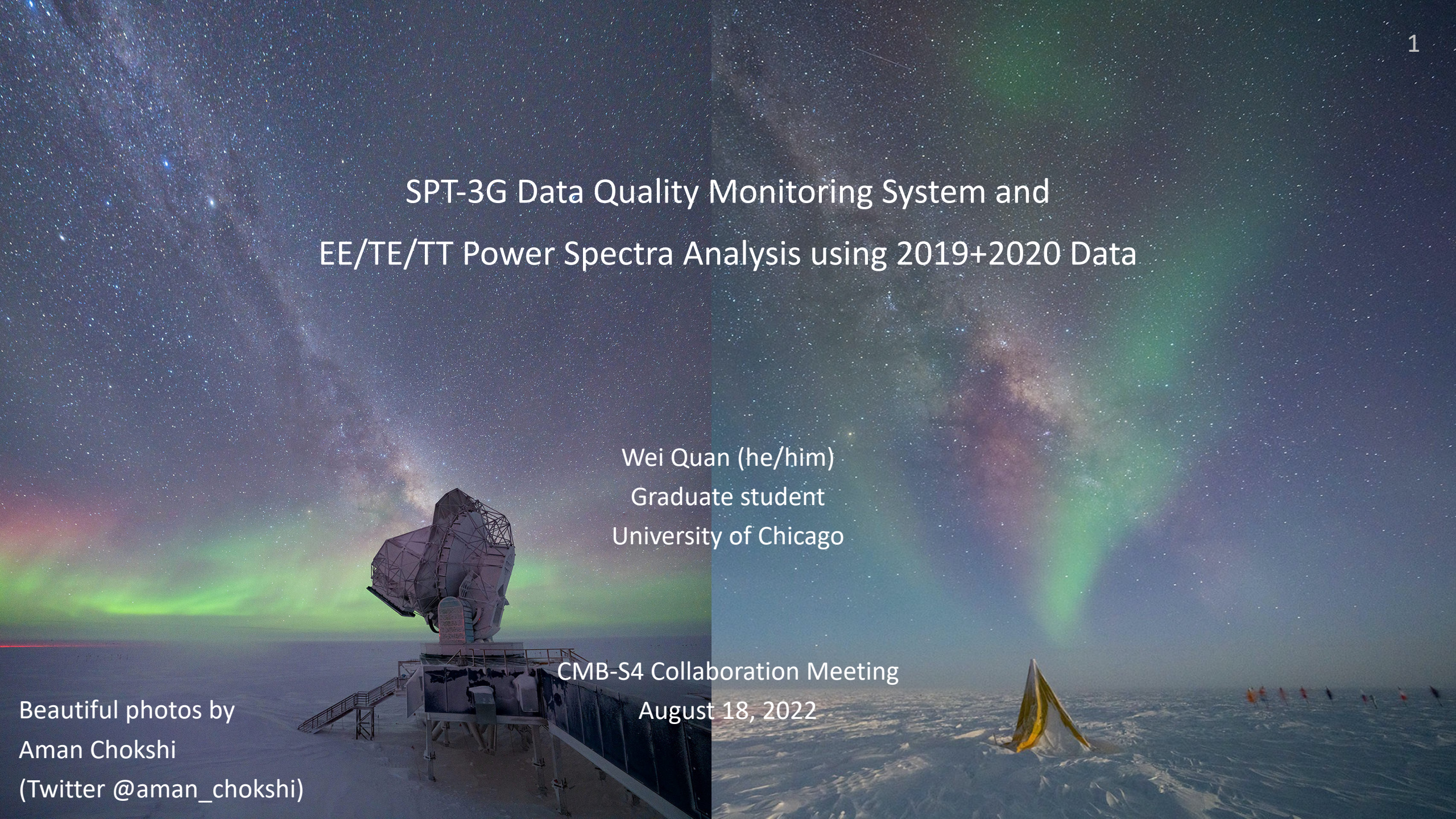


# SPT-3G Data Quality Monitoring System and EE/TE/TT Power Spectra Analysis using 2019+2020 Data

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University of Chicago

CMB-S4 Collaboration Meeting  
August 18, 2022

Beautiful photos by  
Aman Chokshi  
(Twitter @aman\_chokshi)





Hello!

I am a graduate student at the Univ. of Chicago.

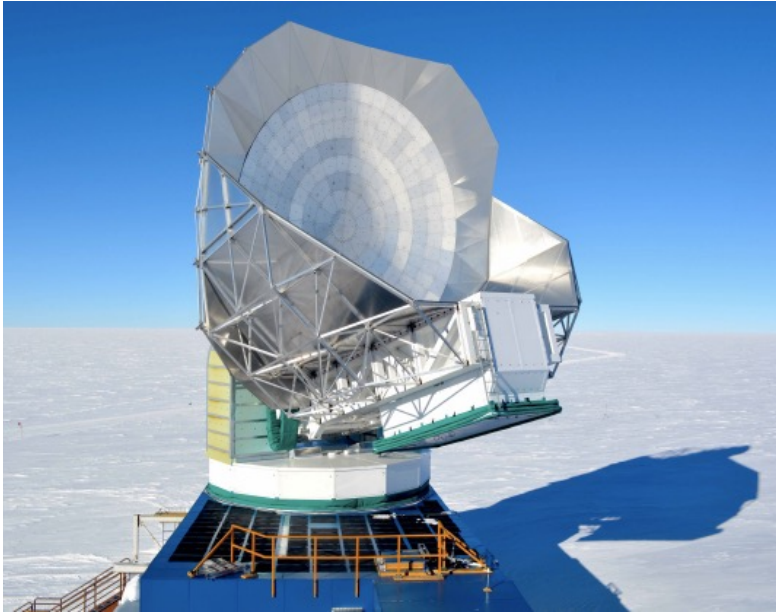
- I have been working on SPT-3G for several years.
- My advisors are Tom Crawford and John Carlstrom.
- I am hoping to graduate at around this time next year and currently thinking about future research directions.

