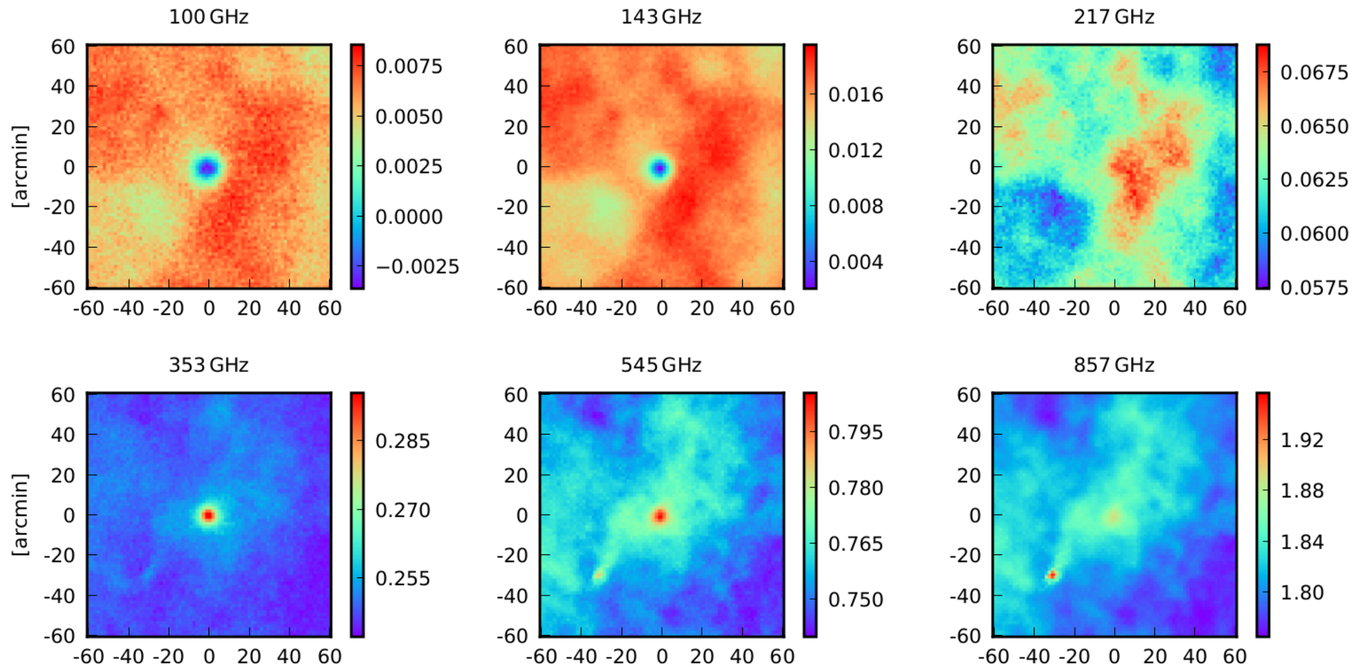
Observations of the relativistic SZ effect: from *Planck* to CCAT-prime

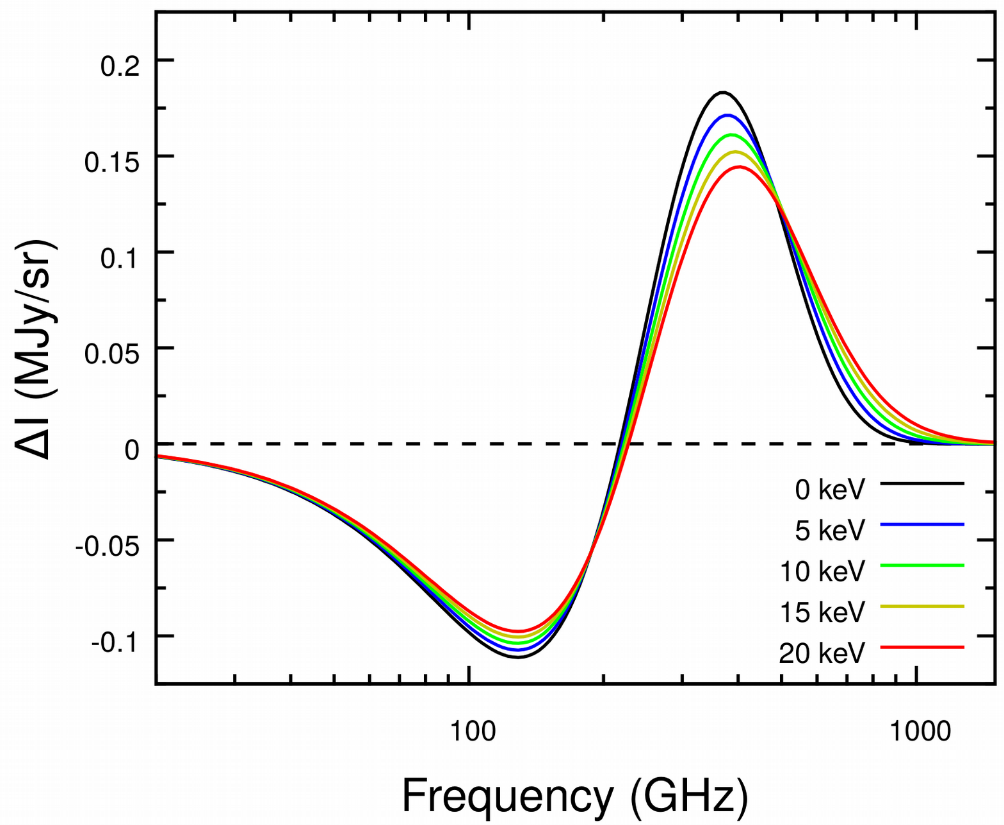


Jens Erler

Kaustuv Basu, Jens Chluba & Frank Bertoldi

Erler et al., accepted by MNRAS (arXiv:1709.01187)

Relativistic corrections to the tSZ effect



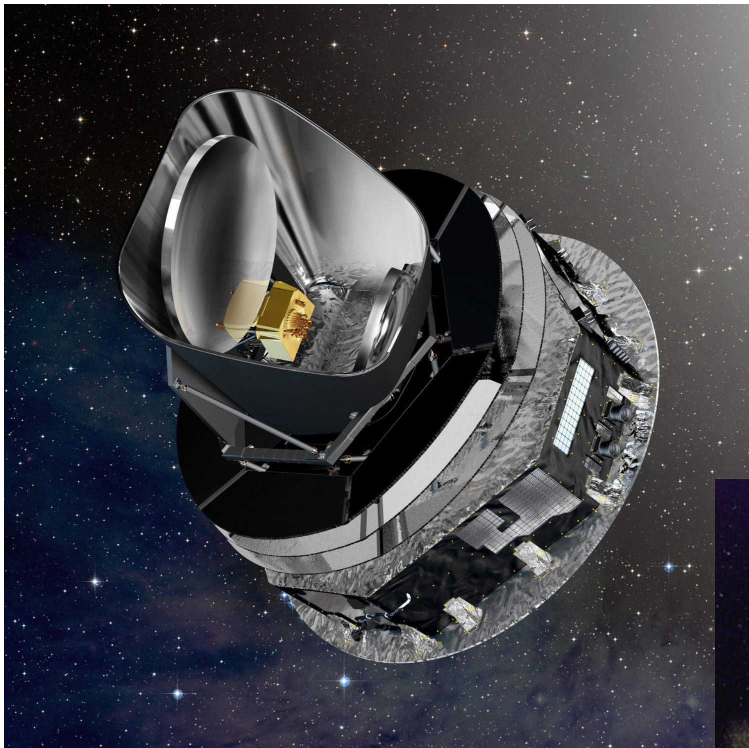
The tSZ rel. corrections allow

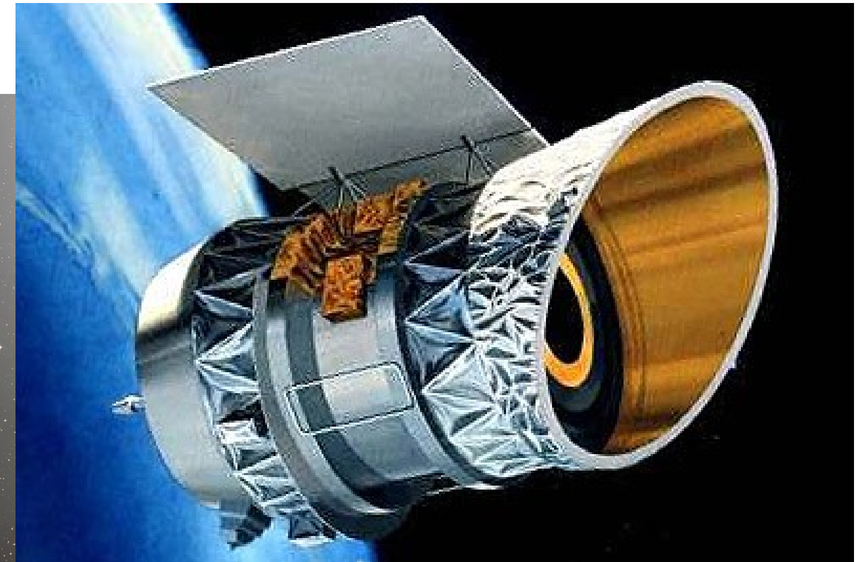
- independent measurement of T_e
- direct measurement of n_e
- Measurements at high z

$$T_{SZ} \approx \langle T_e \rangle_{P_e} = \frac{\int n_e T_e^2 \, dl}{\int n_e T_e \, dl}$$

The temperature of the ICM is tightly related to the total (hydrostatic) mass of galaxy clusters

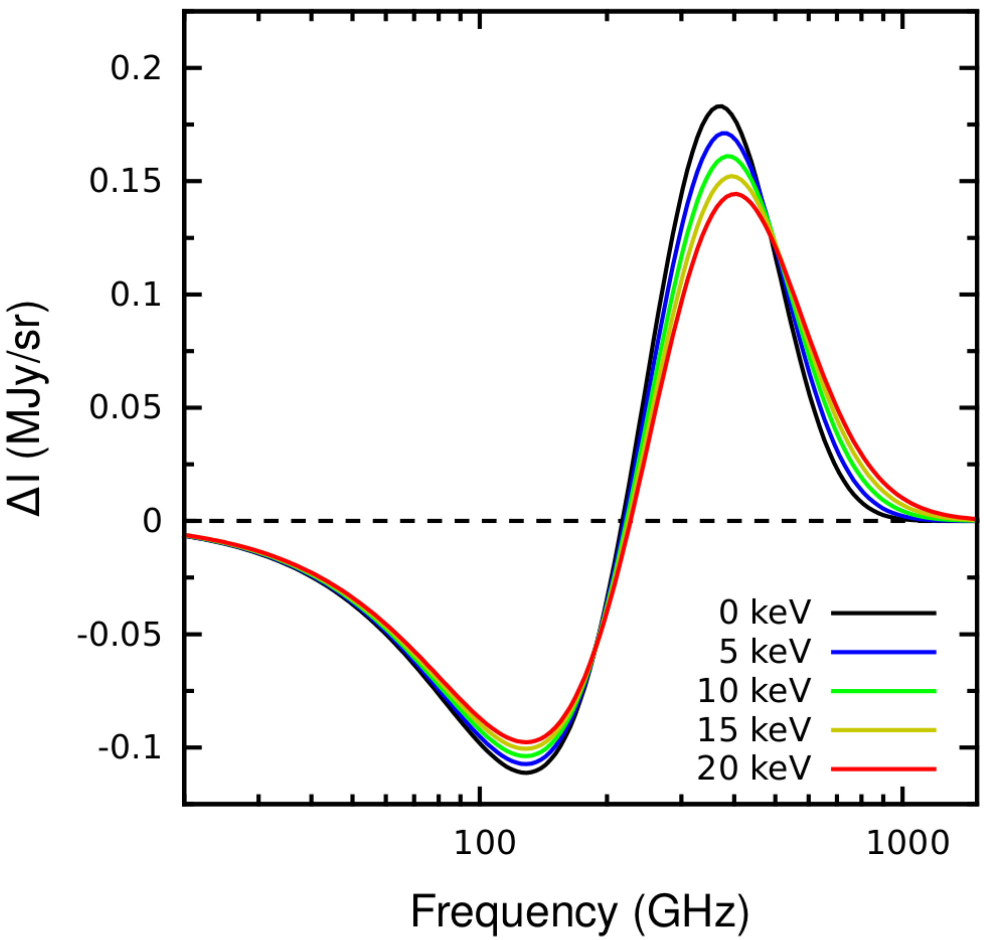
The data





Credit: NASA / ESA Planck Collaboration

Why use *Planck* to study the rSZ effect



- *Planck* covers the entire SZE spectrum
- *Planck* has all-sky coverage
- Good sensitivity
- Drawback: low resolution

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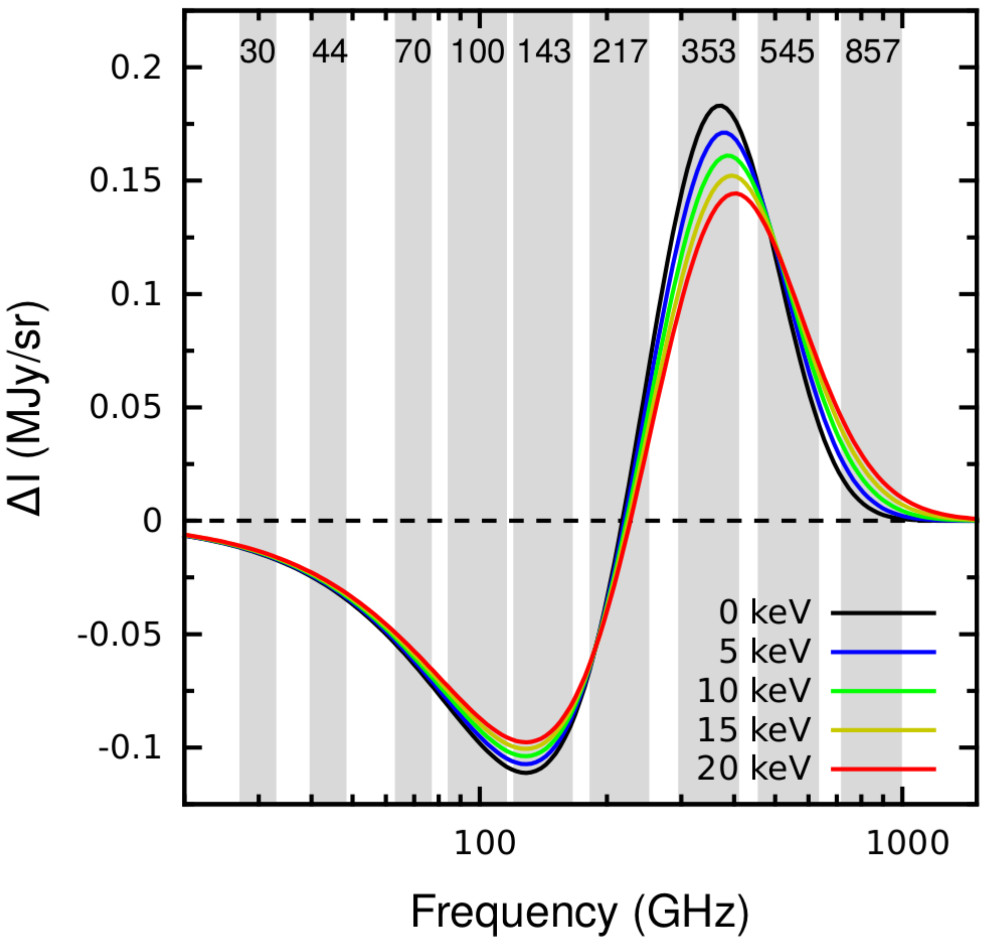

