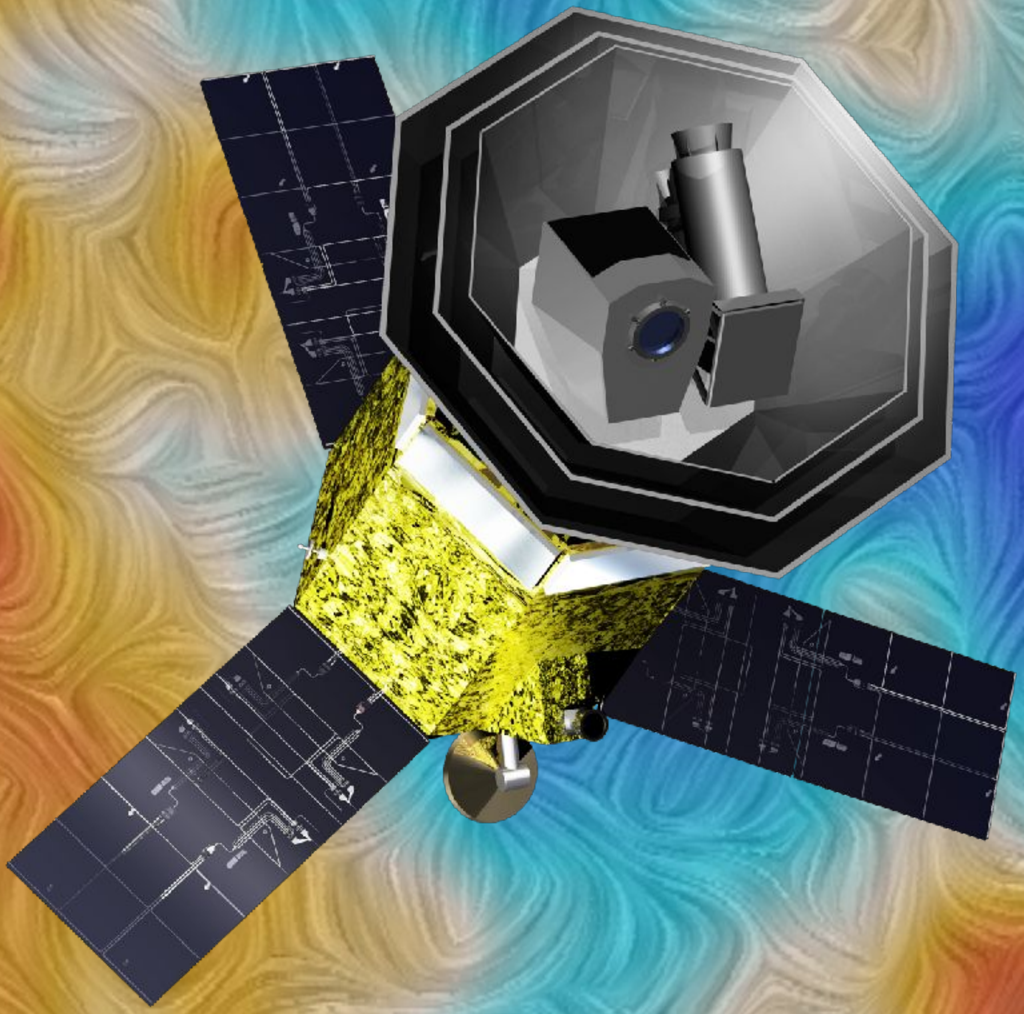


LiteBIRD

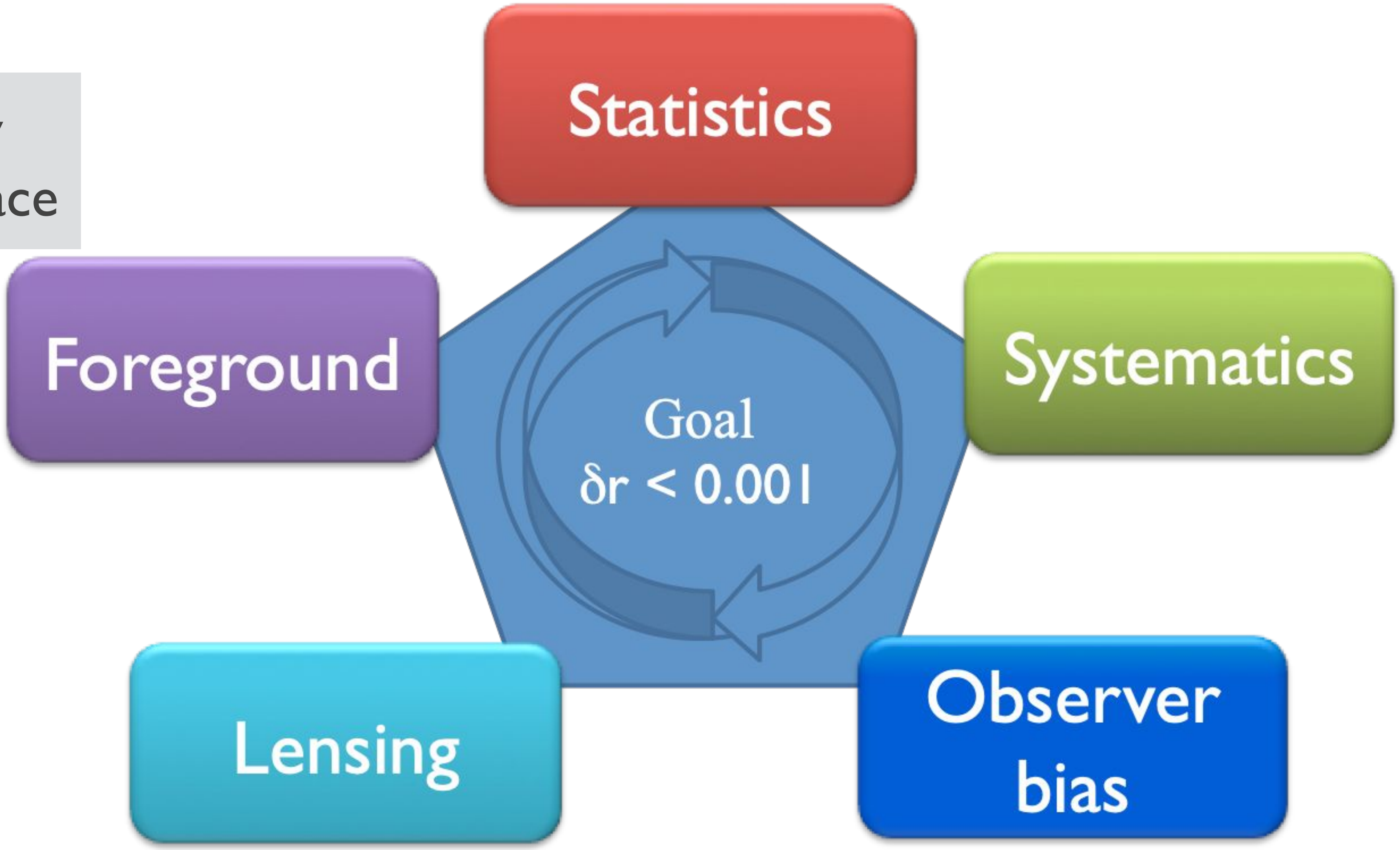
synergy with other projects

M.Tristram

LiteBIRD-day

Critical Factors

High Sensitivity Detectors



Statistics

Large frequency coverage from Space

Foreground

Goal

$\delta r < 0.001$

Mitigation and Control of Systematics

Systematics

Continuously Rotating HWP

Lensing

Observer bias

Focused on largest multipole scales

All-sky survey

Noise

$$\text{Noise} \propto \frac{\text{“Sensitivity”}}{\text{Integration time}^{1/2}}$$

- **sensitivity better in space** (no atmosphere, no ground)
- **integration better in space** (no sun, no moon, no weather)

rule of thumb: **1 det in space = 100dets on the ground**

Advantage space

Systematics

- **Stable environment**: any systematic related to the Sun, Earth (including ground and atmosphere), or Moon is lower or absent in space
- Coverage of the **full sky** requires multiple sites from the ground, raising many issues
- Anything related to **stability and continuity** of instrumentation and operations is better in space
- Current **calibration** of ground data is based on Planck measurements
- For the calibration of **polarisation**, LiteBIRD rely on ground calibration and internal EB nulling. Precise measurements of an astrophysical polarized source from the ground could extend LiteBIRD science case.
- A drawback of space is the effect of **cosmic rays** on direct-detection systems

Advantage space

Angular resolution

- Resolution

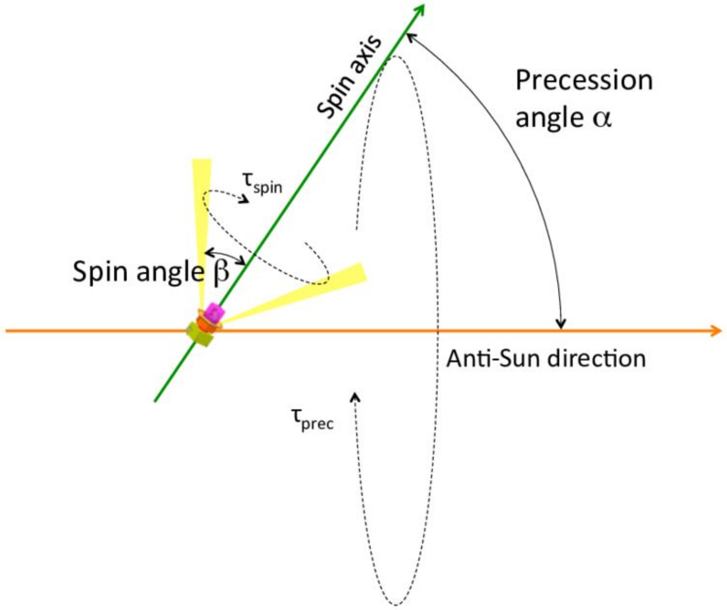
$$\text{Beam size} \propto \frac{\lambda}{D}$$

