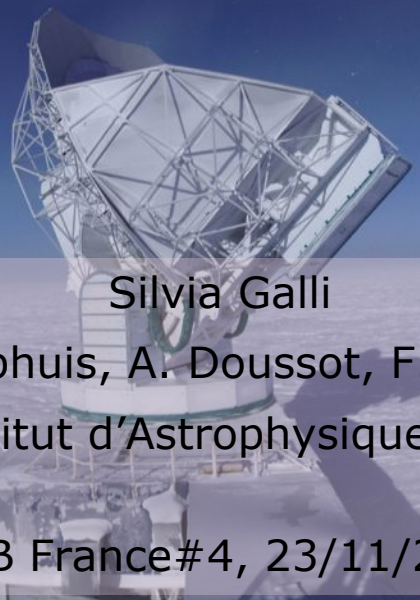
Updates from SPT-3G



Silvia Galli

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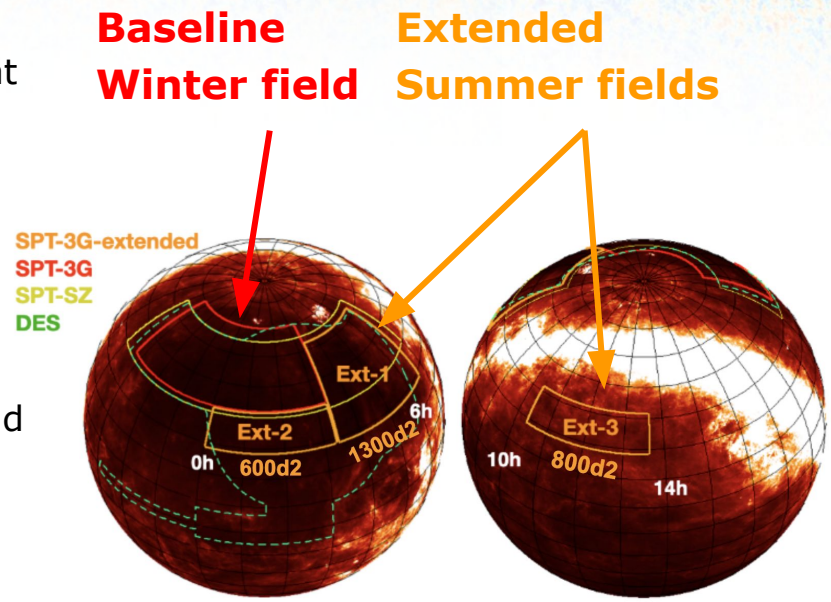
CMB France#4, 23/11/2021

The South Pole Telescope

- SPT is a **10m telescope** at the Amundsen-Scott station at South Pole, lead by the **University of Chicago**.
  - SPT-SZ 2007-2011 (2500deg2, intensity only, 95, 150, 220 GHz)
  - SPTpol 2012-2016 (500deg2, polarization, 95, 150 GHz).
  - **SPT-3G** is the third generation camera, taking data from 2017 (main survey 2019-2023/24, intensity and polarization)
- **SPT3-3G has high resolution (1.2'@150Ghz) and high sensitivity (2.2μK-arcmin) with 16 000 at 95, 150, 220 GHz**.
- Our goal is to measure **cosmological parameters** that will be as tight or **tighter than** the ones from **Planck**.



SPT-3G (2017-2023)	
95, 150, 220 GHz	
1500 deg^2 Winter (baseline)	3000 deg^2 Summer (extended)
@150 GHz in TT 2018: 15μK-arcmin 2019+2020: 5μK-arcmin Goal: **2.2μK-arcmin**	@150 GHz 2yr: **12 μK-arcmin**

SPT-3G expected to reach comparable to ~**S4** in the winter field by the end of observations in the next two years
.