Before coming to Chicago,

- I got my bachelor's degree from the Univ. of Washington.
- I grew up in China and then Japan. (Always moving east!)

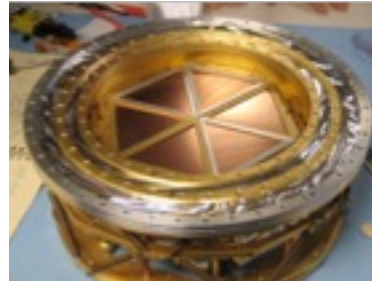


# A quick introduction of the South Pole Telescope



South Pole Telescope

- 10 m primary mirror
- 1.6'/1.2'/1.0' resolution at 95/150/220 GHz



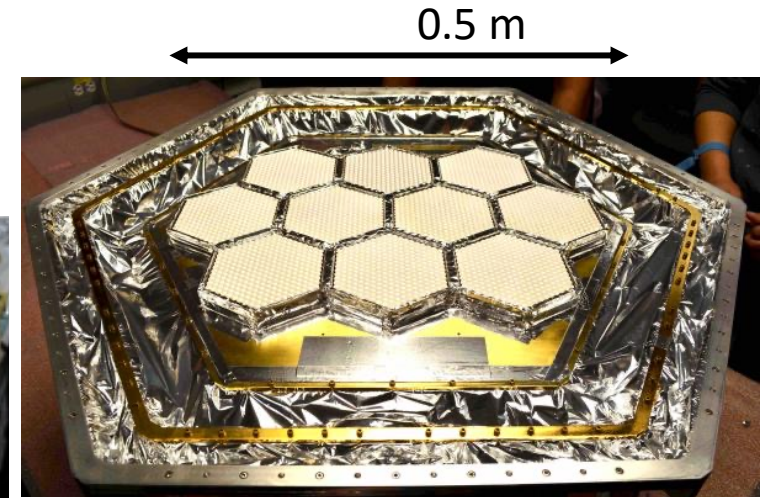
SPT-SZ focal plane

- 2007 - 2011
- 960 bolometers
- 95/150/220 GHz



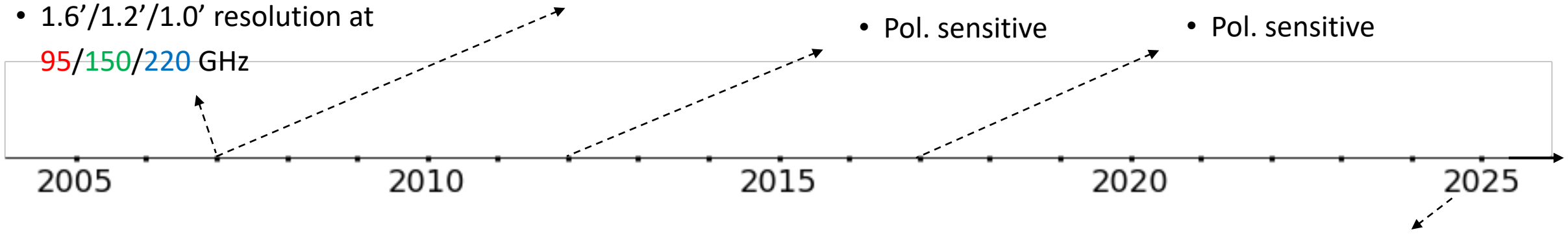
