THE LiteBIRD Mission

Daniela Paoletti
For the LiteBIRD Collaboration

Daniela Paoletti is funded by ASI-LiteBIRD

LiteBIRD

Lite satellite for the study of *B*-mode polarization and Inflation from cosmic background Radiation Detection

LiteBIRD is the fourth generation of satellites dedicated to the observation of the Cosmic Microwave Background-CMB

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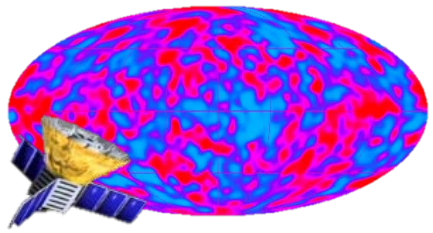
COBE 1991

Discovered the CMB anisotropies



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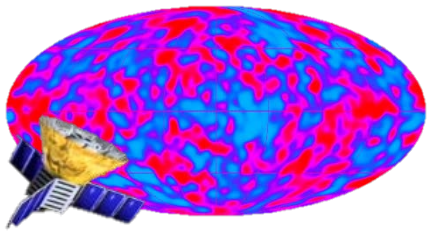
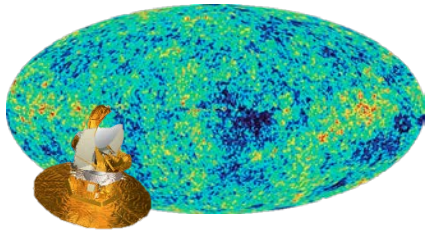


WMAP 2001-2012

Measured the cosmological parameters



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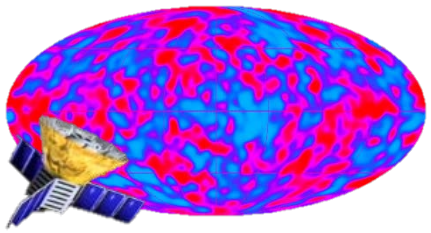

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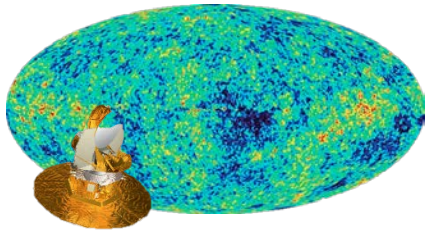
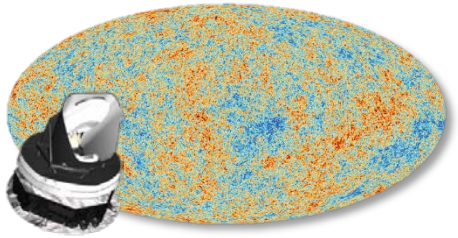


Planck 2009-2013

Opened the era of precision cosmology



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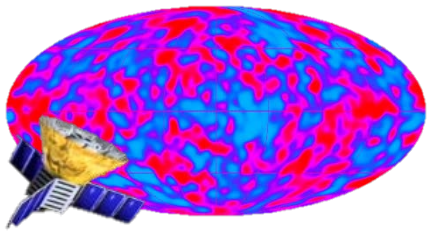

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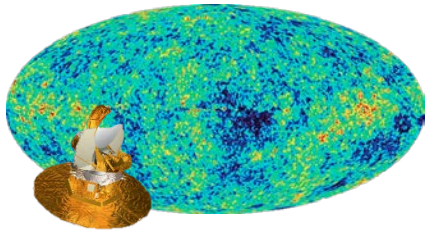

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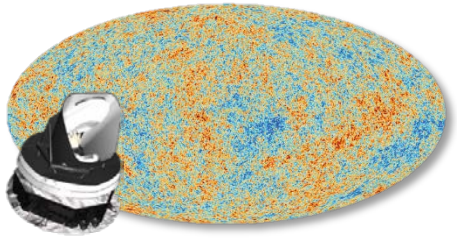
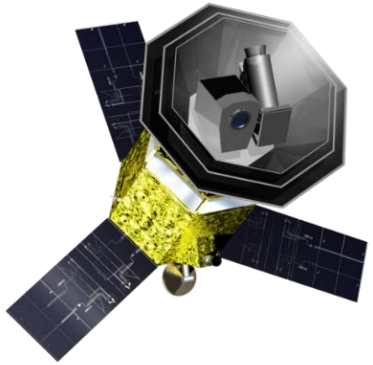
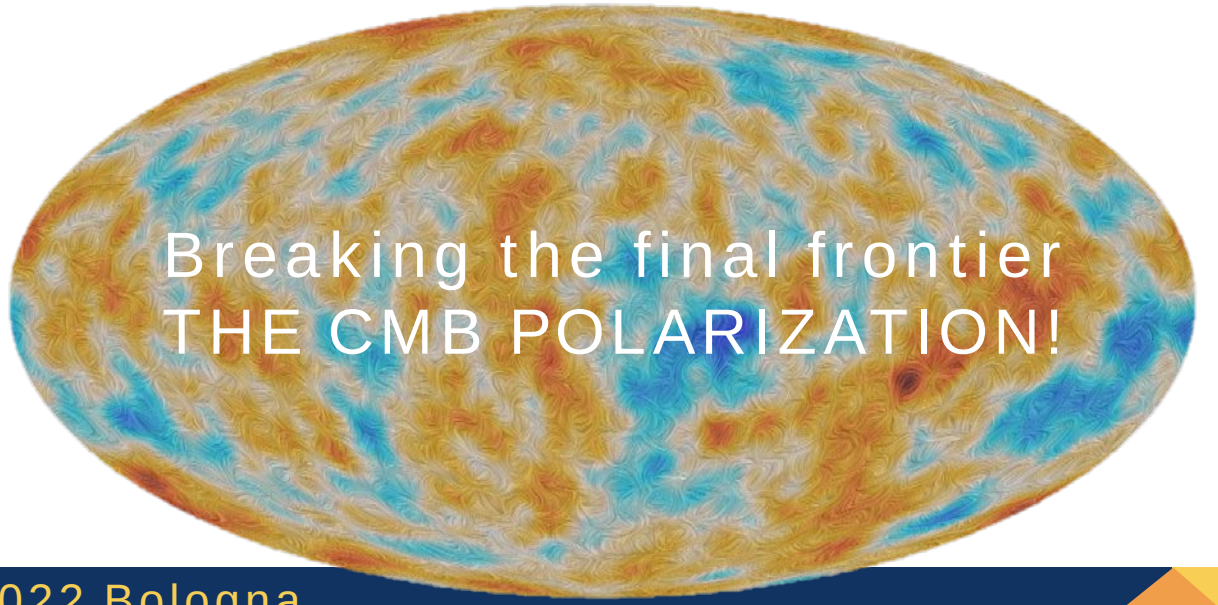