- 2 arcmin resolution is ~ 5m diameter telescope
- big telescopes are too expensive for space
- access to **small scales from the ground**

Advantage ground

- Scanning strategy

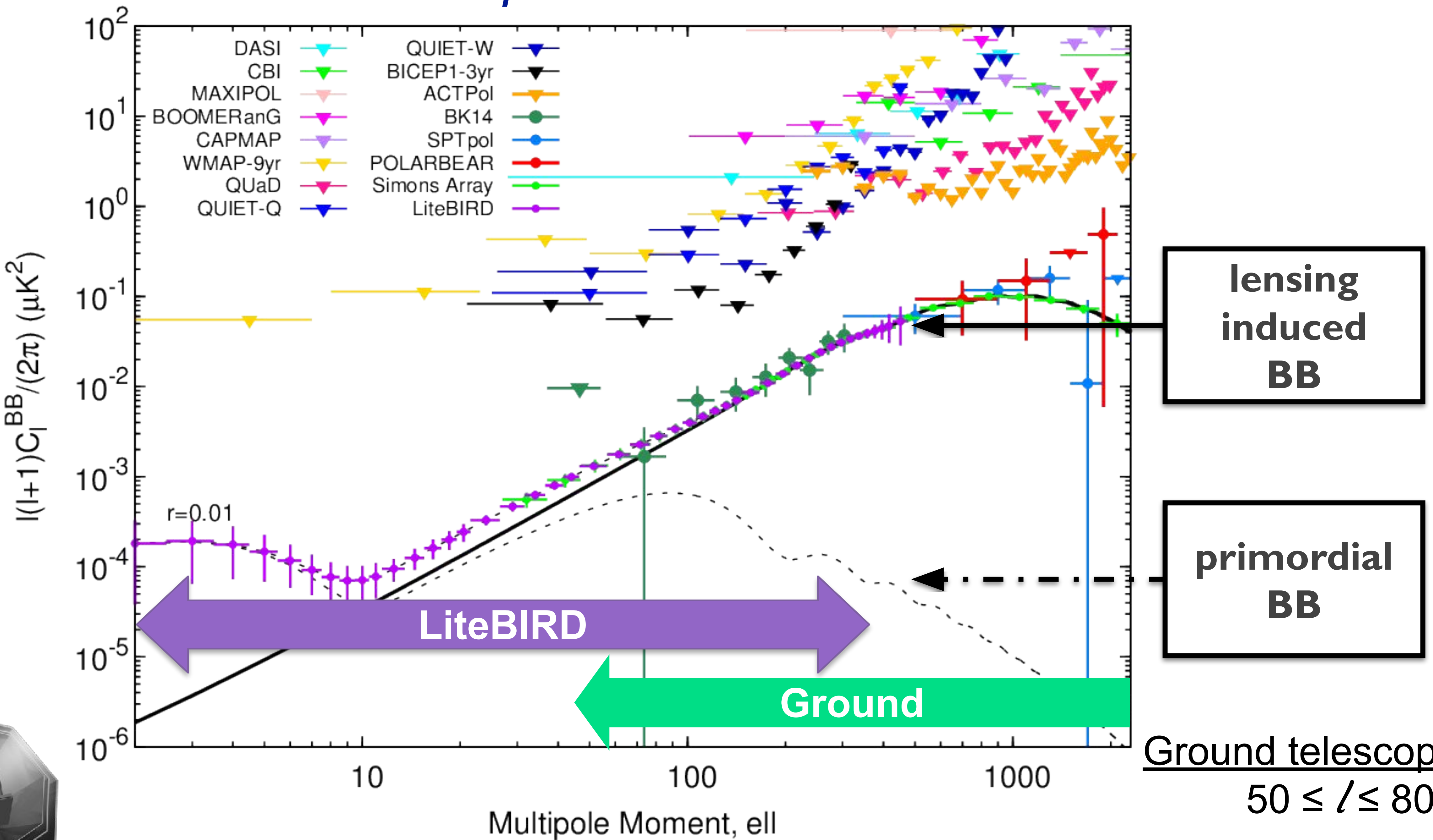
- full-sky is much easier from L2
- access to **large scales from space** (low multipoles)



Advantage space

Angular resolution

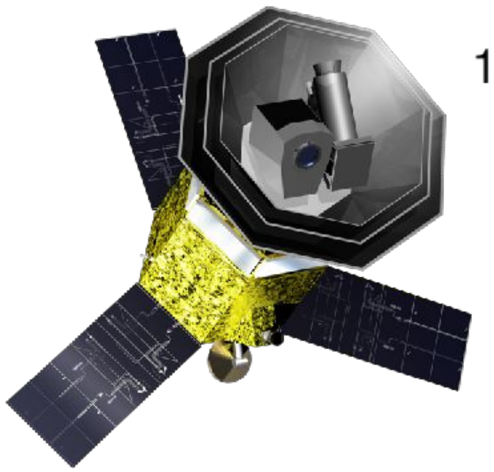
a powerful duo



lensing induced BB

primordial BB

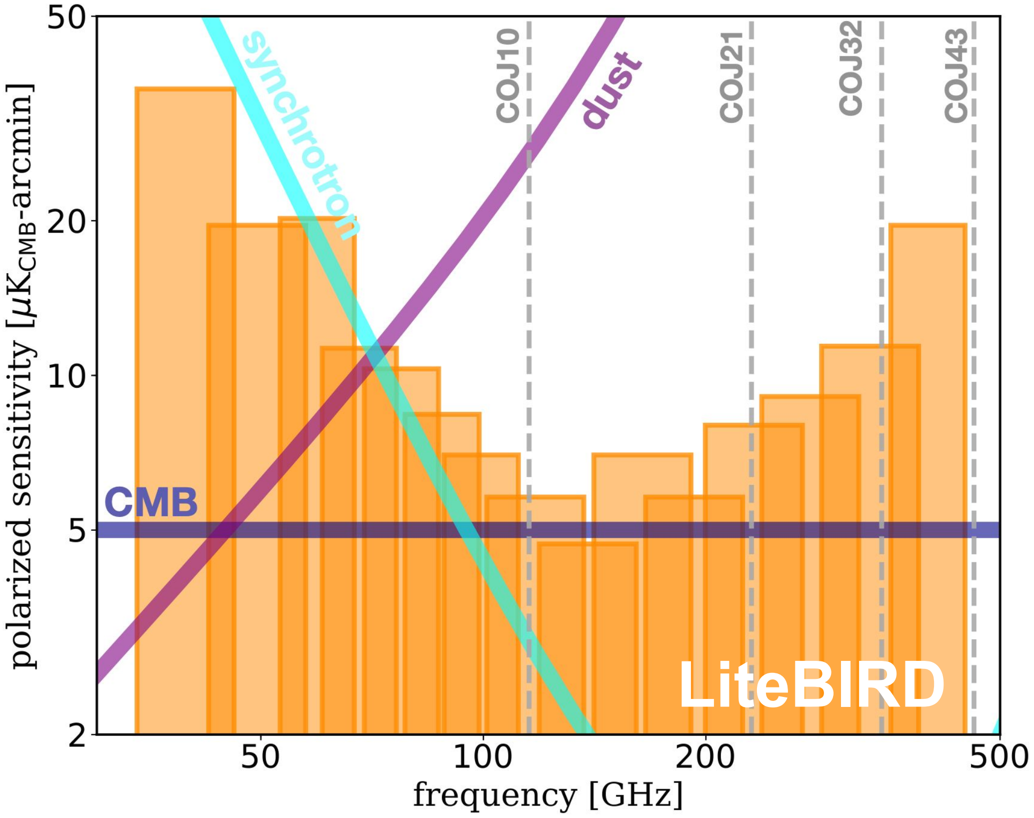
LiteBIRD
$2 \leq \ell \leq 300$
σ(r) <0.001

