Challenges in forthcoming CMB datasets

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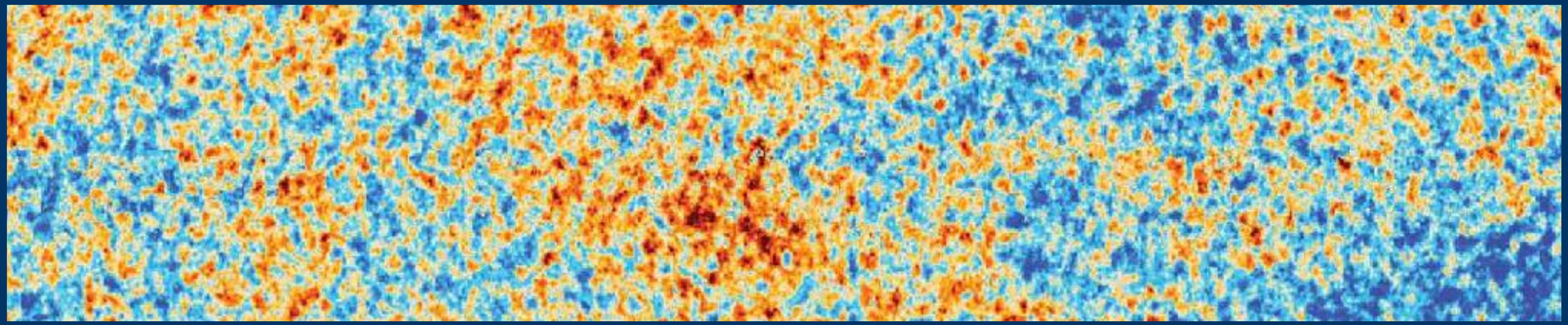
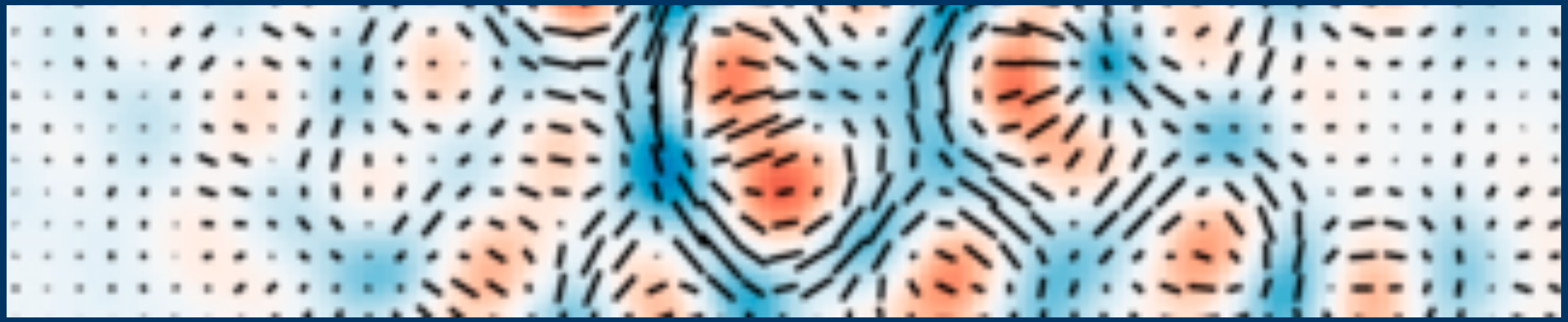
CMB anisotropies and primordial gravitational waves