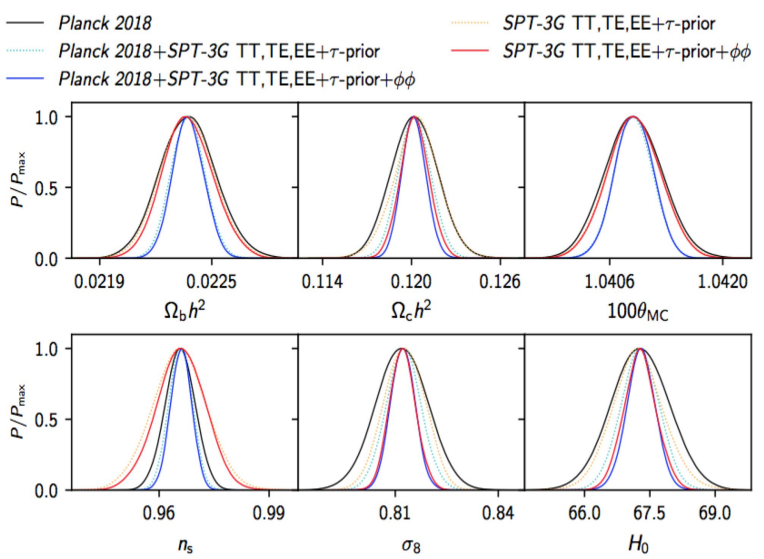
SPT-3G will be super powerful

1. **SPT-3G winter alone** will be able to constrain H_0 and other parameters **as well or better than Planck**! (except for n_s, which are more sensitive to sample variance).

   a. **σ(H0)=0.66 Km/s/Mpc** and **σ(σ_8)=0.006** from SPT3G lensed TT,TE,EE+tauprior(0.007) (without any other Planck data). Comparable precision to Planck.
   b. **Adding ϕϕ σ(H0)=0.34 and σ(σ_8)=0.004** (* ignores correlations between lensed spectra and ϕϕ).
   c. **SPT-3G winter 5yr +Planck will improve most parameters by a factor of 2.**

2. We will test LCDM in different regimes from Planck. We will be able to constrain many extended models e.g. for tensions.

3. **Summer fields have the potential to further improve these numbers (~20%).**



Planck 2018: **H_0=67.36±0.54** Km/s/Mpc
(TTTEEE+ϕϕ) **σ_8=0.8111±0.0060**
Riess 2021: H_0=73.04±1.04
DES Y3: = σ_8=0.733±0.039 (LCDM+mnu)

We will be leading the knowledge of the universe with this data. This comes with great responsibility!

THIS LEVEL OF PRECISION REQUIRES A ROBUST ANALYSIS PIPELINE!

SPT members at IAP

Postdoc:
Federica Guidi
Summer fields

Postdoc:
Ali Rida Khalifeh
Extended models

Research Engineer:
Aristide Doussot
Simulations

PhD student:
Etienne Camphuis
2YR Winter fields

Staff:

Karim Benabed

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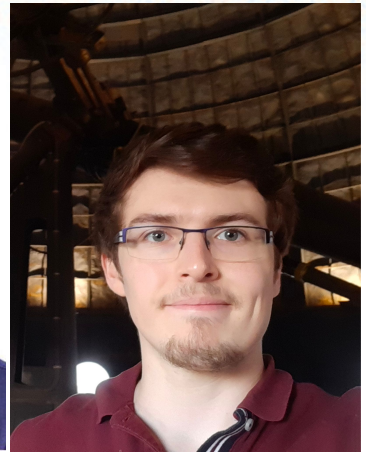