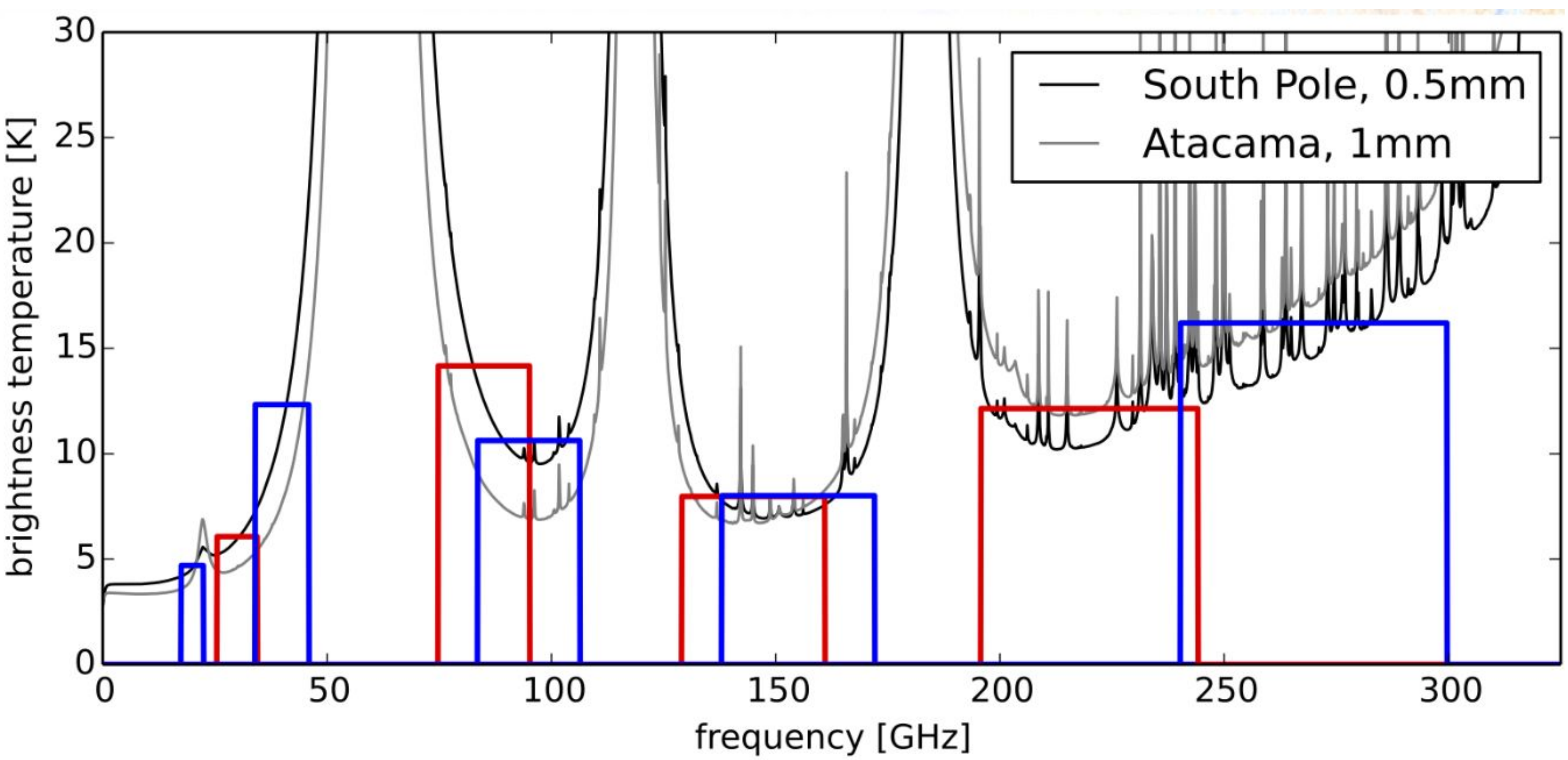


Ground telescopes
$50 \leq \ell \leq 8000$

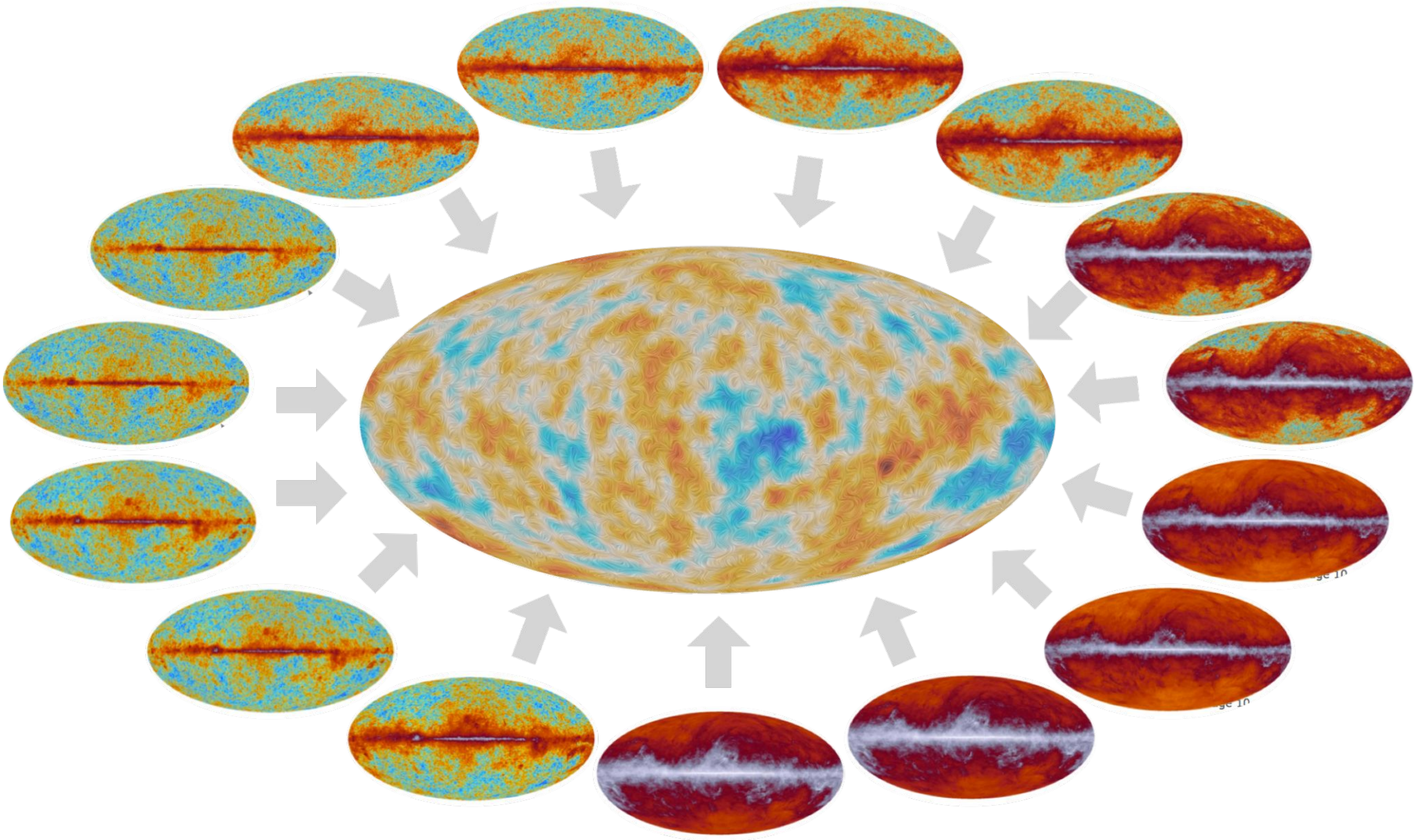
Foregrounds separation

- Depends on frequency coverage, noise, calibration accuracy
- More challenging at low multipoles
  - Need more (all) sky
  - Foreground fluctuations are larger on large scales
- From the ground, observations are limited to a few discrete windows, which do not cover the foreground minimum