T,±100 uK



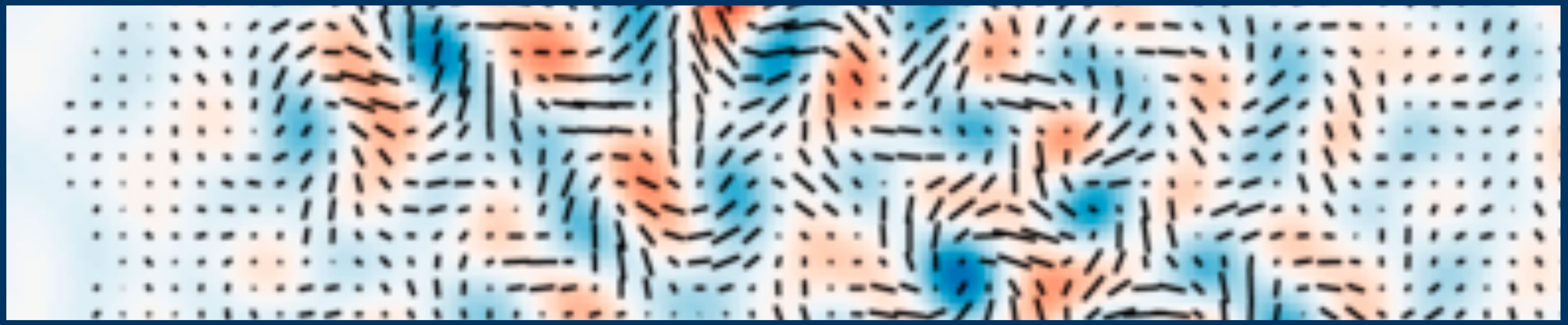
Credits: Planck Collaboration

E,±1 uK



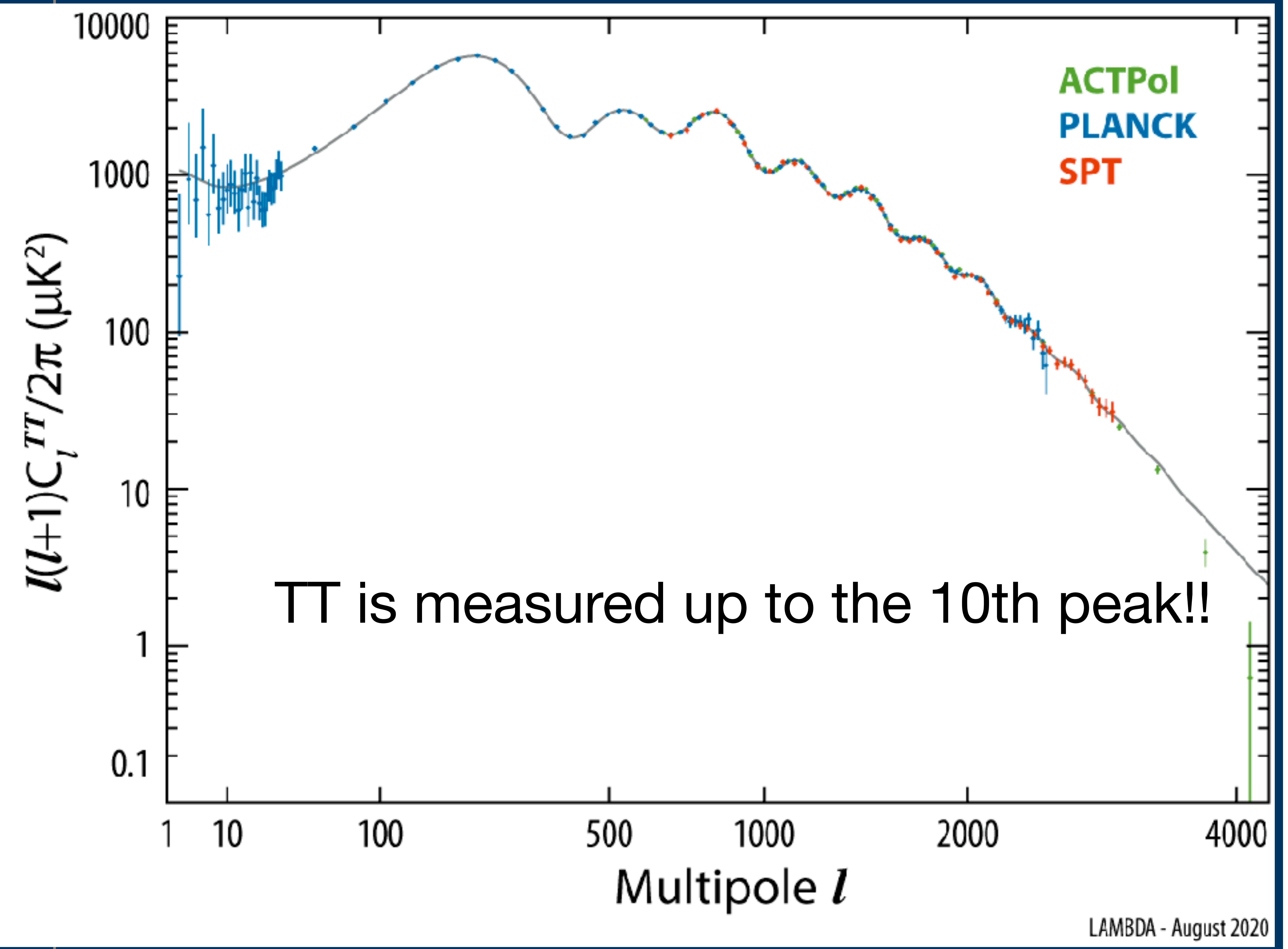
Credits: Bicep2/Keck Collaboration

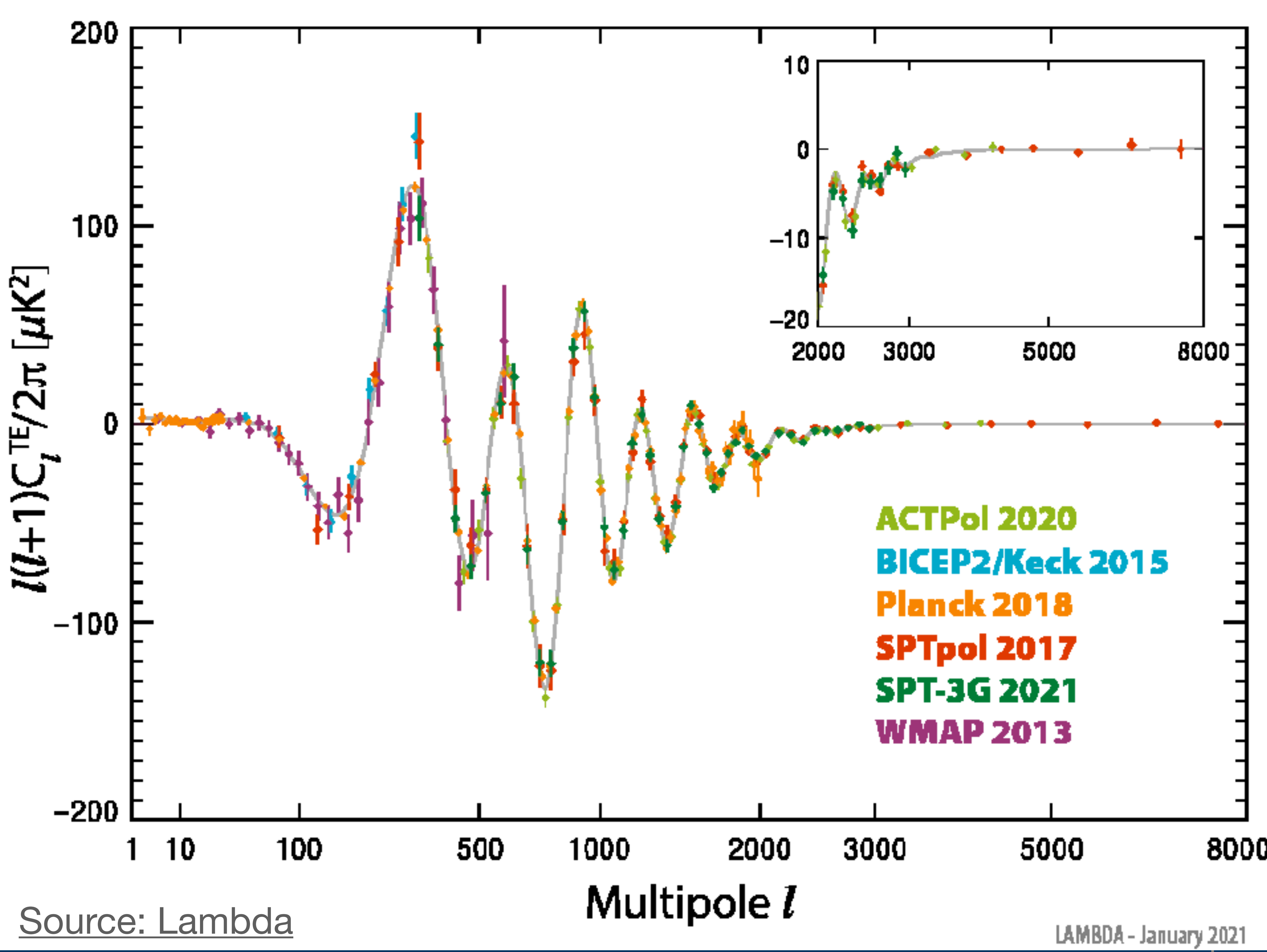
B,±0.3uK



Credits: Bicep2/Keck Collaboration