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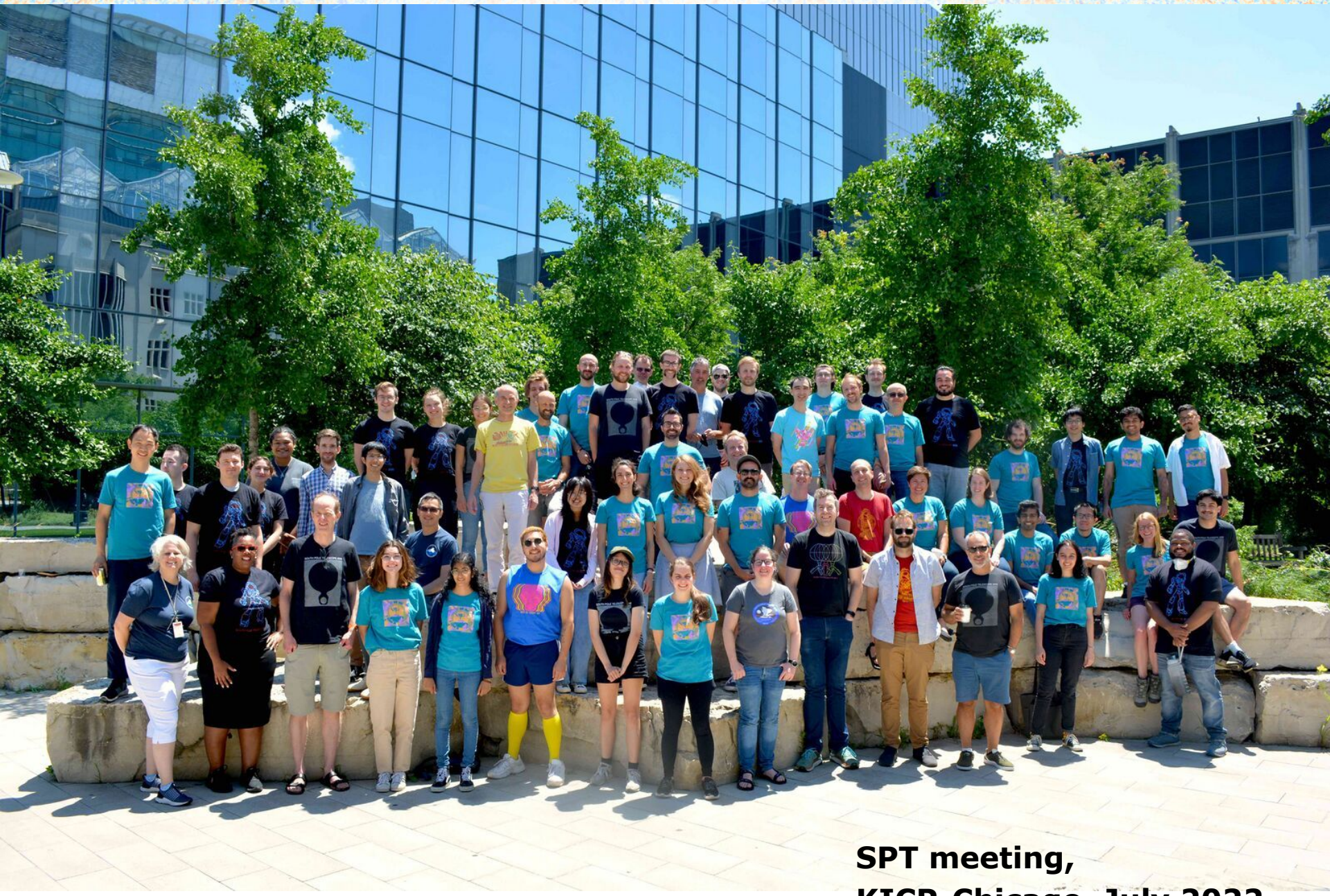


SPT meeting,
KICP-Chicago, July 2022

A few results

First release of SPT-3G on cosmological parameters 2018.

- Balkenhol, et al., Constraints on LCDM extensions from the SPT-3G 2018 EE and TE power spectra, 2021.
- Dutcher, D., et. al., Measurements of the E -mode polarization and temperature-E -mode correlation of the CMB from SPT-3G 2018 data, 2021.

Estimation of covariance matrices for the next SPT-3G release

- Camphuis, E., Benabed, K., Galli, S., Hivon, 'E., Lilley, M., 2022,Accurate CMB covariance matrices: exact calculation and approximations, 2022

Constraining cosmological tensions with SPT

- Smith, T.~L., Lucca, M., Poulin, V., Galli, S. et al., 2022,Hints of Early Dark Energy in Planck, SPT, and ACT data: new physics or systematics? 2022