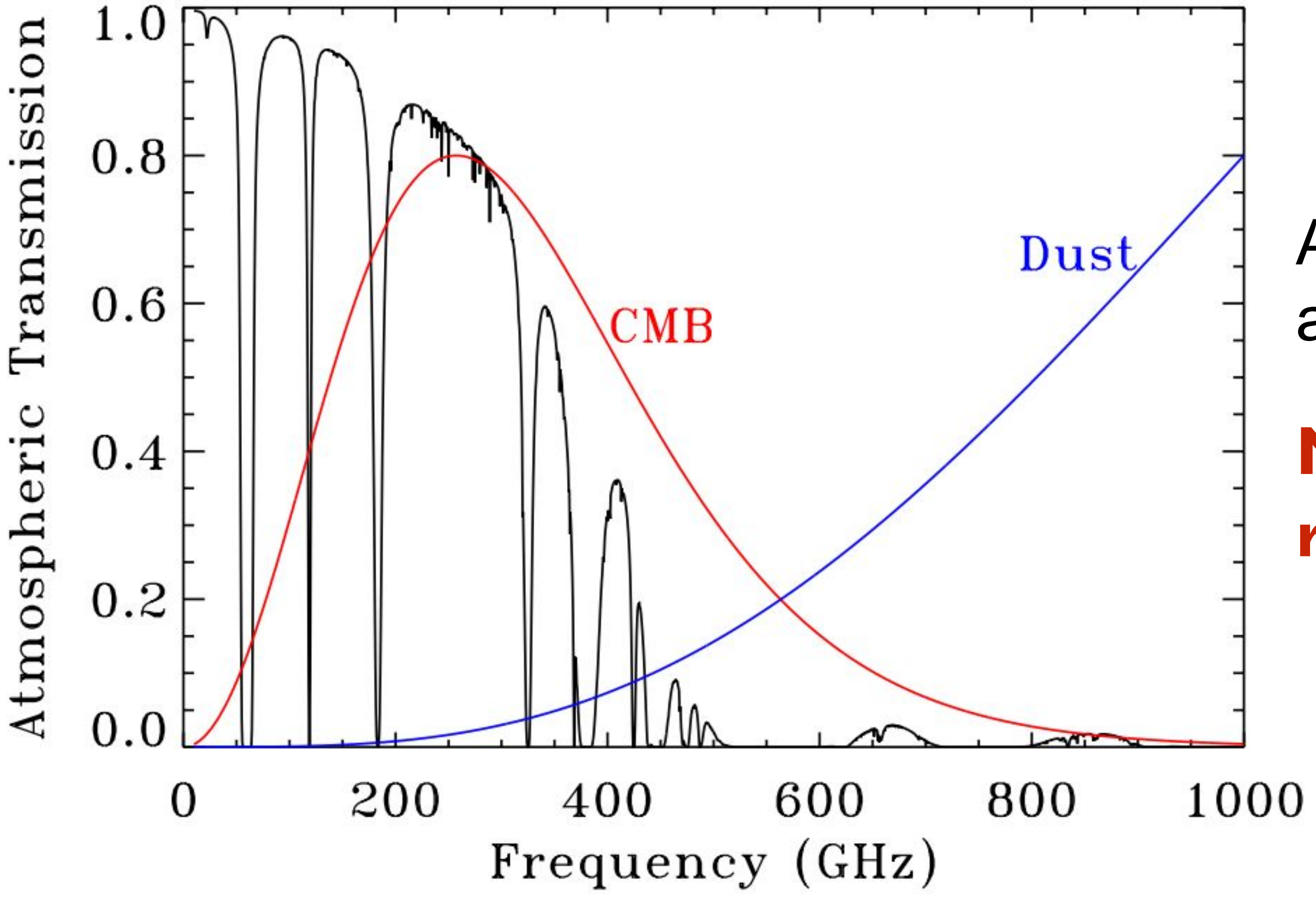


Foregrounds



Foregrounds

- Current analysis of ground data used dust tracers from Planck (e.g. BICEP/Keck)
- LiteBIRD will deliver Galactic foreground maps for cleaning CMB ground data (dust and synchrotron)



Atmosphere is opaque at frequencies above 300 GHz

Mapping high frequencies requires a space observatory

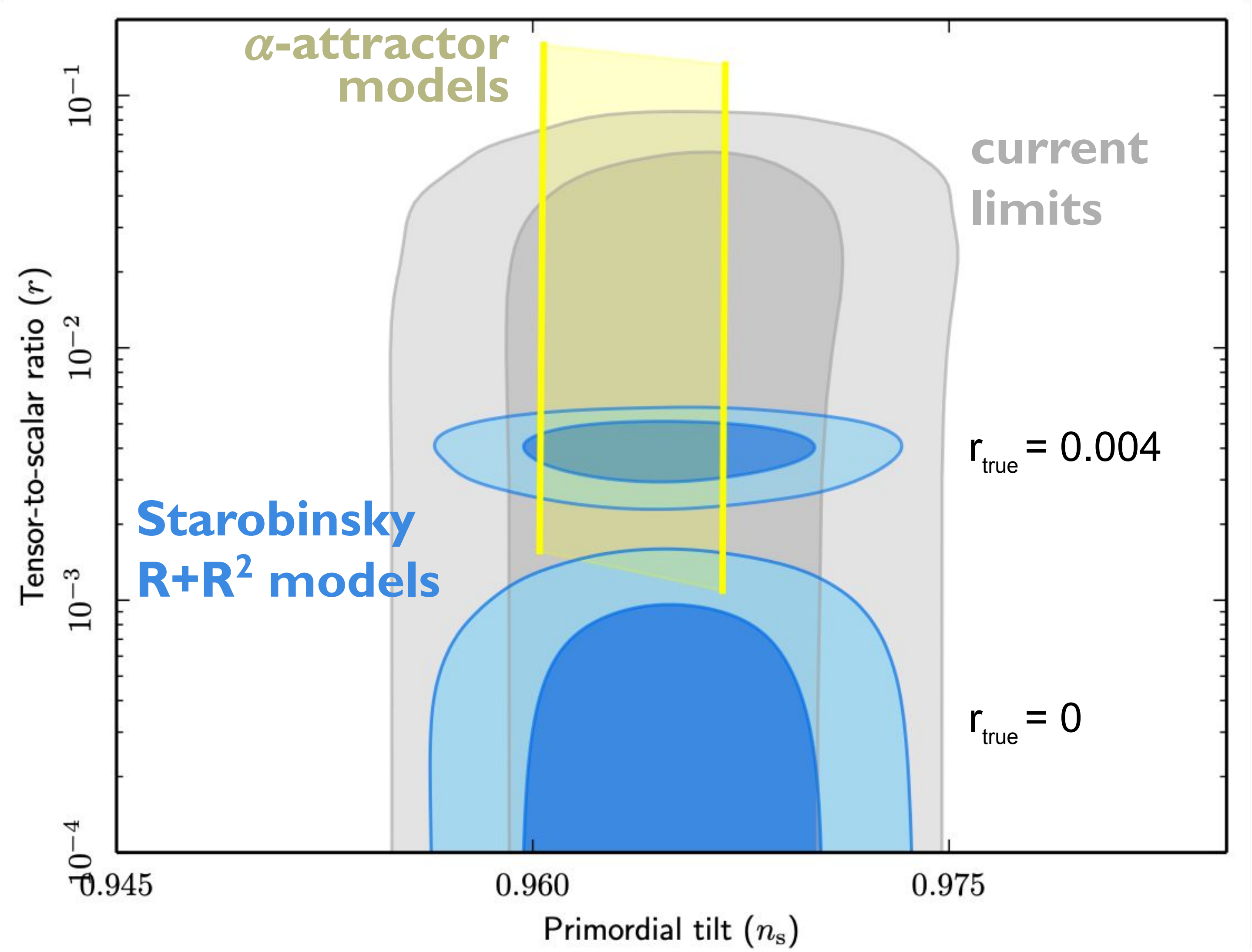
Primordial gravitational waves

Full Success

- $\sigma(r) < 10^{-3}$ (for r=0, no delensing)
- $>5\sigma$ observation for each bump of the BB spectrum (for $r \geq 0.01$)

Rationale

- Large discovery potential for $0.005 < r < 0.05$
- Simplest and well-motivated $R+R^2$ "Starobinsky" model will be tested
- Clean sweep of single-field models with characteristic field variation scale of inflaton potential greater than m_{pl} *[Linde, JCAP 1702 (2017) no.02, 006]*



