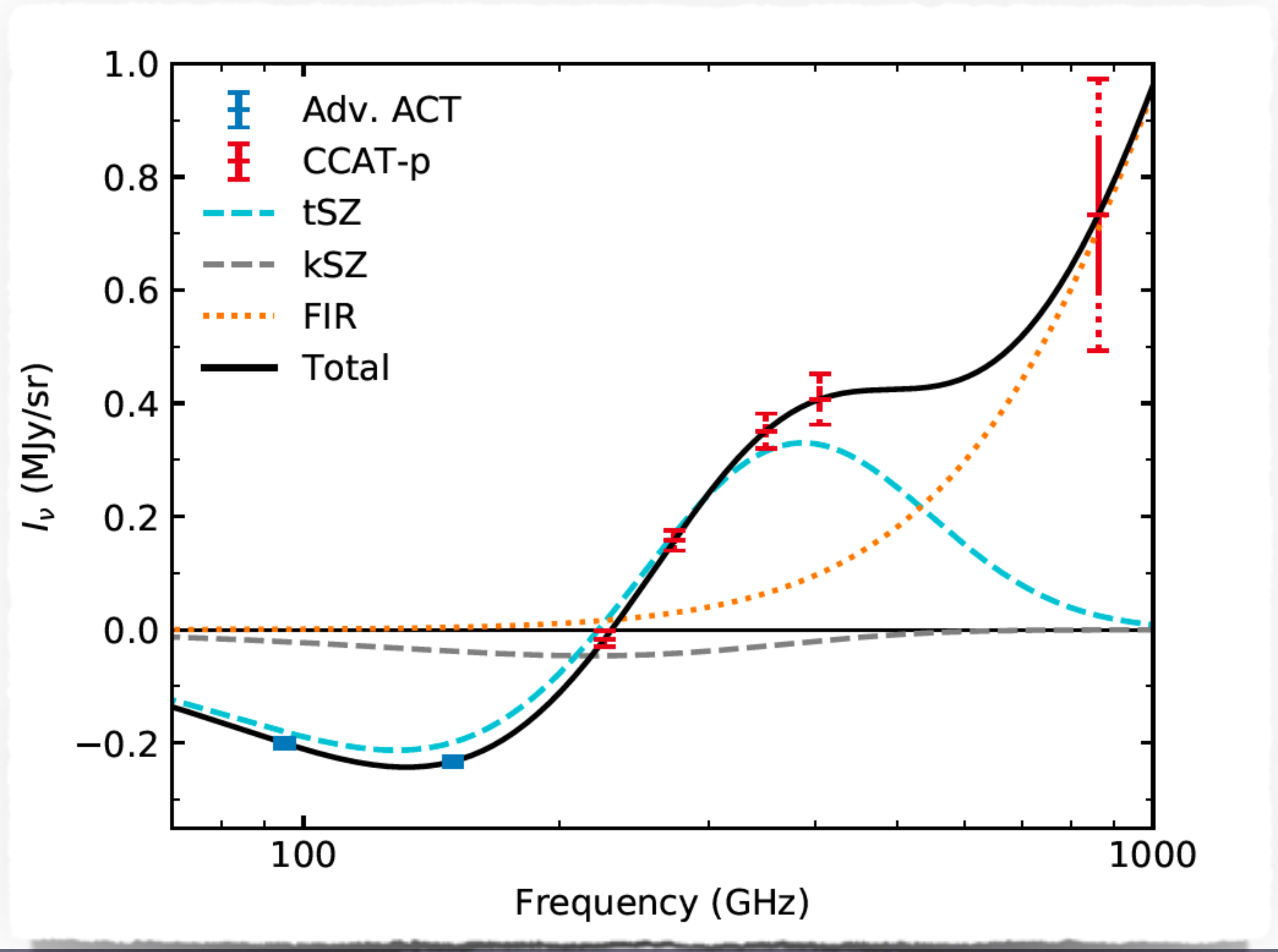
SZ-critical submm bands

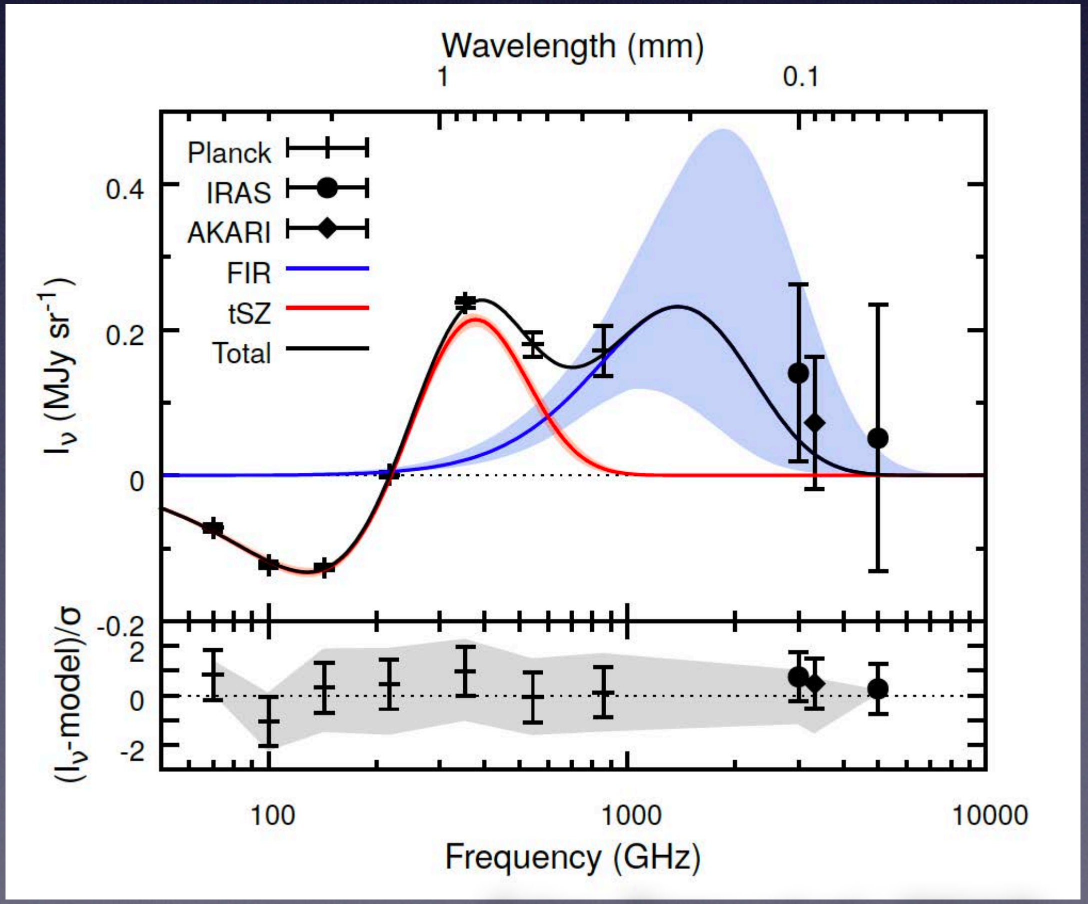
Adding CCAT-prime data to SO (93—280 GHz) does not make a significant difference in the **cluster number counts** (although it may help with sample purity).