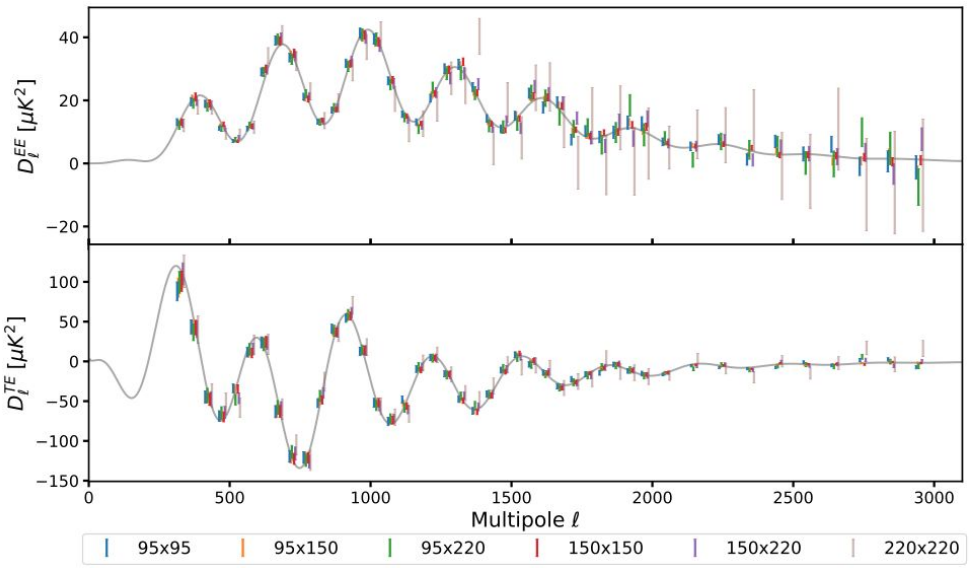
- Galli, S., Pogosian, L., Jedamzik, K., Balkenhol, L., 2022, Consistency of Planck, ACT, and SPT constraints on magnetically assisted recombination and forecasts for future experiments.

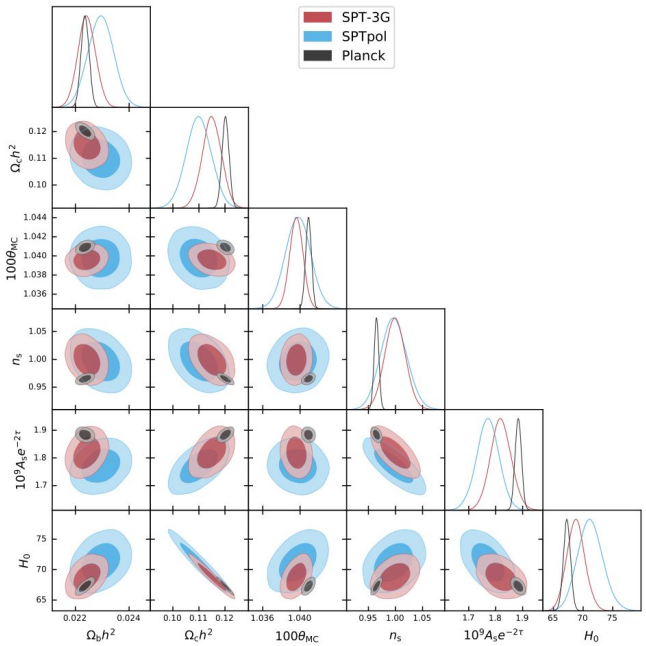
Study of systematics from the SPT-3G

- Galli, S., Wu, W.~L.~K., Benabed, K., et al., 2021, Breaking the degeneracy between polarization efficiency and cosmological parameters in CMB experiments

SPT3G-2018 TEEE (Dutcher+2021, Balkenhol+2021)

- **1500 deg2** region at **95, 150, and 220** GHz taken over a **four month period in 2018**, only half of the focal plane. Flat sky, simulated covariance matrix.
- Already better than SPTpol (3 years of obs.), 21, 15, 58 uK2 in TT @95,150,220 Ghz.
- Errors still three times larger than Planck for the moment.
  Under ΛCDM, on the 5 parameters, Planck and SPT are perfectly consistent.
  - $H_0 = 68.8 \pm 1.5$ km s^{-1} Mpc^{-1}
  - $\sigma_8 = 0.789 \pm 0.016$
  - $A_L = 0.98 \pm 0.12$
- ΛCDM is a good fit to the data, χ^2=513 for 528 bandpowers (PTE=61%).