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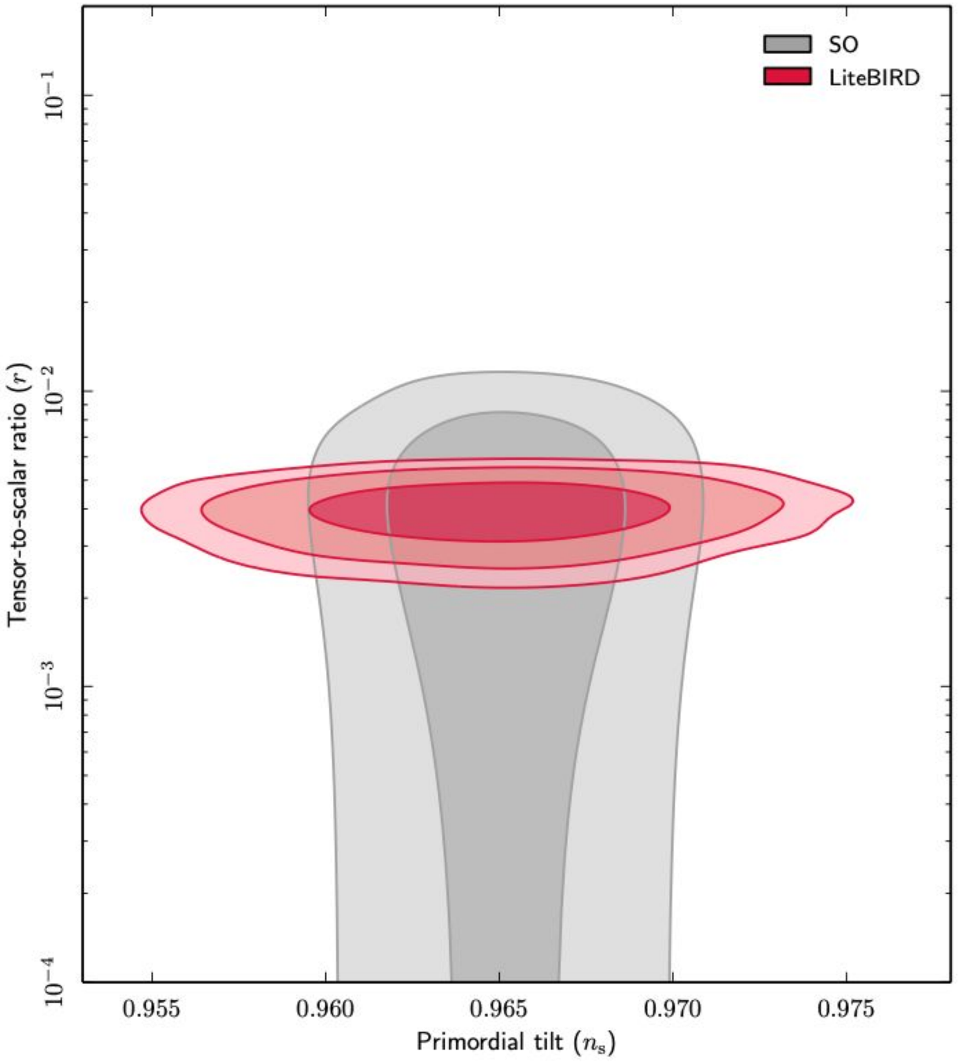
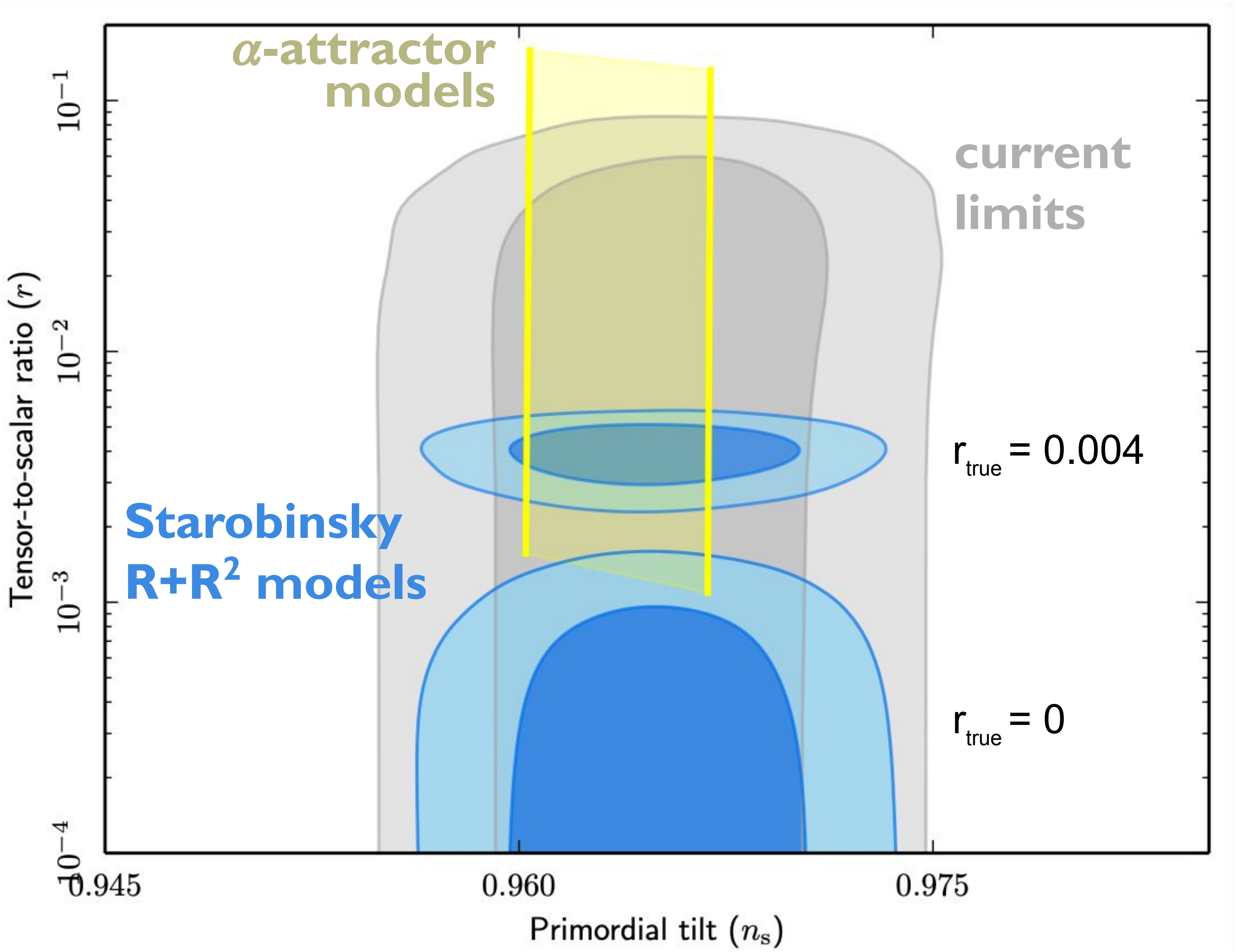
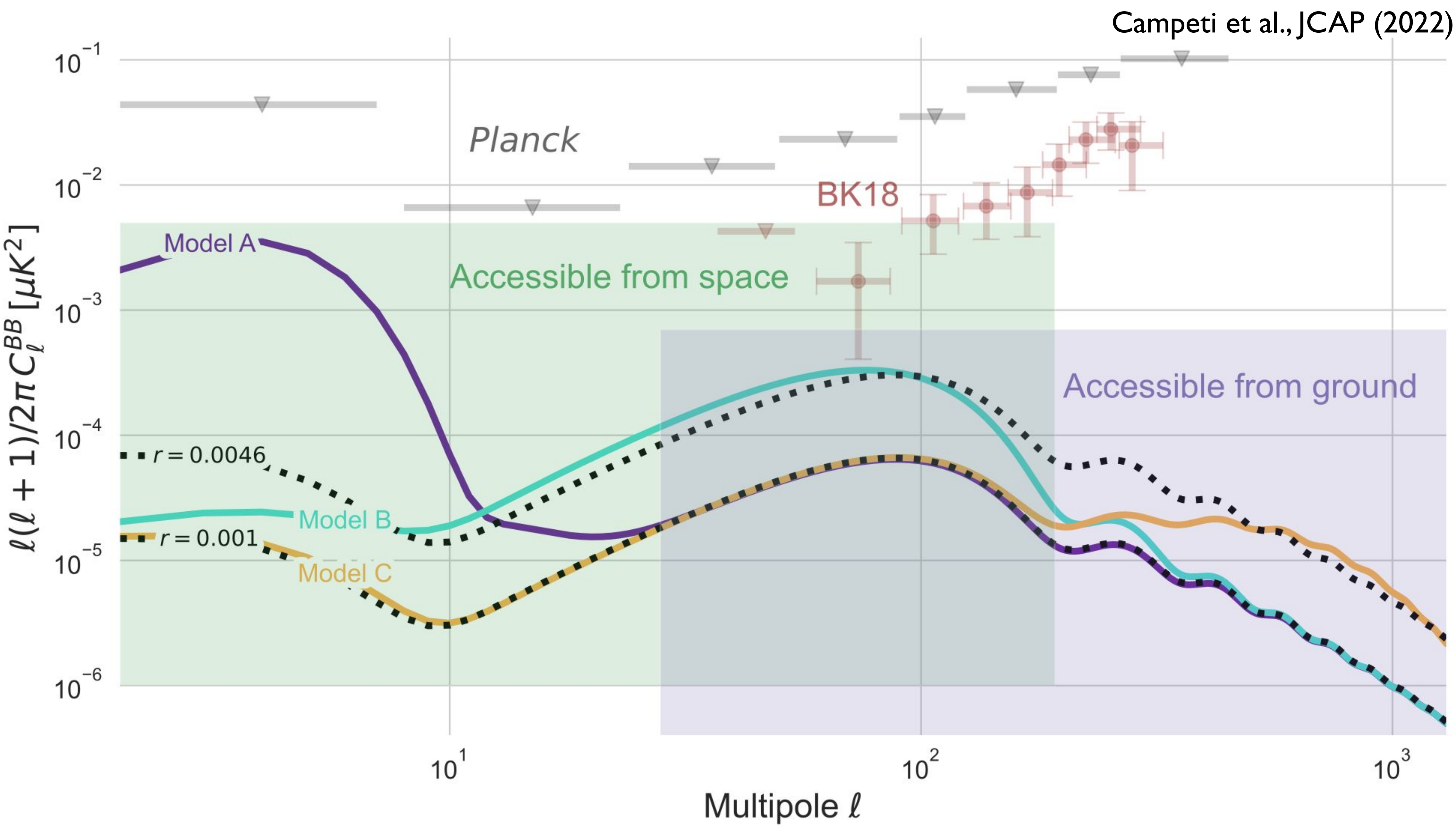