So what is the most significant advantage?
One answer: ***Dust***



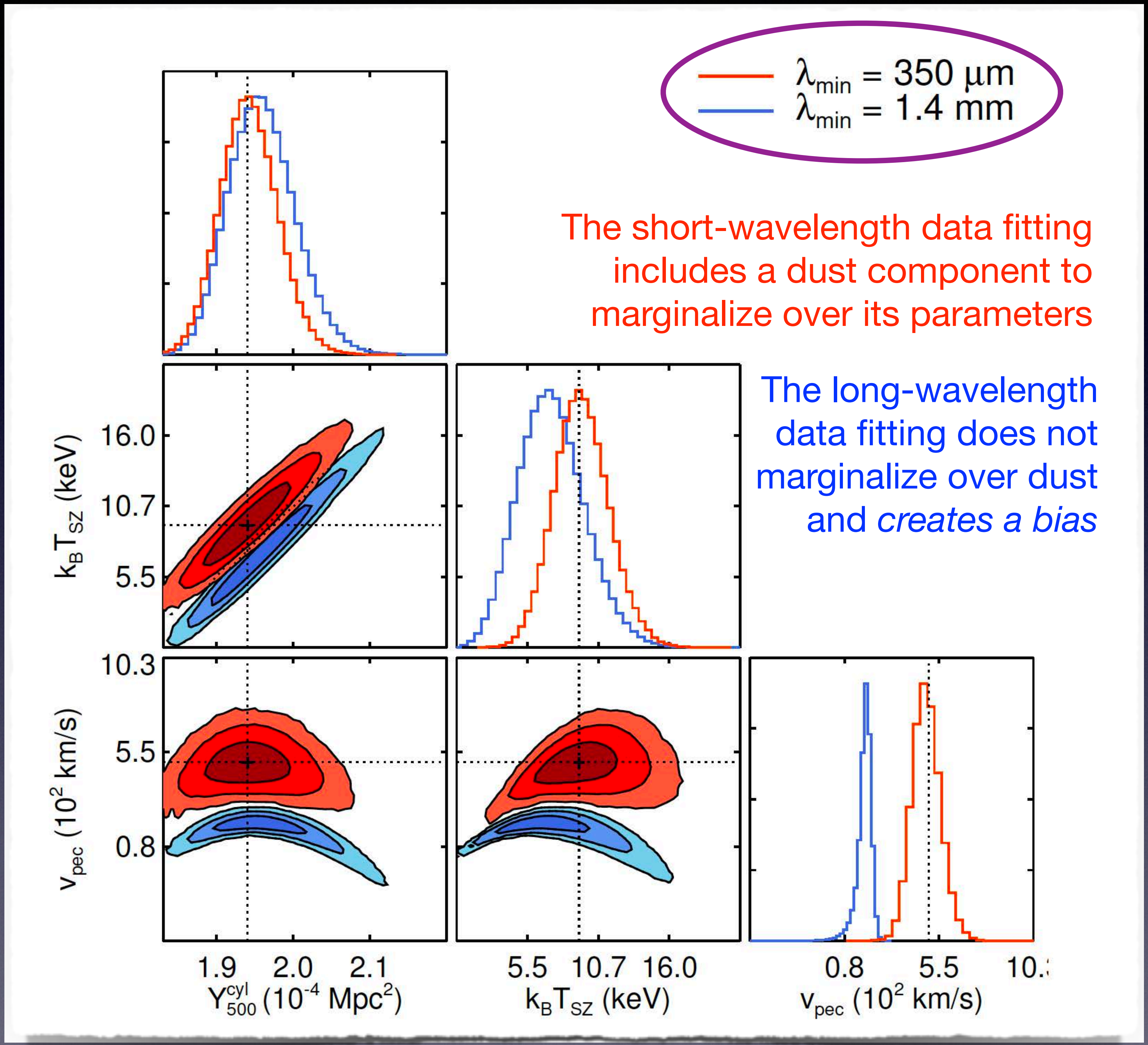
Planck collaboration (2016)





Erler, Basu et al. (2018)

Far-IR bias on kSZ and rSZ

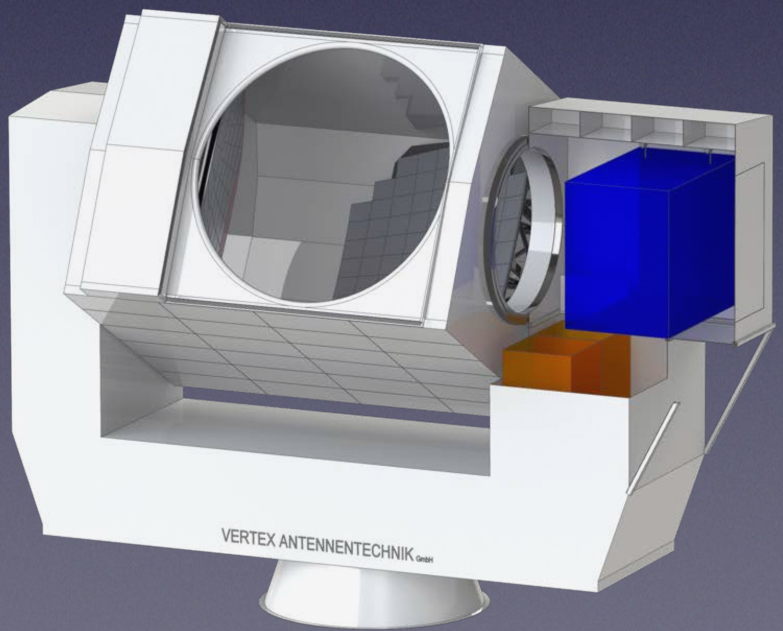


Basu, Erler+ in prep.
See also **Astro2020 White Paper, 1903.04944**

We build a dust model from the difference between the matched filtering and aperture photometry results.