The state of the art of CMB spectra

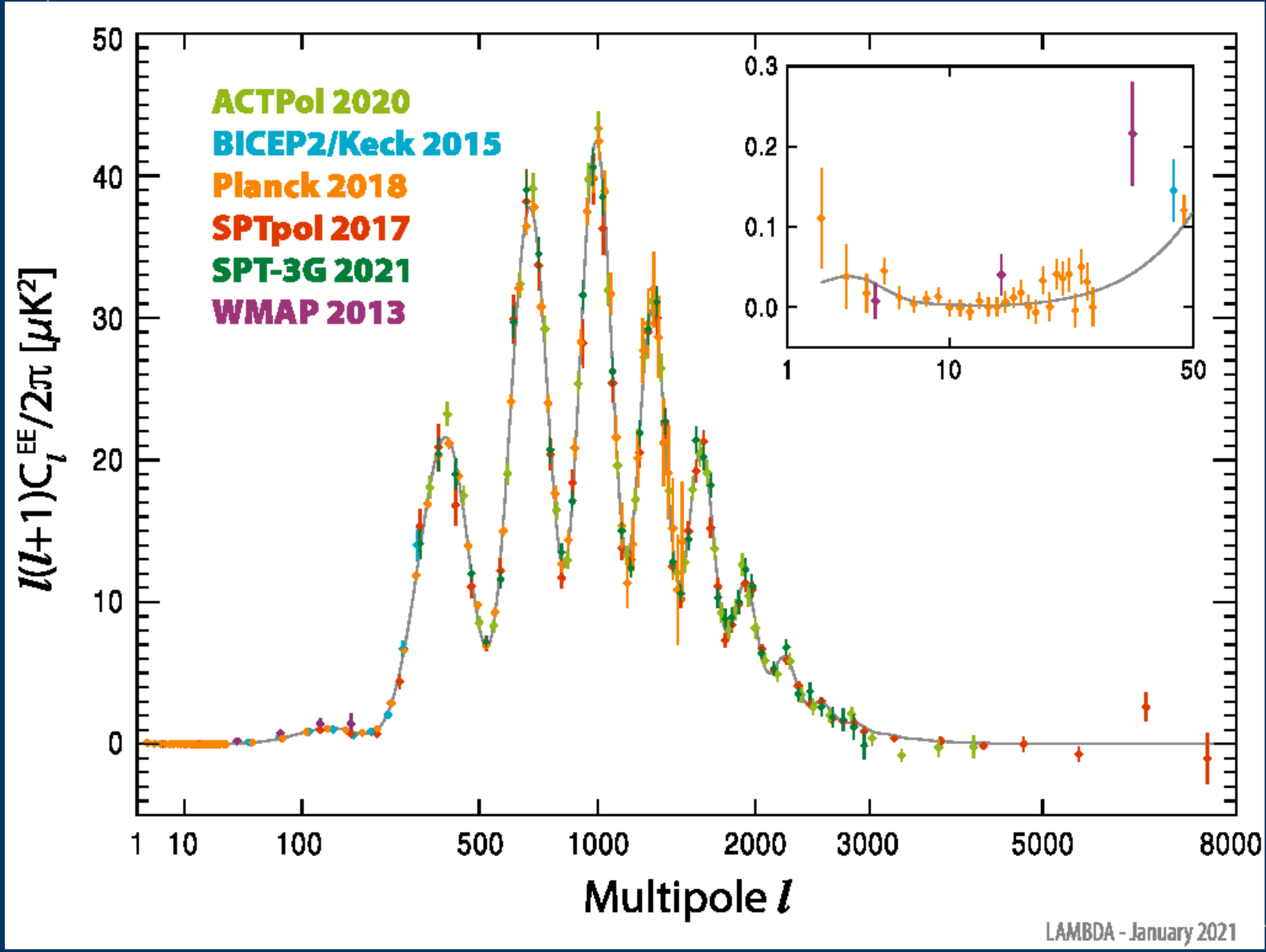


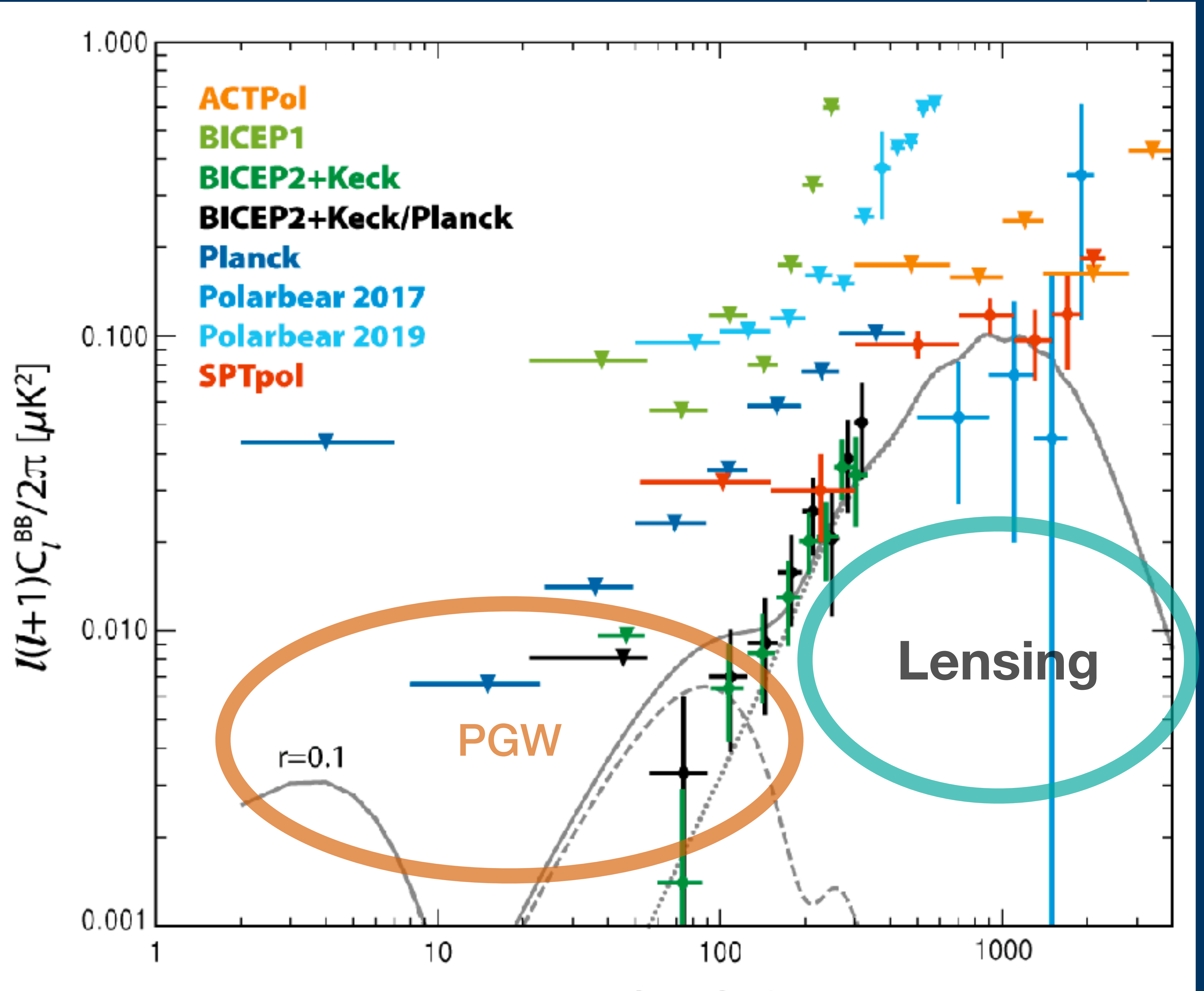


Source: Lambda

The state of the art of CMB spectra

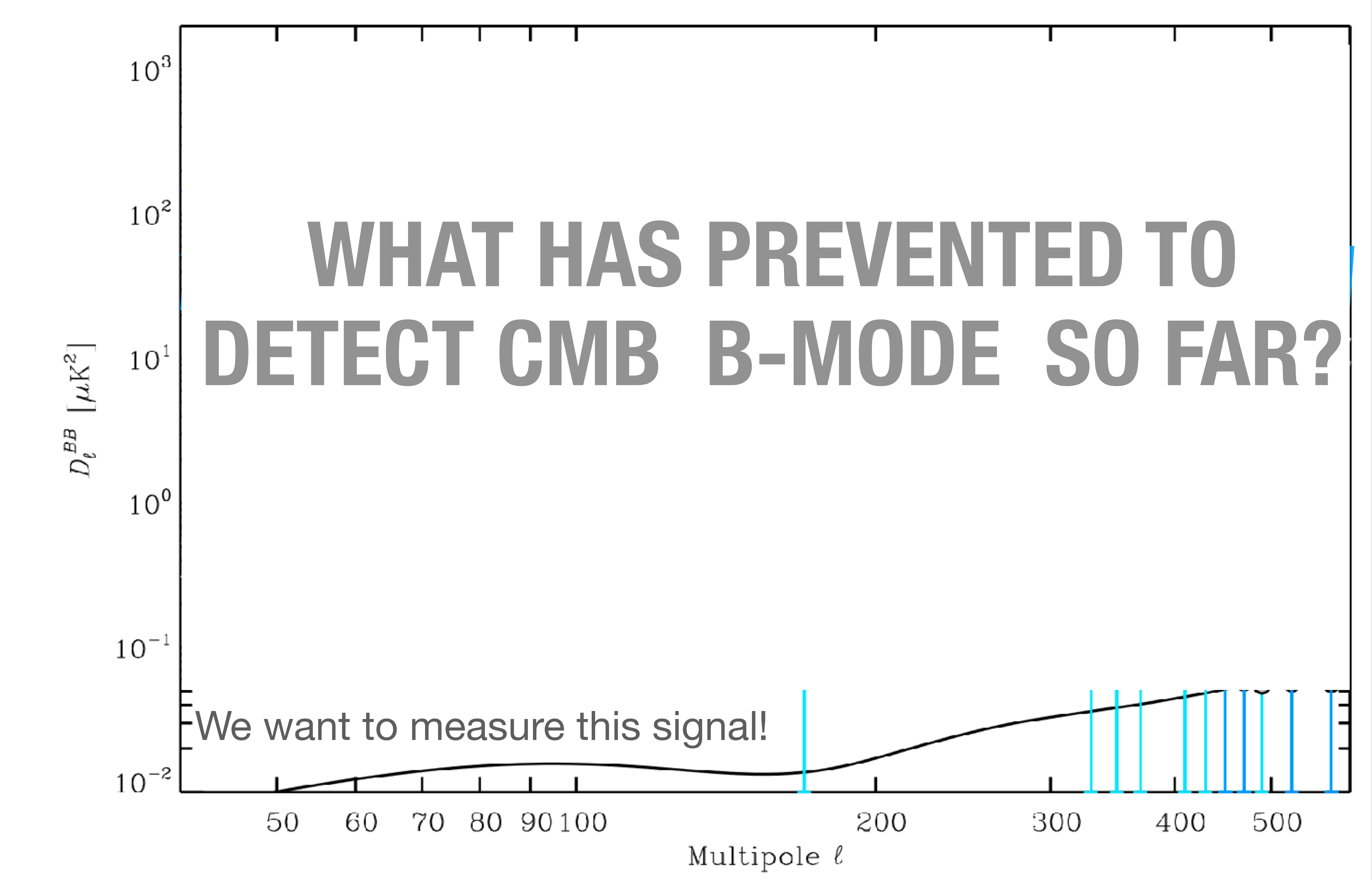
Lensing B-modes have been detected, no detection on the primordial ones…yet

