A flexible model of the microwave sky for CCAT-prime

first applications and how to use it

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Context

What is this microwave sky ?

A flexible model of the microwave sky

- A high resolution (native pixel size $\approx 0.86'$) microwave sky model based on full-sky maps templates produced from dark matter only simulations.
- Developed by Jens Erler and Maude Charmetant.

Goals

- To realistically reproduce the major microwave sky components.
- To make it easy to use by everyone, like a "black box".

CCAT-p : Why is it interesting ?

- Produce realistic maps of the microwave sky at the CCAT-p frequencies for map-based predictions.
- Each of the components of the microwave sky can be turned on or off, including the 1/f sky noise.

Microwave sky model

Simulations providing full-sky templates

CITA WebSky model

- Dark matter only peak-patch (Stein et al. 2020). The authors paint halos coming from the collapse of 12228^3 Particles in a 15,4 Gpc box.
- https://mocks.cita.utoronto.ca/index.php/Large_Scale_Structure_Mocks

Sehgal Simulations

- Dark matter only N-body simulations (Sehgal et al., 2010).
- https://lambda.gsfc.nasa.gov/simulation/tb_sim_ov.cfm

Simons Observtory (SO) Simulations

- Based on the (Sehgal et al., 2010) simulations.
- tSZ and CIB were rescaled to match measurements from Planck Collaboration (2014d), (2016h)
- https://lambda.gsfc.nasa.gov/simulation/tb_sim_ov.cfm

Components of the microwave sky

component	template	effective resolution	limitations
	diffuse high-z backgrounds		
CMB	SO, CITA, Sehgal, or any C_ℓ	$N_{\rm side} = 4096$, $0.86'$	–
CIB	SO, CITA, or Sehgal	$N_{\rm side} = 4096$, $0.86'$	extrapolation for $\nu > 350$ GHz necessary for SO and Sehgal
	Galactic foregrounds		
synchrotron	PySM, model 's1'	$N_{\rm side} = 512$, $6.9'$	low spatial resolution
free–free	PySM, model 'f1'	$N_{\rm side} = 512$, $6.9'$	low spatial resolution
thermal dust	PySM, model 'd1'	$N_{\rm side} = 512$, $6.9'$	low spatial resolution
AME	PySM, model 'a1'	$N_{\rm side} = 512$, $6.9'$	low spatial resolution
	point sources		
radio PS	SO & Sehgal	$N_{\rm side} = 4096$, $0.86'$	complicated SED, only linear interp. for $30 < \nu < 350$ GHz not available for CITA
	galaxy clusters		
tSZ	SO, CITA, Sehgal	$N_{\rm side} = 4096$, $0.86'$	no working halo catalogs no rel. corr. applicable
kSZ	SO, CITA, Sehgal	$N_{\rm side} = 4096$, $0.86'$	no working halo catalogs
	Noise		
white noise	given sensitivities	arbitrary	–
atmosheric noise	Choi et al. (2019)	arbitrary	only at SO and CCAT-p freq. no tools to simulate characteristic "stripy" survey noise

Figure: Table from Jens Erler. The Python SkyModel (PySM) from (Thorne et al. 2017)

How to use the developed microwave sky ?

- Code is fully available on Github : `https://github.com/MaudeCharmetant/CCATp_sky_model`

```
def ccatp_sky_model(freq, sensitivity = None, components = 'all', nside_out = 4096,
    lmax = None, beam_FWHM = None, template = 'CITA', unit = 'cmb'):
    ###
return(allsky_map)
```

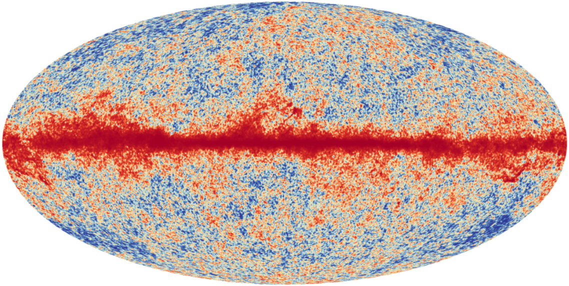

Figure: Map containing all the components, generated from the SO templates at 143 GHz.

Applications

Diverse use of the microwave sky model

tSZ-kSZ correlation work by Maude Charmetant

- All-sky maps to test component separation, via ILC and CILC methods.