SPTpol focal plane

- 2012 - 2016
- 1,600 bolometers
- 95/150 GHz
- Pol. sensitive



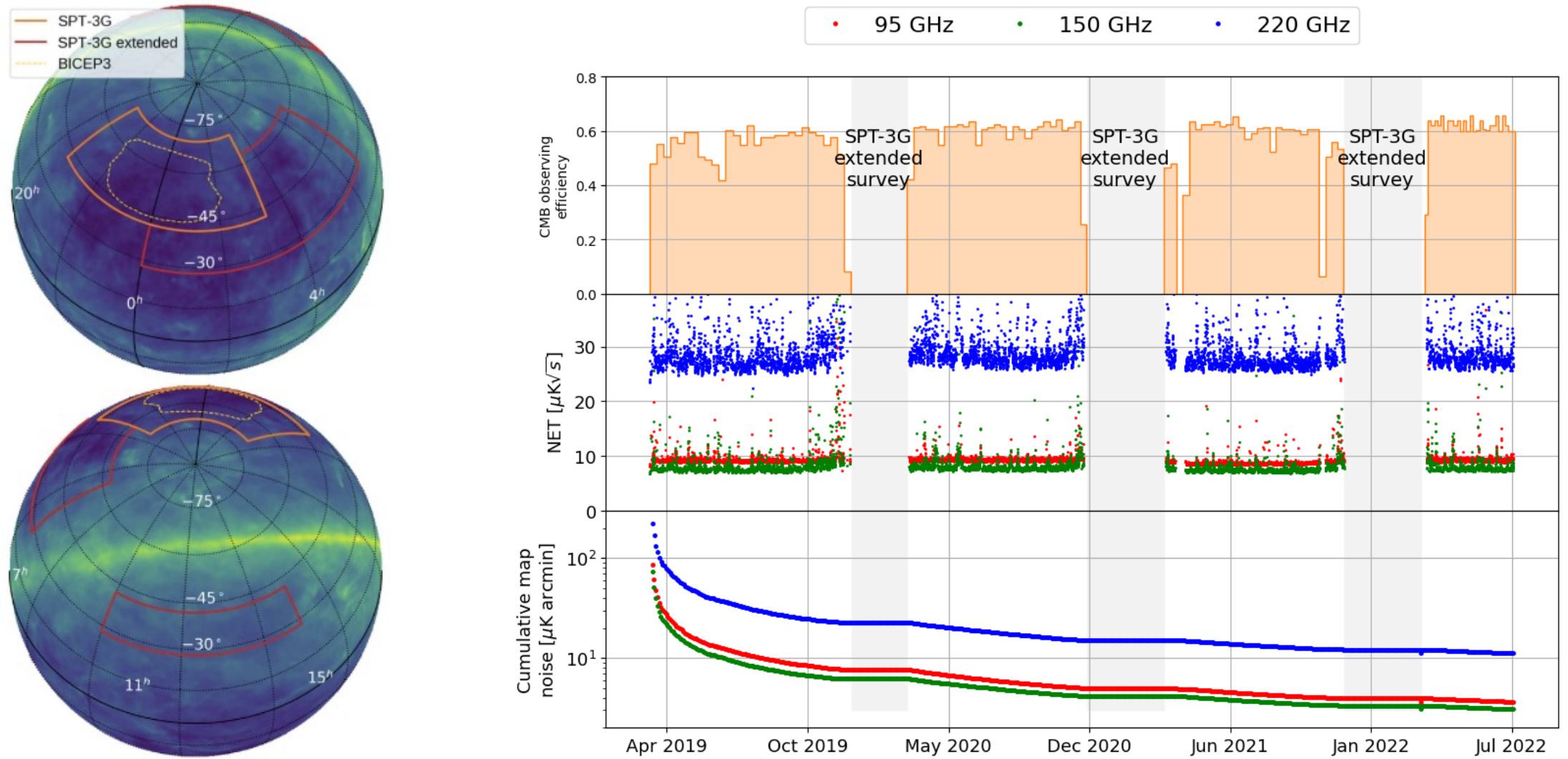
SPT-3G focal plane

- 2017 - present
- 16,000 bolometers
- 95/150/220 GHz
- Pol. sensitive



SPT-3G+ planned to be deployed



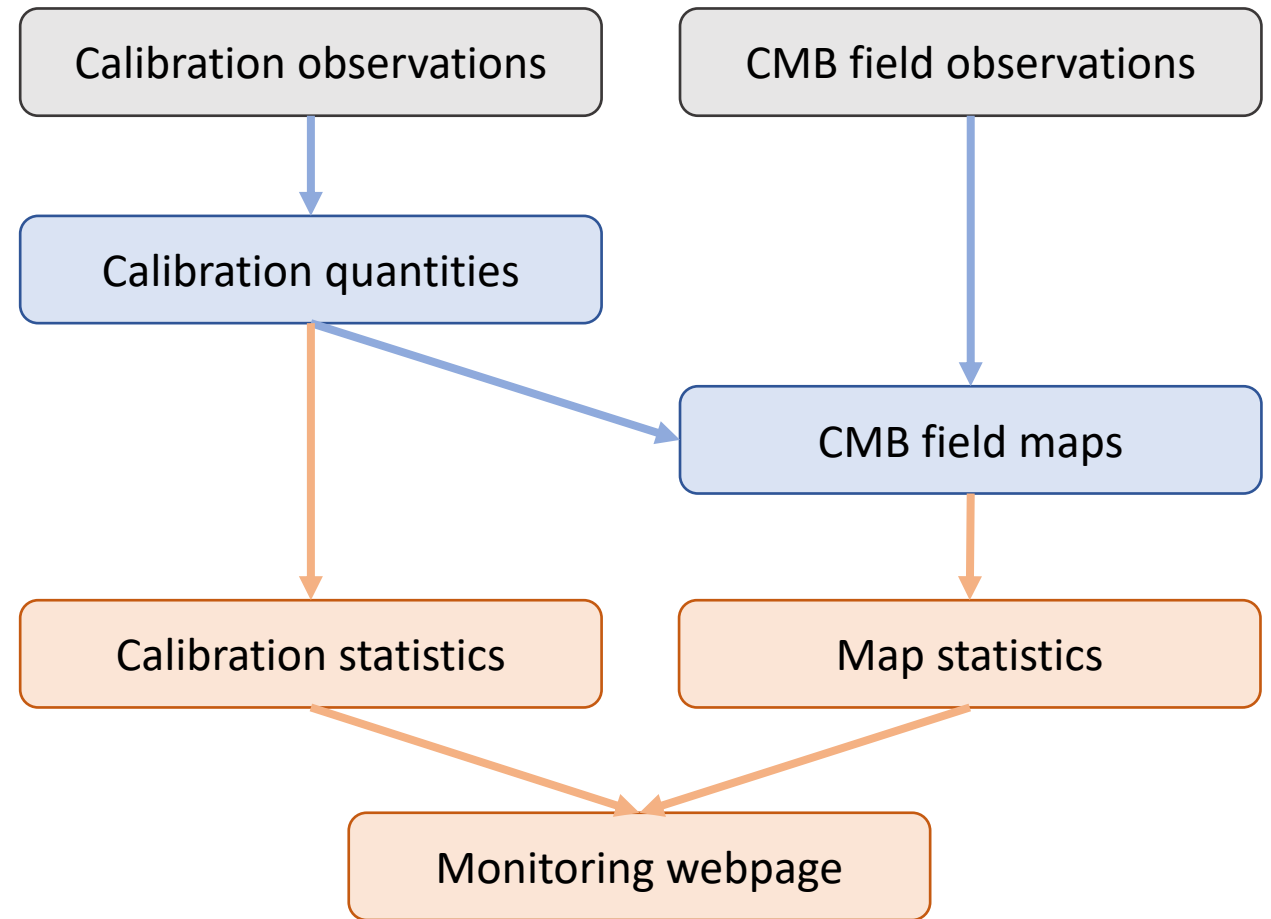


Figures adapted from [J. A. Sobrin et al, 2022 ApJS 258 42.](#)



At the south pole, a few pipelines automatically process our data to help with stable operations.