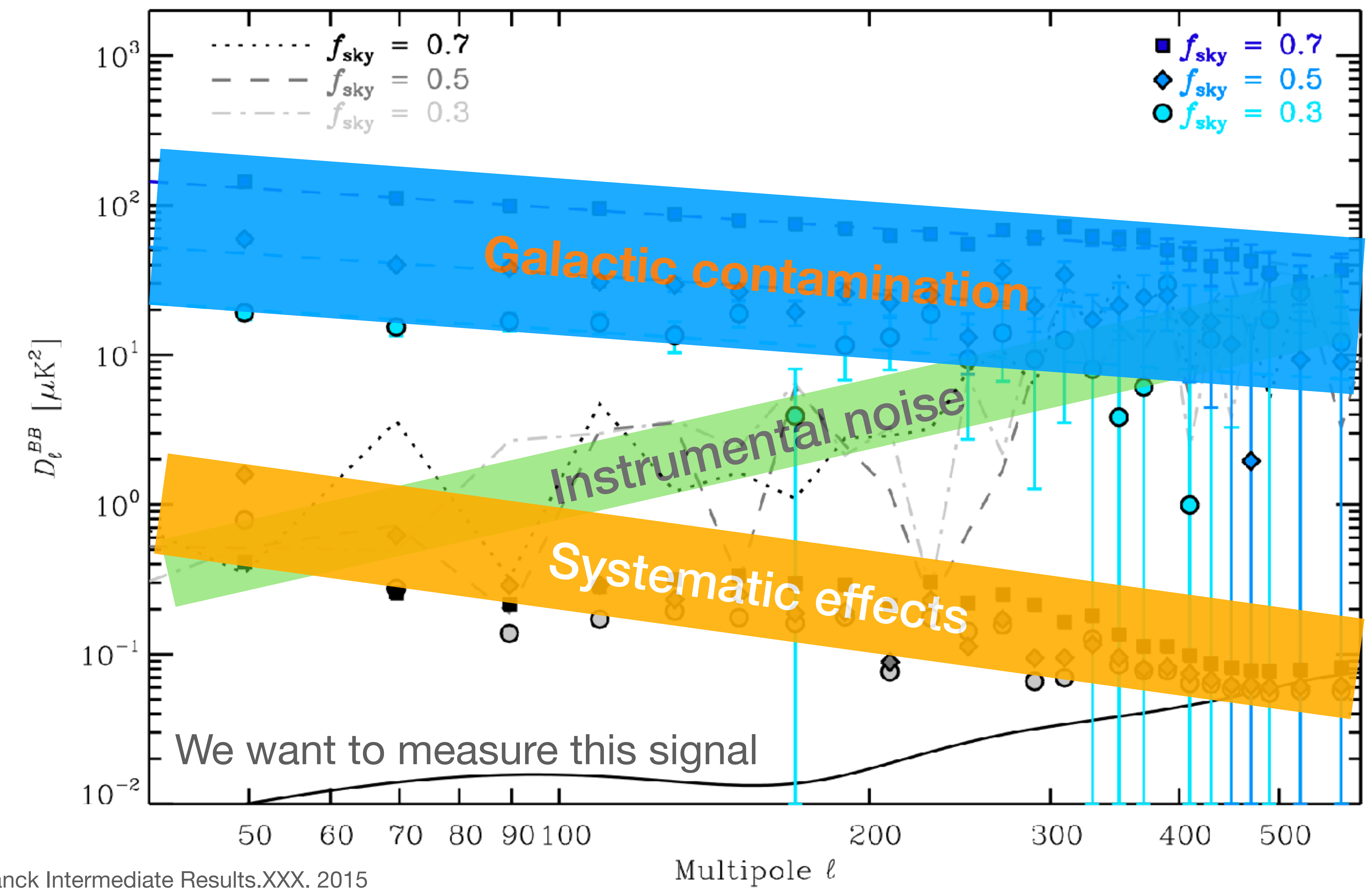




Source: Lambda

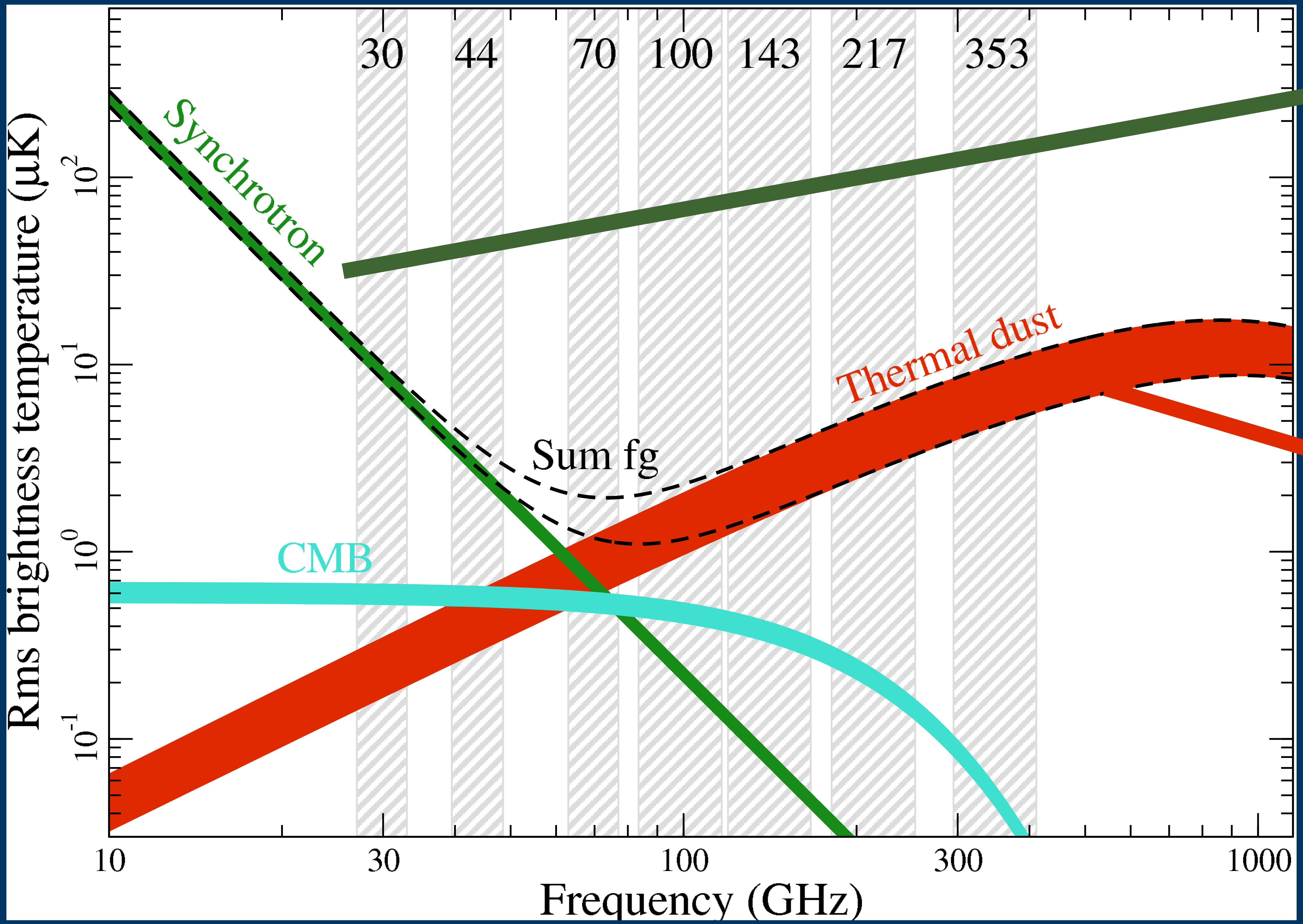
WHAT HAS PREVENTED TO DETECT CMB B-MODE SO FAR?