2029 LiteBIRD
Will open the era of FUNDAMENTAL COSMOLOGY

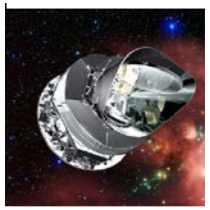




LiteBIRD Joint Study Group

Over 300 researchers from Japan, North America and Europe

Team experience in CMB experiments, X-ray satellites and other large projects (ALMA, HEP experiments, ...)





LiteBIRD Global F2F meeting
December 11-13, 2019 at MPE

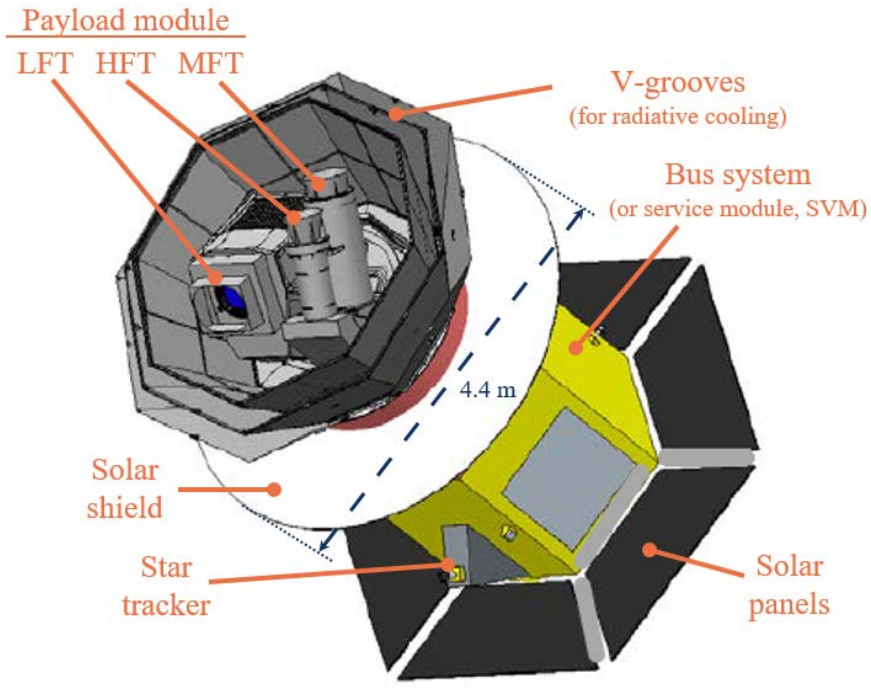

LiteBIRD

LiteBIRD

LiteBIRD goal is to perform the final measurement of the CMB polarization on large angular scales by achieving an unprecedented sensitivity from space and performing the best data cleaning possible.

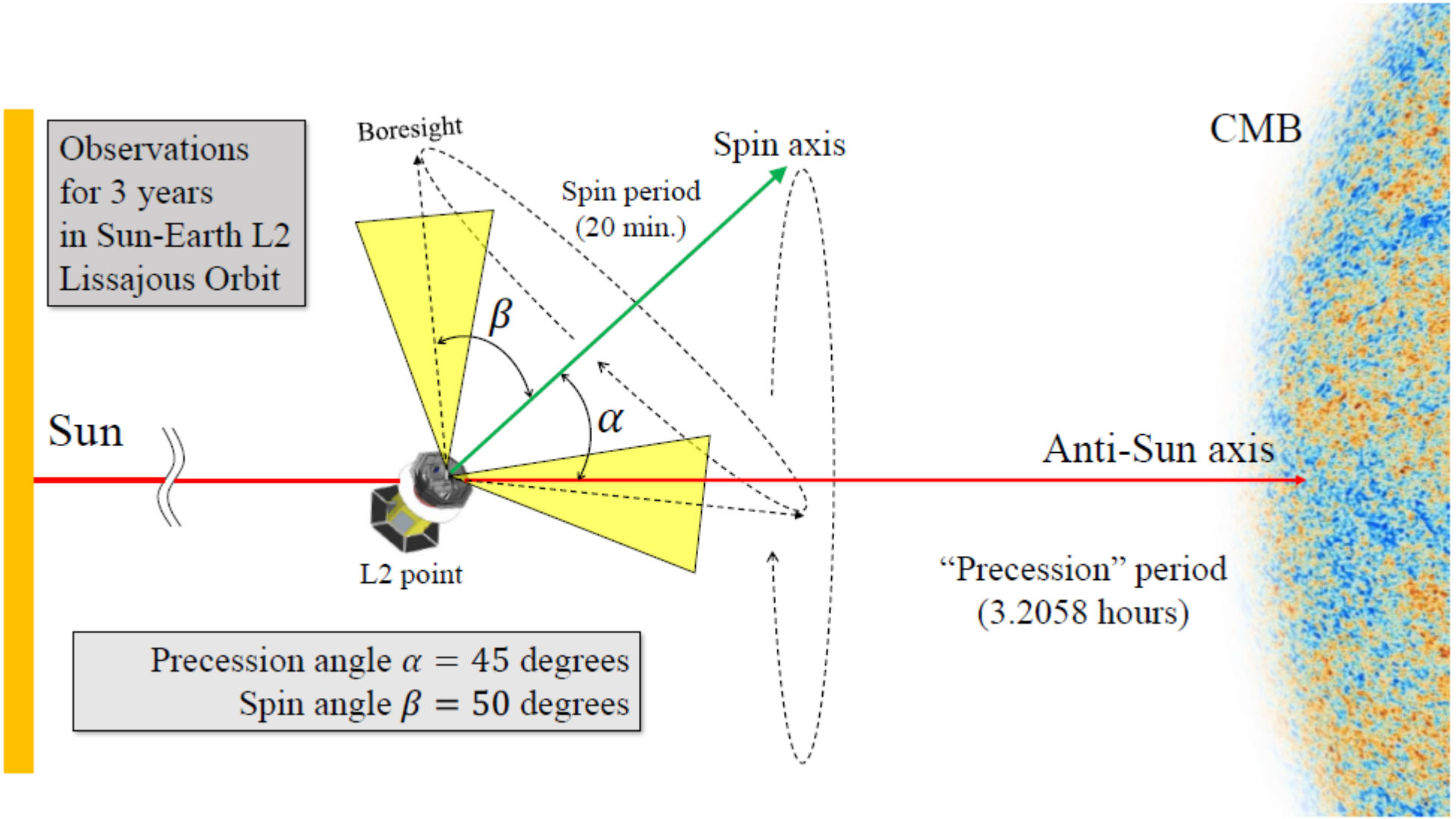
LiteBIRD in pills:

