SPT-3G: Maps of the Millimeter-wave Sky from 2019–2020 Data

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mm Universe 2025
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(A beautiful photo by Geoff Chen)

New Results from SPT-3G!

- New measurements of the TT/TE/EE spectra of the CMB and the resulting cosmological parameter constraints!

- Information on the paper, a pre-recorded webinar, and a live Q&A session at https://pole.uchicago.edu

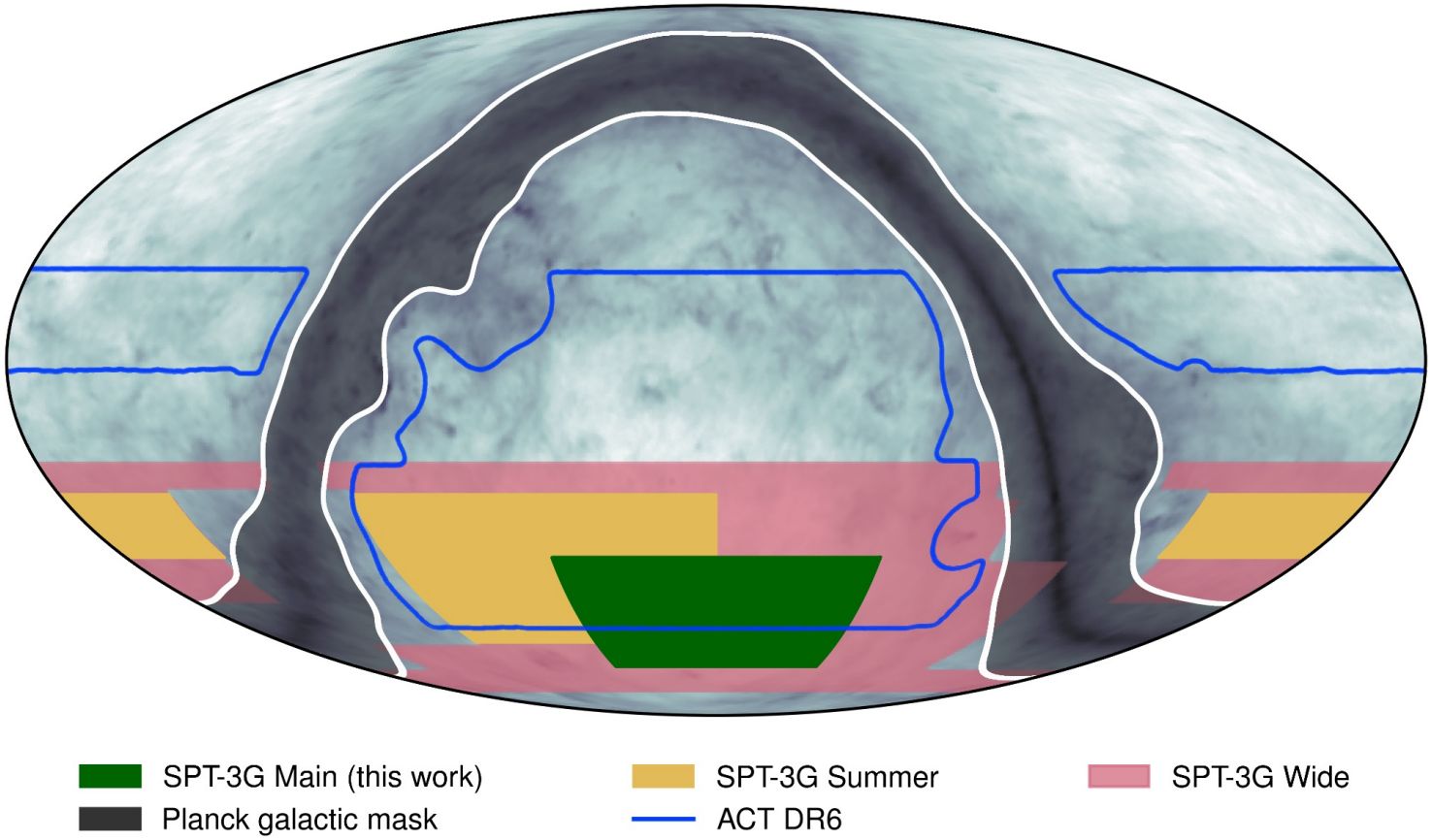
- The topic of this talk: the CMB maps used for the measurements and constraints

Many people contributed to the production of the maps!