1. Raw data from calibration observations are analyzed to result in calibration quantities.
2. Calibration quantities and raw data from field observations are combined to result in maps.
3. Calibration quantities and maps are analyzed to result in summary statistics and data quality metrics.
4. Summary statistics and data quality metrics are displayed on a webpage.



I have been actively involved in the development and maintenance of our data quality monitoring system together with Adam Anderson, Sasha Rahlin, and others.



**Calibration Observations** | Field Observations: Winter | Summer | Summer-b | Summer-c | Weather Etc | Fridge Cycles | Read Me

Wafer

w172 |  w174 |  w176 |  w177 |  w180 |  w181 |  w188 |  w203 |  w204 |  w206 |  all

Recent

last\_30

last\_07

last\_03

last\_01

Yearly

2022

2021

2020

2019

2018

Monthly

000000

## Calibrator

Plots last modified: 2022-08-16T01:48:36.960Z (UTC)

### Low Elevation

4.0 Hz calibrator response (all)  
20 < el < 56

median calibrator response [mW]

observation time (UTC)

90 GHz  
150 GHz  
220 GHz

4.0 Hz calibrator S/N (all)  
20 < el < 56

median calibrator S/N

observation time (UTC)

90 GHz  
150 GHz  
220 GHz

Number of bolos with calibrator S/N > 20 at 4.0 Hz (all)  
20 < el < 56

number of alive bolos

observation time (UTC)

90 GHz  
150 GHz  
220 GHz

### High Elevation



Calibration Observations **Field Observations: Winter** Summer Summer-b Summer-c Weather Etc Fridge Cycles Read Me

Recent

- last\_30
- last\_07

Yearly

- 2022
- 2021
- 2020
- 2019

Monthly

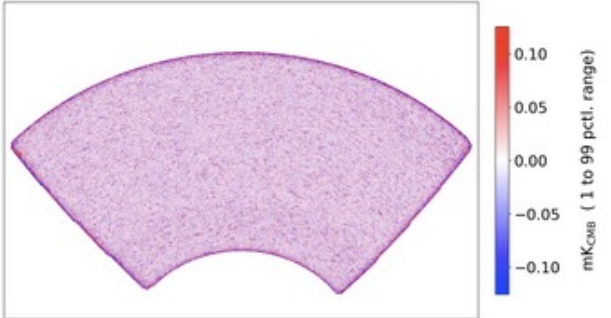
- 202208
- 202207
- 202206
- 202205
- 202204
- 202203

## Maps

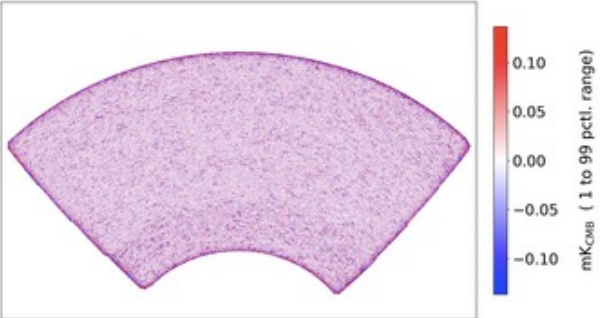
Plots last modified: 2022-08-15T23:10:30.000Z (UTC)

### T Maps

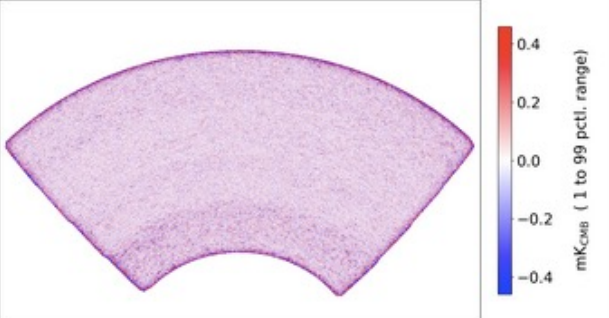
1500d winter field 95GHz coadded T maps  
(data taken between 08-Aug and 15-Aug, {el 0: 15, el 1: 12, el 2: 10, el 3: 8})  
(0.25' map smoothed with 1.0' Gaussian)



1500d winter field 150GHz coadded T maps  
(data taken between 08-Aug and 15-Aug, {el 0: 15, el 1: 12, el 2: 10, el 3: 8})  
(0.25' map smoothed with 1.0' Gaussian)




1500d winter field 220GHz coadded T maps  
(data taken between 08-Aug and 15-Aug, {el 0: 15, el 1: 12, el 2: 10, el 3: 8})  
(0.25' map smoothed with 1.0' Gaussian)




### TT Weight Maps


1500d winter field 95GHz coadded TT weight maps  
(data taken between 08-Aug and 15-Aug, {el 0: 15, el 1: 12, el 2: 10, el 3: 8})



1500d winter field 150GHz coadded TT weight maps  
(data taken between 08-Aug and 15-Aug, {el 0: 15, el 1: 12, el 2: 10, el 3: 8})



1500d winter field 220GHz coadded TT weight maps  
(data taken between 08-Aug and 15-Aug, {el 0: 15, el 1: 12, el 2: 10, el 3: 8})





Calibration Observations **Field Observations: Winter** Summer Summer-b Summer-c Weather Etc Fridge Cycles Read Me

Recent

last\_30

last\_07

Yearly

2022

2021

2020

2019

Monthly

202208

202207

202206

202205

202204

202203

## Fluctuations in Maps

### Noise Levels of T Maps

Calibration Observations
Field Observations: Winter
Summer
Summer-b
Summer-c
Weather Etc
Fridge Cycles
Read Me