- **JAXA's L-class mission selected in May 2019**
- **Expected launch in late 2029 with JAXA's H3 rocket**
- **All-sky 3-year survey, from Sun-Earth Lagrangian point L2**
- **Large frequency coverage (40–402 GHz, 15 bands)**
- **70–18 arcmin angular resolution for precision measurements of the CMB B-modes**
- **Final combined sensitivity: 2.2 μK·arcmin**
- **Three telescopes on board – Low-Medium-High frequency telescopes. LFT – crossed-Dragone; MFT+HFT= MHFT two refractive telescopes mounted on a common structure**
- **Each telescope is equipped with an Half Wave Plate modulator to better identify the polarization signal and reduce the 1/f noise**
- **Multi-chroic transition-edge sensor (TES) bolometer arrays cooled to 100 mK**



- Mass: 2.6 t
- Power: 3.0 kW
- Data: 17.9 Gb/day

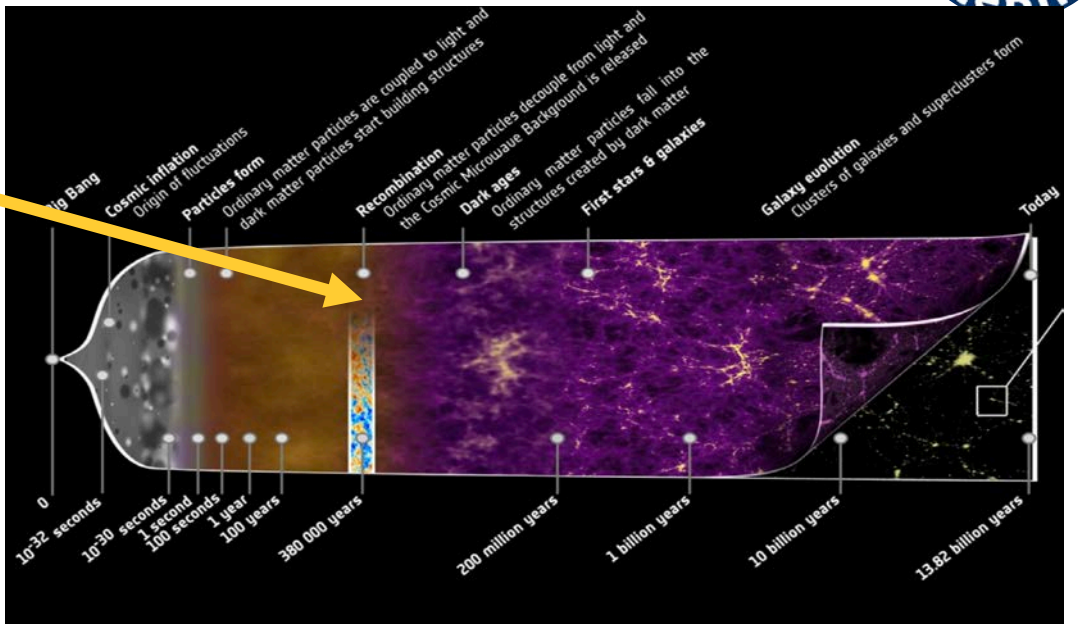
LiteBIRD scanning strategy

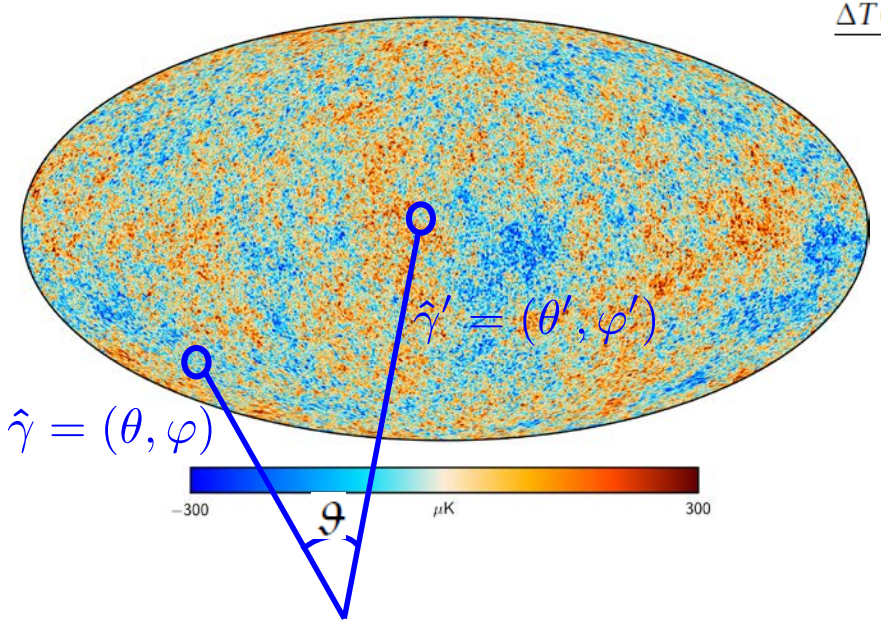


LiteBIRD Coll – PTEP- arXiv:2202.02773

CMB

Thermal relict radiation from the Big Bang.
Emitted at recombination when radiation decouples from the baryonic component.
Anisotropies are a snapshot of matter fluctuations at recombination.
From the angular power spectrum of CMB anisotropies we can constrain the parameters of the cosmological model both for the background and pertubartions including the initial conditions for quantum fluctuations from inflation