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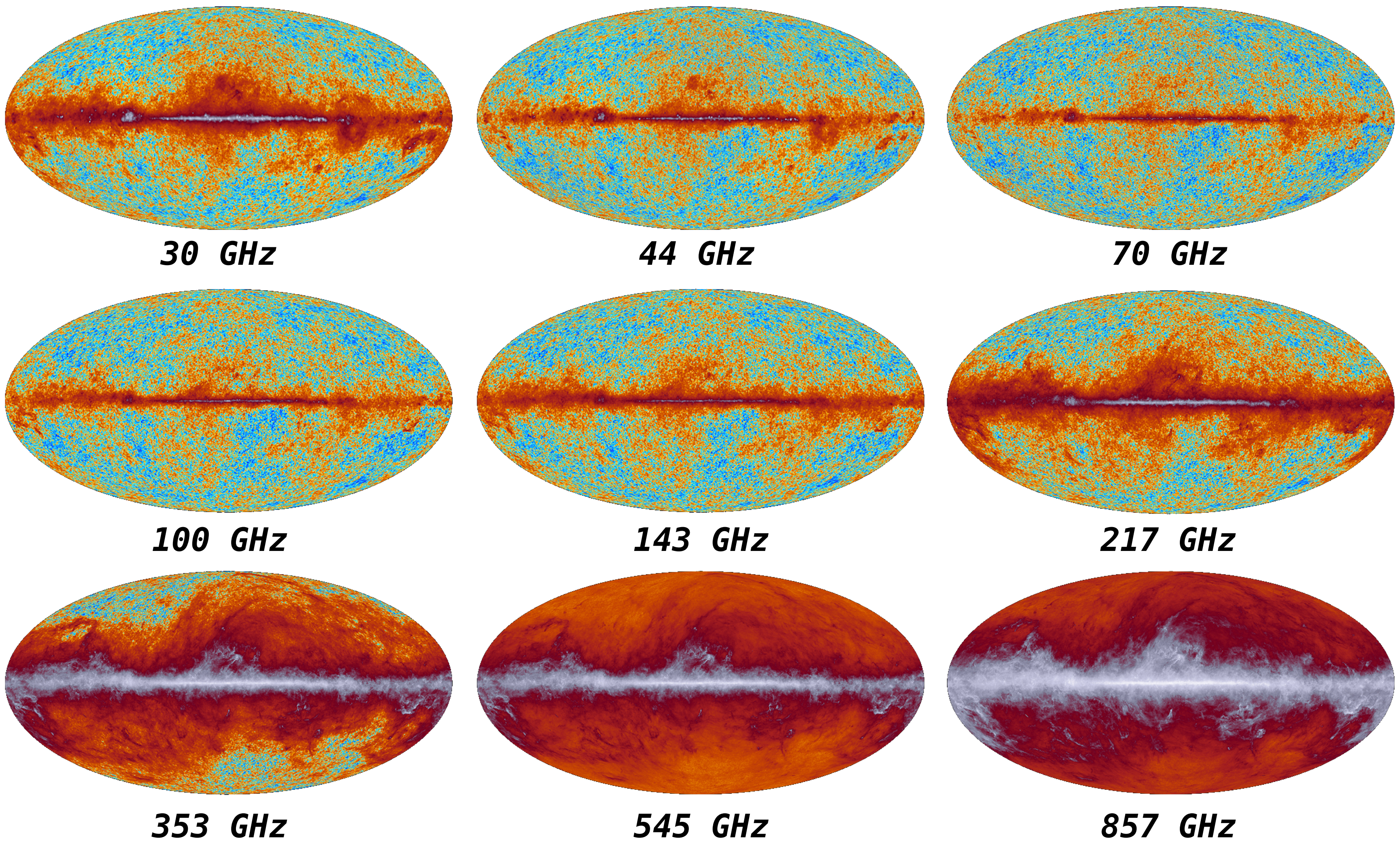
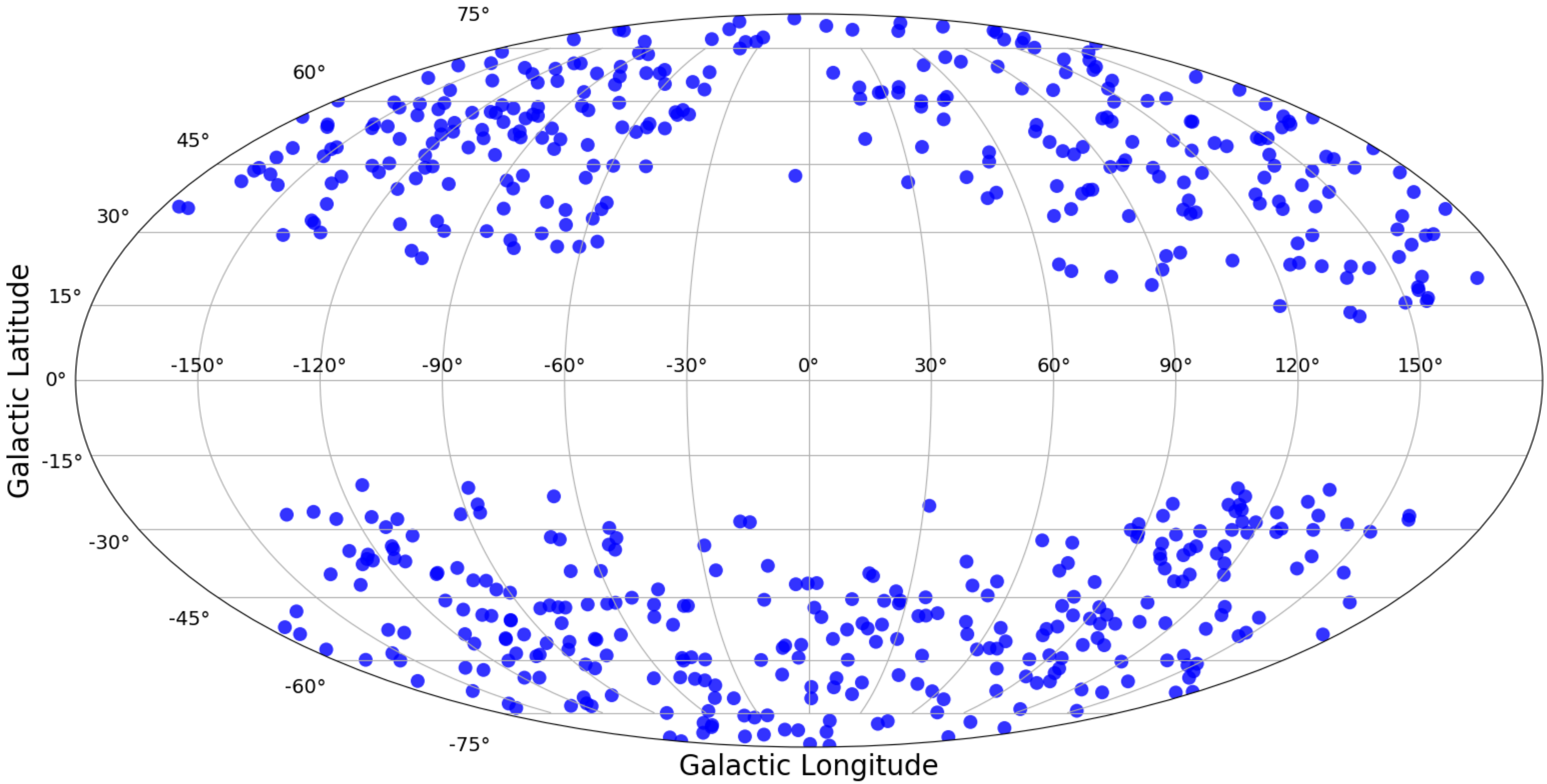
Galactic Foregrounds



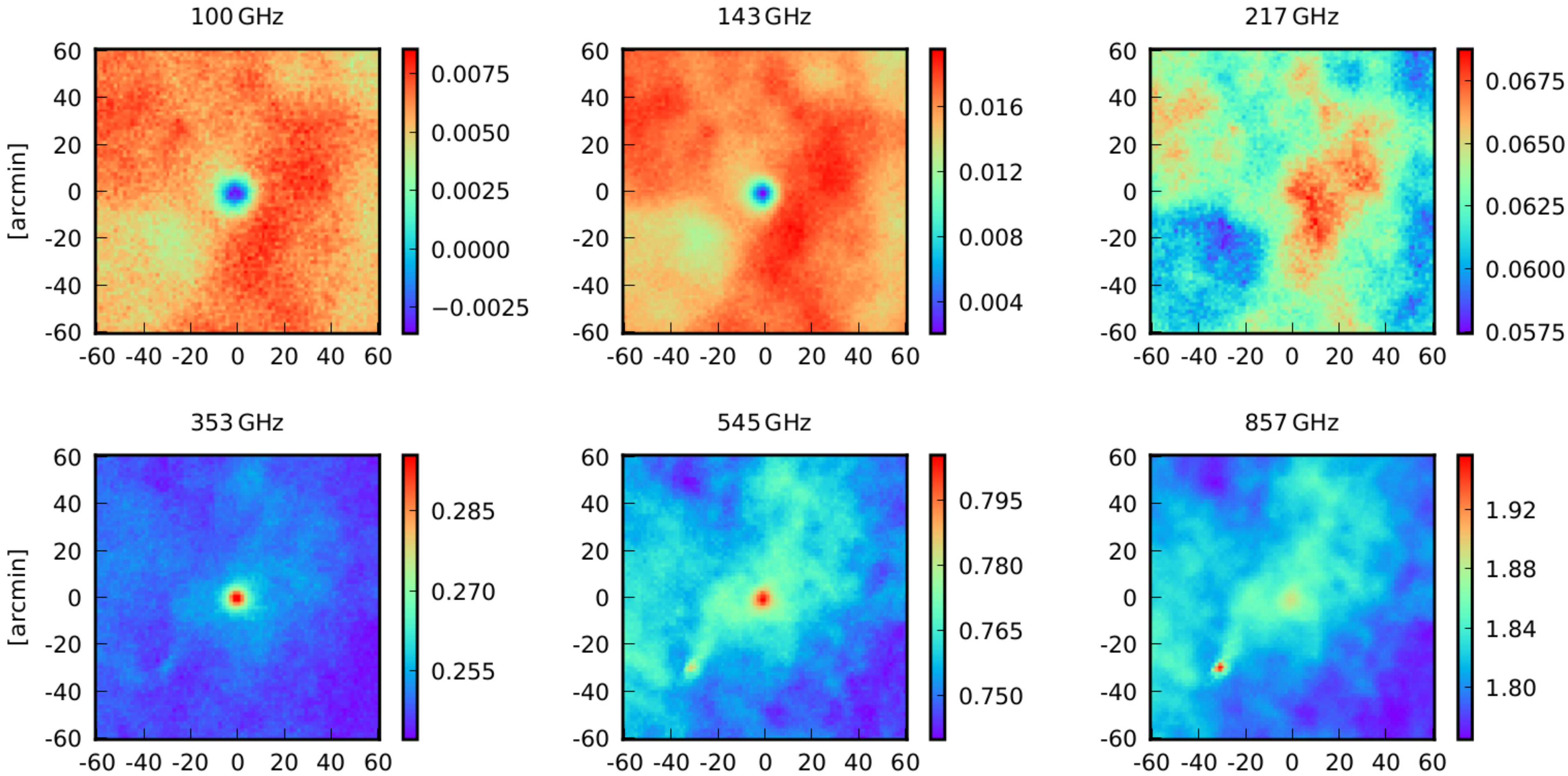
Credit: ESA Planck Collaboration

Sample Selection



Erler et al., accepted by MNRAS (arXiv:1709.01187)

Stacked Cluster Sample



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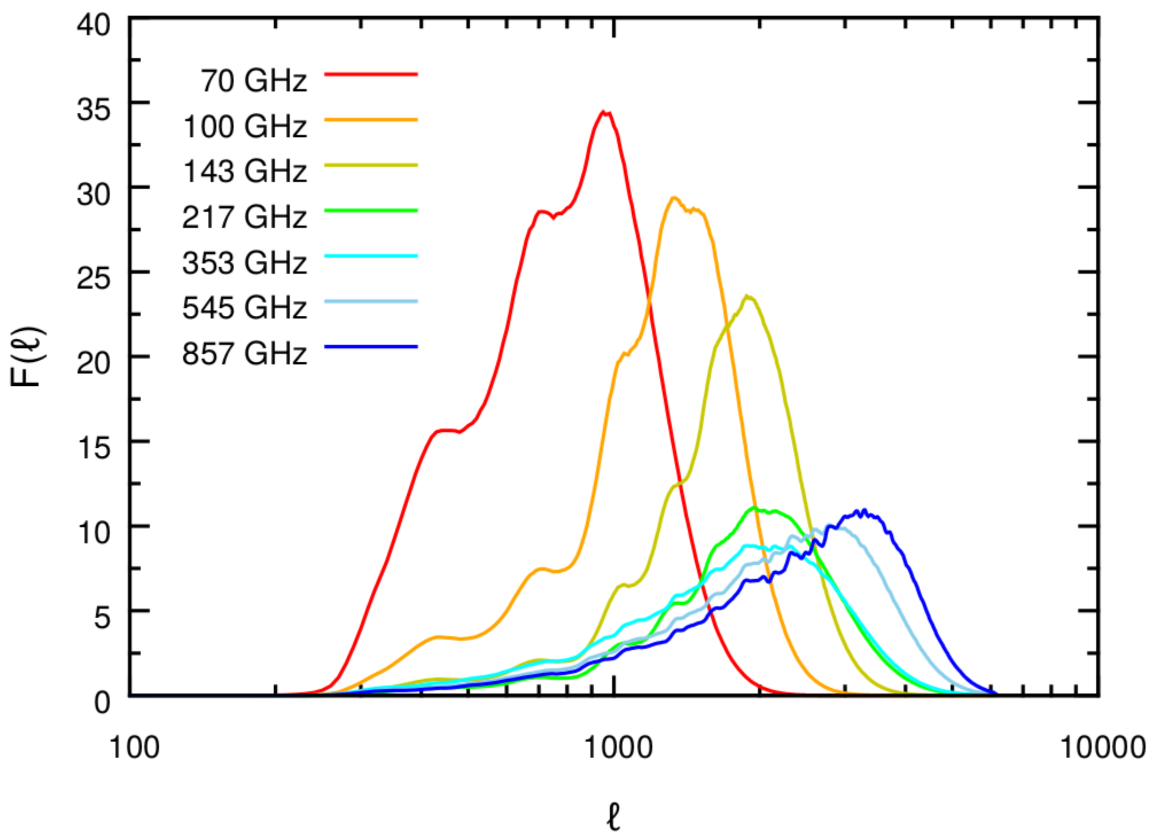
Matched Filtering

Spatially uncorrelated foregrounds are reduced by matched filtering

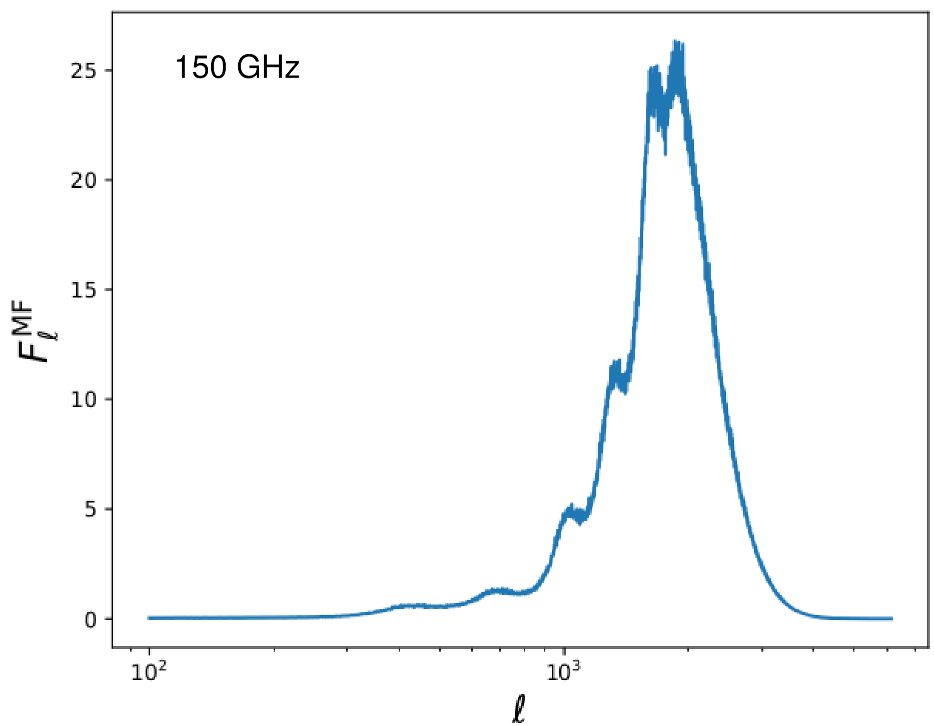


Erler et al., accepted by MNRAS (arXiv:1709.01187)

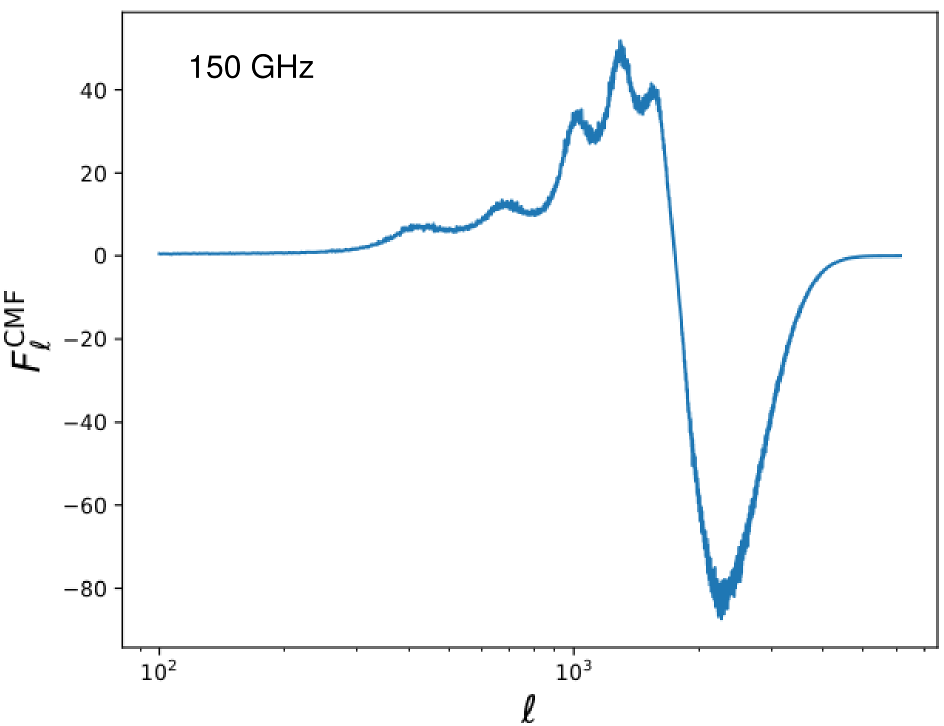
Expanding the MF concept

Additional constraints can help to reduce contamination by point sources

matched filter



constrained matched filter



Erler et al. in prep.