Angular resolution



only space can achieve measurement in the two bumps

Delensing with ground data

Extra Success

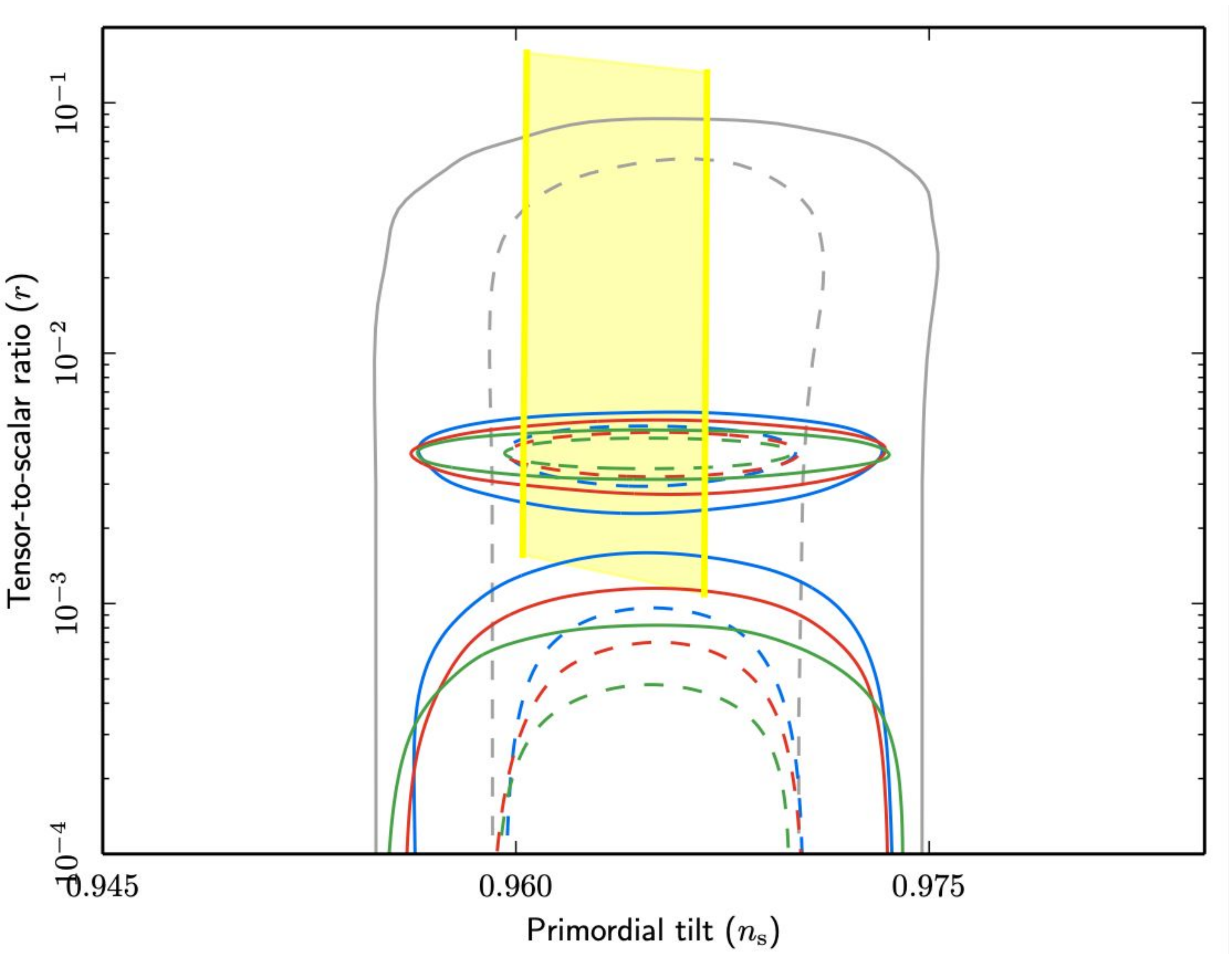
- improve σ(r) with external observations
- delensing improvement to σ(r) can be a factor ≥ 2

Aiming at detection with >5σ in case of Starobinsky model

Baseline

+ delensing w/Planck CIB & WISE

+ extra foreground cleaning w/ high-resolution ground CMB data

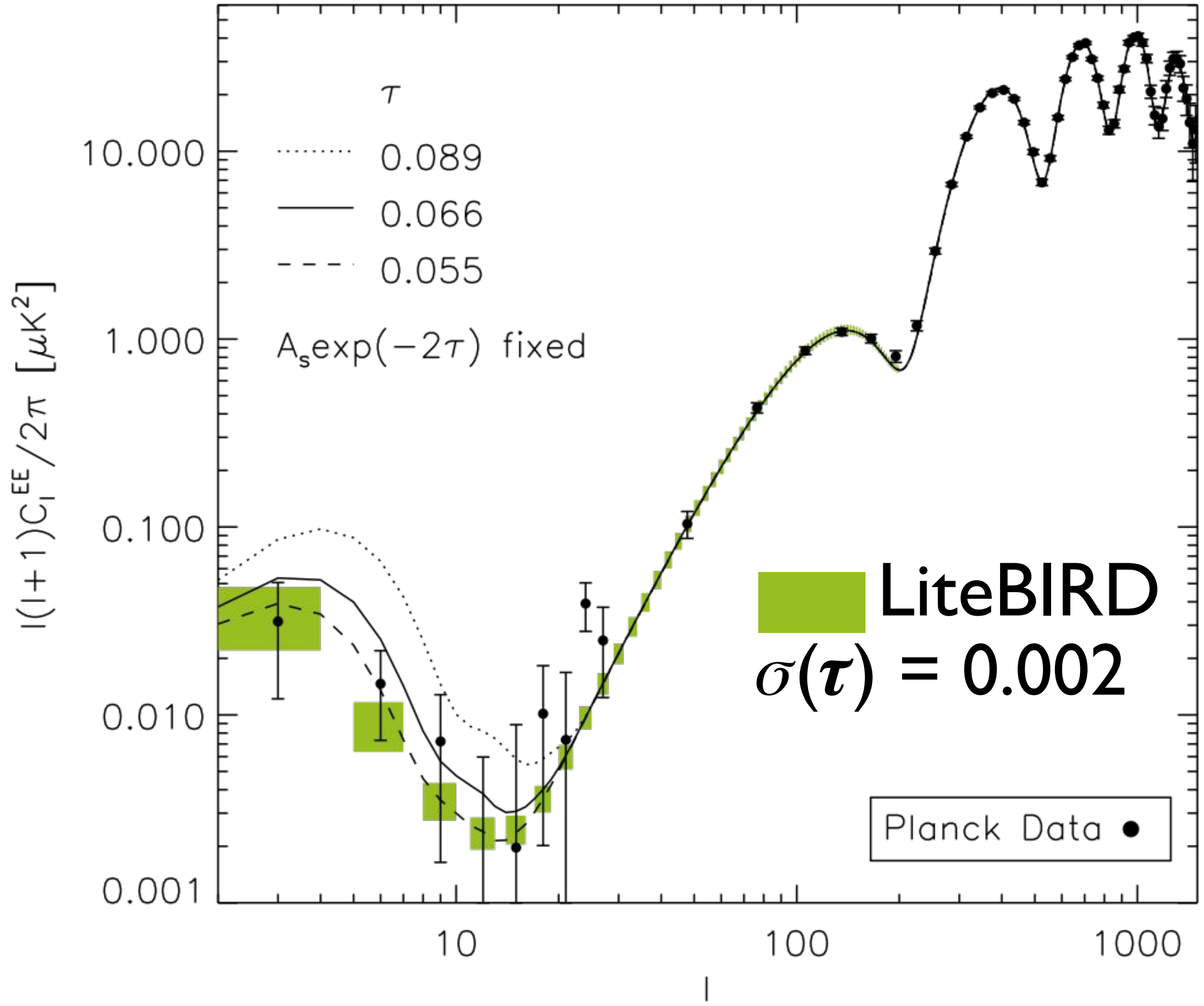


MOU LiteBIRD & CMB-S4

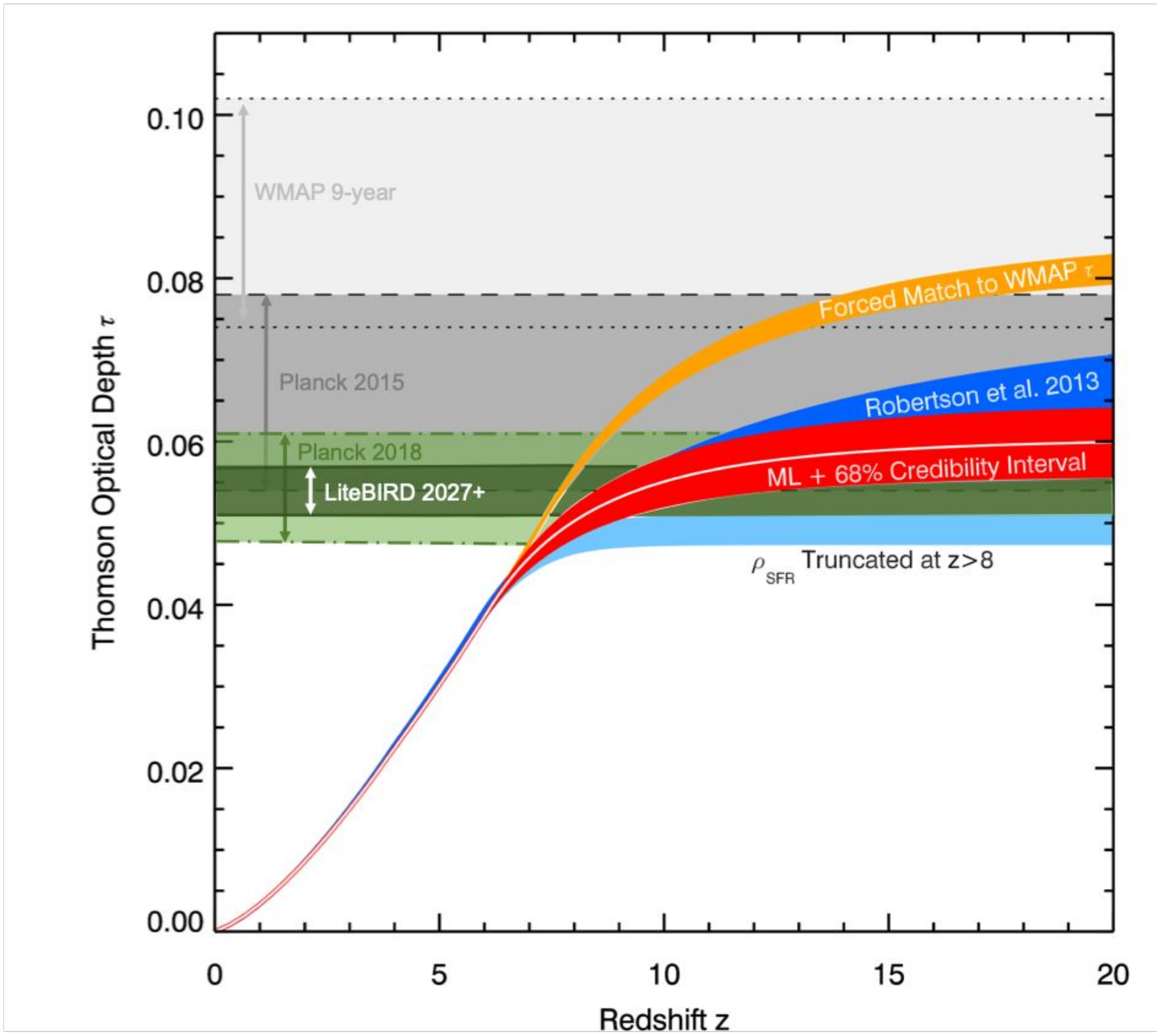
complementarity with ground-based measurements