$$\frac{\Delta T(\theta,\phi)}{T} = \sum_{l=0}^{\infty} \sum_{m=-l}^{m=+l} a_{lm} Y_{lm}(\theta,\phi)$$

$$C_l \equiv \langle |a_{lm}|^2 \rangle,$$

E modes

B modes

CMB is polarized and polarization is expressed throught the combination of Stokes parameters

$$\mathbf{P}(\hat{\gamma}) = \nabla \mathbf{E} + \nabla \times \mathbf{B}$$

E-modes: even under parity

B-modes: odd under parity

GOALS

E-MODE POLARIZATION

To perform a cosmic variance limited measurement of the signal

- Origin of large scale anomalies
- Reionization
- Initial conditions
- Exotic models

B-MODE POLARIZATION

To perform a measurement at the limit of r<0.001

- COSMIC INFLATION!
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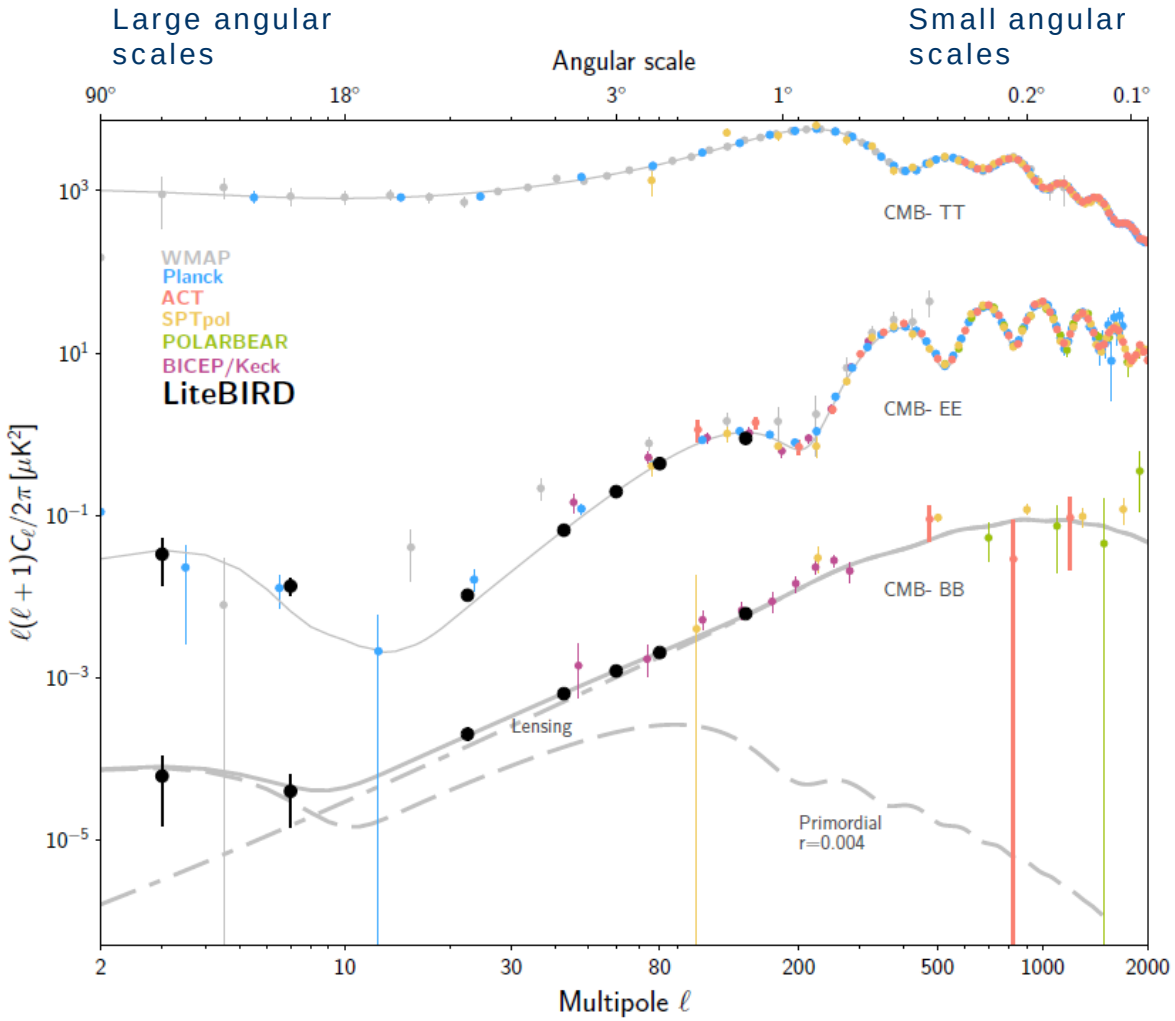
- Parity violations
- Fundamental physics
- Exotic cosmo models
- UltraExotic cosmo models
- Beyond-exotic cosmo models



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WHY SPACE?

Why do we spend money to go on space for observing the CMB? Space limits the number of detectors (but better sensitivity:1 in space=100 on ground) and the resolution due to the dimensions of the telescope so why?