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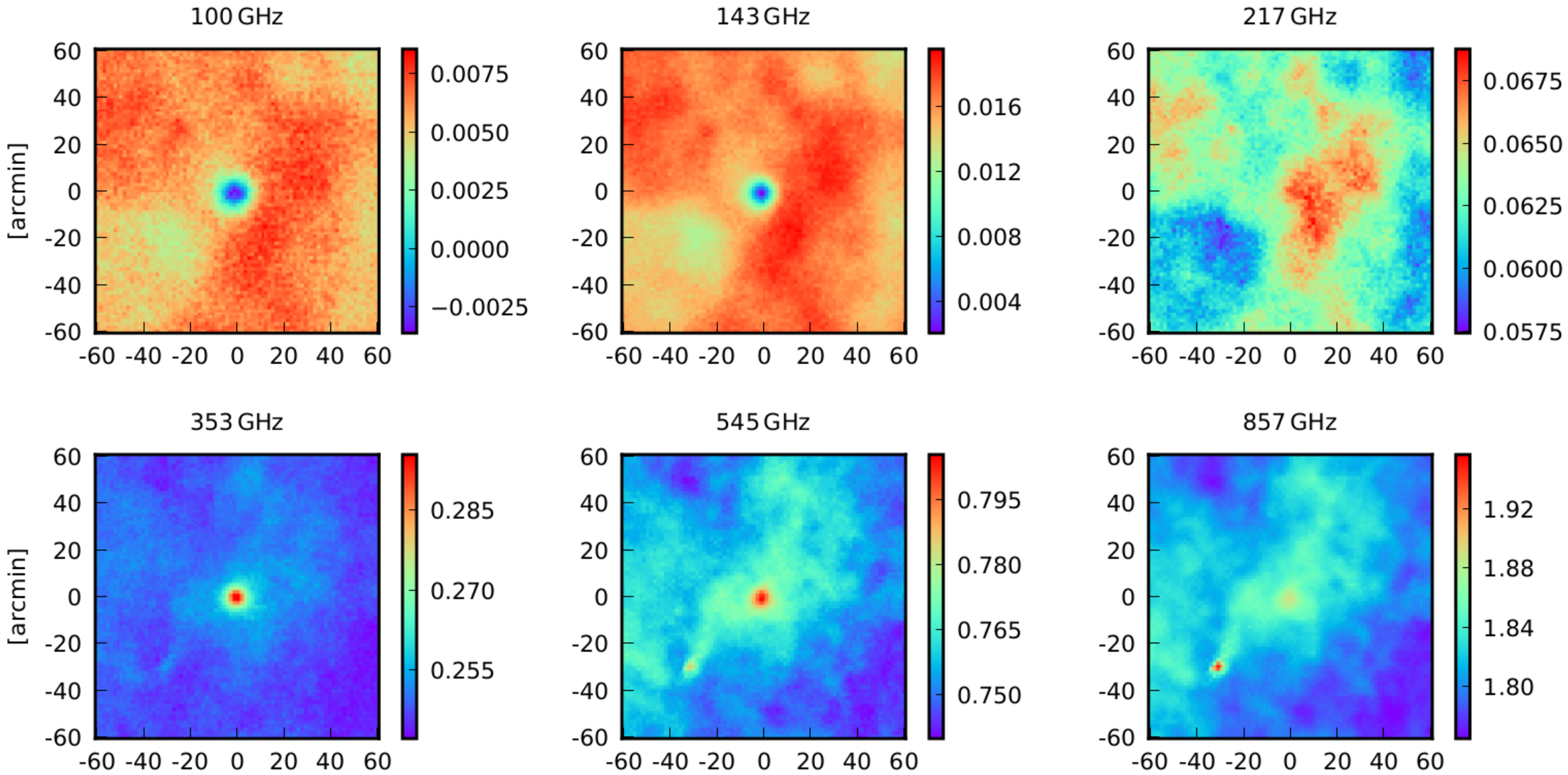
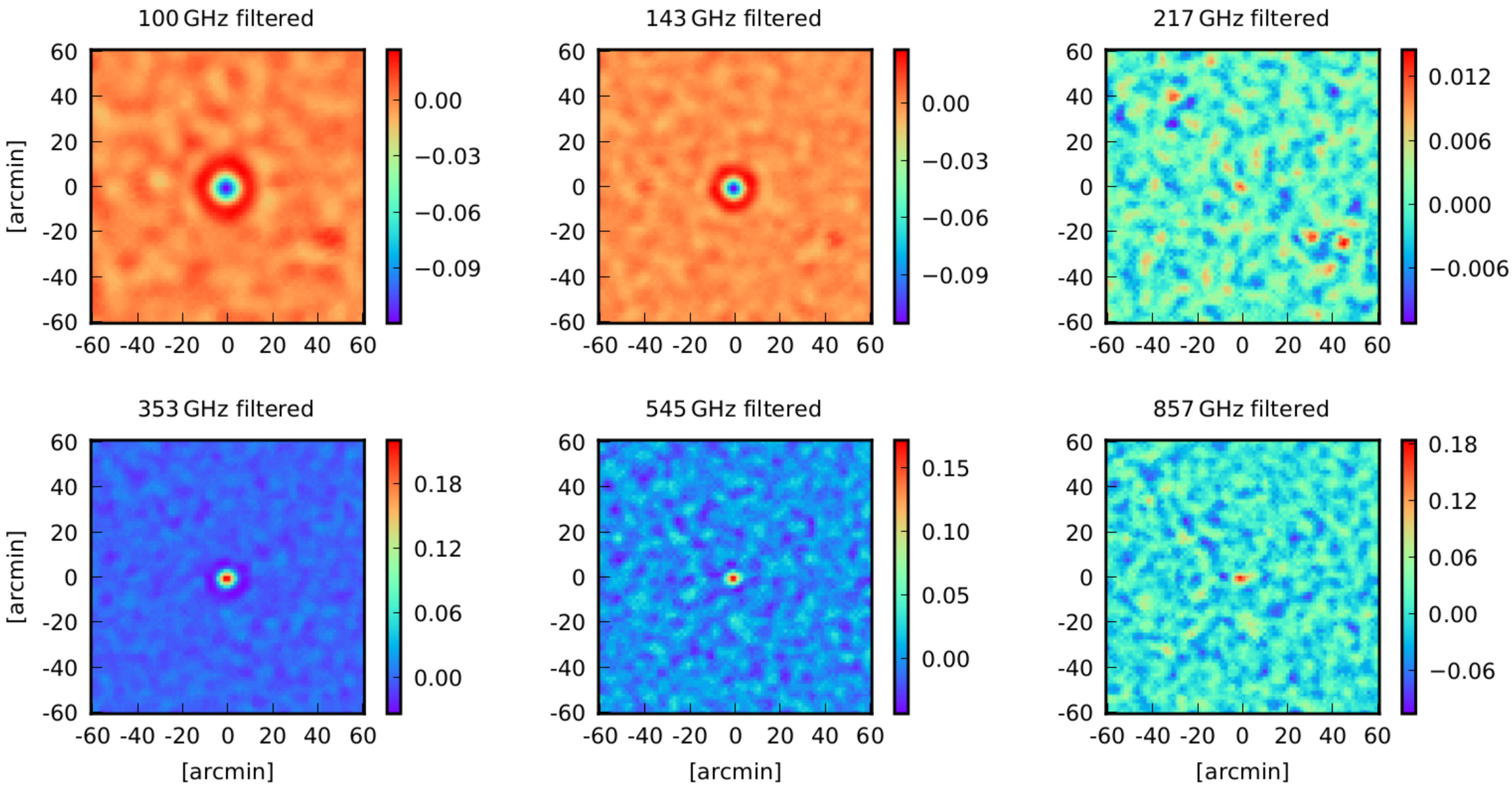


Erler et al., accepted by MNRAS (arXiv:1709.01187)

Stacked Cluster Sample



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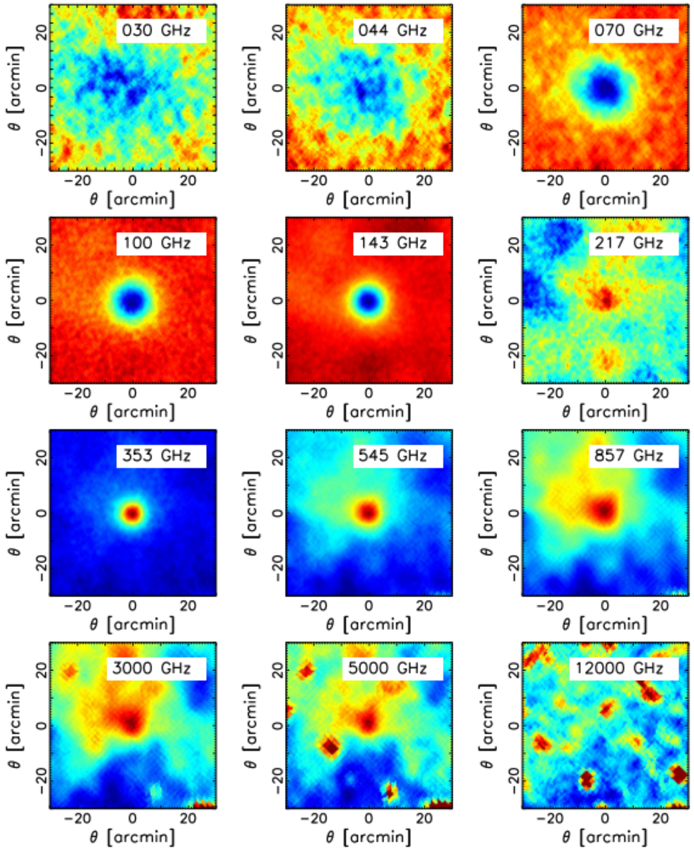
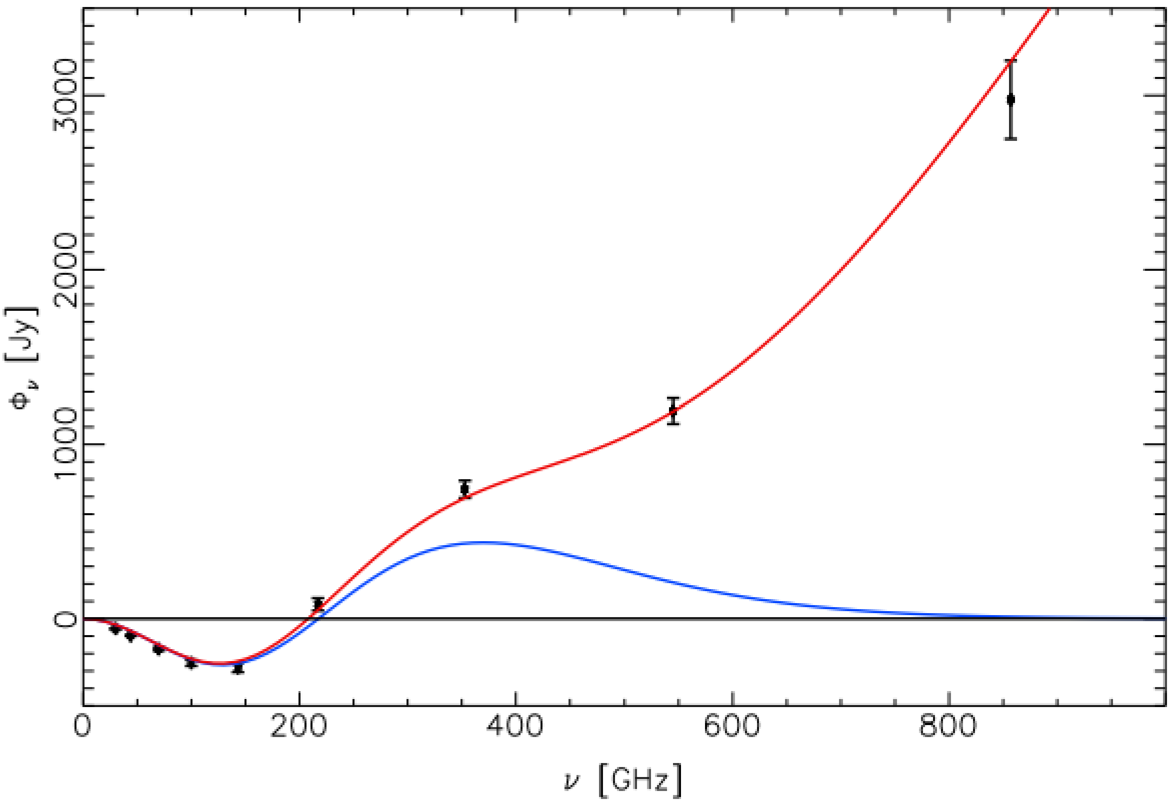
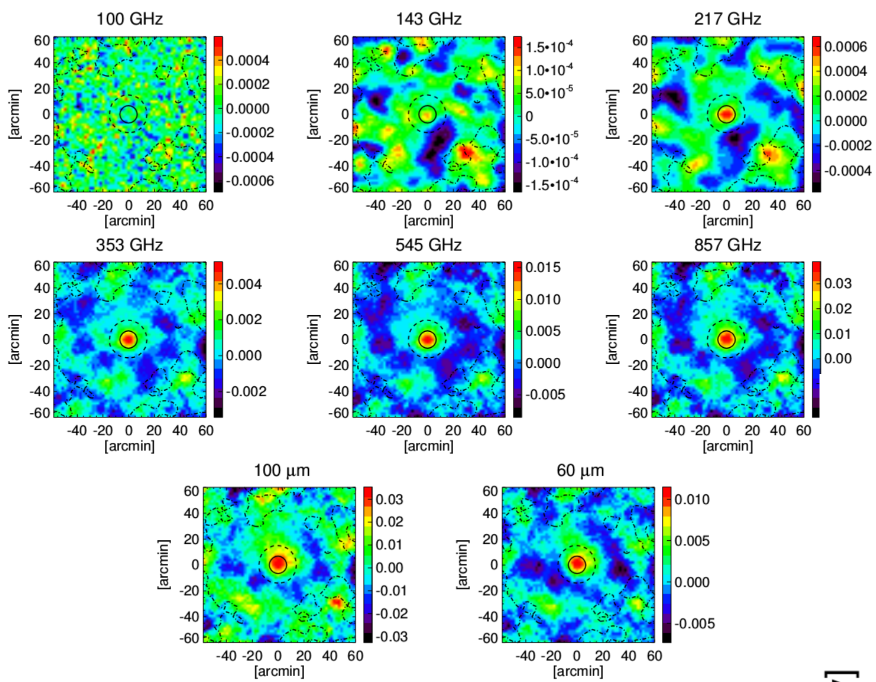
FIR emission from galaxy clusters