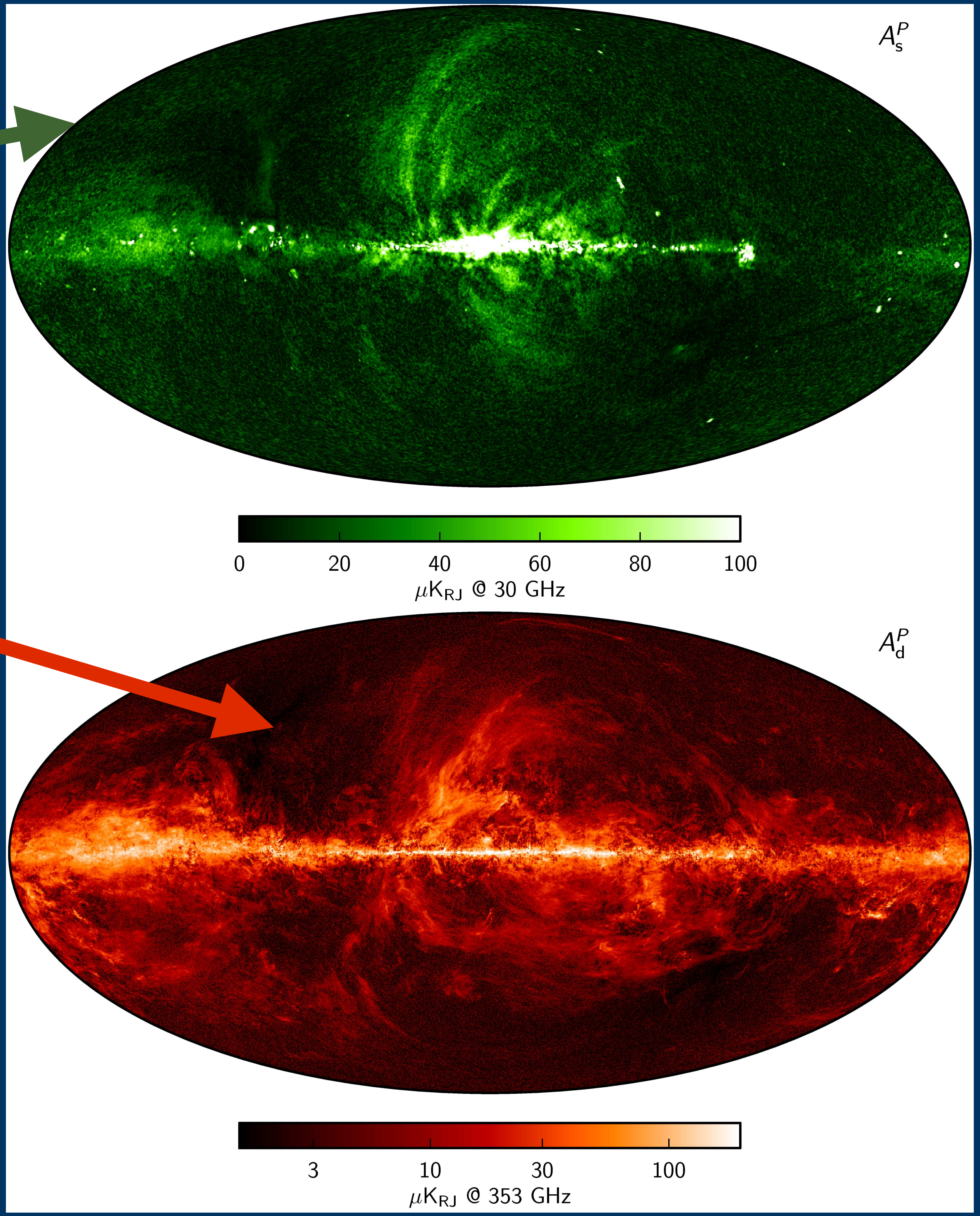


Planck Intermediate Results.XXX. 2015

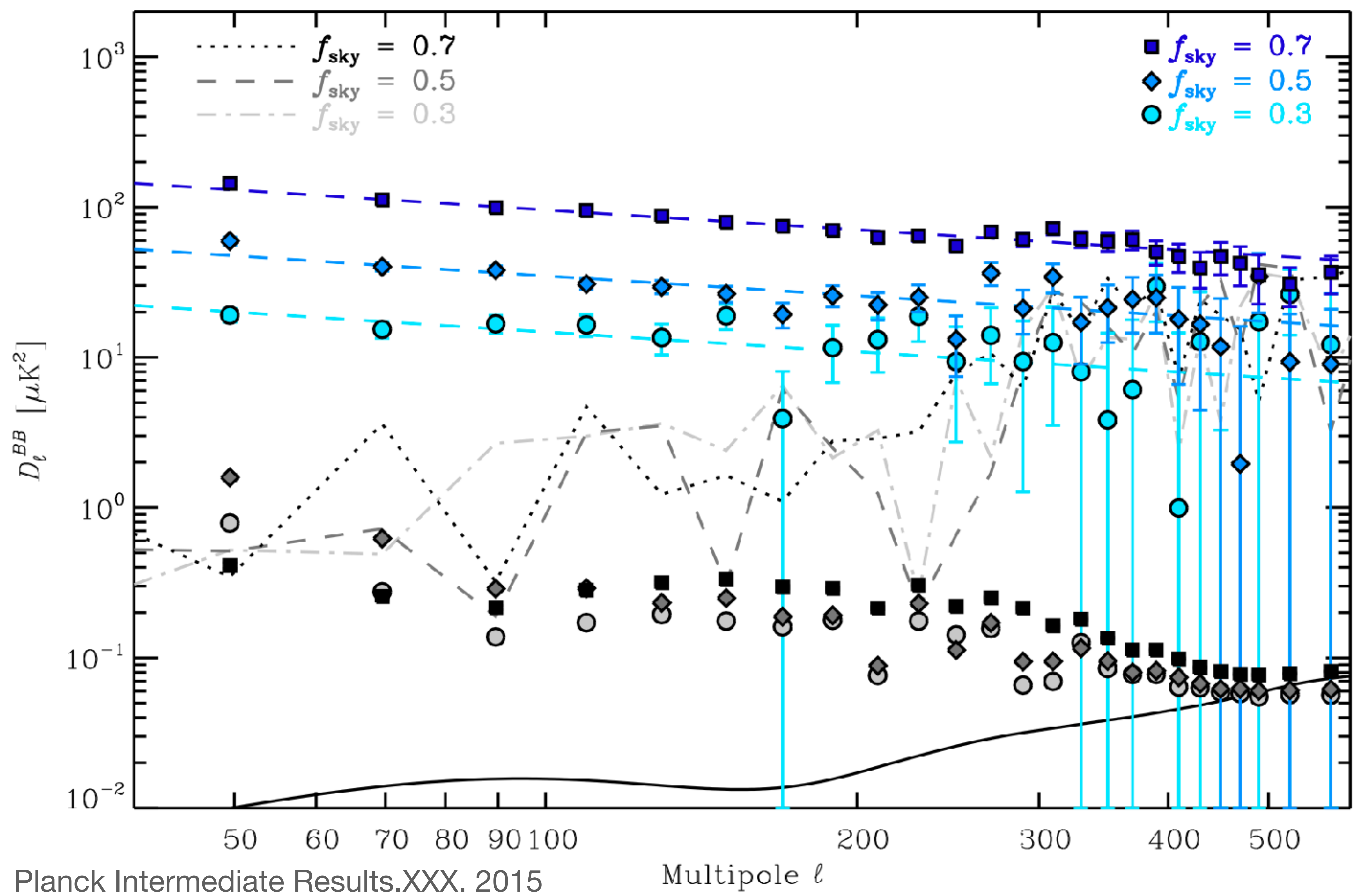
1. Galactic Foregrounds



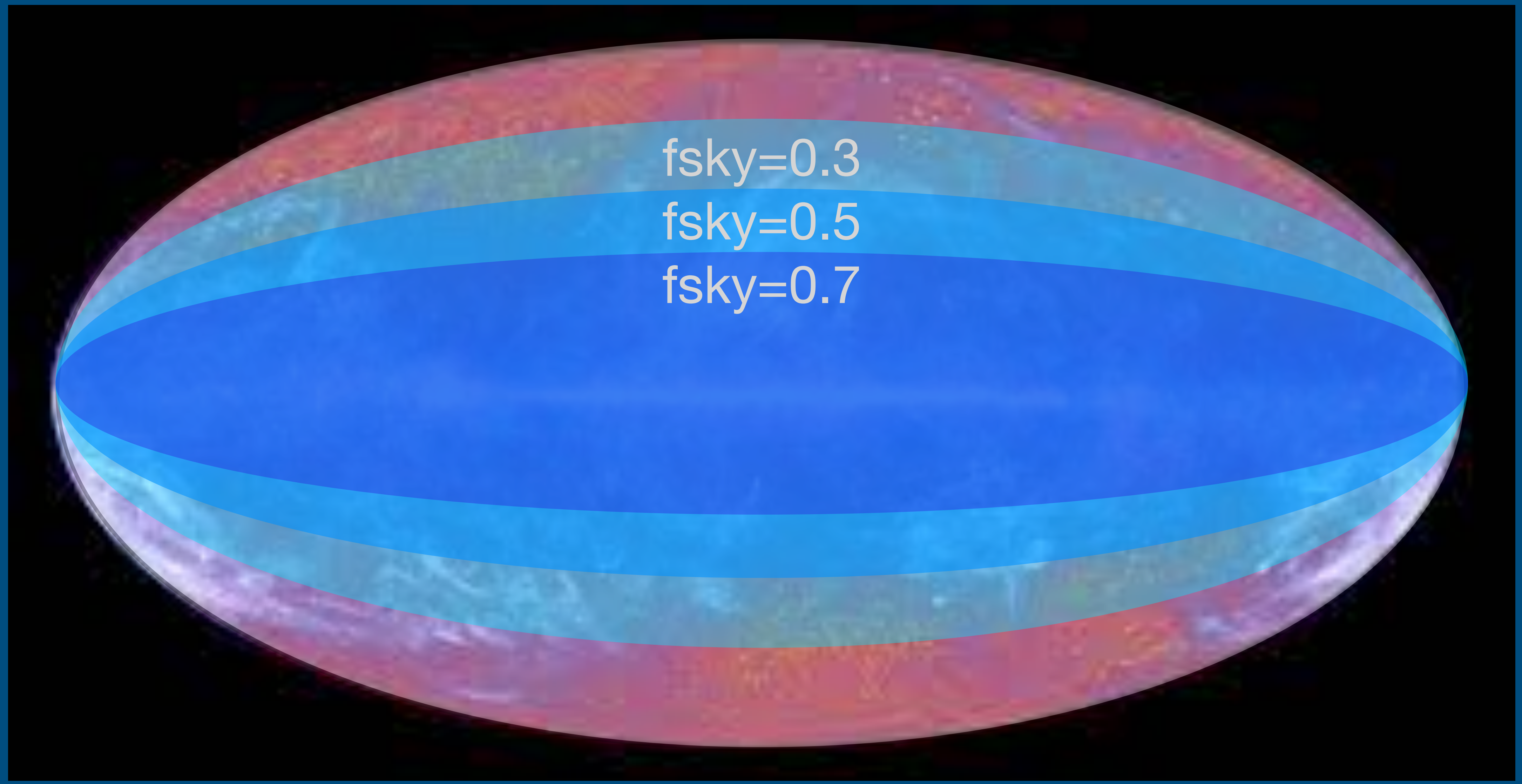
Planck Collaboration 2016



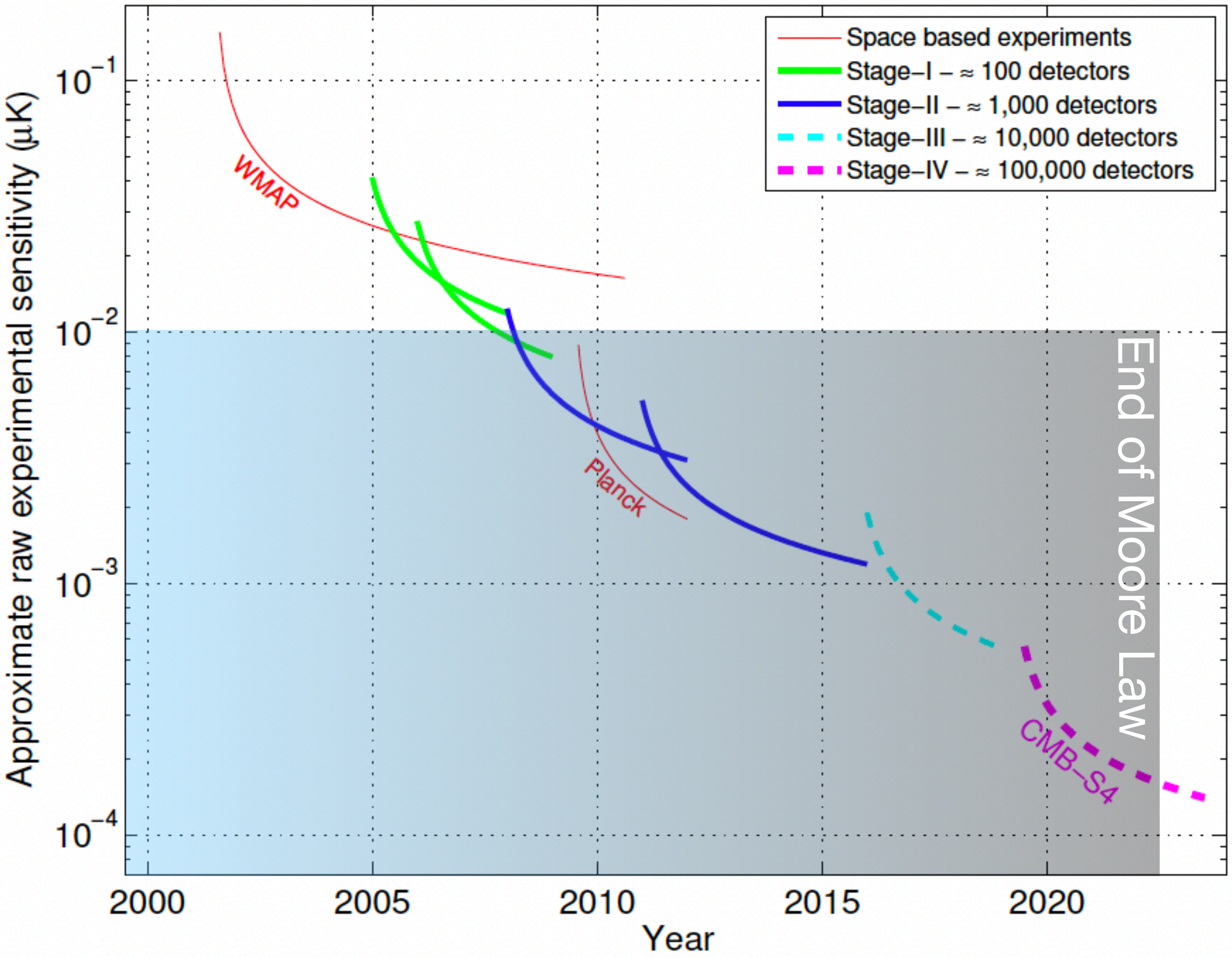
2. Systematics effects



Planck Intermediate Results.XXX. 2015

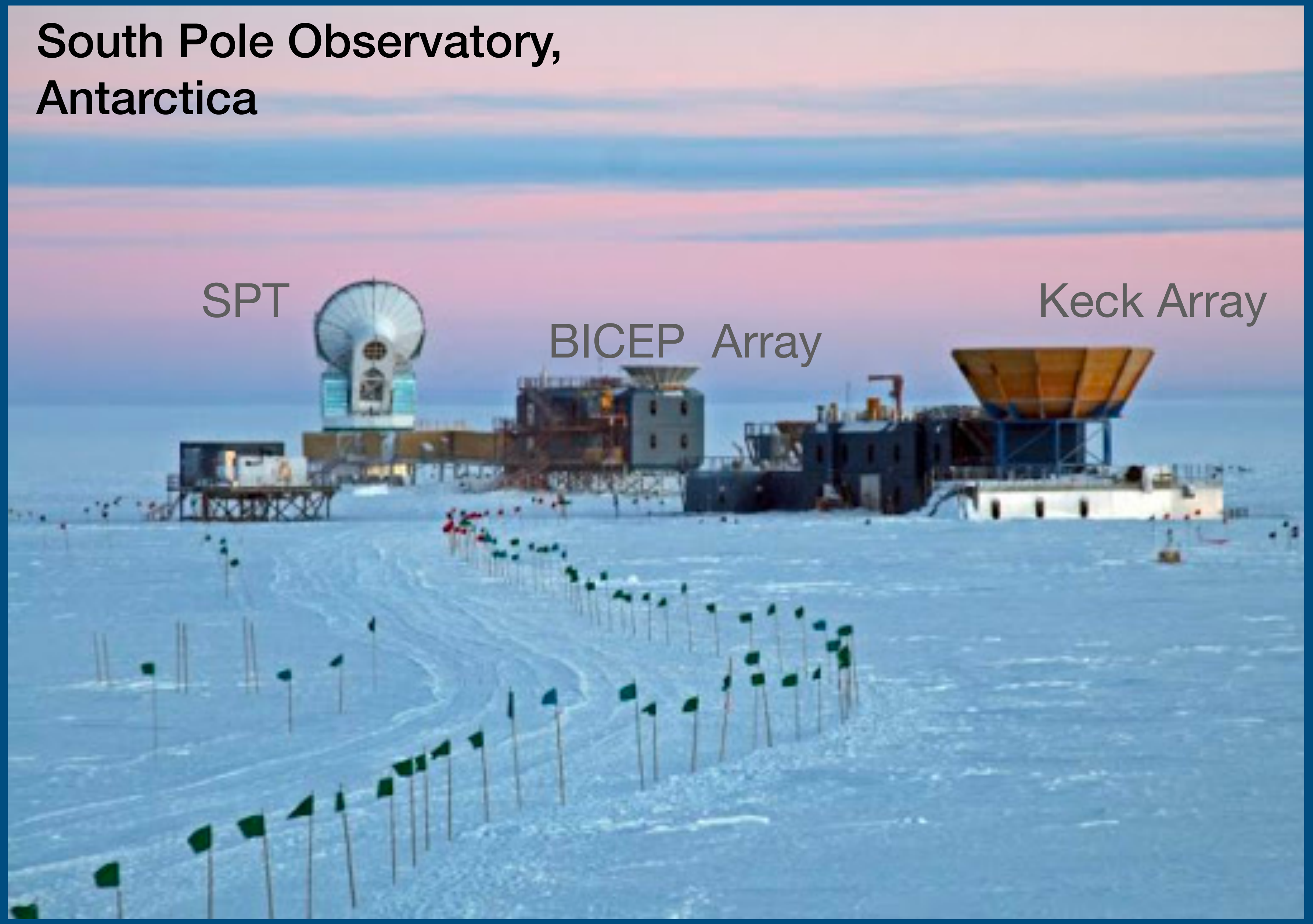


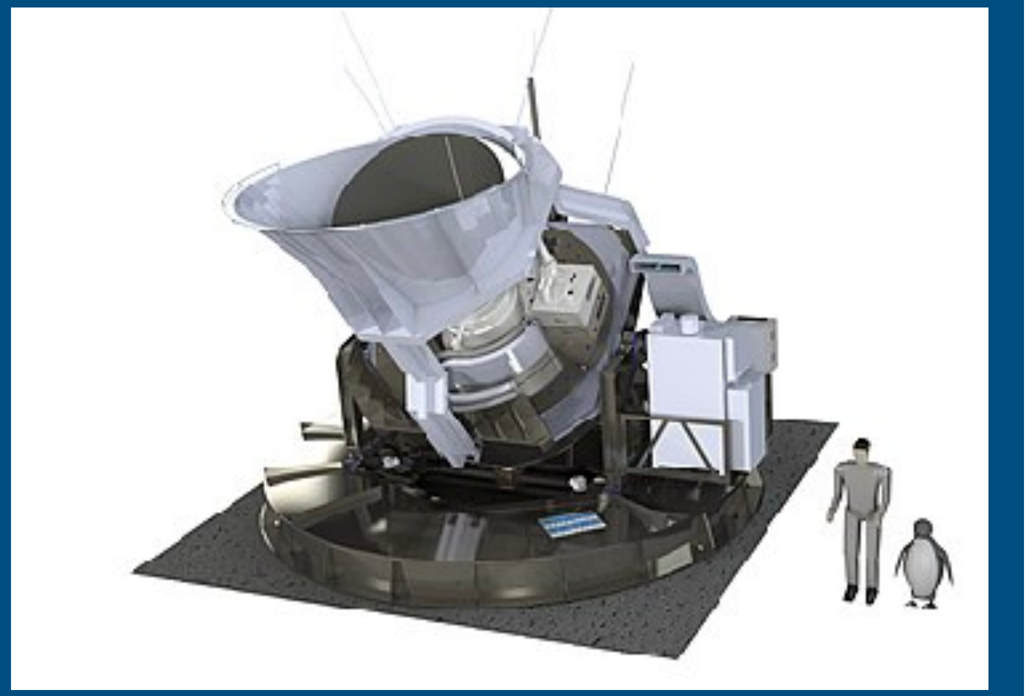
3. Sensitivity

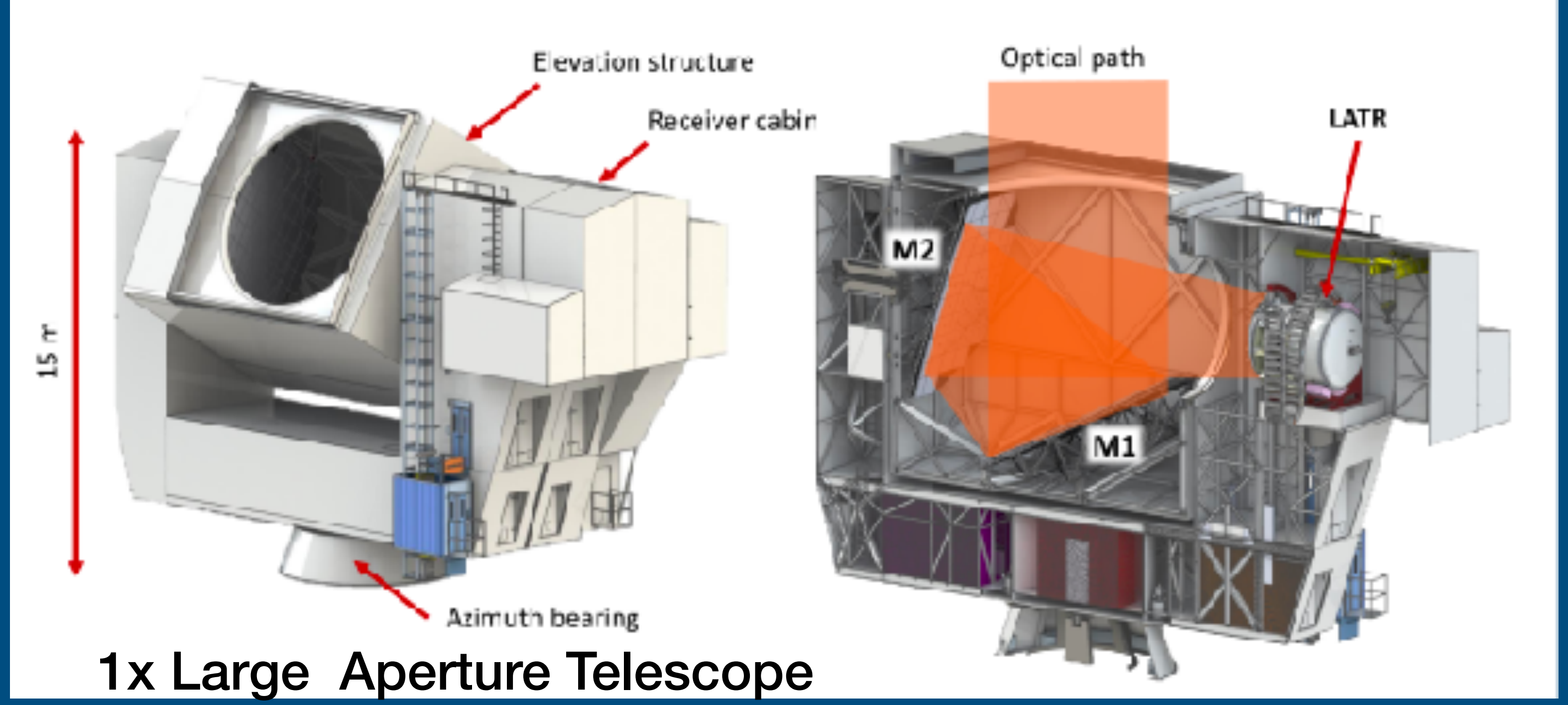


CMB Stage4 Concept Design Review 2020

CMB forthcoming experiments
Ground-based







>100,000 detectors observing at:

- multiple resolutions (both degree and arcminute)
- Multiple frequency bands 20-200 GHz

CMB forthcoming experiments

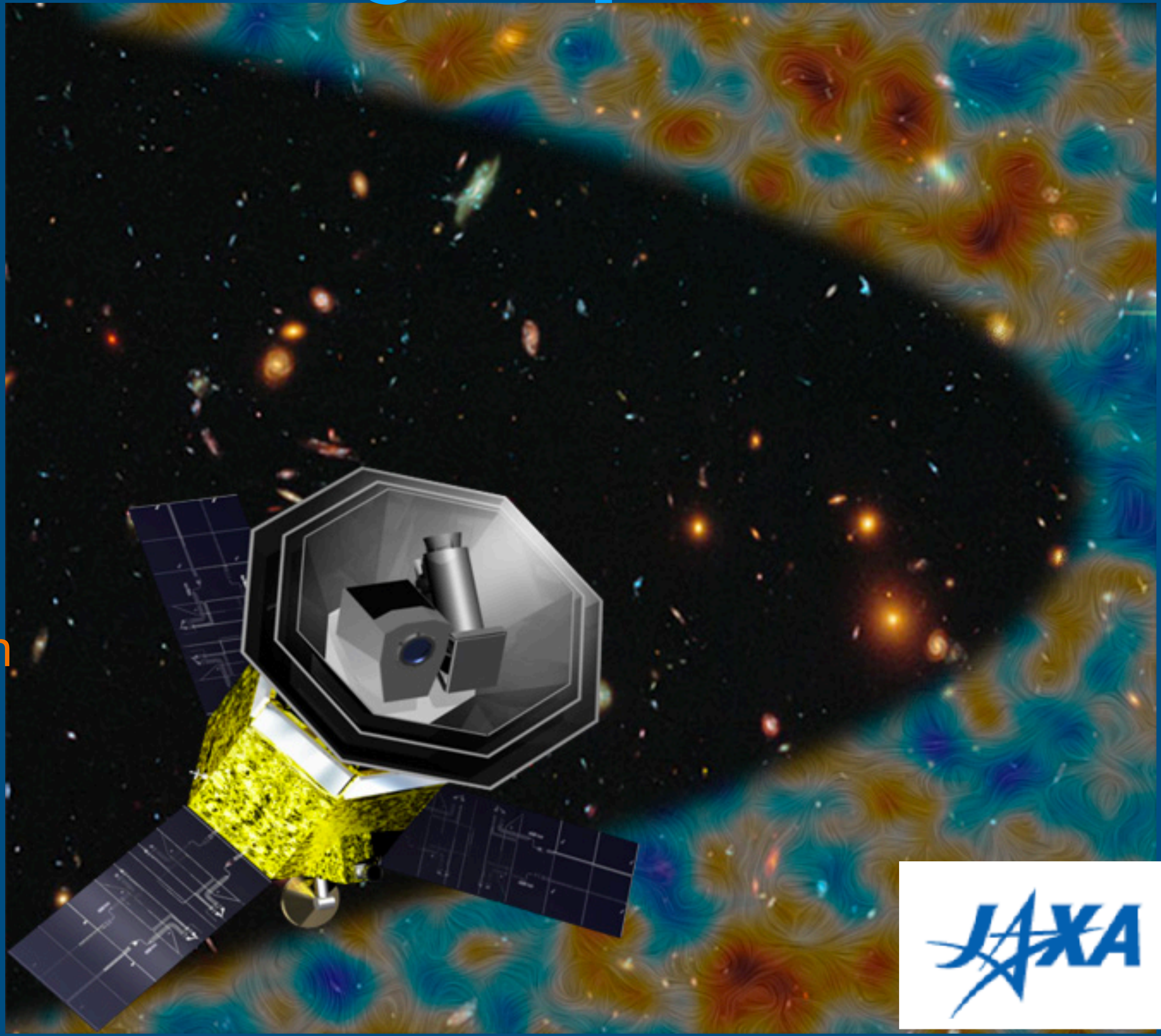
Space-mission

LiteBIRD