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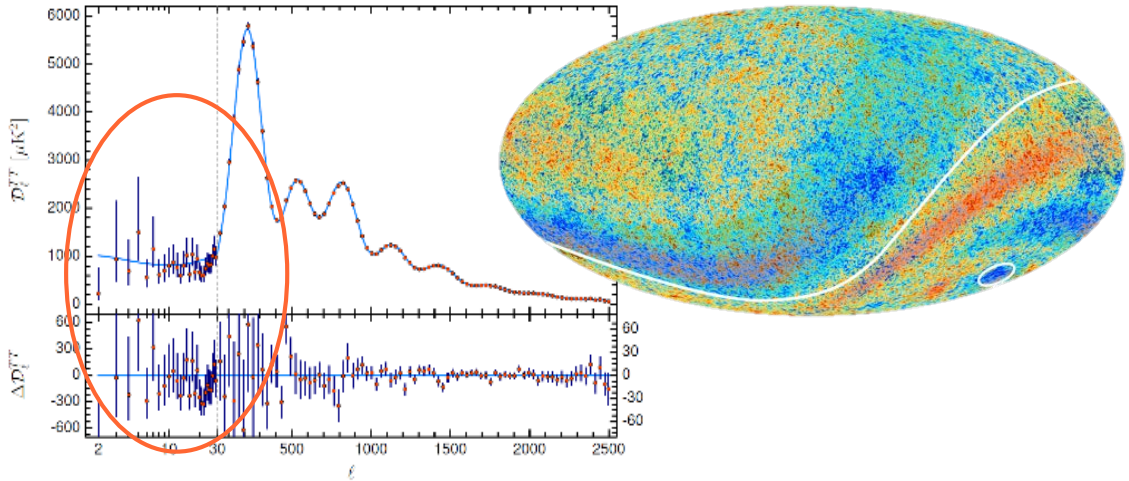
Large scales anomalies and features.
LiteBIRD will detect possible anomalies in polarization (therefore putting to the test the statistical fluke anomaly and the primordial origin).

So we need large scales...



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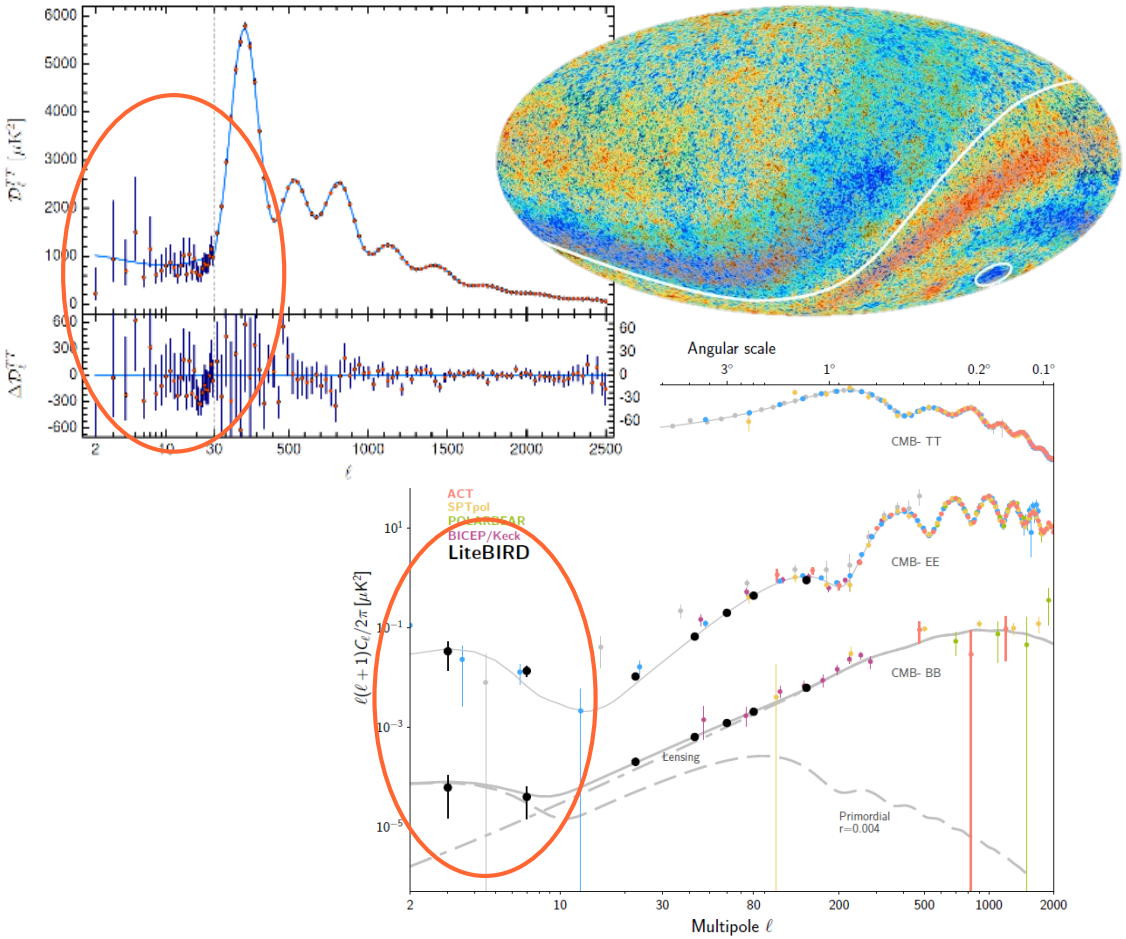
The reionization bump is on large scales...