CCAT-p forecasts by Jens Erler

- Testing of cluster extraction and survey yields, via matched multi-filtering method.

ntSZ analysis by Vyoma Muralidhara

- Realistic noise covariance for predicting individual cluster spectral fit.

Cross-correlation of tSZ-kSZ

Cosmology : Why study tSZ-kSZ ?

- Could provide a new way to detect kSZ.
- tSZ-kSZ cross-correlation study probes the total amount of baryons in halos. The goal is to study if that could account for the missing baryons.

CCAT-p : Why study tSZ-kSZ ?

- Due to its unique location, CCAT-prime will allow measurements of the SZ effect to unprecedented precision and a clean separation of tSZ and kSZ.
- Possibility to remove CIB biases from both.

Wiener filtering

- Filter made to maximise the response of the signal compare to the noise.

$$W_l = \frac{C_l^{kSZ}}{C_l^{Noise}} \text{ where } Noise = kSZ + CMB + WN$$

Simulating a Planck-like experiment

- We consider a noise of $N = 33\mu K$-arcmin for Planck and a beam of $7'$.

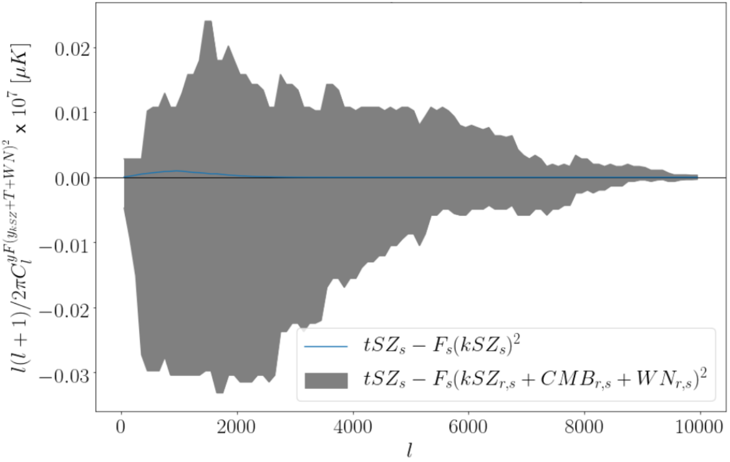

Figure: Using the template SO. Blue: target signal, Grey: 1σ credible interval.

Simulating a CCAT-p like experiment

- We consider a noise of $N = 7\mu K$-arcmin for CCAT-prime and a beam of $1'$.

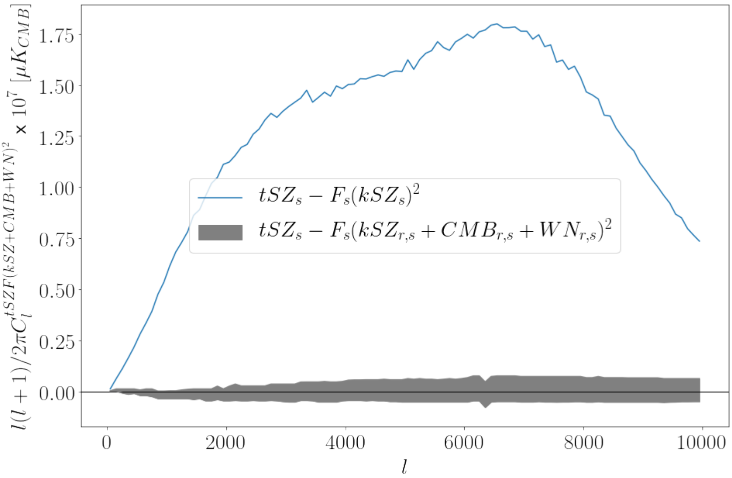

Figure: Using the template SO. Blue: target signal, Grey: 1σ credible interval.

Conclusion

Advantages of the microwave sky

- Can produce a map at any given frequency.
- Allows to choose which component to include between 30 and 860GHz.
- Allows to choose the final resolution of the map and its units.
- Possibility to include sky noise (smooth realizations).
- Can simulate any experiments, e.g. CCAT-prime, PICO, SPT-3G.

Conclusion

- Jens Erler and I created a microwave sky model available for all collaboration members that can be used for realistic map-based CCAT-prime predictions.
- Using this microwave sky model, we see that detection of the kSZ effect might be achieved, via tSZ cross-correlation, with a CCAT-p like experiment.