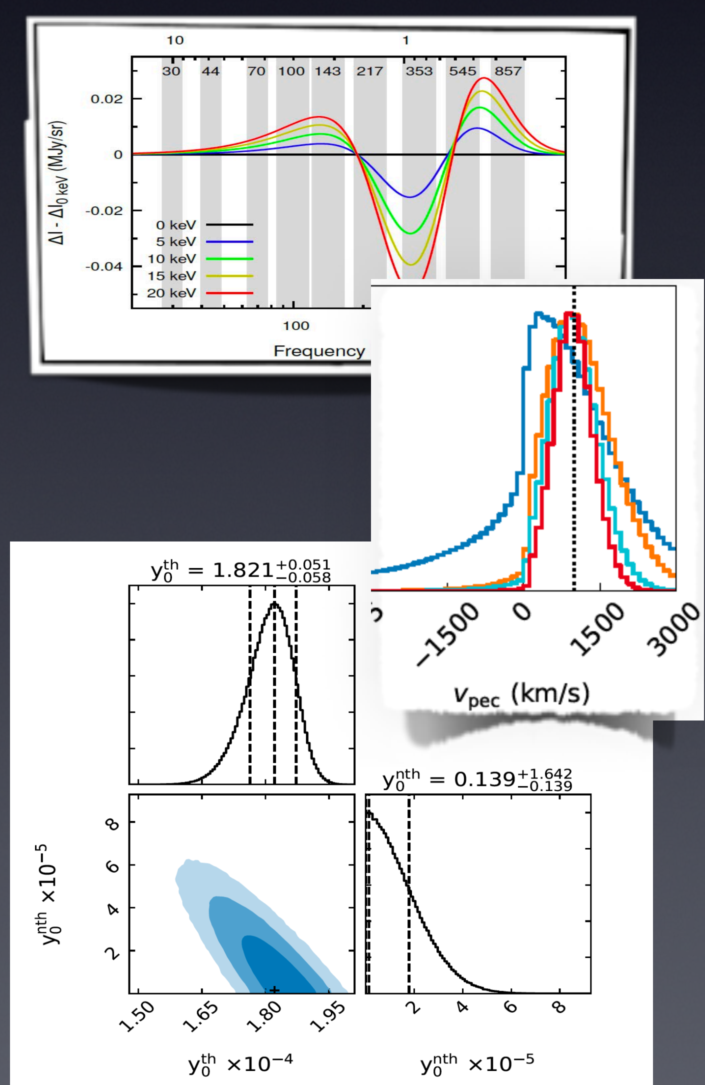
The A_{dust} shown here lies at the upper limit of the allowed range. 😊

Also, only white noise is used to highlight these kSZ/rSZ biases.

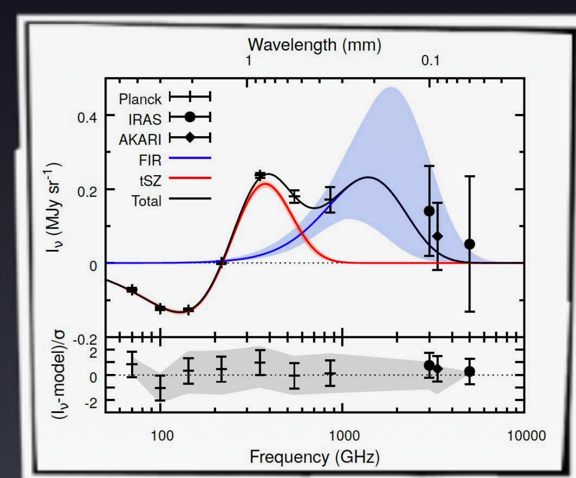


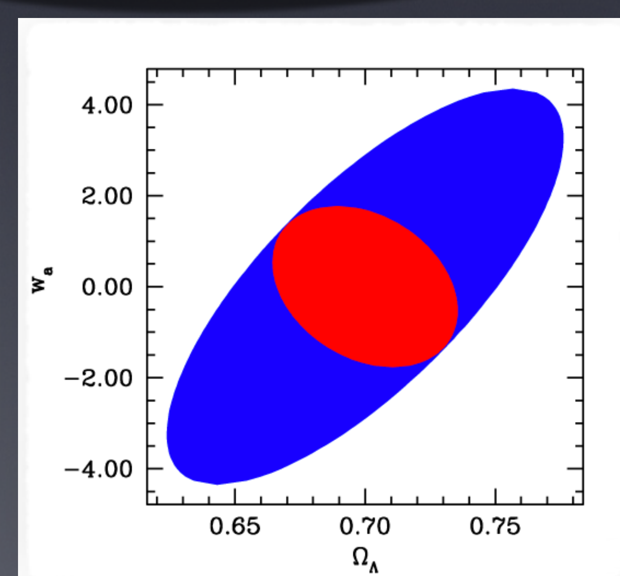
Take-away points

A rich variety of SZ spectral sciences are expected become feasible this decade.



SZ temp and velocity measurements will have fundamental roles in cosmology.





High-Freq (≥220 GHz) data from CCAT-prime will be critical for all other SZ experiments.