Reionization

A **cosmic variance limited** measurement of EE on large angular scales will be an important, and guaranteed, legacy for LiteBIRD



🟩 LiteBIRD
$\sigma(\tau) = 0.002$

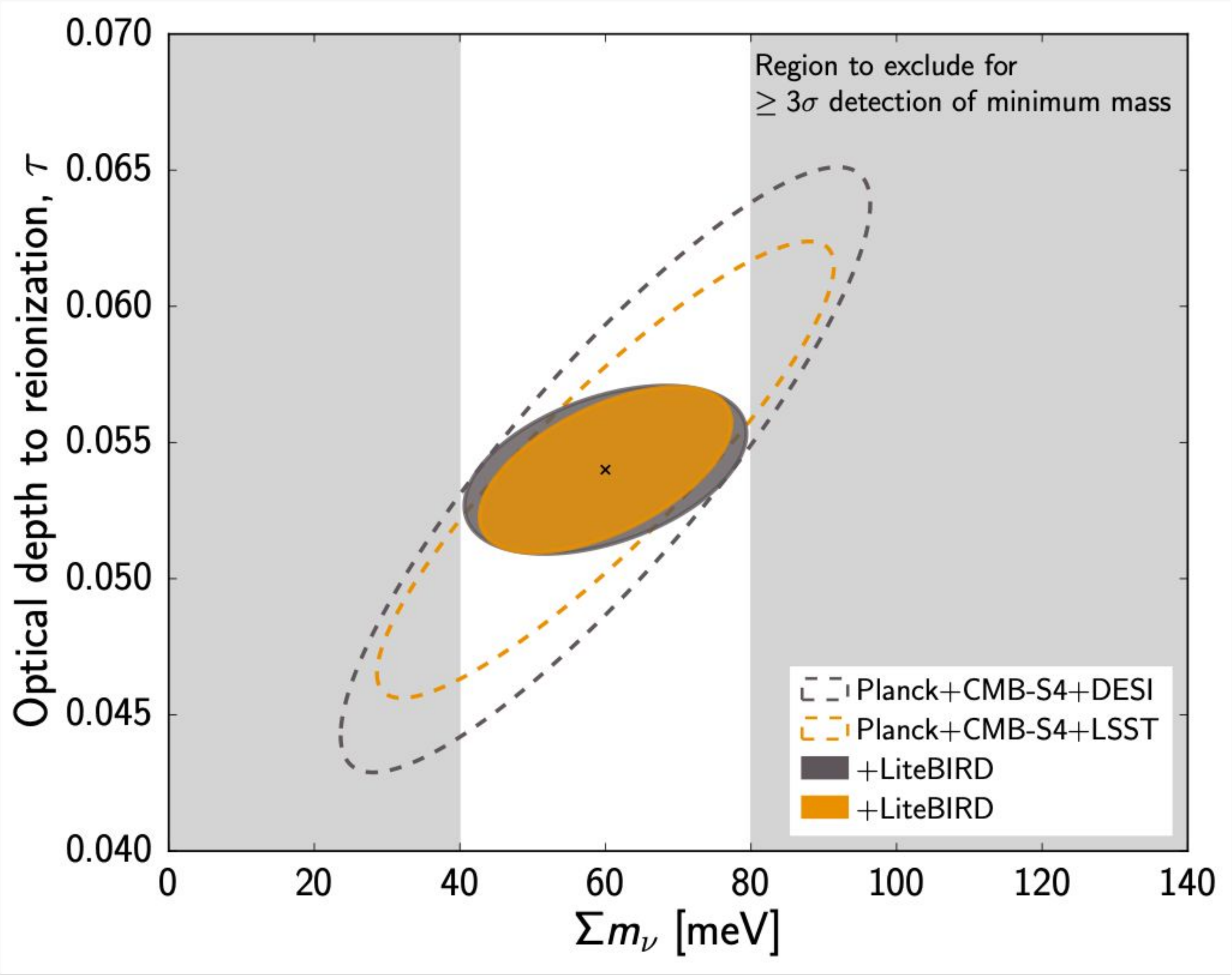


only accessible from space

Neutrino sector

Improvement in reionization optical depth measurement implies:

- $\sigma(\Sigma m_\nu)$ = 15 meV
- **determine neutrino hierarchy**
  normal v.s. inverted
- **measurement of minimum mass**
  ≥ 3σ detection NH,
  ≥ 5σ detection for IH

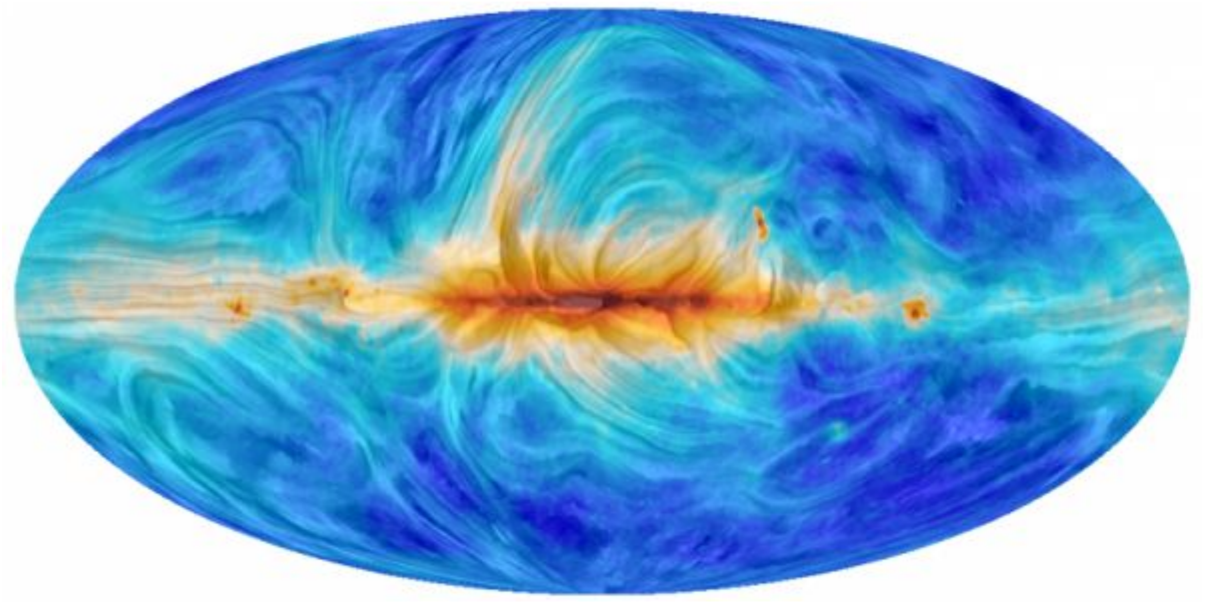


complementarity with ground-based measurements

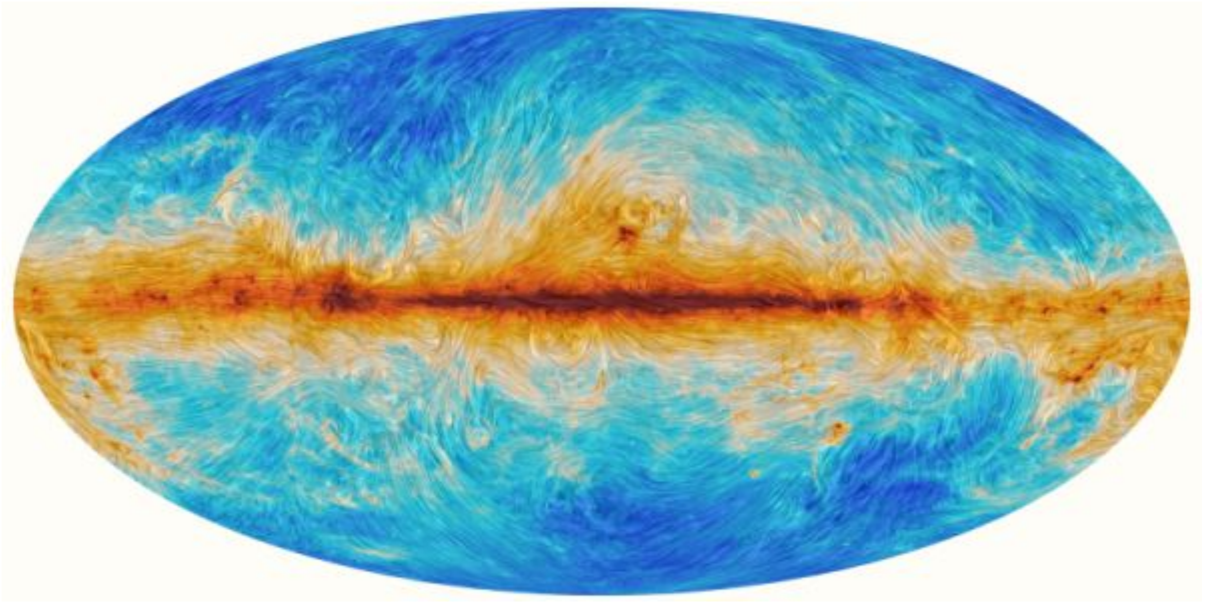
Galactic science

With frequency range from 34 to 448 GHz and access to large scales LiteBIRD will gives constraints on