r~0.001 at $>5\sigma$ C.L.

- 22 frequency bands (40-400 GHz)
- 10-70 arcmin resolution

~4500 detectors



LiteBIRD

INFN
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CSA ASC

cnes
CENTRE NATIONAL D'ÉTUDES SPATIALES

ASI
Agenzia Spaziale Italiana

JAXA
Japan Aerospace Exploration Agency

Time Ordered Astrophysics Scalable Tools (TOAST)

- Simulation framework with C++ backend and python wrapper
- Tools for distributing data among multiple processes and nodes
- Generic operators for common data-reduction tasks (filtering, pointing expansion,imaging)
- Basic classes for performing I/O in a limited set of formats
- Modules for simulating noise and systematic effects
- Experiment specific simulation framework (S4, SO, Litebird,*Planck*)
- Hybridization with GPU using JAX

- NASA TRL Demo: First Litebird full Focalplane simulations run performed at NERSC Super Computing center
- Total computational cost : ~80kcpuh on **1000 Perlmutter nodes** w/o GPUs

NERSC

Berkeley
UNIVERSITY OF CALIFORNIA

Space Sciences Laboratory
UC Berkeley
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BERKELEY LAB


Simulation Workflow
Satellite scanning strategy
Pointing info
Solar Dipole
Per-detector sky alm (pysm3- low complexity)
Per-detector GRASP blm
Beam Convolution
Scan Template for Calibration (T-only foregrounds, top-hat bpass)
Detector Time constant convolution
Calibration systematics (Gain errors, FP thermal fluctuations, slow drifts)
Noise (1/f+ white+ cosmic rays)
Cross-Talk
Reduction Workflow
Toast3 destriper
Mitigate Cal. systematics
Mitigate Cross-talk
Deconvolve detector time constant
Map-Maker
Analysis Workflow
Comp-Sep (HILC)
Delensing
Delta-r from systematics residuals

Coping with forthcoming *criticalities*

1. **Foregrounds** ML techniques to model Galactic emission (Farsian et al 2020, Thorne et al 2021, Krachmalnicoff&Puglisi 2021) and clean CMB maps (Puglisi&Bai 2020, Bennet et al 2020, Puglisi et al. 2022);
2. **Systematic effects** require innovative techniques to both efficiently injects and optimally mitigate them all;
3. **Low sensitivity** thanks to the high number of detectors requires a computationally intensive approach (->CN1 SPOKE3) ;
4. **Survey strategy Optimization** -> minimizing *metrics* built from the volume spanned by instrument parameters;