Etienne Camphuis (IAP), Cail Daley (Saclay), Federica Guidi (IAP), Nicholas Huang (Berkeley), Yuuki Omori (UChicago), ...

New Dataset

- SPT-3G D1: observations of the Main field taken in the 2019 and 2020 austral winter observing seasons (March to November)



New Dataset (continued)

- Within SPT-3G, D1 is much larger than our previous dataset for TT/TE/EE (from 2018 observations)
  - ~2x detectors
  - ~4x observing time
- Within the CMB community, D1 is from a small and deep survey complementing surveys done by *Planck* and ACT for TT/TE/EE measurements

Dataset	Observed Sky Fraction [%]	Coadded Noise Level [μK-arcmin]
Planck PR3	100	35
ACT DR6	45	10
SPT-3G D1	4	3.3

Planck numbers based on *Planck 2018 results IV*
ACT numbers from *Næss, Guan, Duivenvoorden, Hasselfield, Wang, et al., 2025*

From Timestreams to Maps

- One polarization-sensitive detector measures a linear combination of T/Q/U.

$$I_t = g\left[T + \frac{\gamma}{2-\gamma}(Q\cos 2\alpha + U\sin 2\alpha)\right] + n_t$$

- Multiple measurements from multiple detectors allow maximum-likelihood estimation of T/Q/U.

- The covariance matrix is not diagonal in the presence of correlated low-frequency noise and is large. Inverting the matrix leads to expensive computation.

- A simplification: apply high-pass filters to timestreams to reduce off-diagonal elements. The T/Q/U estimation simply becomes binning timestreams with inverse-variance weights. But: need to characterize the filter transfer functions through simulations (e.g. *Hivon et al., 2002*).

From Timestreams to Maps (continued)

- Specific filter-and-bin parameters for this work:
  1. Subtraction of polynomials and sinusoids from timestreams to remove information below ℓ of 300
  2. Inverse of timestram PSDs in the ℓ range [400, 4000]
  3. HEALPix pixels (`nside=8192`) for curved-sky power-spectrum pipelines

- Parameters for different SPT analyses vary
  - High-pass cutoff values
  - Weighting schemes
  - Pixel shapes and resolutions