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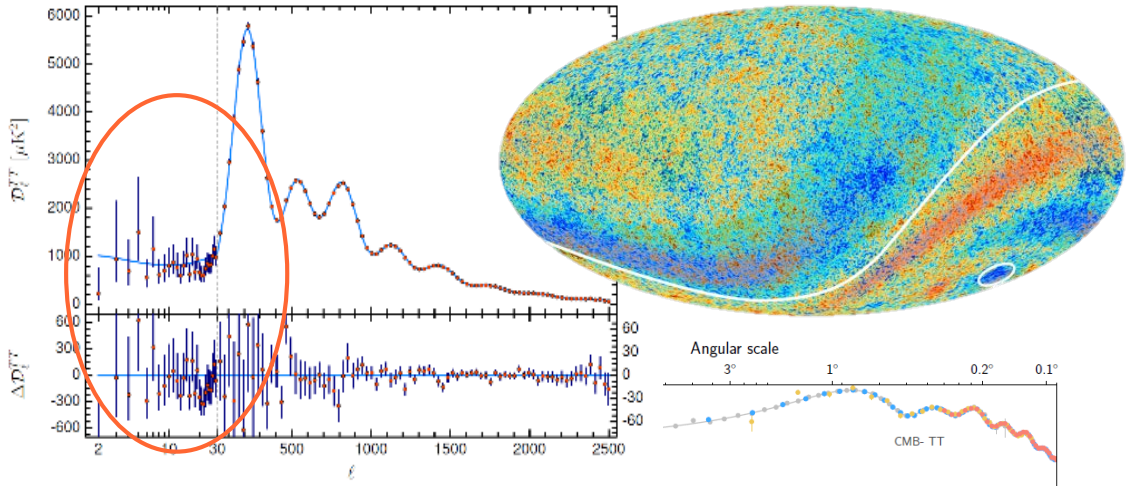

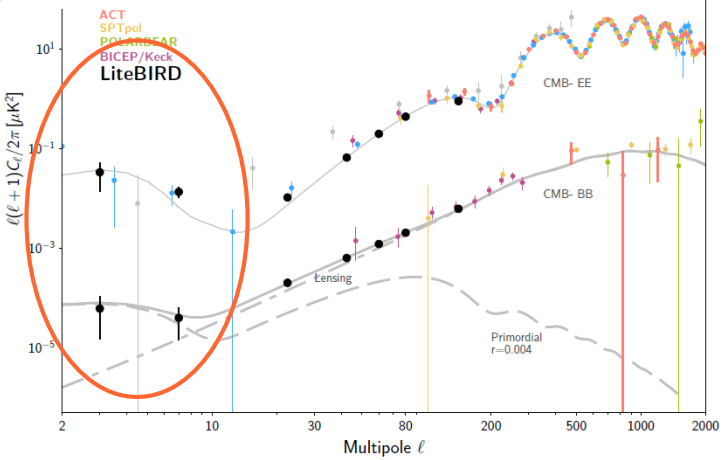

The MAIN GOAL of LiteBIRD are B-modes!
Considering the lensing signal covering the intermediate and small scales...

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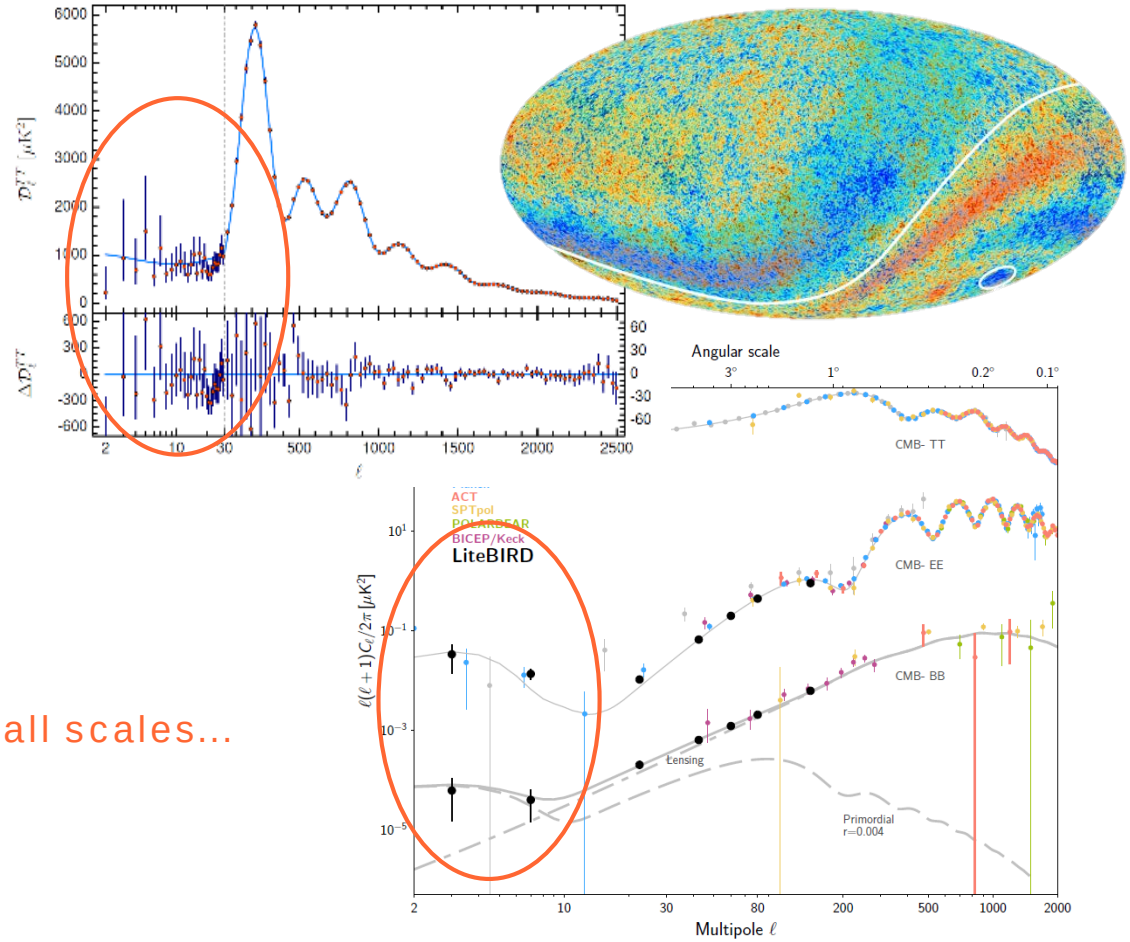

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Only from space we can have the largest scales!