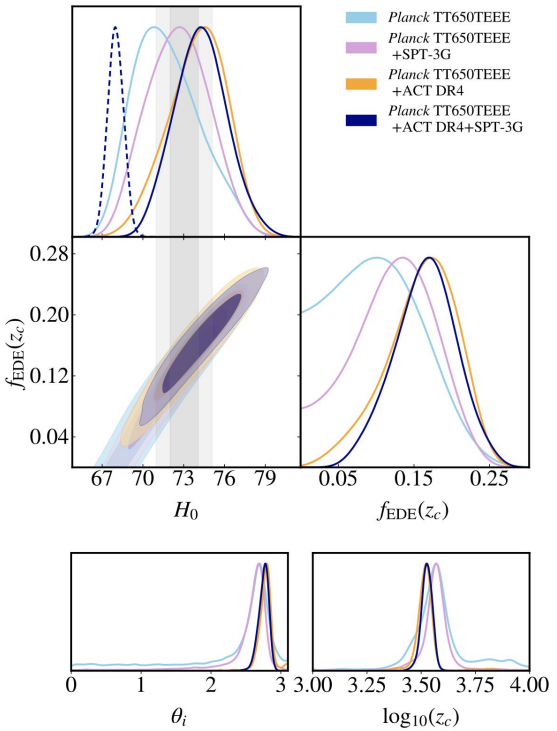


Early Dark Energy and Hubble tension

1. EDE assumes the presence of an ultra-light scalar field φ slow-rolling down an axion-like potential of the form $V(\varphi) \propto [1-\cos(\varphi/f)]^n$, where f is the decay constant of the field.

2. Parametrized by 3 parameters: f_{EDE} fraction of the total energy density in EDE at the critical redshift z_c with an initial field value θ.

3. EDE helps with the Hubble tension because the accelerated expansion of the universe at z~3000 allows the decrease of sound horizon r_s without spoiling too much the damping tail (although it still decreases Silk damping).



We showed that there are small hints of Early dark energy from Planck, Planck+ACT or Planck+SPT, if one excises the Planck TT>650.

T. L. Smith, M. Lucca, V. Poulin, G. F. Abellan, L. Balkenhol, K. Benabed, S. Galli, R. Murgia 2022

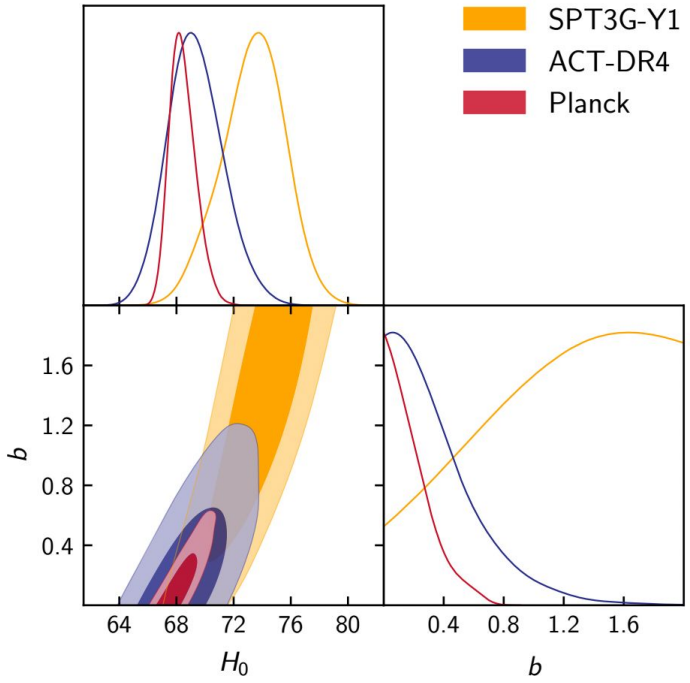
see also La Posta et al. 2022

Primordial magnetic fields and CMB

- Goal: set constraints and forecasts on PMF (Pogosian & Jedamzik 2020)
- This PMF model creates clustering in baryons at very small scales. b is the clustering factor

$$b \equiv \left(\frac{\langle \rho_b^2 \rangle - \langle \rho_b \rangle^2}{\langle \rho_b \rangle^2} \right)$$

- Makes recombination happen earlier, changing the width of the last scattering surface.
- It has an impact on position of the peaks (hence alleviate H_0 tension), damping tail, polarization amplitude.
- It is a <u>toy model</u>.