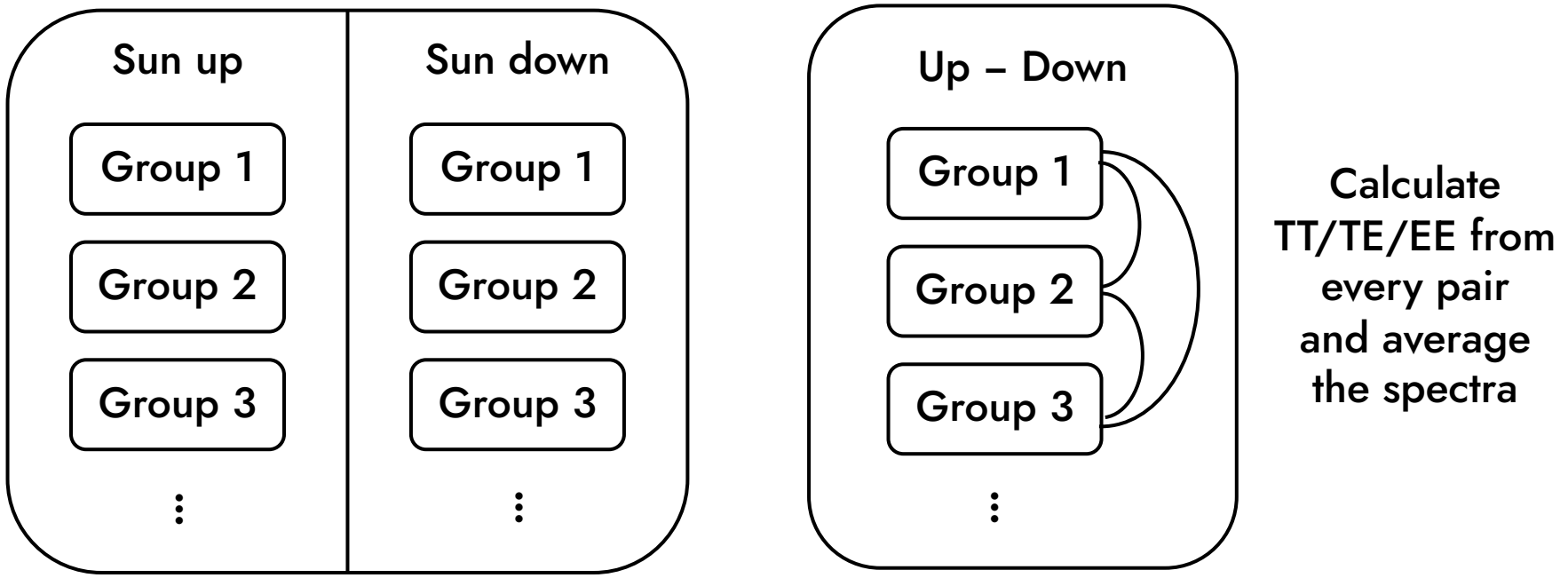
Calibration and Cleaning of Maps

- A series of calibration and cleaning steps to correct for collective effects of inaccuracies in detector properties specified in the filter-and-bin pipeline

Step	Property	Effect of Inaccuracies	Calibration Method
1	g	Multiplicative bias in T/Q/U	Cross-correlate T with *Planck* and scale T/Q/U
2	g	Copies of T maps leaked to Q/U	Cross-correlate T with Q/U and subtract copies of T from Q/U
3	α	Mixing of Q/U	Find angles nulling EB/TB and rotate Q/U
4	γ	Multiplicative bias in Q/U	Cross-correlate Q/U with *Planck* and scale Q/U

Null Tests

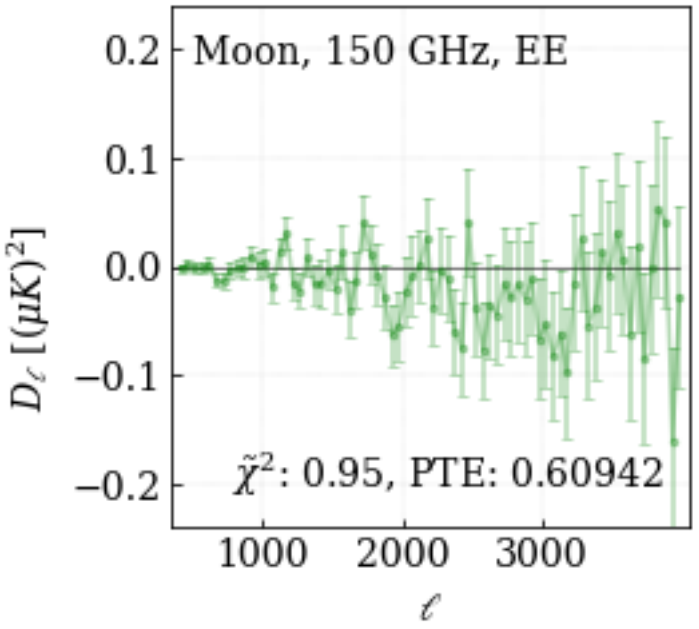
- A suite of map-level intrafrequency consistency tests to probe potential systematic errors