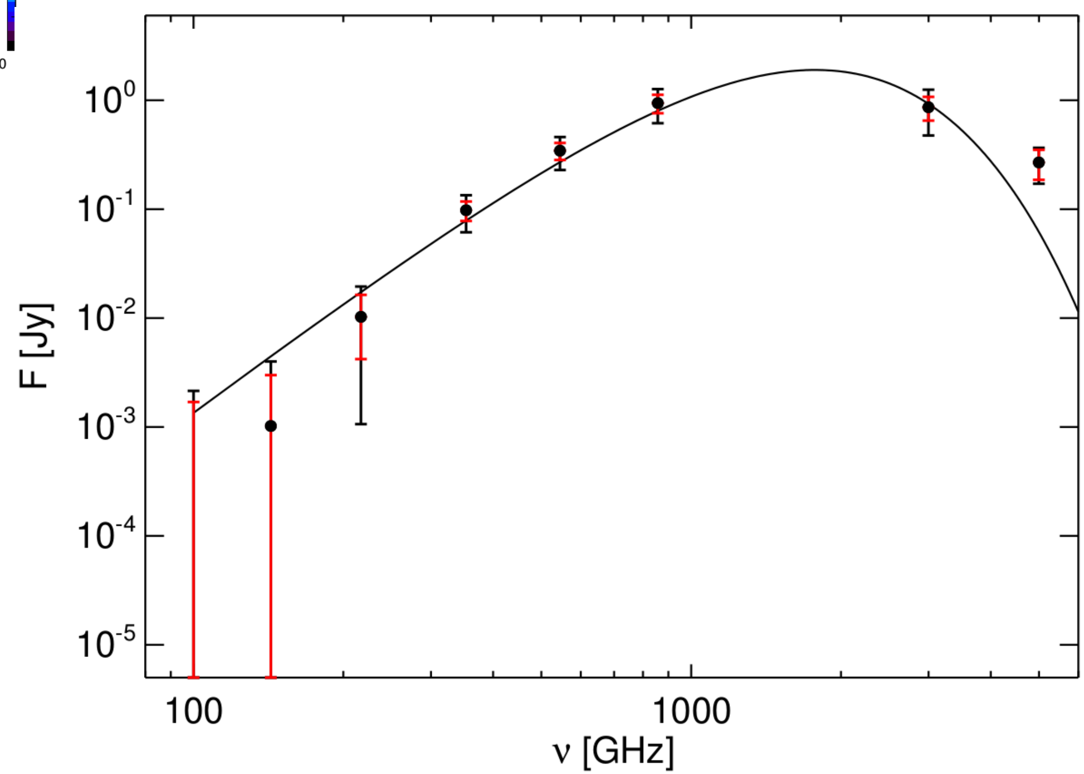




Reference: Planck 2015 results XIII

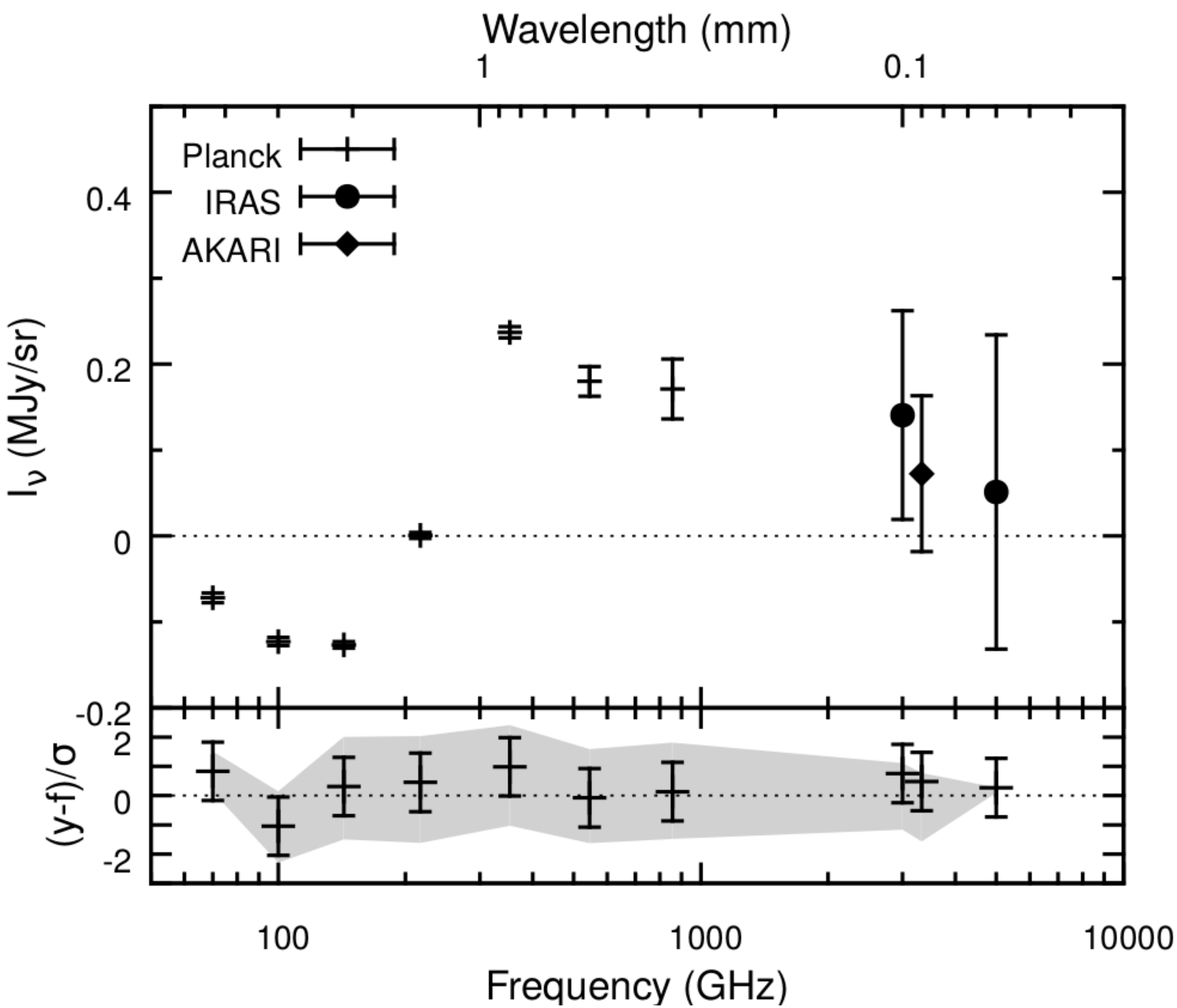
FIR emission from galaxy clusters





Reference: Planck intermediate results XLIII

Extracted Spectrum



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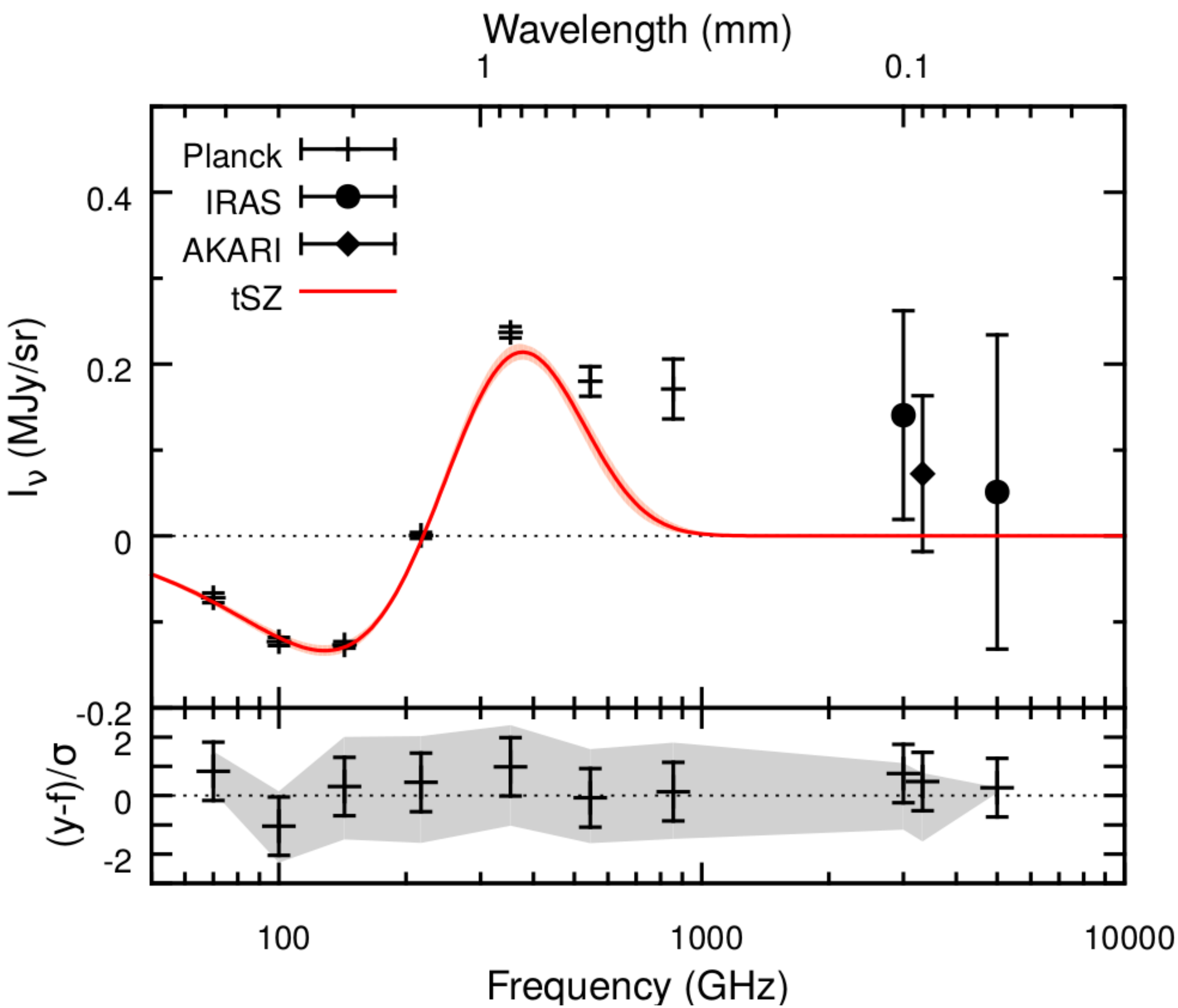
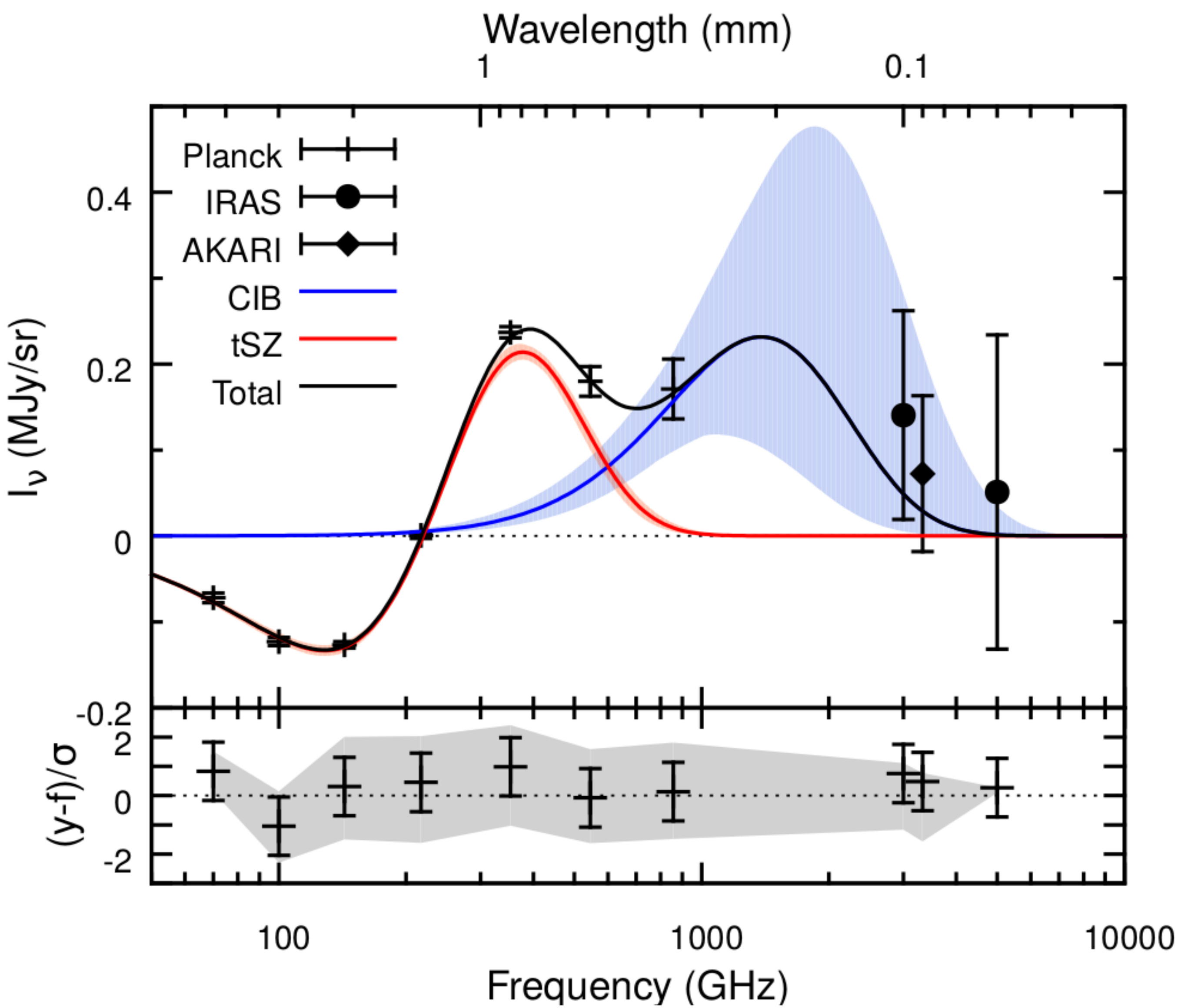
Extracted Spectrum

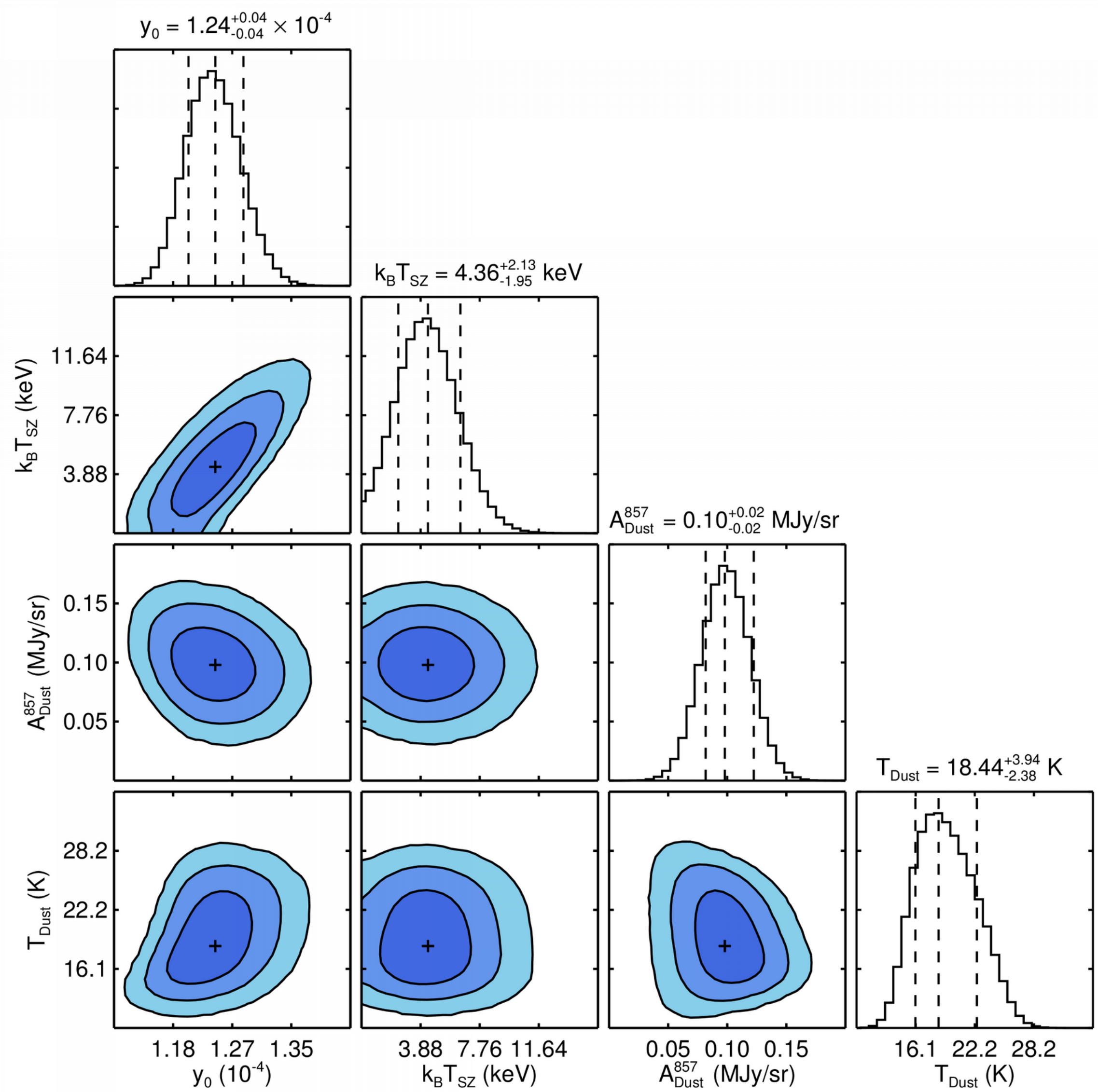


Extracted Spectrum



Erler et al., accepted by MNRAS (arXiv:1709.01187)

Results



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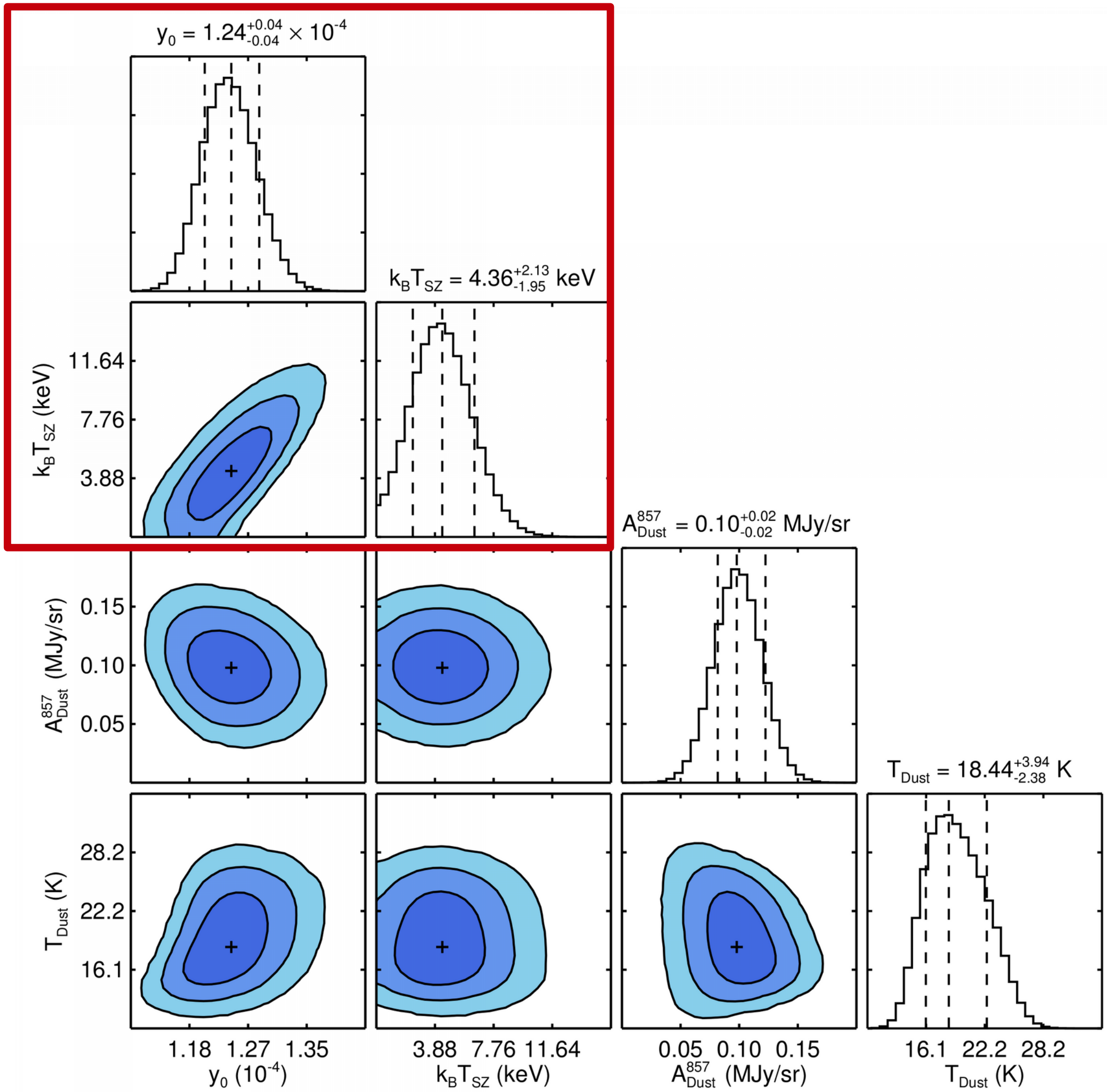