Recent

last\_30

last\_07

Yearly

2022

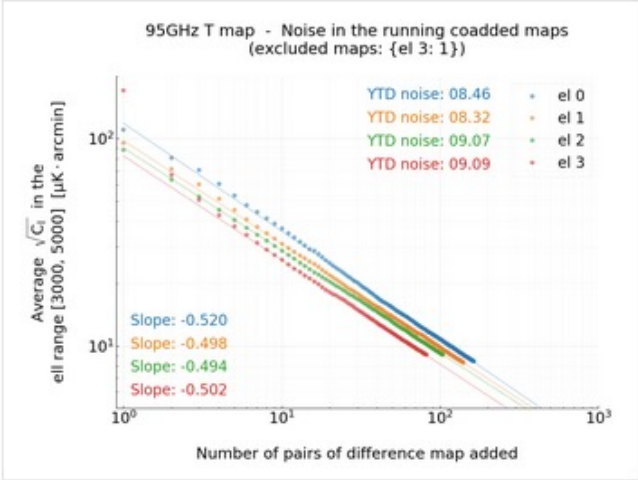
2021

2020

2019

### Noise Levels of Running Coadded T Maps

95GHz T map - Noise in the running coadded maps  
(excluded maps: {el 3: 1})



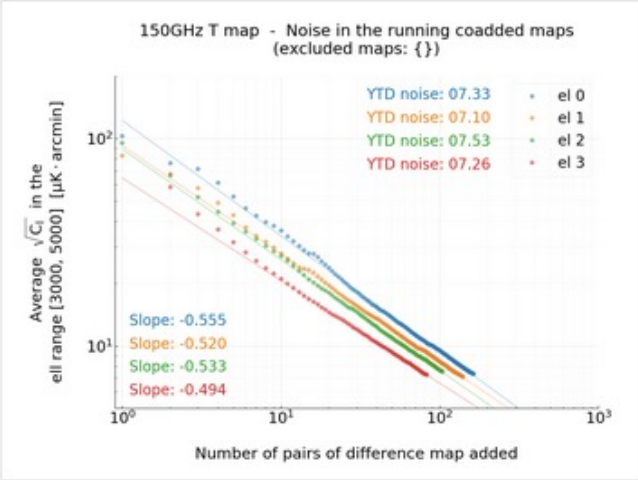
Average  $\sqrt{C_r}$  in the ell range [3000, 5000] [ $\mu\text{K} \cdot \text{arcmin}$ ]

Number of pairs of difference map added

Slopes: -0.520, -0.498, -0.494, -0.502

YTD noise: 08.46, 08.32, 09.07, 09.09

150GHz T map - Noise in the running coadded maps  
(excluded maps: {})



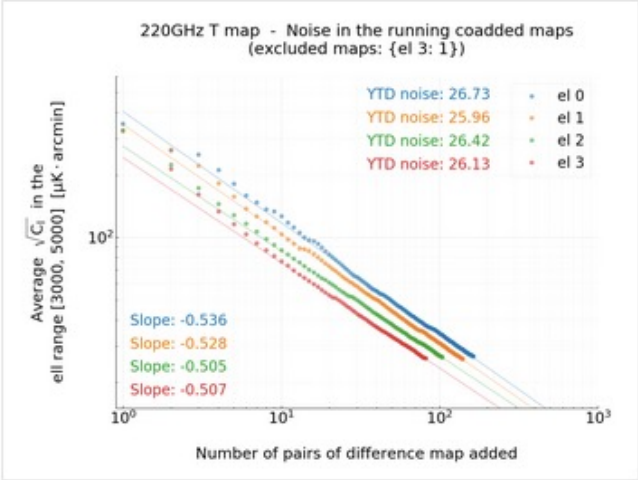
Average  $\sqrt{C_r}$  in the ell range [3000, 5000] [ $\mu\text{K} \cdot \text{arcmin}$ ]

Number of pairs of difference map added

Slopes: -0.555, -0.520, -0.533, -0.494

YTD noise: 07.33, 07.10, 07.53, 07.26

220GHz T map - Noise in the running coadded maps  
(excluded maps: {el 3: 1})



Average  $\sqrt{C_r}$  in the ell range [3000, 5000] [ $\mu\text{K} \cdot \text{arcmin}$ ]