SPT-3G TEEE less constraining then ACT-DR4 for PMF because ACT-DR4 includes TT (which breaks in particular the ns-omb degeneracy).

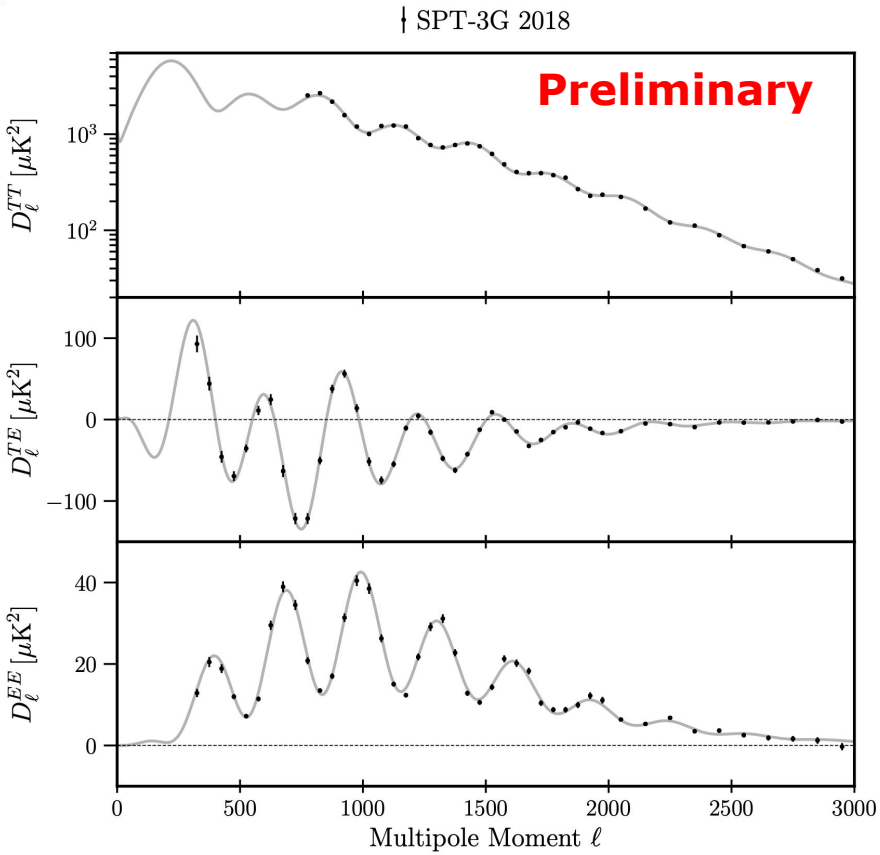
This project was key to realize that we needed to include TT, and to also to better understand our covariance matrix.

S. Galli,L. Pogosian, K. Jedamsik , L. Balkenhol 2021

SPT-3G 2018 TTEEE (in preparation)

SPT-SZ (2007-2011)	**SPTpol (2012-2016)**	**SPT-3G (2017-2023)**	
95, 150, 220 GHz	95, 150 GHz	95, 150, 220 GHz	
2500 deg^2	500 deg^2	1500 deg^2 Winter (baseline)	2500 deg^2 Summer (extended)
18 μK-arcmin@150 GHz	5.5 μK-arcmin@150 GHz	@150 GHz 2018:15μK-arcmin Goal:**2.2μK-arcmin**	@150 GHz 2yr:**12 μK-arcmin**
Temperature only (Story+ 2012)	Polarization only (Henning+ 2017)	**Release 2018:** Polarization only (Balkenhol+ et al. 2021, Dutcher+) Polarization+Temperature (Balkenhol+ in preparation)	