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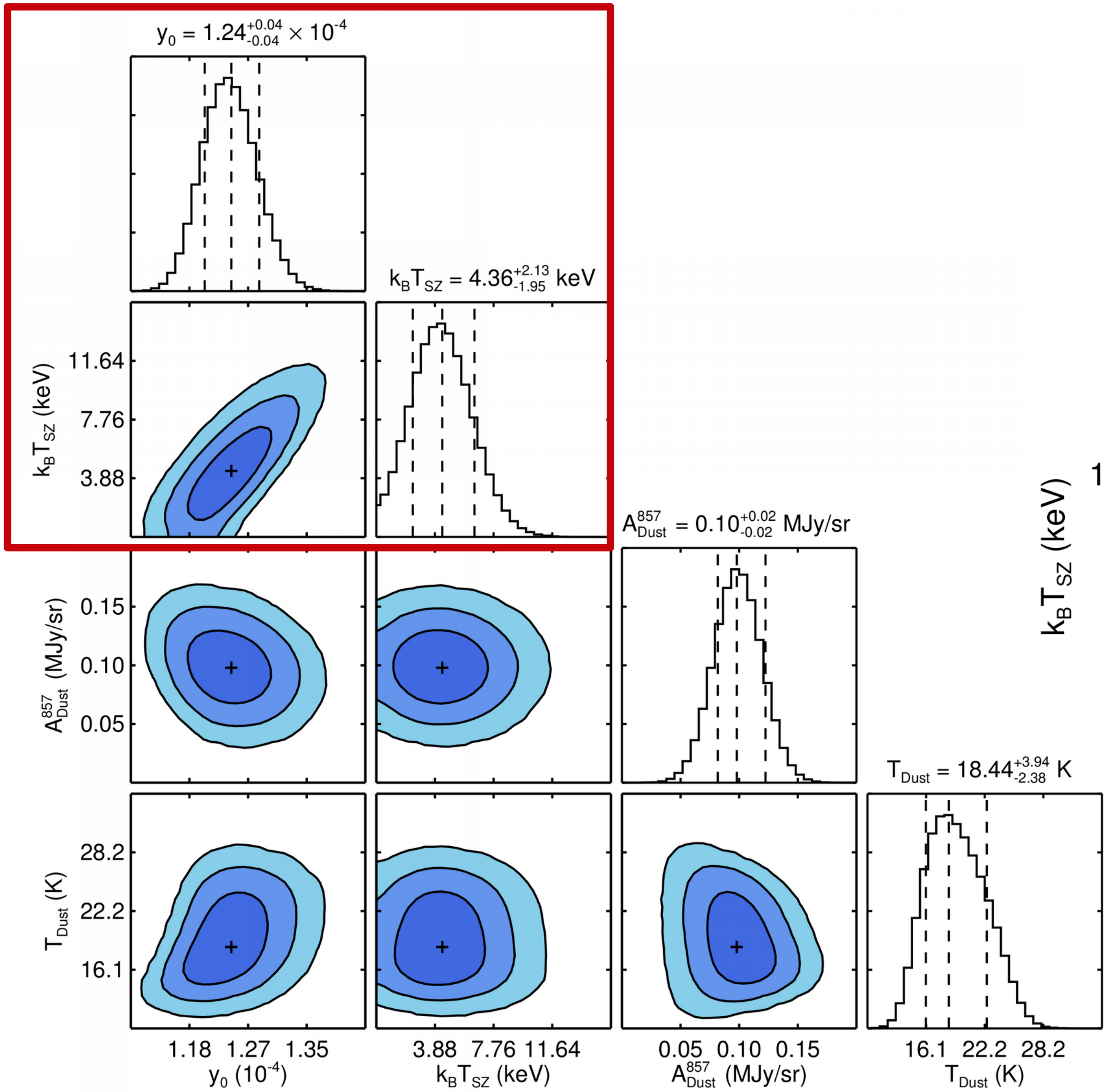
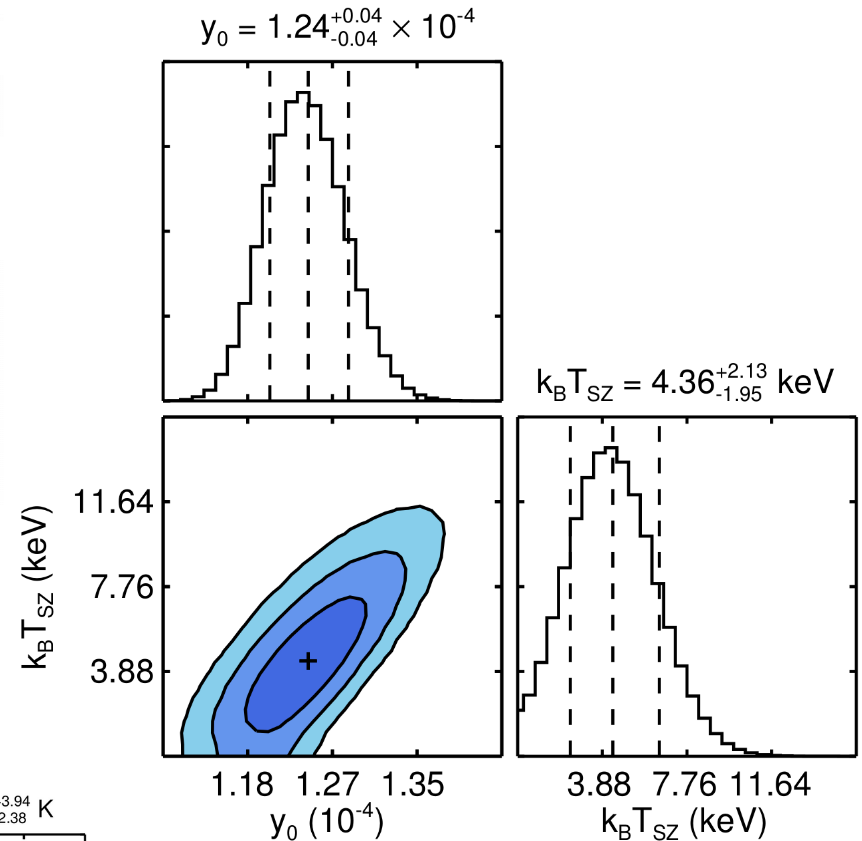


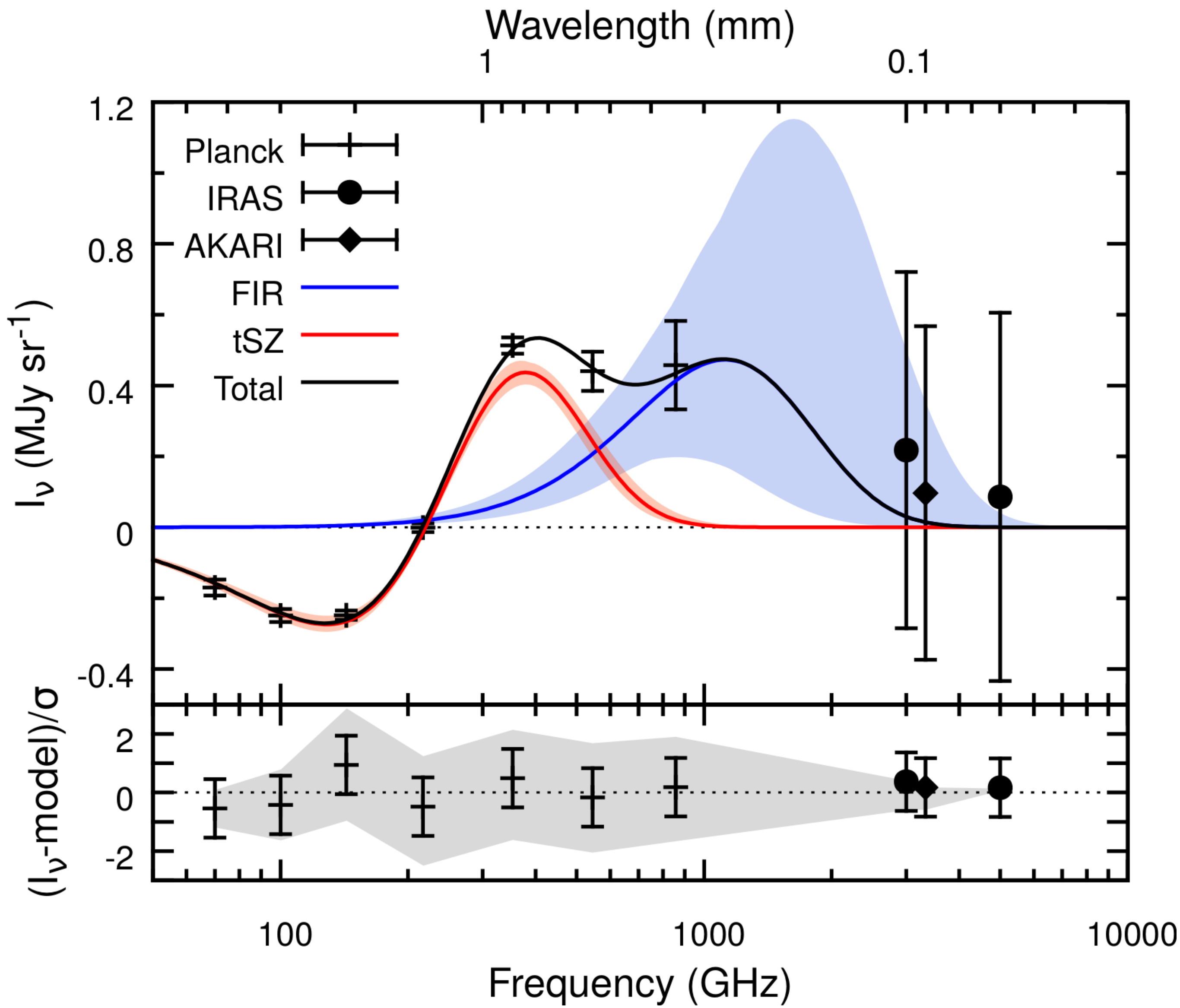


$T_{SZ} = 4.4 \pm 2$ keV

$\langle T_X \rangle = 6.9$ keV

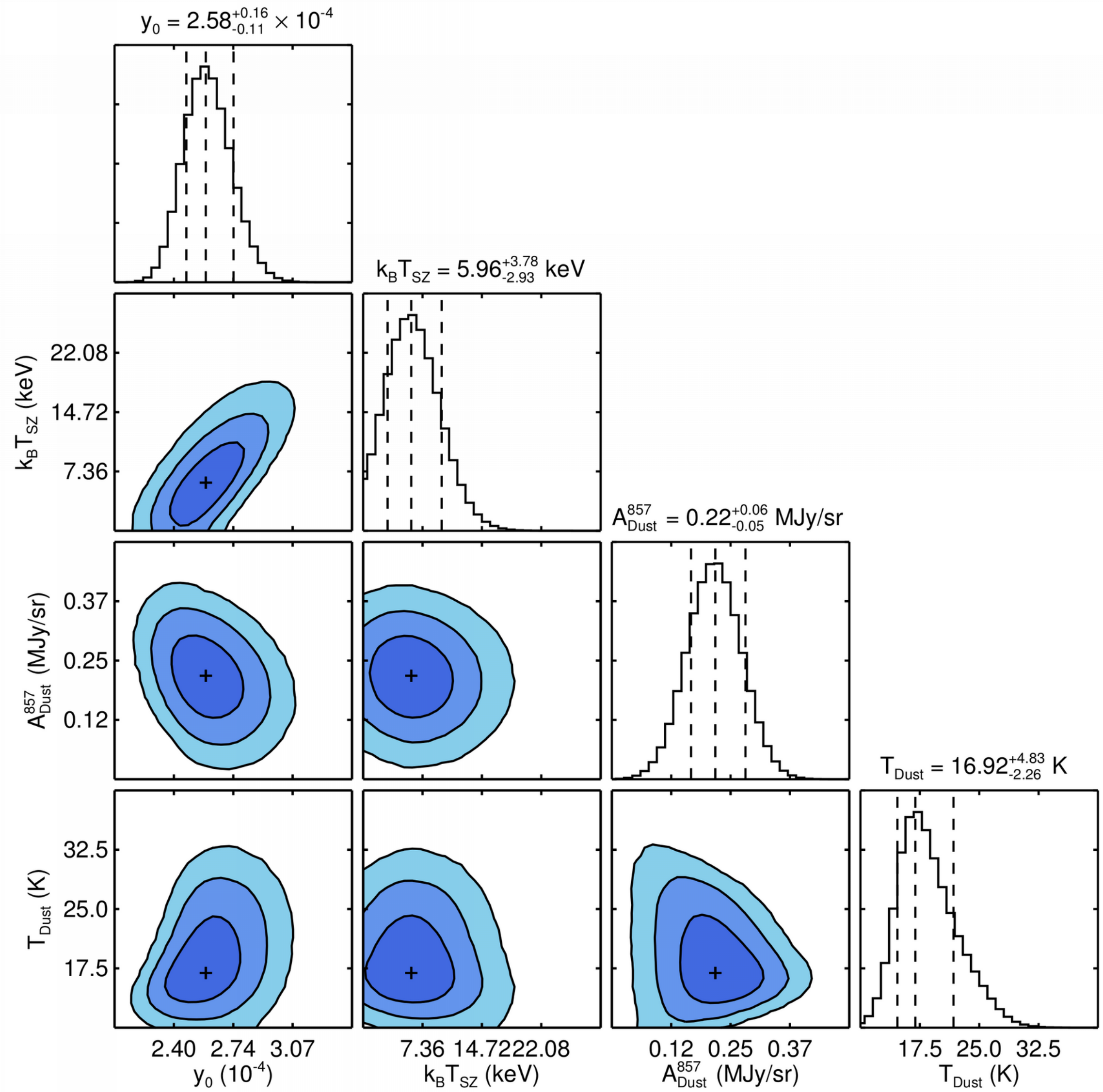
Erler et al., accepted by MNRAS (arXiv:1709.01187)

Extracted Spectrum: hottest 100



Erler et al., accepted by MNRAS (arXiv:1709.01187)

Results: hottest 100



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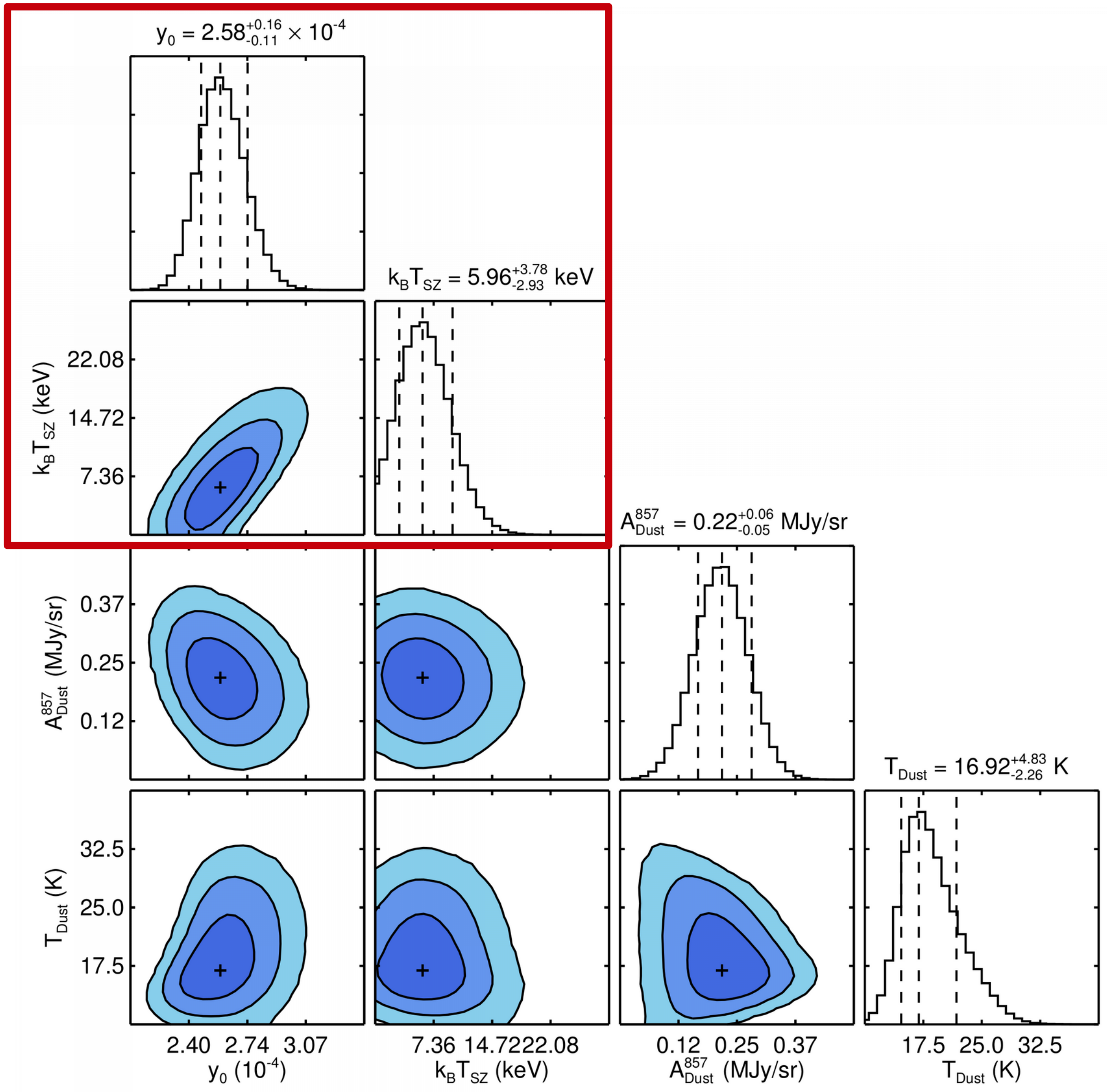
Results: hottest 100