- Characterisation of the foregrounds SED
- Large scale Galactic magnetic field
- Models of dust polarization grains



Synchrotron



Dust

only accessible from space

Spectral distortions

- Anisotropic CMB spectral distortions could be measured well
  - LiteBIRD forecasts comparable to PIXIE! (15 bands are many)
  - Multi-field effects or non-Bunch-Davies initial conditions
    - Spatially-varying chemical potential distributions [Pajer-Zaldarriaga 2012, Ganc-Komatsu 2012]
    - Effects on $C_\ell^{\mu\mu}$, $C_\ell^{\mu T}$
- Frequency Space Differential measurements for detecting any spectral distortion [Mukherjee-Silk-Wandelt 2018]
  - Use inter-frequency differences only

interesting theoretical ideas need experimental assessment:

- include 1/f noise, systematic errors, etc...
- use advantages of multi-color detectors
- use "controlled imperfection" of HWP for gain calibration

Synergy with other probes

- Lensing

LiteBIRD E-modes

\+

CMB-S4 high-resolution

→ improve our knowledge of the projected gravitational lensing produced by the large-scale structure

- Integrated Sachs-Wolf effect

improvement on ISW signal (~20%)

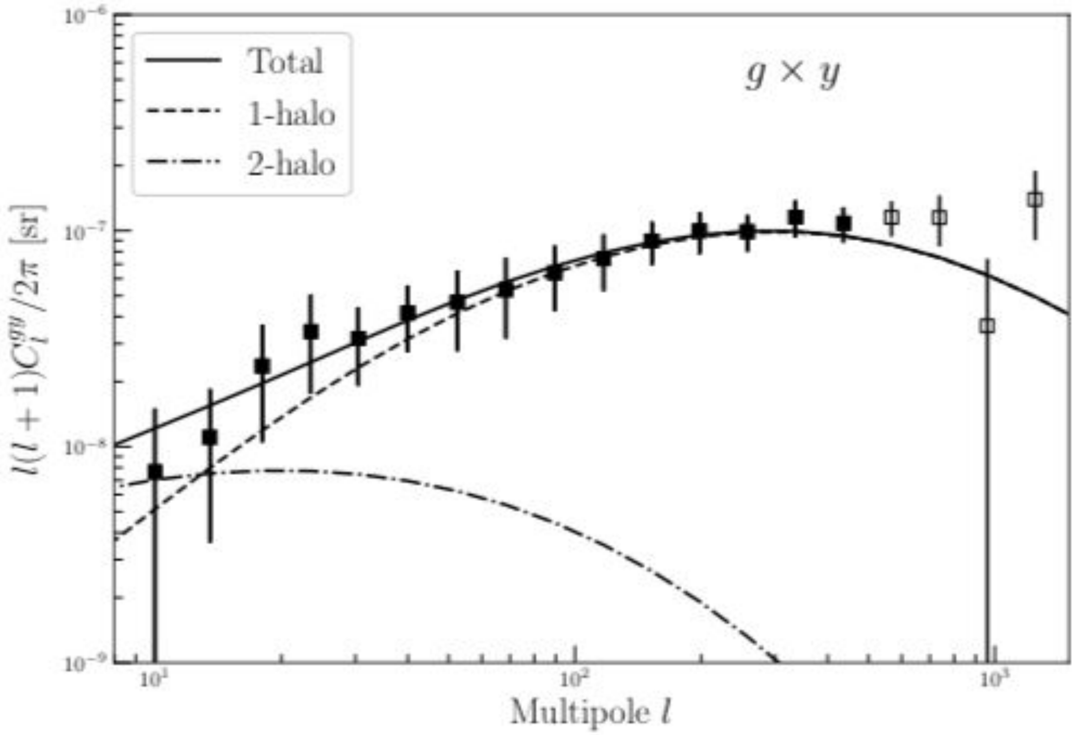
- Galaxy surveys

full-sky map of hot gas
(thermal SZE)

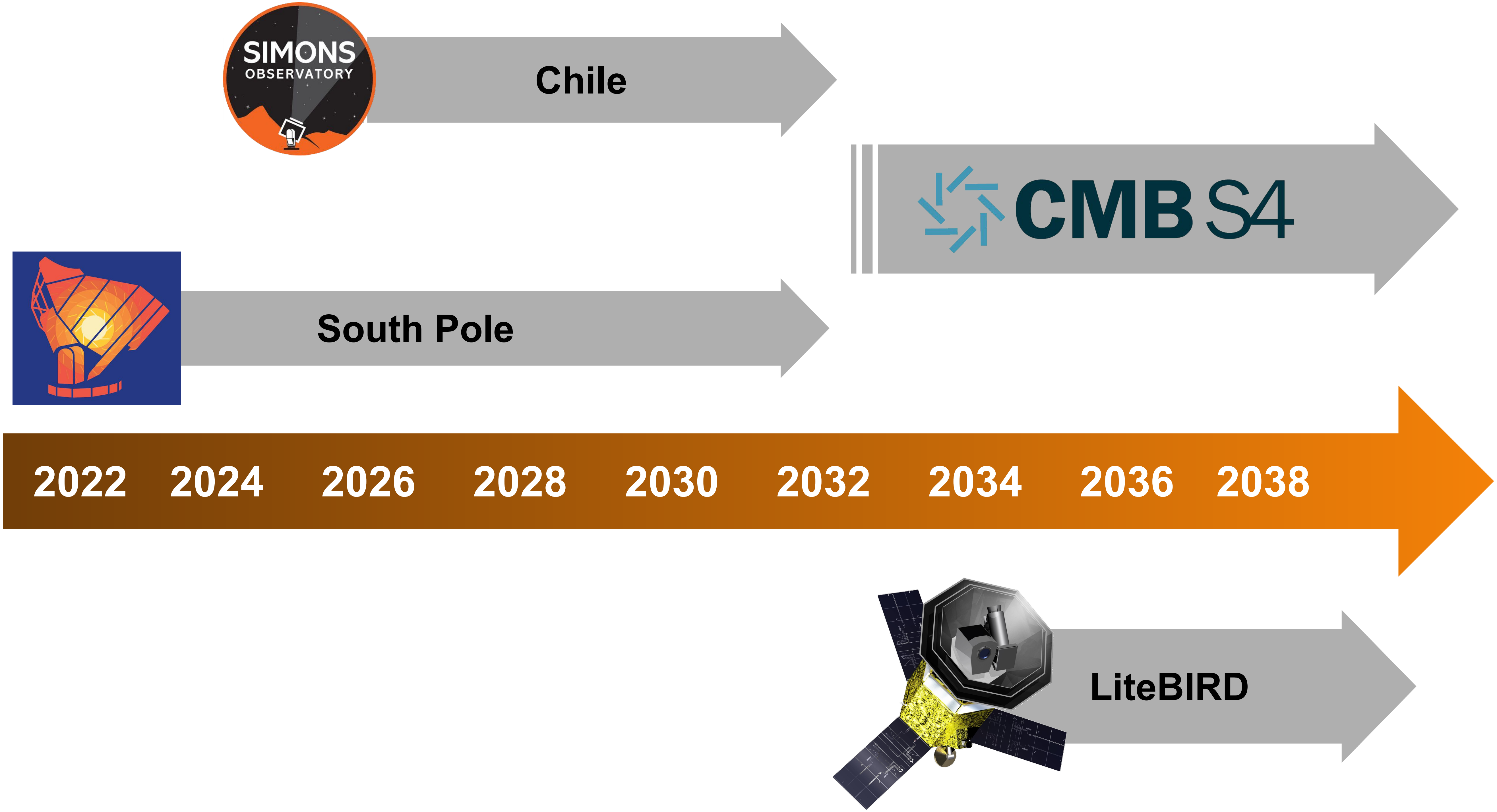
$\otimes$

3D distribution of the matter
(galaxy survey)

how gas traces the matter in the Universe



Schedule



SIMONS OBSERVATORY

Chile

CMB S4

South Pole

2022 2024 2026 2028 2030 2032 2034 2036 2038

LiteBIRD