Including TT into SPT-3G



L. Balkenhol+ in preparation

Ratio of error bars on LCDM

SPT-3G 2018/ACT-DR4

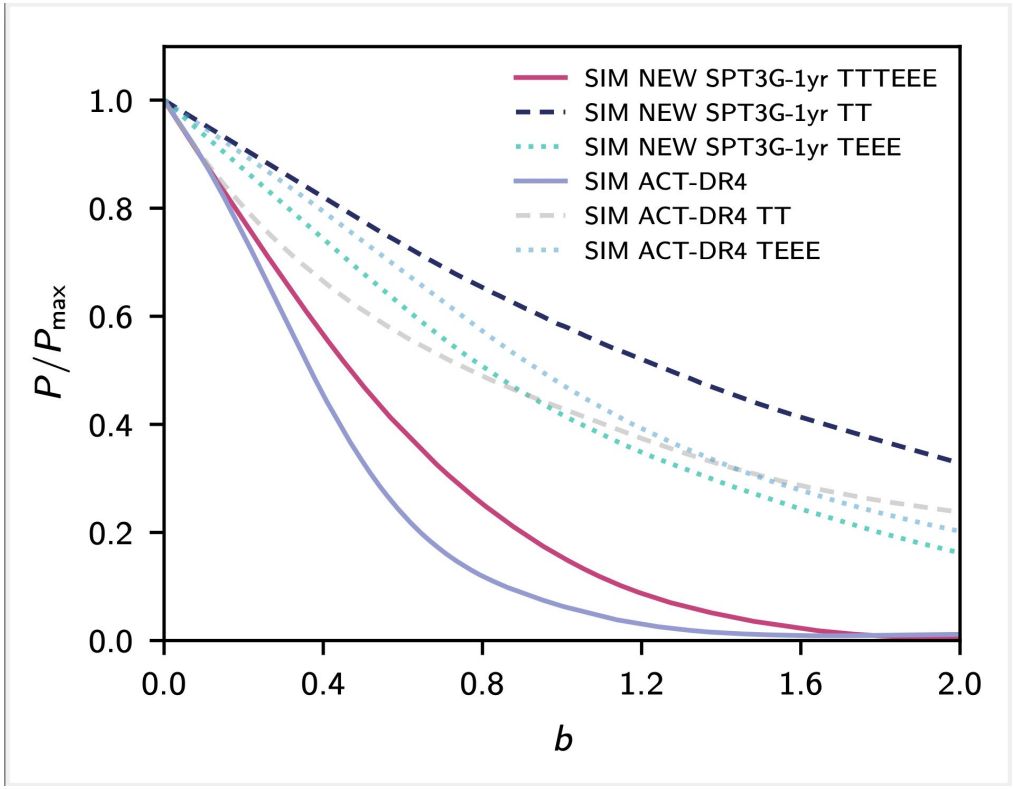
SPT/ACT	TTTEEE	TEEE
obh2	1.03	0.91
omch2	1.02	0.84
H0	1.01	0.83
logA	1.05	0.8
theta	1	0.88
ns	1.07	0.82
omegam*	0.98	0.83
clamp*	1.08	0.72
sigma8*	1.06	0.82

SPT-3G 2018 TTTEEE and ACTDR4 and have same constraints.

SPT3G 2018 TEEE sets stronger constraints w.r.t to ACT by ~20%.

It will be crucial to ensure consistency between the two experiments.

Simulations for SPT-3G TTTEEE 2018 on PMF



SPT-3G 2018 TTTEEE and ACTDR4 have comparable constraining power also on the PMF.

L. Balkenhol+ in preparation

Preliminary

Innovations in SPT-3G 2018 TTTEEE

Blinding: We implemented a blinding procedure. We imposed to pass a number of null tests and consistency checks at the power spectrum and parameter level. We learnt a lot and improve for the next release.

Emulator of Boltzmann code: use of Cosmopower (Alessio Spurio-Mancini et al 2022) to speed up chains allowed us to perform a ton of consistency tests at the parameters level. Alessio worked with us to train Cosmopower for our needs.

https://github.com/alessiospuriomancini/cosmopower/

Covariance matrix: Improved the conditioning of the matrix, now more precise.

What's next 2019/2020

- SPT-3G 2018 TTTEEE should be published in a few weeks.
- Lensing from 2018 data
- Next release: SPT-3G 2019/2020 results (several months away) from winter field (Etienne's talk) and summer fields (Federica's talk).
- Lensing from 2019/2020.

nnovations in the pipeline

- Analytical covariance matrix instead of numerical one (to increase accuracy) (Camphuis+ 2022)
- Impainting of point sources instead of masking (see Etienne's talk)
- Curved instead of flat sky
- Cosmopower
- Blinding