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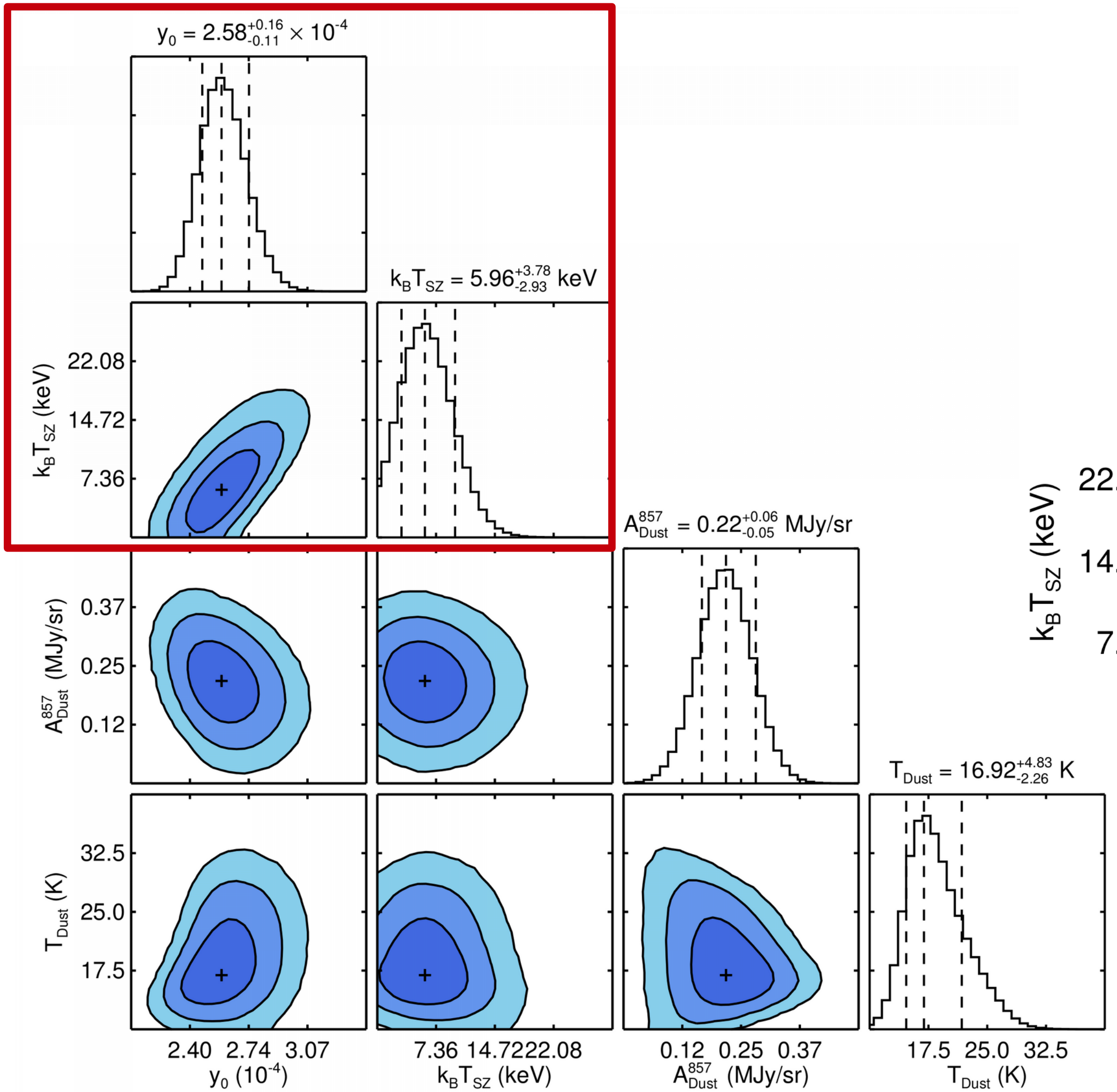
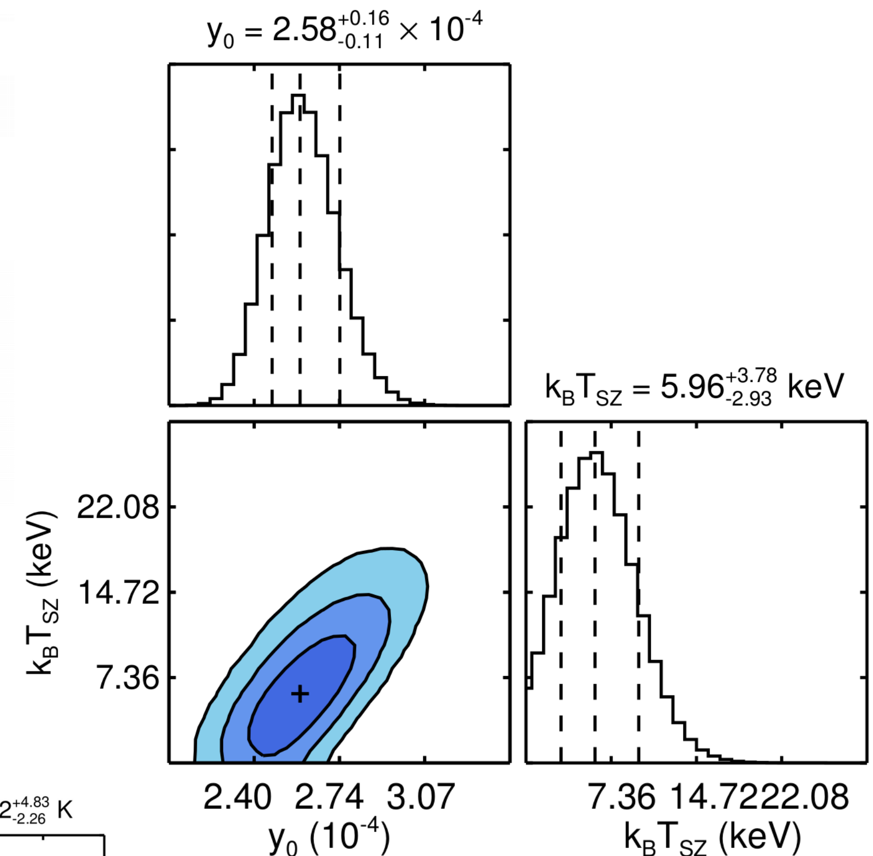




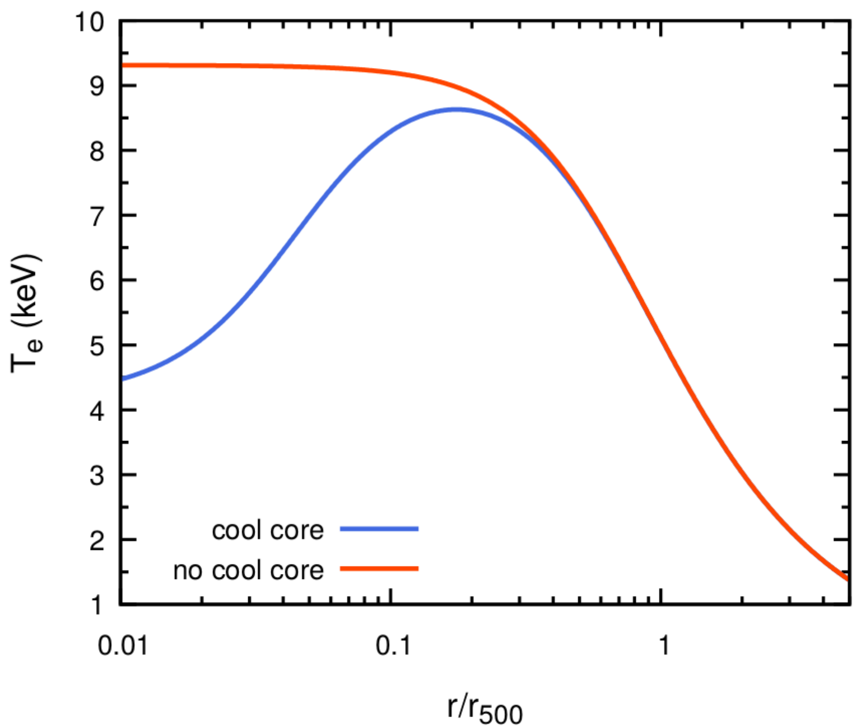
$T_{SZ} = 6.0 \pm 3.4$ keV

$\langle T_X \rangle = 8.5$ keV

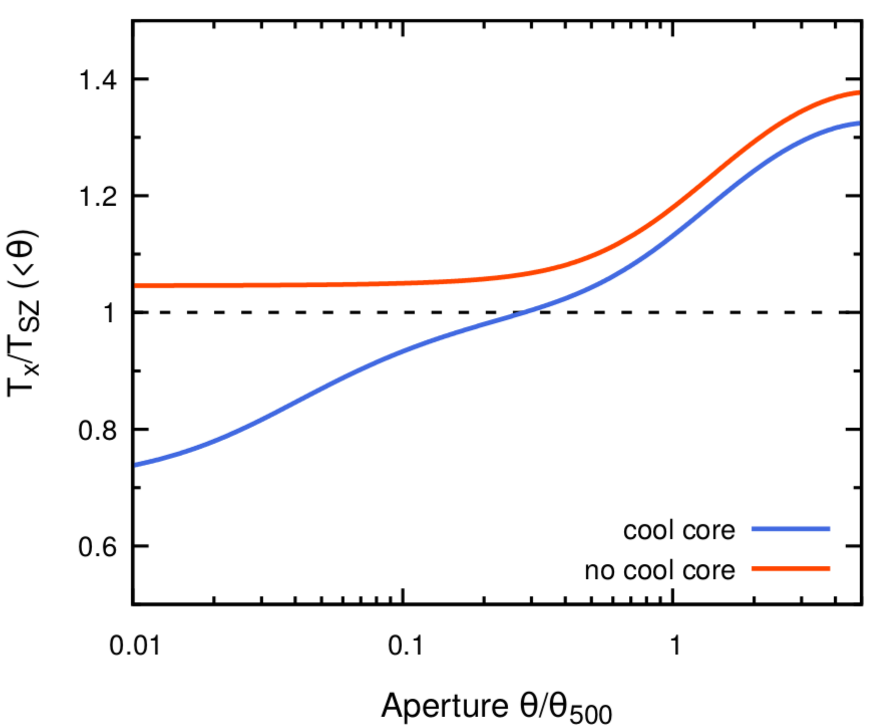
How does T_{SZ} compare to T_X?

Using simple analytical models and $w_X = n_e^2 T_e^{-\frac{3}{4}}$ as well as $w_{SZ} = n_e T_e$ we find that $T_X \gtrsim T_{SZ}$

3D T_e profiles

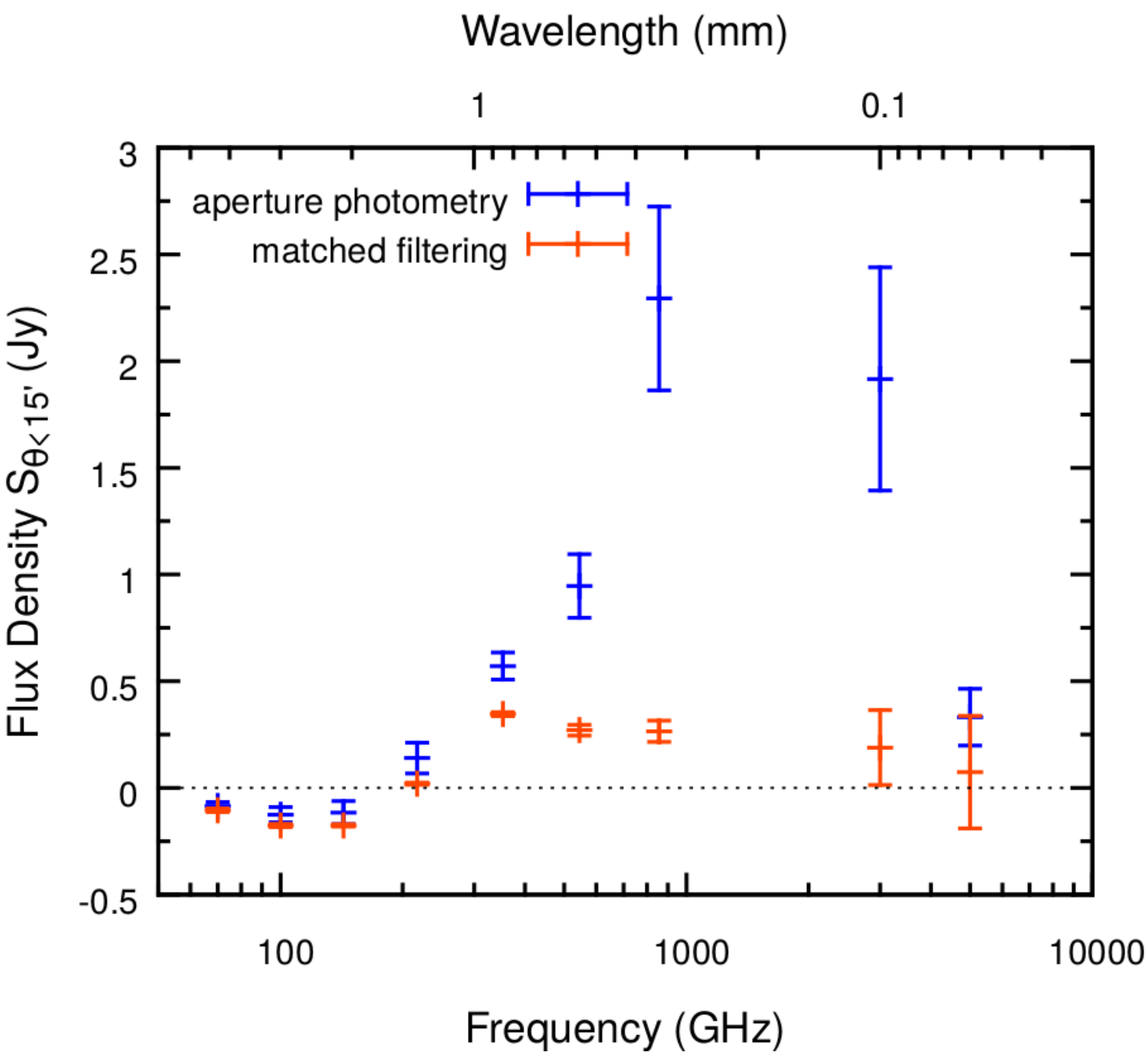


Aperture-average T_X/T_{SZ}



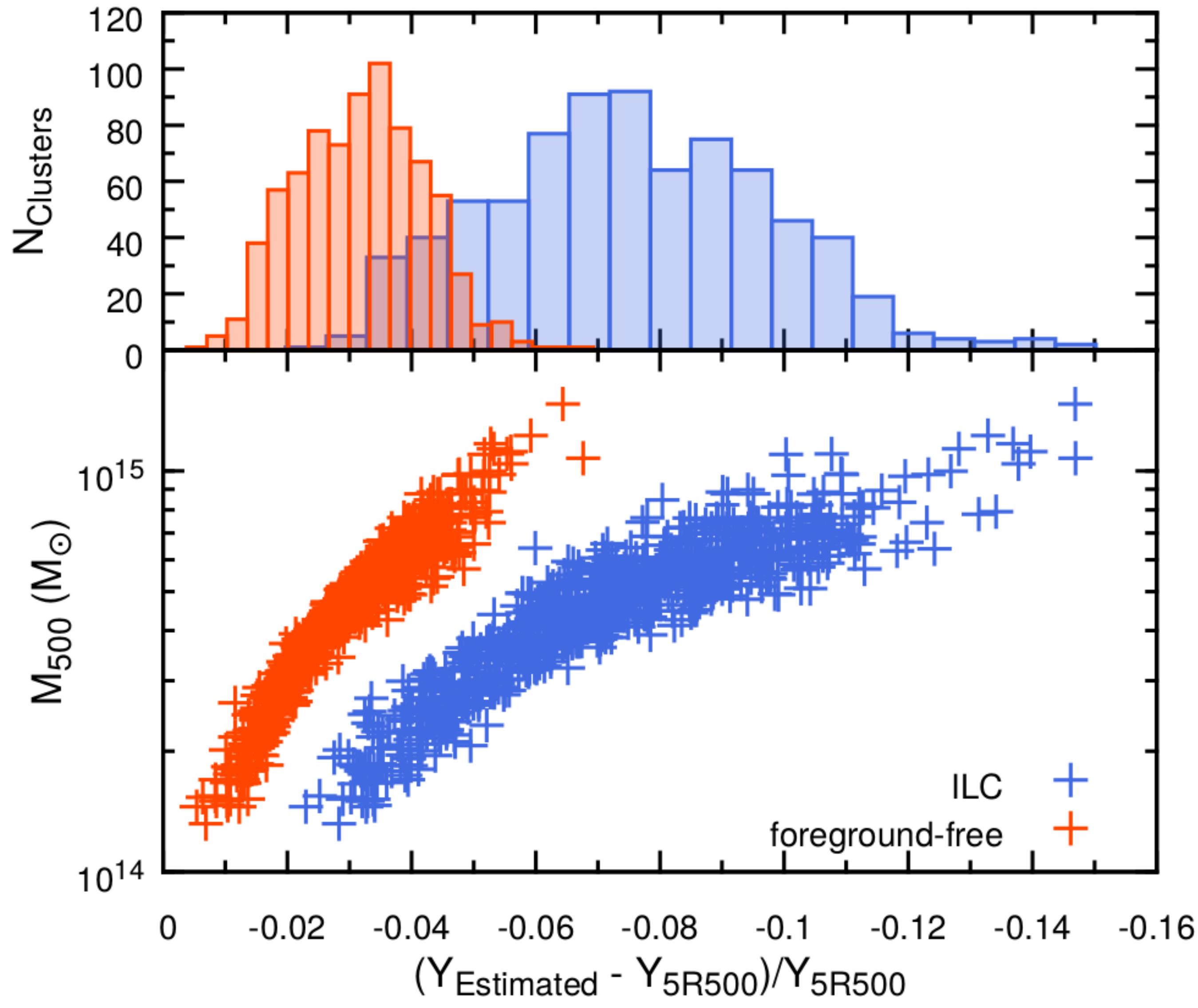
Erler et al., accepted for publication in MNRAS (arXiv:1709.01187)