Number of pairs of difference map added

Slopes: -0.536, -0.528, -0.505, -0.507

YTD noise: 26.73, 25.96, 26.42, 26.13

Monthly

202208

202207

202206

202205

202204

202203

### Noise Levels of Individual T Maps

95GHz T map - Distributions of the noise levels of individual maps



bin size = 4.18e+00

MED = 1.51e+02, MAD = 2.22e+00

Modes: 1.51e+02, 1.38e+02, 1.30e+02, 1.13e+02

ra0hdec: 44.75, 52.25, 59.75, 67.25

150GHz T map - Distributions of the noise levels of individual maps



bin size = 4.18e+00

MED = 1.28e+02, MAD = 5.19e+00

Modes: 1.26e+02, 1.13e+02, 1.05e+02, 8.82e+01

ra0hdec: 44.75, 52.25, 59.75, 67.25

220GHz T map - Distributions of the noise levels of individual maps



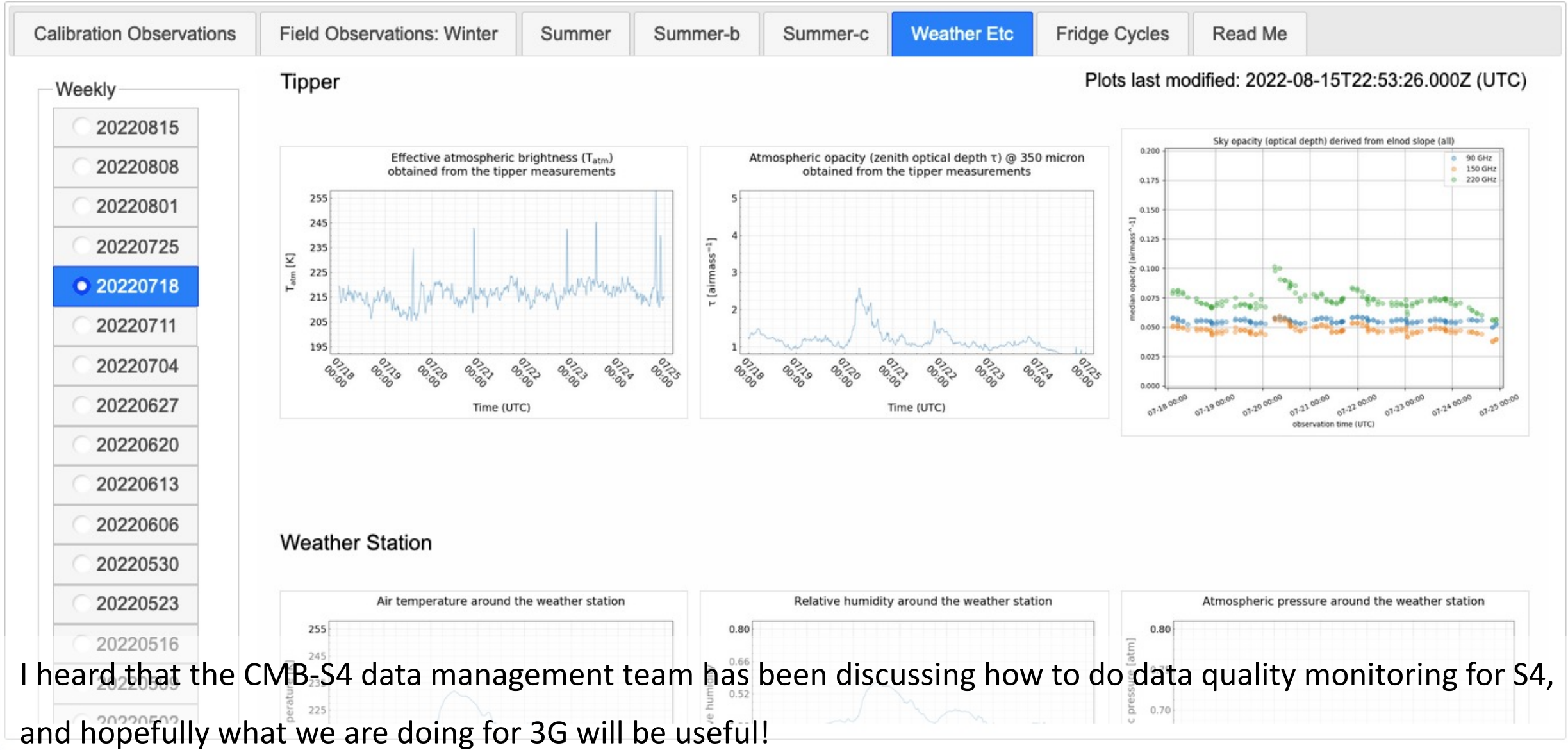
bin size = 1.21e+01

MED = 4.68e+02, MAD = 1.76e+01

Modes: 4.48e+02, 4.11e+02, 3.63e+02, 3.27e+02

ra0hdec: 44.75, 52.25, 59.75, 67.25





I heard that the CMB-S4 data management team has been discussing how to do data quality monitoring for S4, and hopefully what we are doing for 3G will be useful!

Several exciting analysis projects are underway using the 2019+2020 data.

- Low- $\ell$  BB, high- $\ell$  TT, mid- $\ell$  EE/TE/TT power spectra
- Lensing reconstruction/delensing
- Point source finding, cluster finding

etc.

I am leading the EE/TE/TT project using 2019+2020 winter data together with Etienne Camphuis, a graduate student at the Institut d'Astrophysique de Paris (IAP).



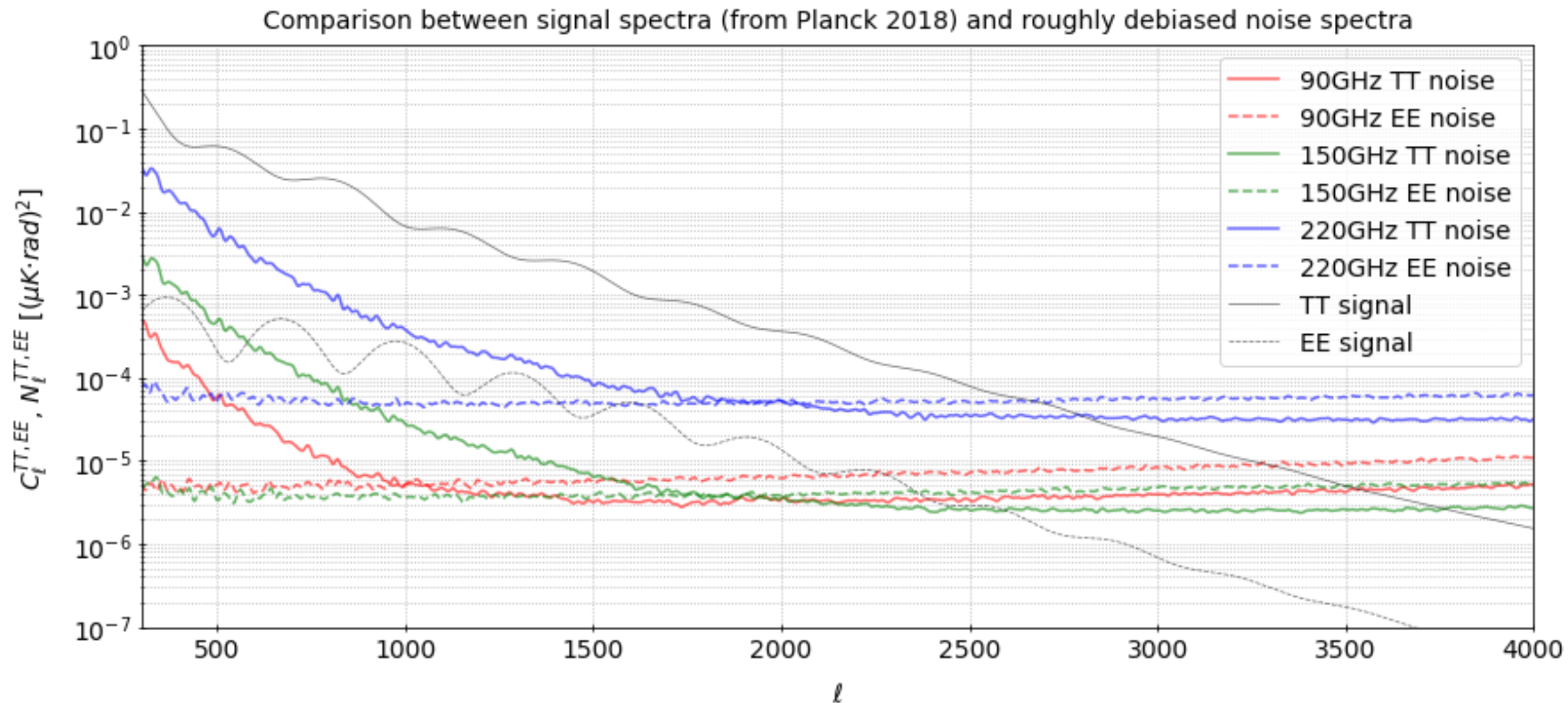
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Like our 2018 EE/TE analysis ([Dutcher, Balkenhol et al, Phys. Rev. D 104, 022003](#)), we are using