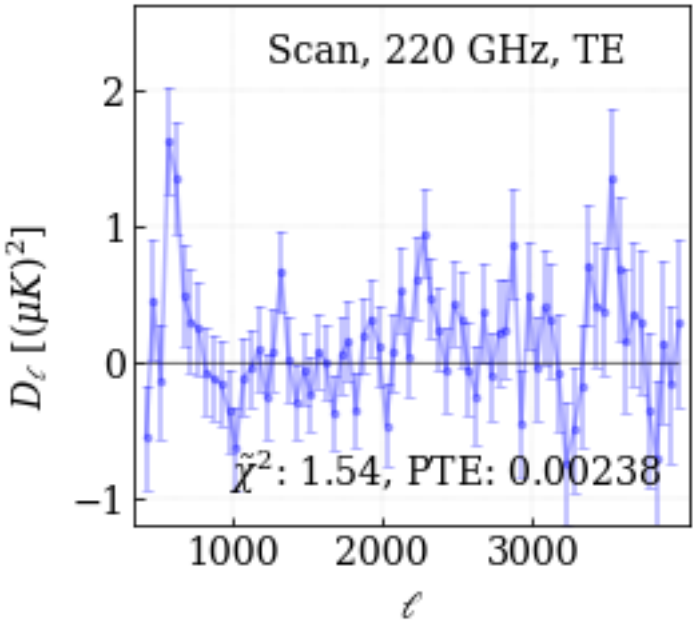


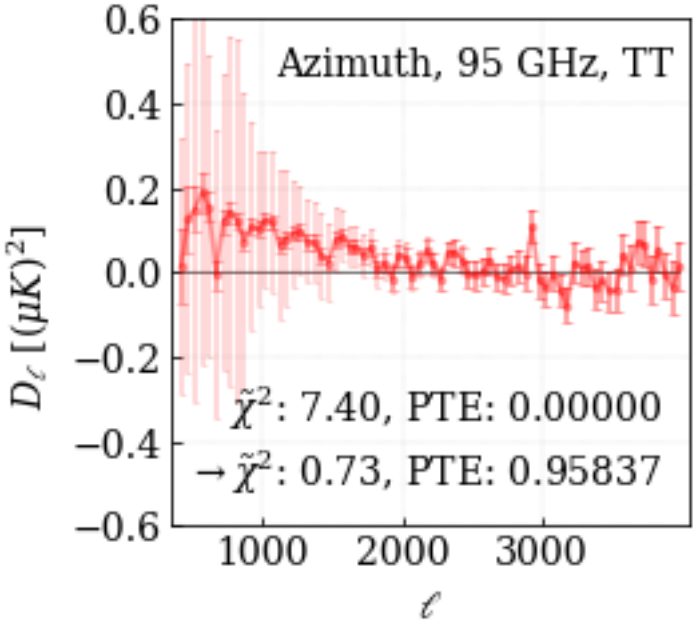
- Types of splits
  - Sun, moon, azimuth, year, scan direction, and detector wafers
  - Total null spectra examined: 54 = 6 splits x 3 bands x 3 spectra

Null Tests (continued)

- Most null spectra (39 out of 54, ~70%) were consistent with expectation within noise
- Large contamination at ℓ of ~600 in most scan and wafer TT/TE/EE null spectra. Mitigated by harmonic-space masking.
- Excess power in a few TT null spectra, but amplitudes well below expected total error bars in power-spectrum measurements