Cluster FIR em. after foreground removal



Erler et al., accepted by MNRAS (arXiv:1709.01187)

Y-bias



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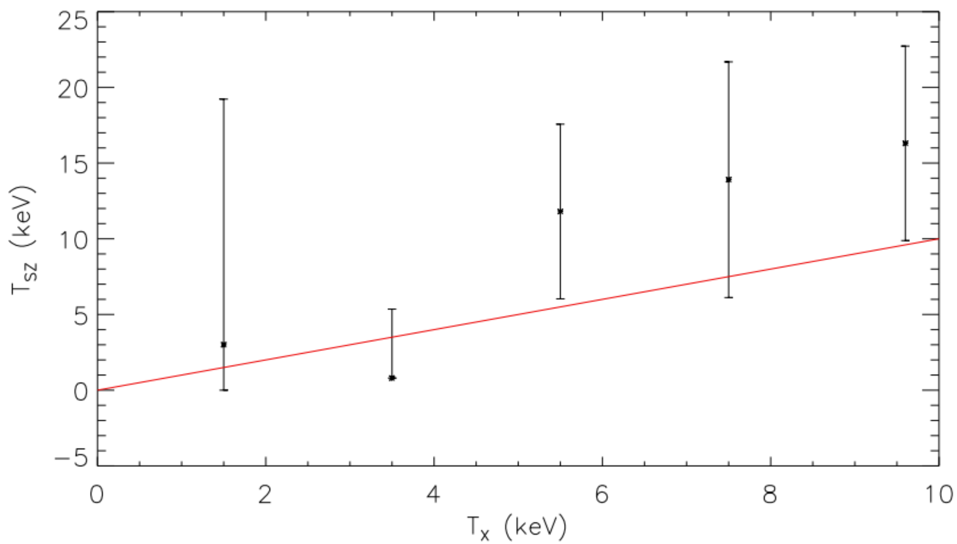
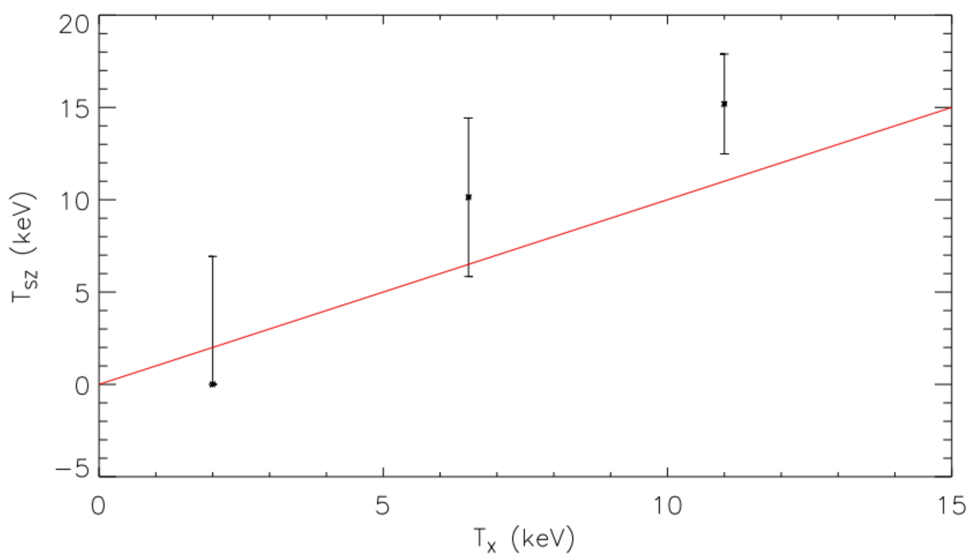
rSZ results from Hurier (2016)



Results for MCXC clusters:

- $T_{SZ} = (1.65 \pm 0.45)\ T_X$
- 3.7σ / 1.4σ significance

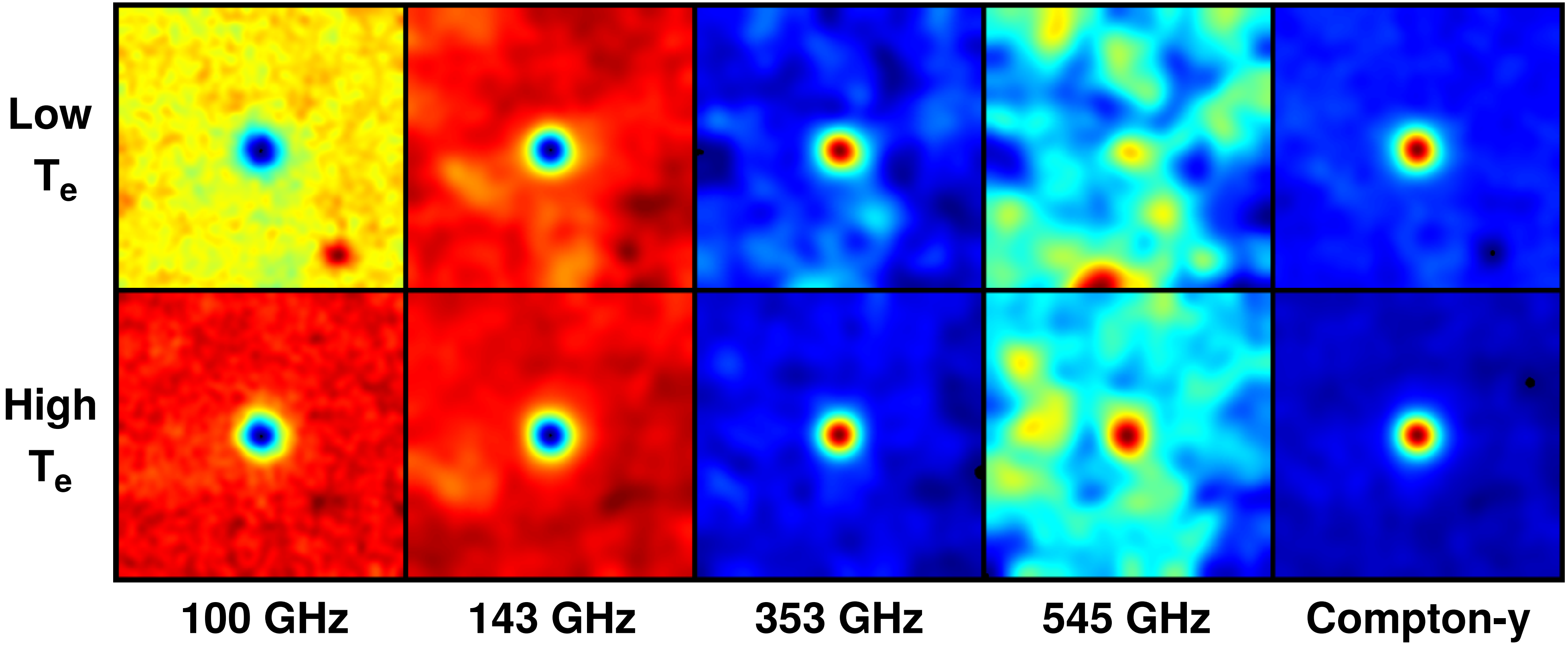


Results for spec. clusters:

- $T_{SZ} = (1.38 \pm 0.26)\ T_X$
- 5.3σ / 1.5σ significance

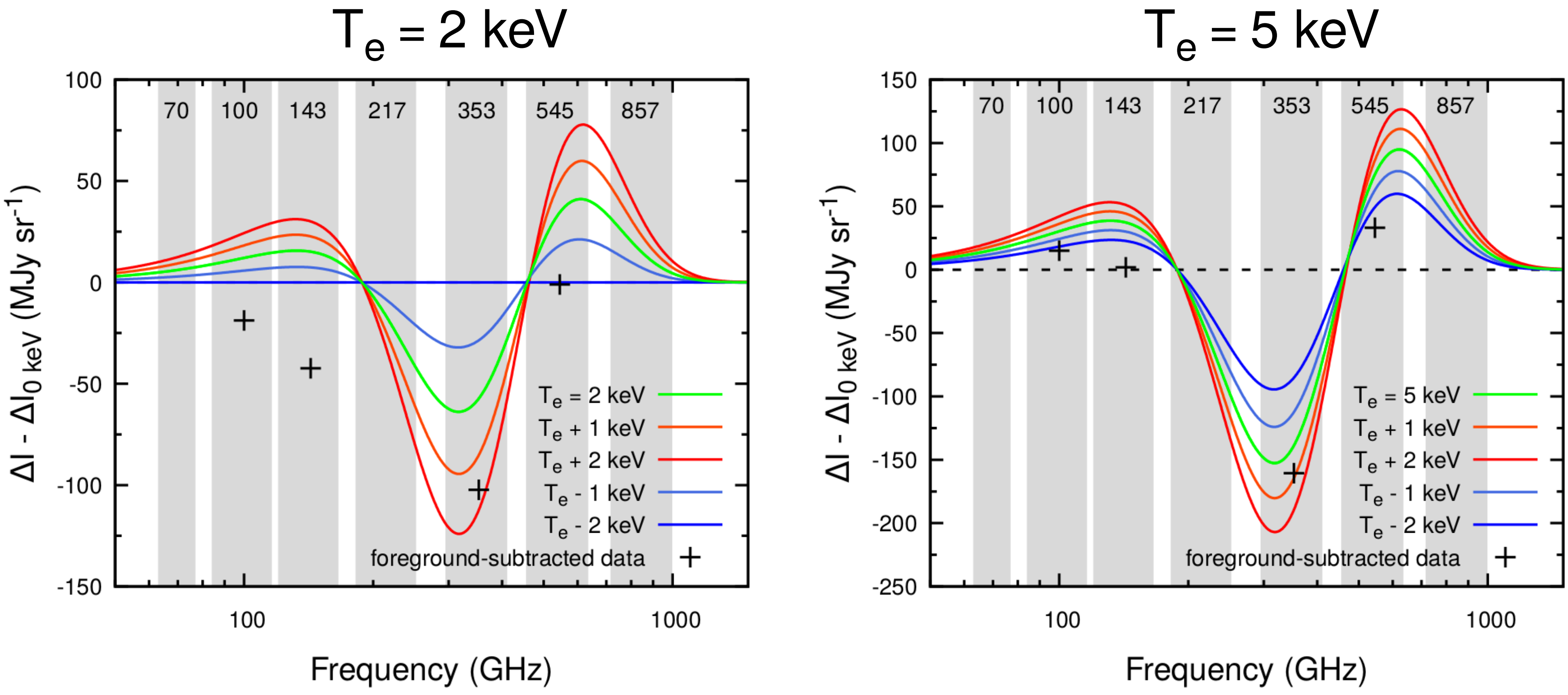
rSZ results from Hurier (2016)

- Stacking analysis of two large samples of clusters
- MCXC clusters with T inferred through L-T relation
- Spectroscopic T_X sample taken from multiple catalogs



The problem with subtracting channels

Subtracting channels for foreground removal can bias rSZ measurements



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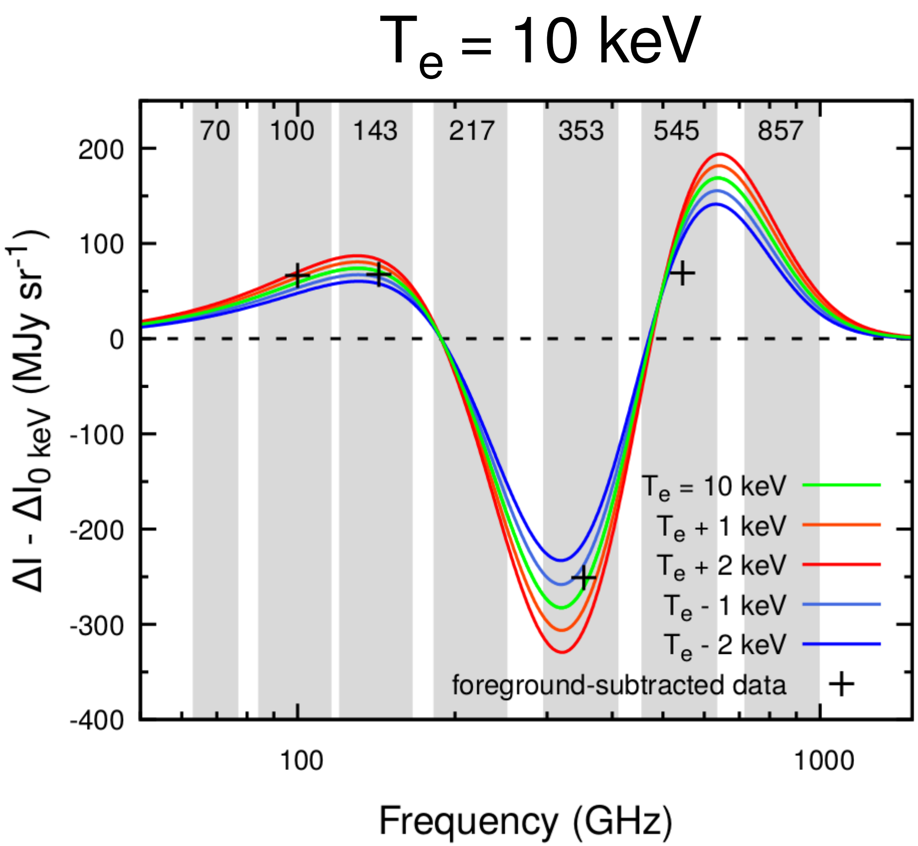
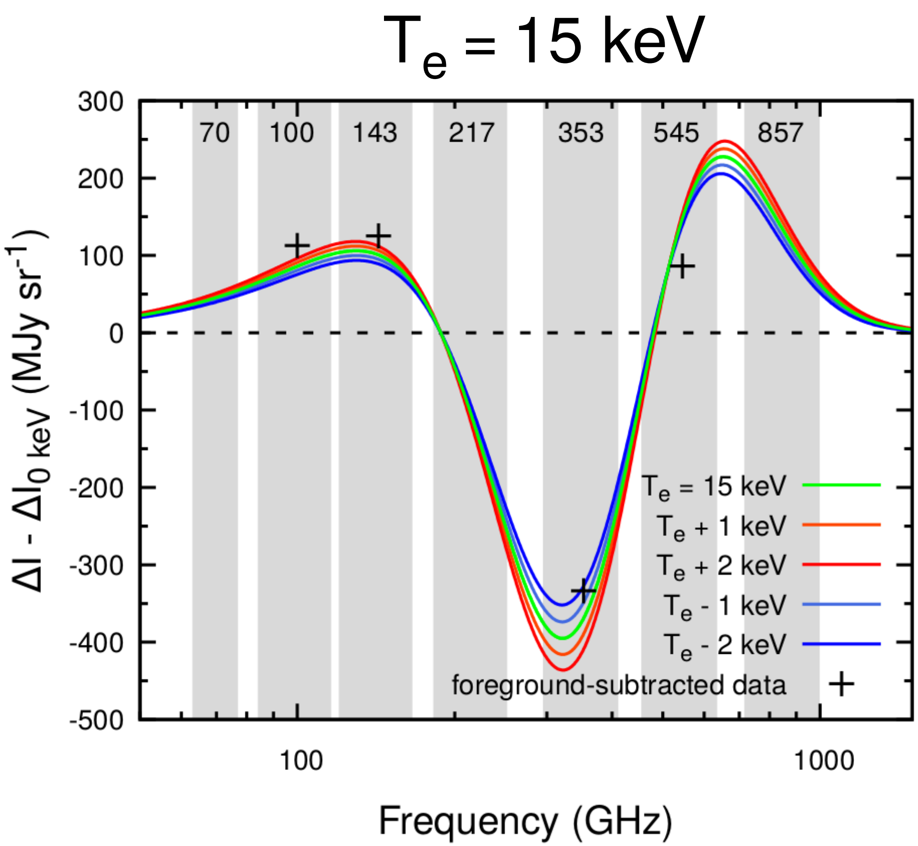
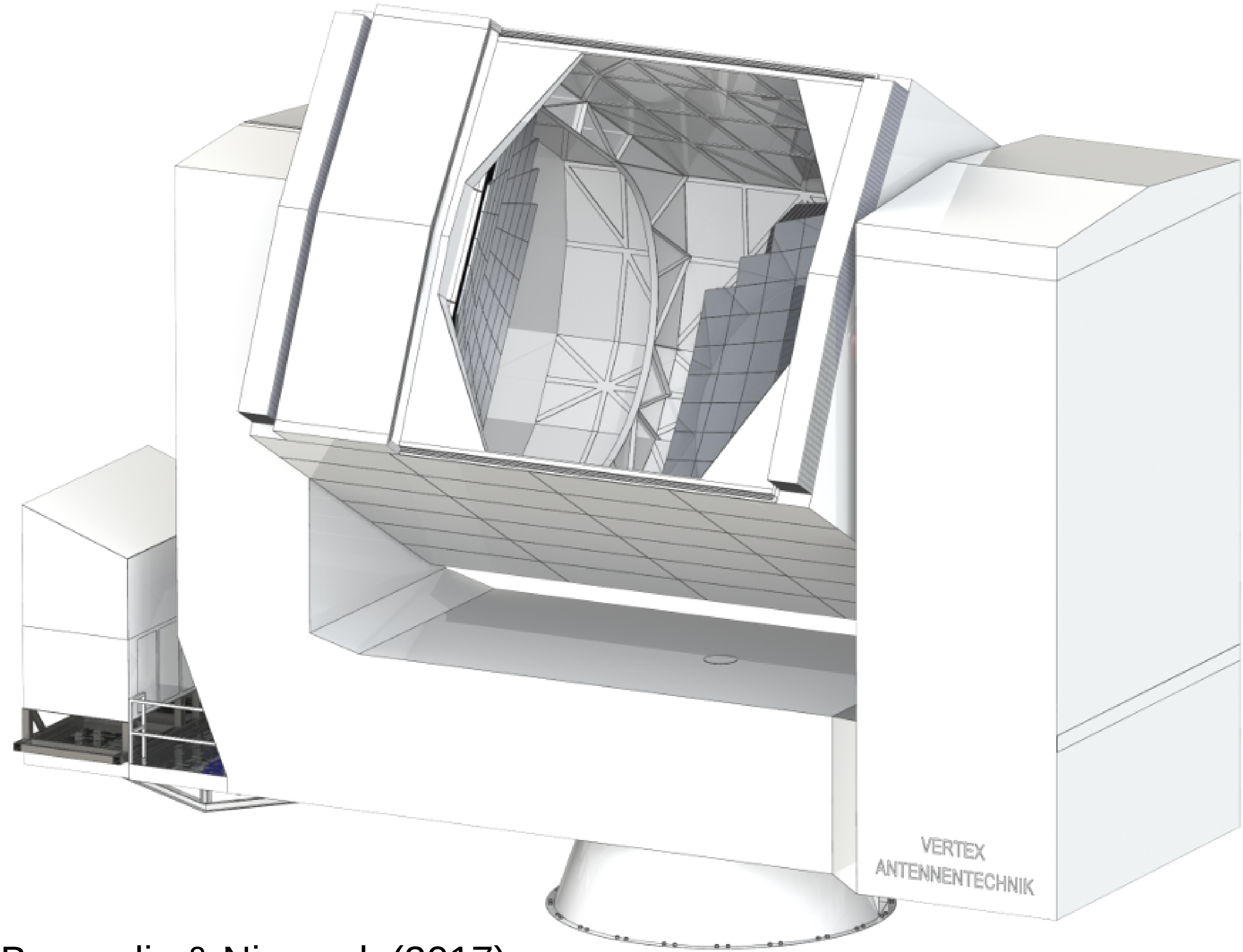