- the MASTER formalism ([Hivon et al, 2002 ApJ 567 2](#)):  
filter timestreams to make them roughly white noise to reduce the full maximum likelihood solution to a simpler bin-and-average method, then estimate the filtering bias using simulations
- a cross-spectrum approach ([Polenta et al, JCAP11\(2005\)001](#)):  
average cross-spectra among a number of partial-depth coadds to reduce the noise bias that might result from an approach of calculating auto-spectra of full coadds

Unlike the 2018 analysis, we are using

- HEALPix maps instead of flat-sky maps (and the [PolSpice](#) program for spectrum estimation) to avoid certain nonideal projection effects
- analytical calculations to build bandpower covariance to reduce the simulations we need to run and the reliance on conditioning techniques ([Camphuis et al, arXiv 2204.13721](#))



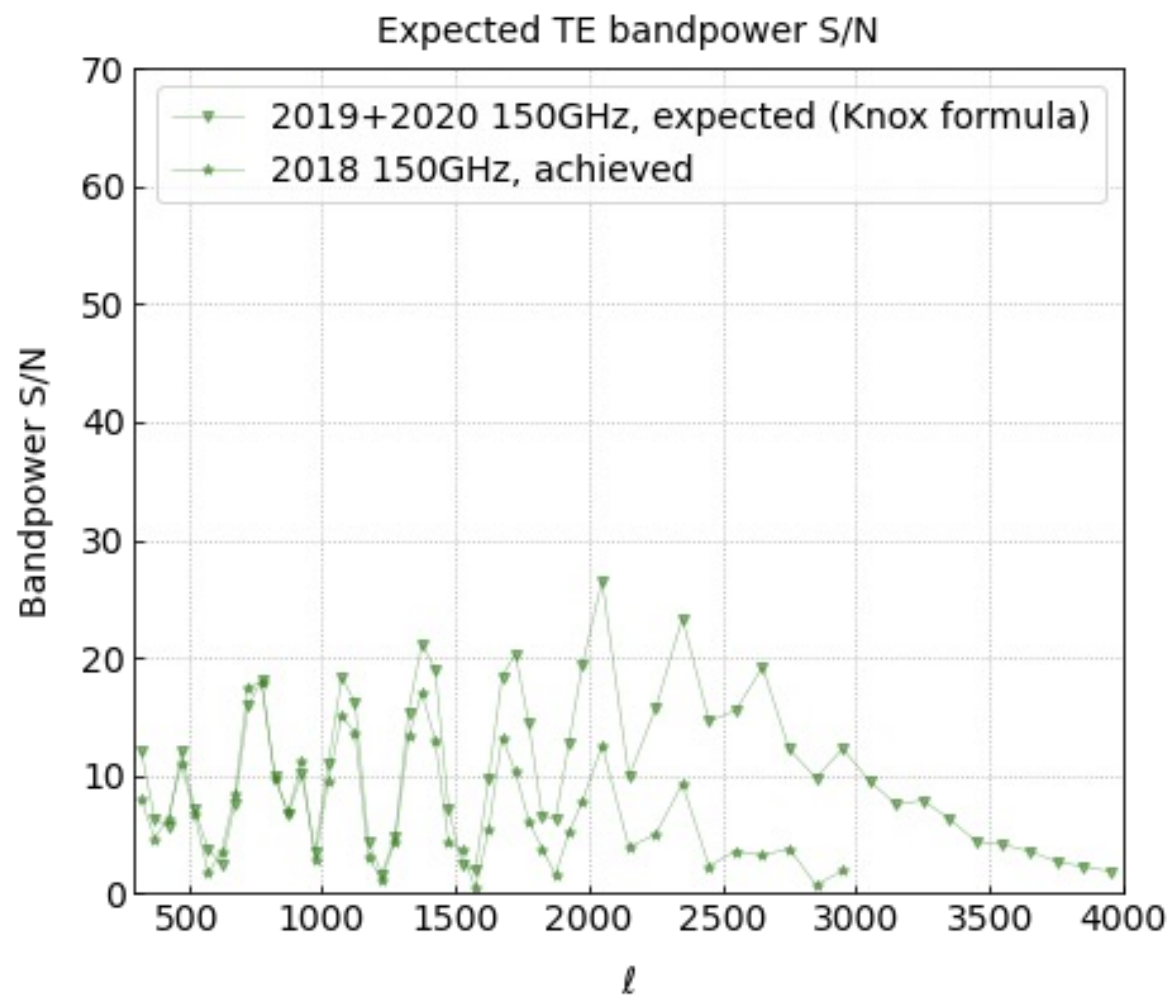
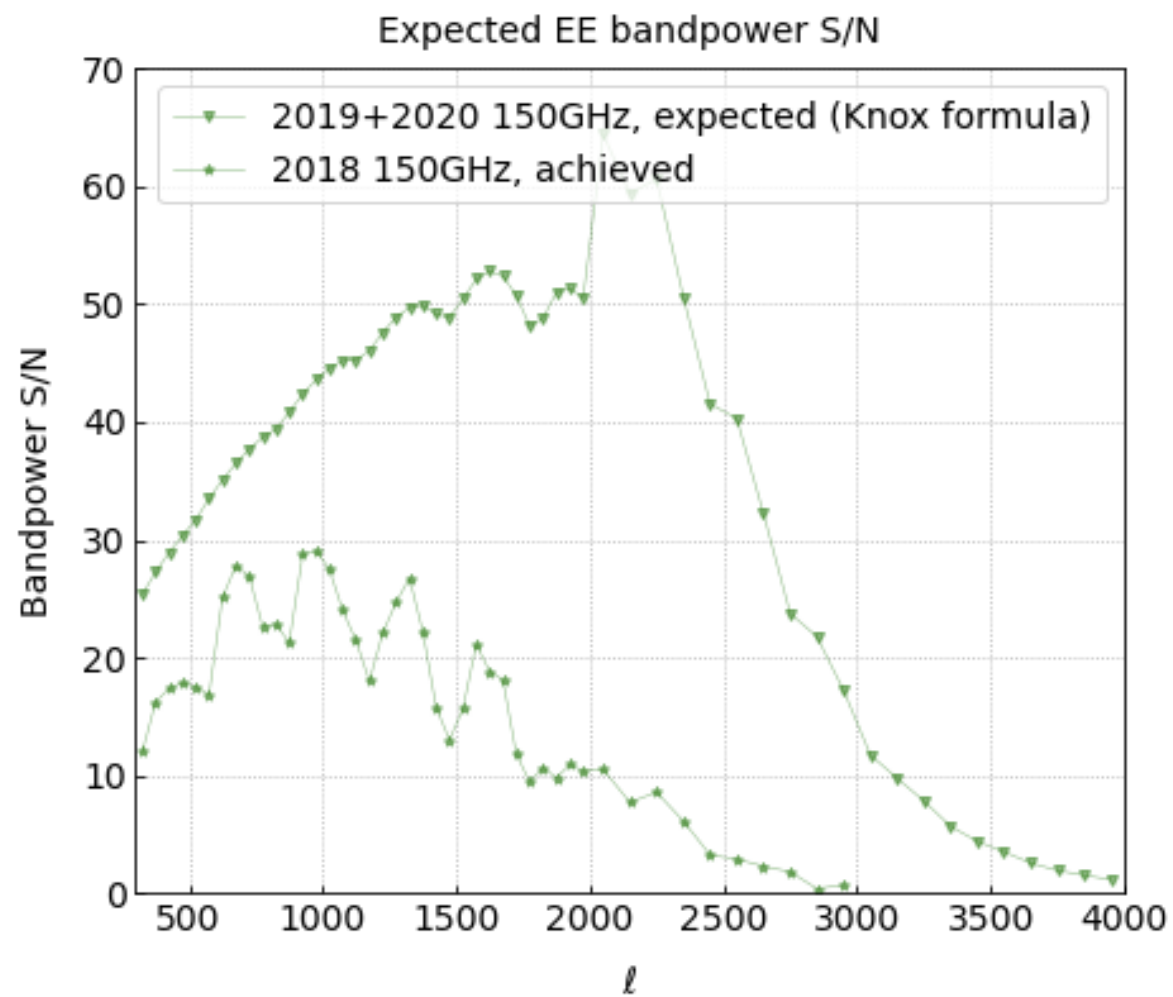


2019+2020 white noise levels are about 3.5 times lower than 2018 ones.

	2018 EE white noise levels <i>(Dutcher, Balkenhol et al.)</i>	2019+2020 EE (TT) white noise levels	2018 EE / 2019+2020 EE
90GHz	29.6	8.1 (5.4)	3.7
150GHz	21.2	6.6 (4.6)	3.2
220GHz	75	23 (16)	3.3

(Noise levels in the units of  $\mu\text{K}\cdot\text{arcmin}$ )

A comparison of bandpower error bars also looks exciting!



2019+2020 EE/TE data are expected to result in more than 50 % smaller error bars on LCDM parameters than 2018 EE/TE.

Forecasting work by Silvia Galli

	$\Omega_b h^2$	$\Omega_c h^2$	$H_0$	$n_s$	$\ln A_s$
$\sigma_{2018} / \sigma_{2019+2020}$	1.9	1.6	1.6	1.5	1.3

(Negligible difference for  $\tau$ )

We would also like to include TT in the analysis, which is expected to result in up to 15 % or so improvements, assuming relevant null tests' results turn out reasonable.

A few ongoing tasks include running null tests and building covariance matrices, and we would like to be able to get the results out in a year timescale.



I have worked on SPT-3G's data quality monitoring system, which has been useful for us to monitor our data and detect issues early on, and this framework will hopefully be a useful reference for CMB-S4.

I am currently working on 2019+2020 EE/TE/TT analysis, which will result in exciting improved constraints of cosmological parameters compared to the 2018 analysis.

Thank you for your attention!



Beautiful photo by  
Geoffrey Chen