WHY SPACE? part 2

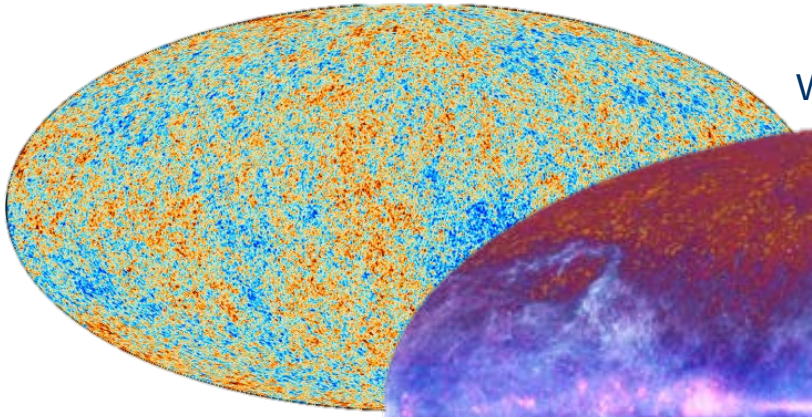
2 - NO ATMOSPHERE

In space there are no clouds! (nevetheless sometimes bolometers in space feel a bit under the space weather)
No atmospheric contamination of the signal

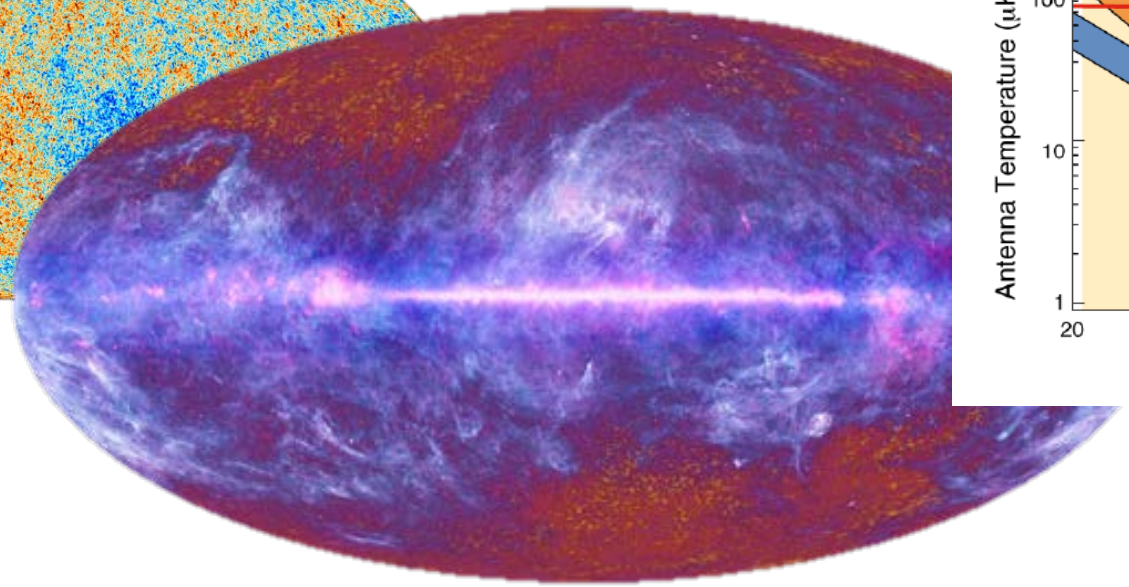
3 - but worth for 10 by itself - FOREGROUNDS

The microwave sky is complicated...very much complicated...in temperature we have

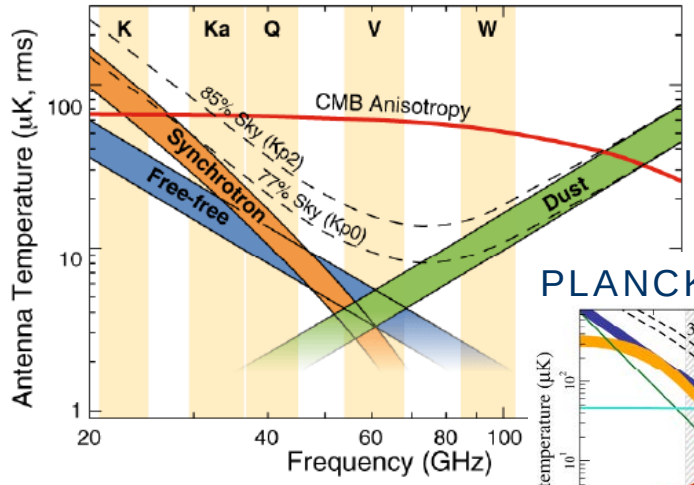
What we want to see



What we actually see

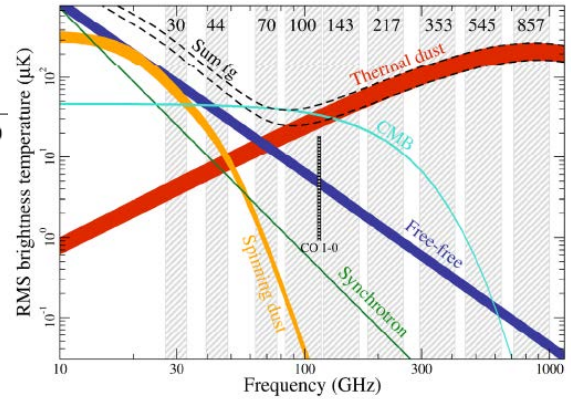


WMAP



The function of sky complexity is a growing monotone in sensitivity

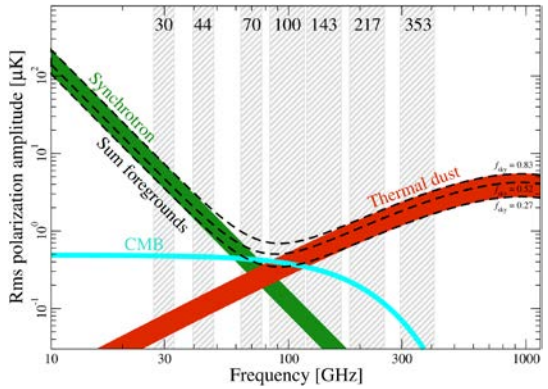
PLANCK



WHY SPACE? part 3

Applying the same complexity function..