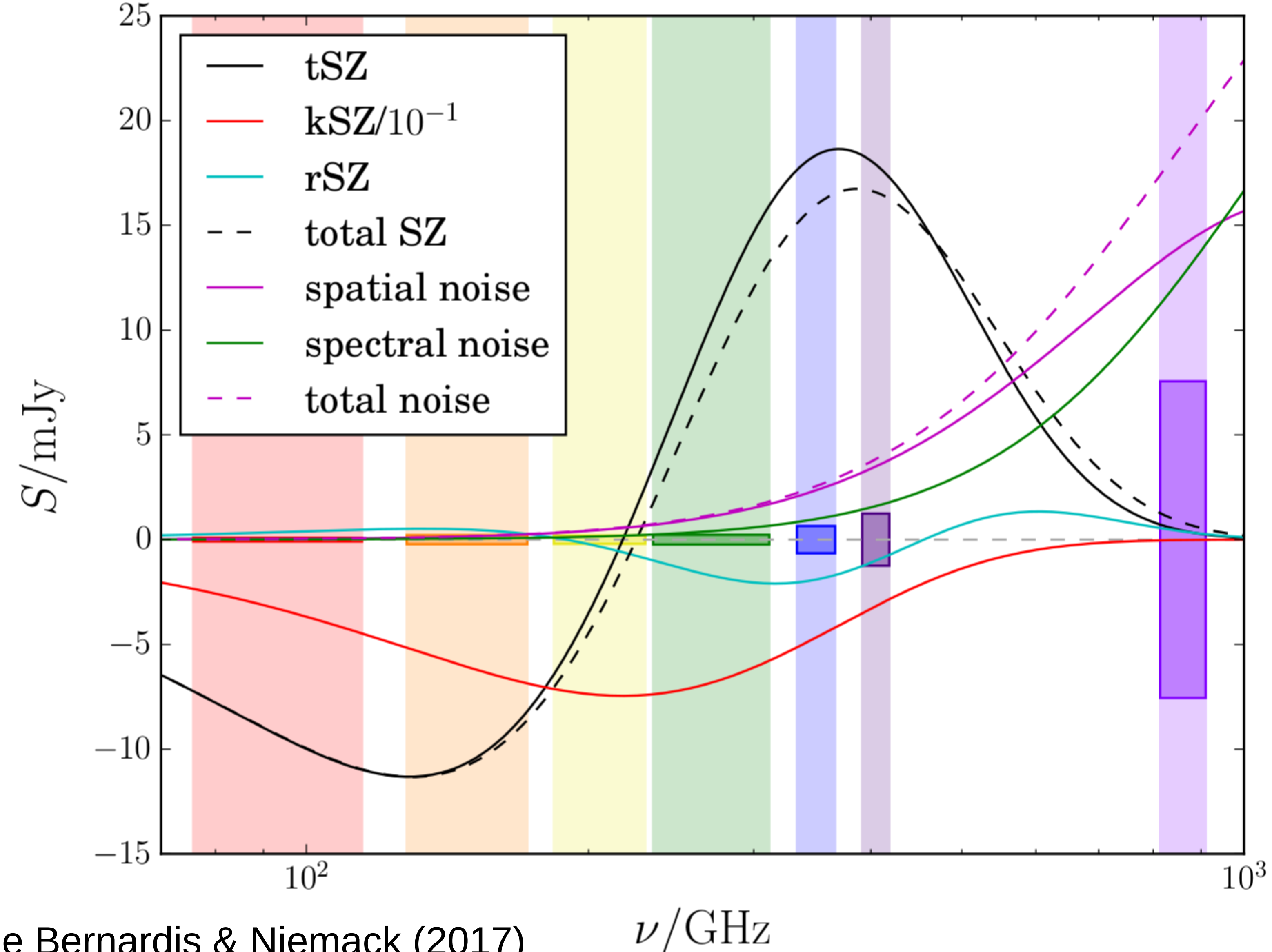


Outlook: CCAT-prime



Mittal, de Bernardis & Niemack (2017)

Outlook: CCAT-prime



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Outlook: CCAT-prime

ν GHz	FWHM arcmin	ΔT mK_{RJ}-arcmin	ΔT mK_{CMB}-arcmin	ΔI kJy/sr-arcmin
		Planck **(all-sky-average full mission data)**		
100	9.68	61.4	77.3	18.9
143	7.30	19.8	33.4	12.4
217	5.02	15.5	46.5	22.5
353	4.94	11.7	156	44.9
545	4.83	5.10	806	46.8
857	4.64	1.90	1.92×10^4	43.5
		CCAT-p (4000 h, 1000 deg^2 survey)		
95	2.2	3.9	4.9	1.1
150	1.4	3.7	6.4	2.6
226	0.9	1.5	4.9	2.4
273	0.8	1.2	6.2	2.7
350	0.6	2.1	25	7.9
405	0.5	3.1	72	16
862	0.2	4.7	6.9×10^4	109

G. Stacey

Erler et al., accepted by MNRAS (arXiv:1709.01187)

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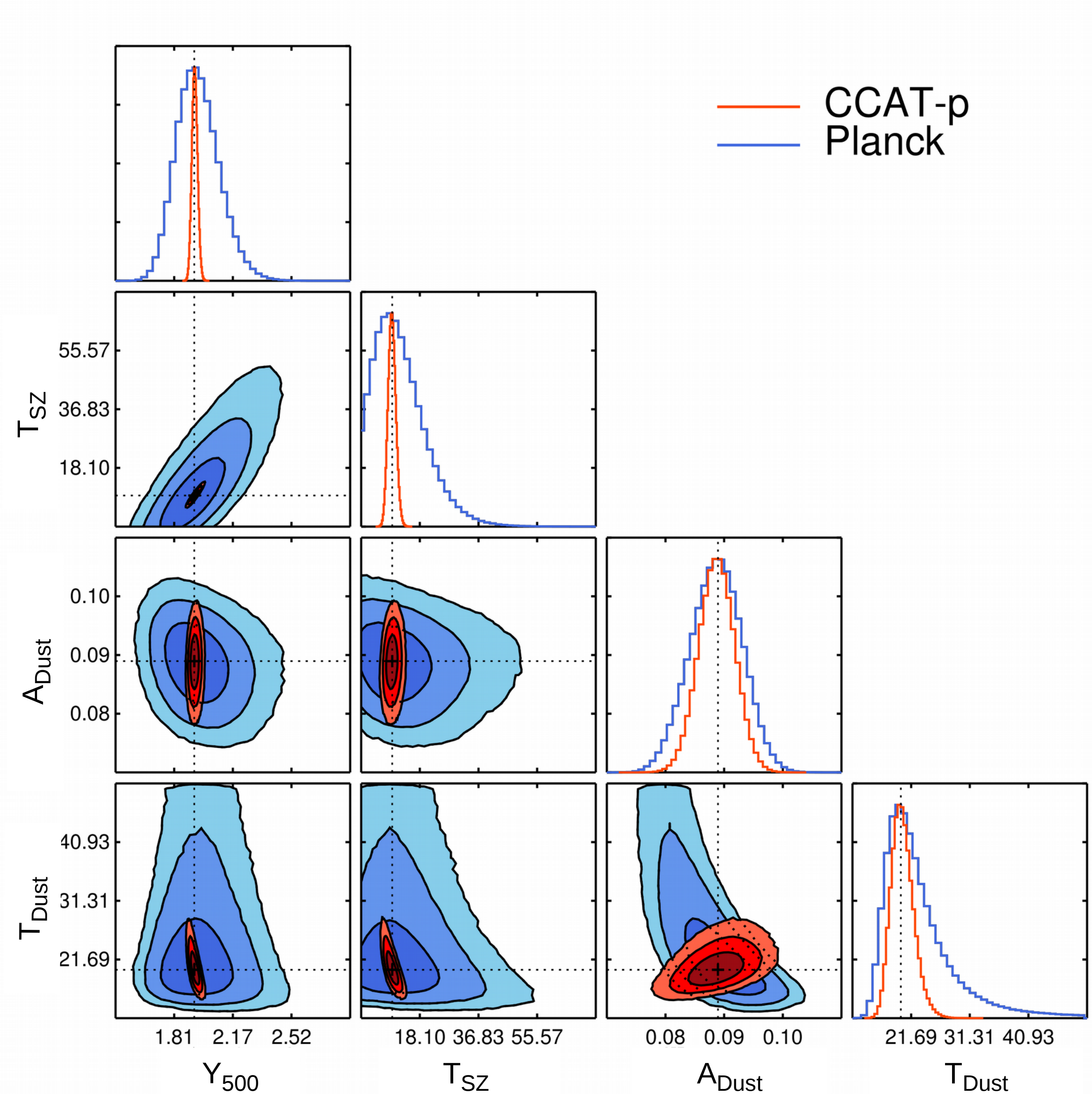
CCAT-prime simulations



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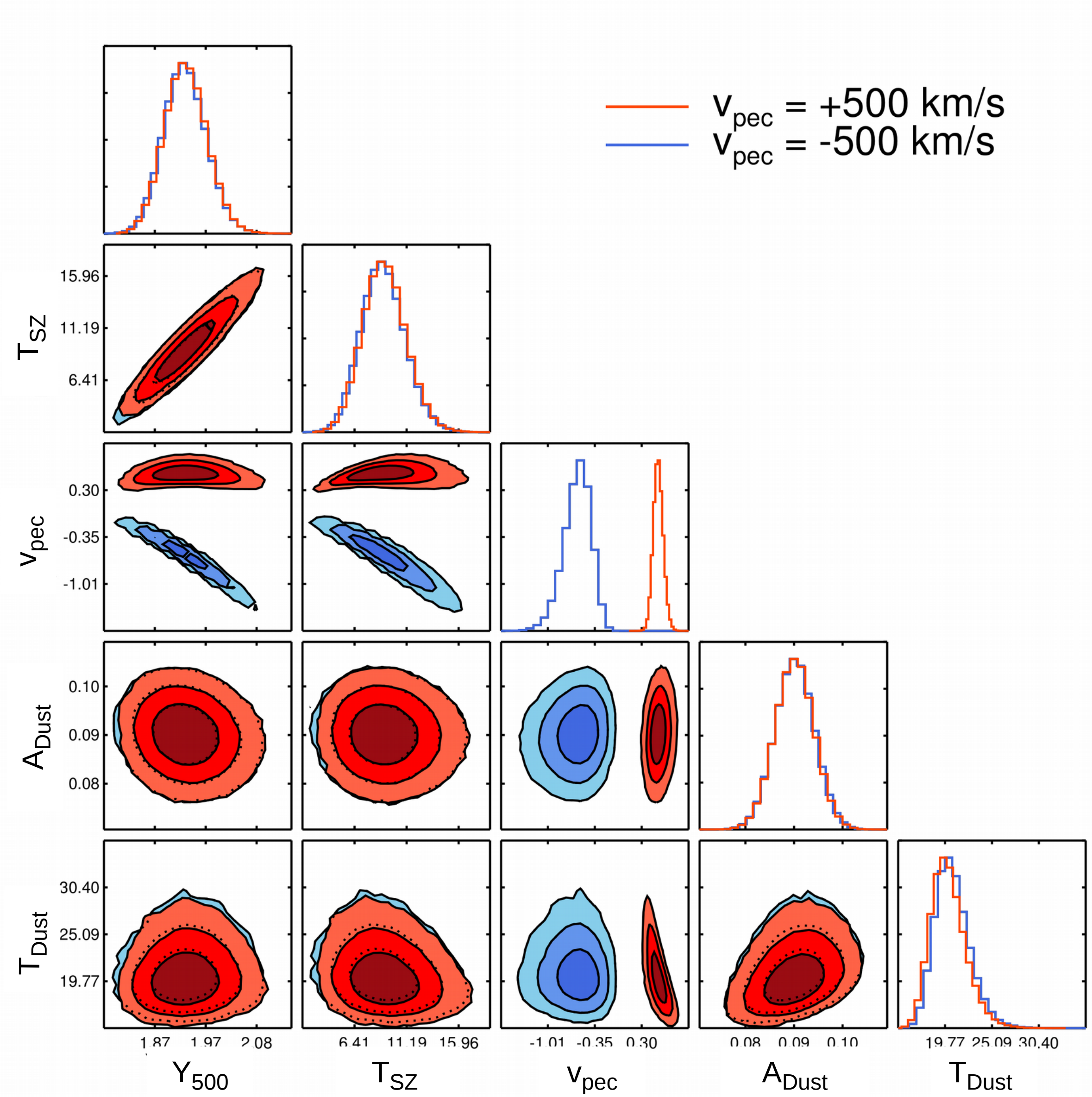
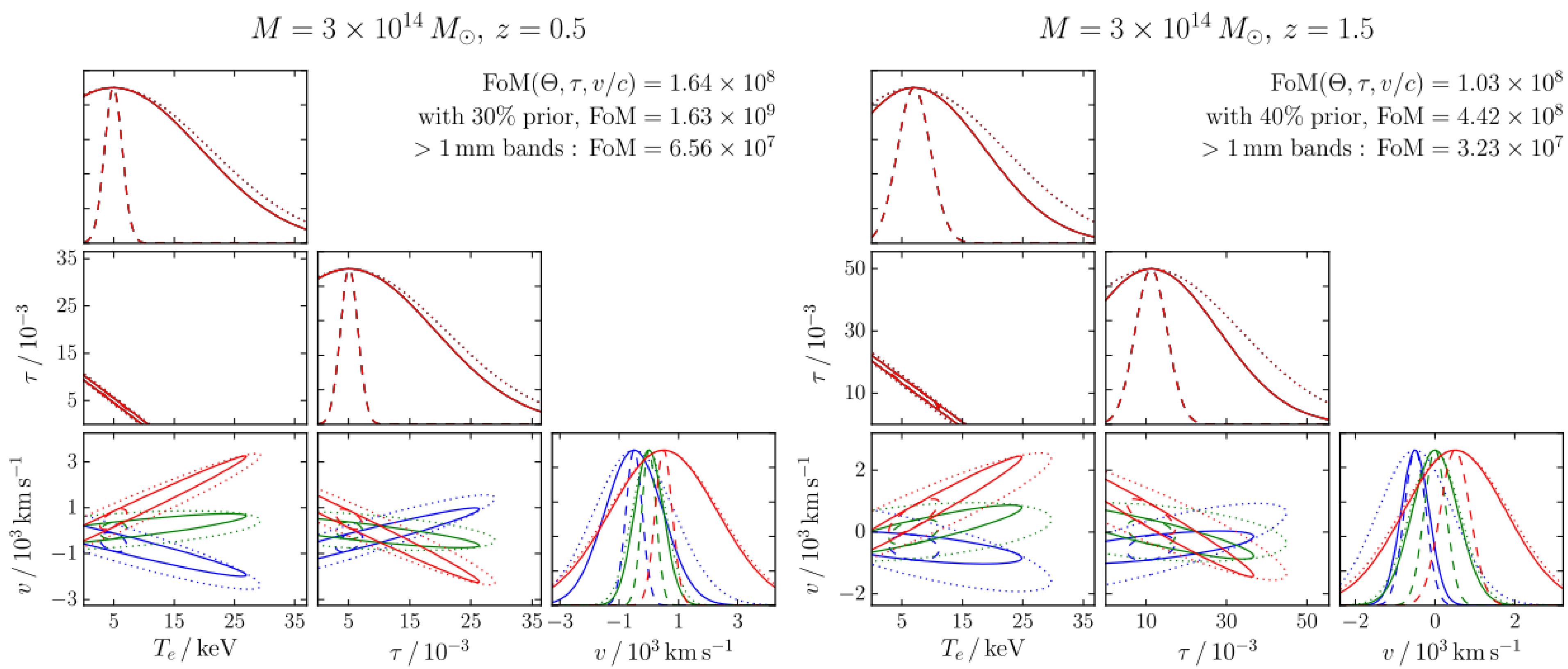
CCAT-prime simulations



Synergies with eROSITA

Temperature priors from eROSITA will improve CCAT-p constraints



See Mittal et al. (arXiv:1708.06365)

Summary

- Rel. corrections to the tSZ allow an independent measure of the ICM temperature
- Galactic foregrounds can be removed efficiently with matched filters
- The ratio T_X/T_{SZ} is a probe of gas clumping
- Neglecting the tSZ rel. corrections will lead to a bias in Y
- CCAT-prime will measure the rSZ and kSZ with high precision