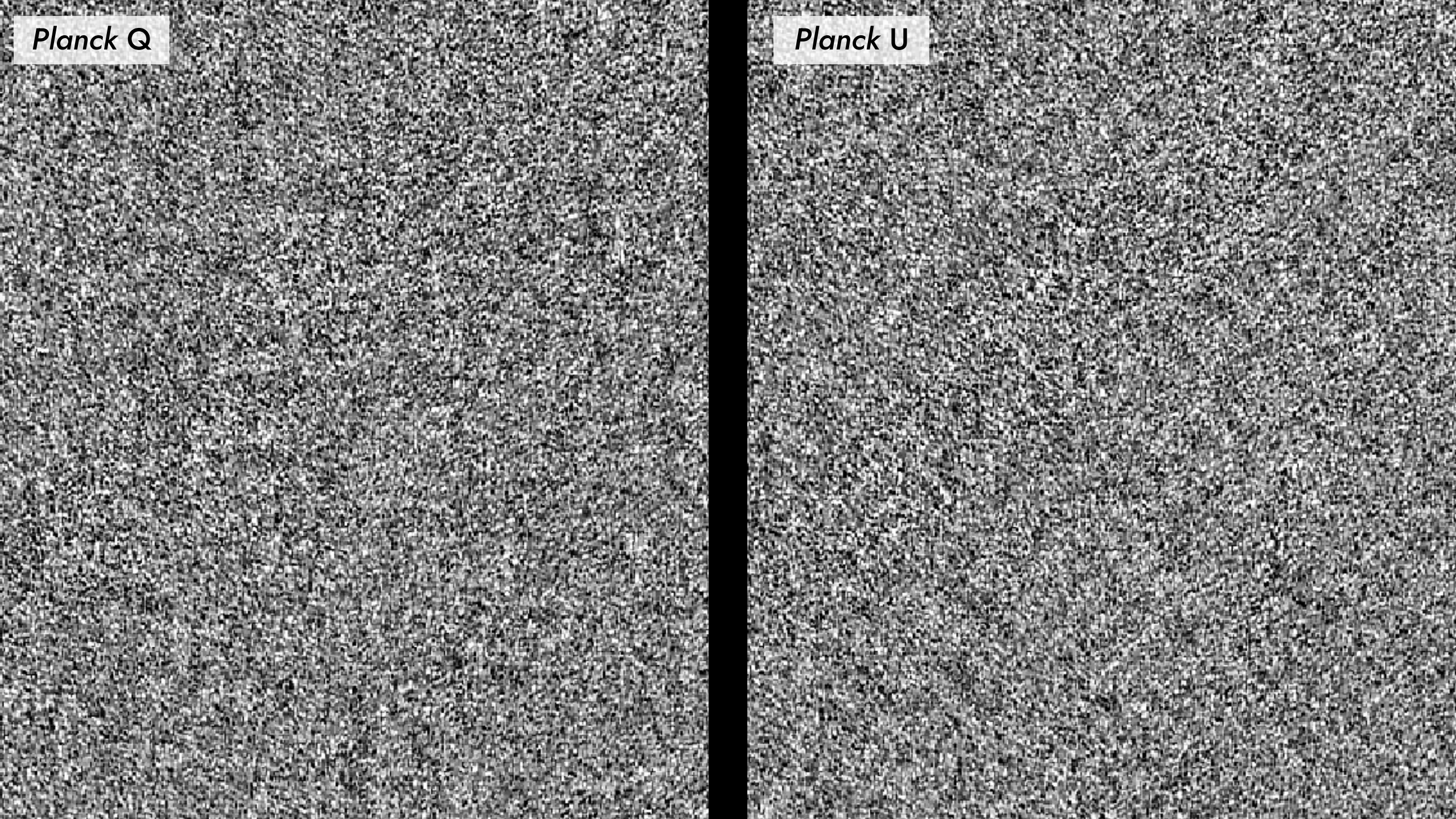




Comparison among Polarization Maps

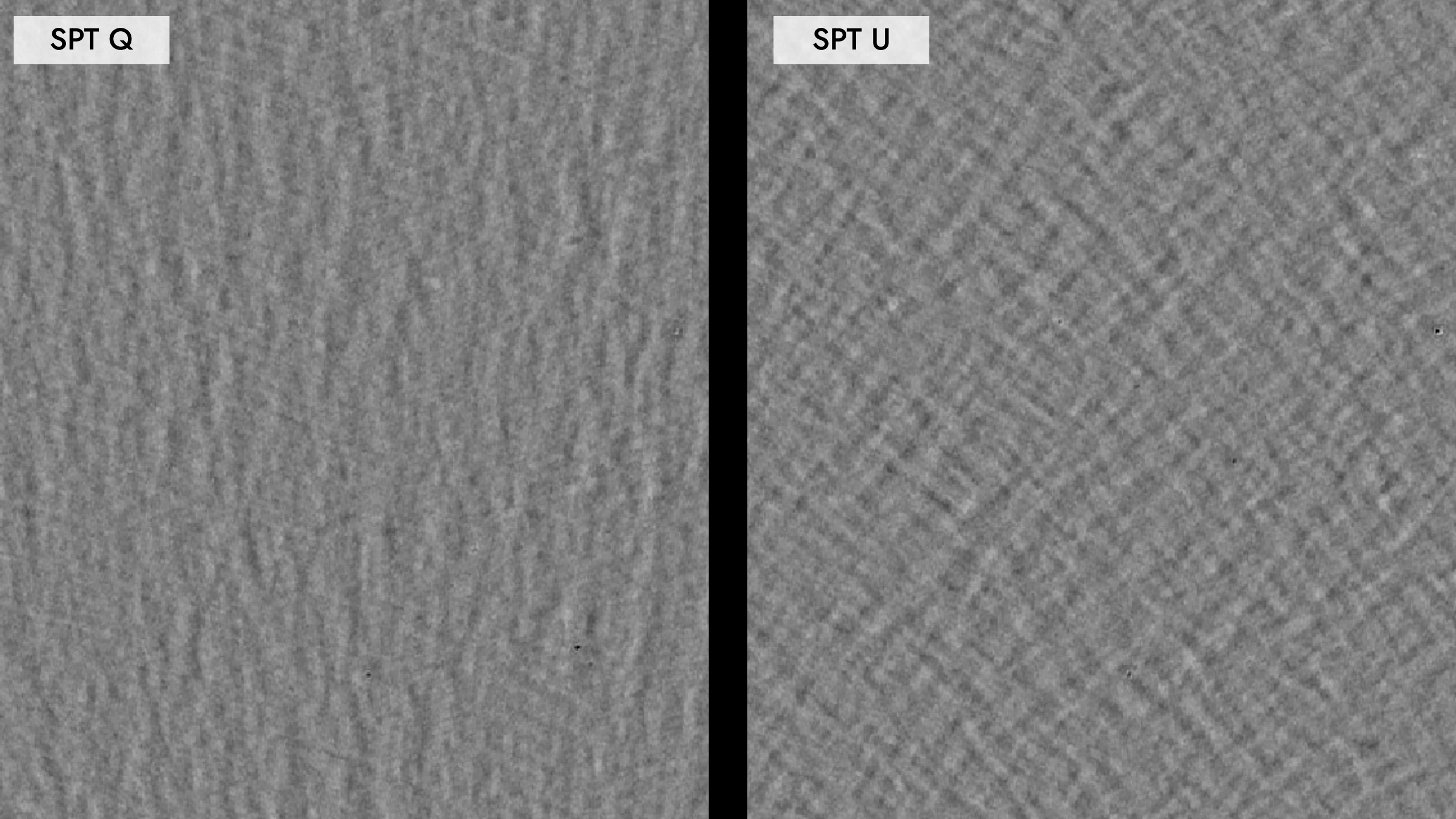
- Three sets of Q/U maps
  - *Planck* PR3 143 GHz (`HFI_SkyMap_143-field-IQU_2048_R3.00_full.fits` from Planck Legacy Archive)
  - ACT DR6 150 GHz (`act_dr4dr6_coadd_AA_daynight_f150_map_healpix.fits` from LAMBDA
  - SPT-3G D1 150 GHz

- Details of the following images
  - Anti-aliasing filter applied to ACT/SPT before plotting (information above ℓ of 6143 removed)
  - A ~12° x ~13° patch in gnomonic projection (`reso=1.7, xsize=410`), center coordinate: (R.A., Dec) = (0^h, -49°)
  - Grayscale ranging from -45 to +45 μK


Planck Q
Planck U

ACT Q

ACT U


SPT Q
SPT U

Publications and Data Release

- Posted yesterday:
  - *Camphuis et al.*, power spectra and likelihood

- Three papers in progress:
  - *Quan et al.*: mapmaking, calibration, null tests
  - *Huang et al.*: beams
  - *Hivon et al.*: filter transfer functions

- Maps and ancillary products will be released this year

Summary

- SPT-3G D1, a new dataset from SPT-3G Main field 2019–2020 observations, is much larger than the 2018 dataset and is a small and deep survey complementing *Planck* and ACT
- We used the filter-and-bin approach to convert timestreams to maps, to which we applied four calibration and cleaning steps
- Null tests revealed a large systematic error, which are mitigated in harmonic space, and some small systematic errors, which have negligible effects on cosmological parameter constraints
- Maps will be publicly available this year

These maps were used for significantly improved SPT-3G measurements of the T&E anisotropies and gravitational lensing of the CMB. The topics of the next two talks!