If this is the sky seen by Planck



How much LiteBIRD will change this scenario?

??

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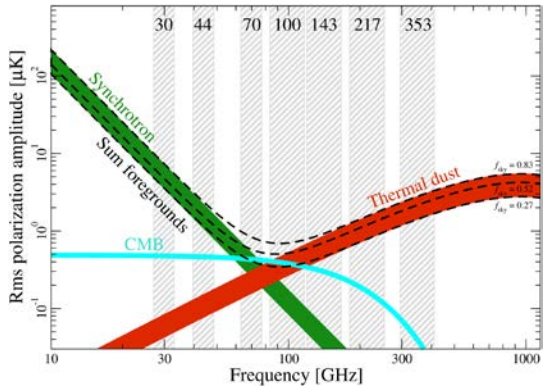

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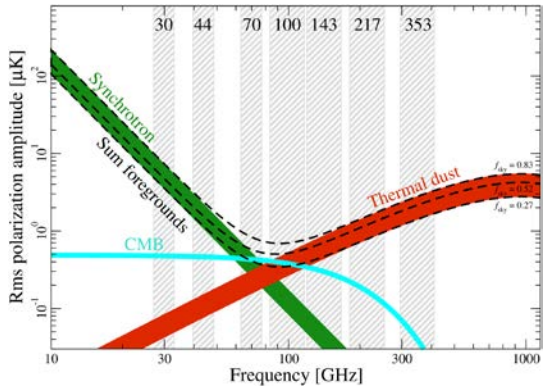
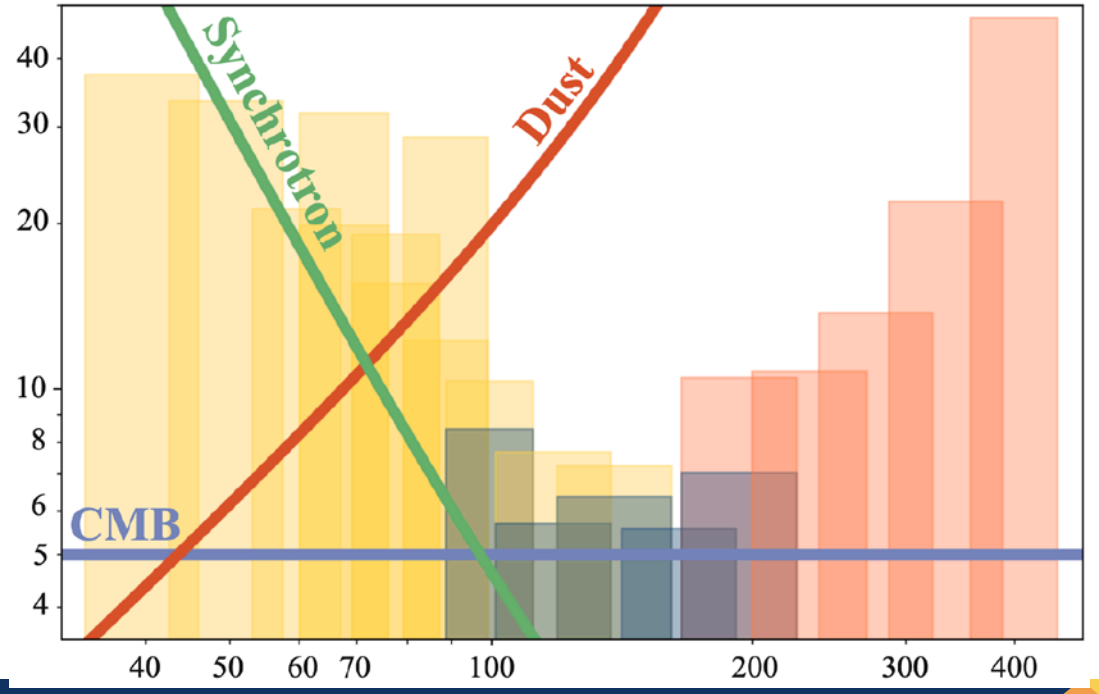


How do we clean from spurious signals our measurements? With component separation algorithms that use the different frequency depedencies of astrophysical signals to separate the different components

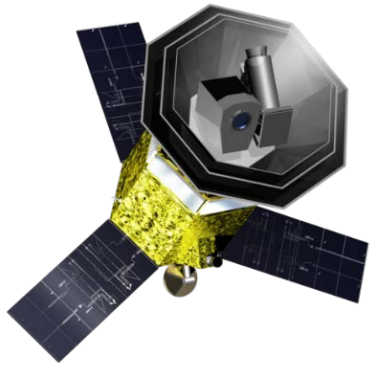
WE NEED FREQUENCY RANGE!!!
LOW FREQUENCIES and VERY HIGH FREQUENCIES to clean from synchrotron and dust and everything may be there and we still don't know

And again in space there are no clouds
Atmosphere strongly limits the high frequencies accessible from the ground to lower than 270 GHz or so.



What a match!

While LiteBIRD will observe the CMB from space also on ground there will be a lot of activity and this gives us a unique opportunity



202X - #10000 detectors both large (fsky 0.4) and small aperture telescopes *Abitbol +2019 arXiv:1907.08284*

202X+ - #100000 detectors. Combination of South Pole and Atacama sites *Abazajian+2019 arXiv:1907.04473*

- FULL SCALES – LARGE AND INTERMEDIATE FROM LITEBIRD SMALL FROM GROUND
- LITEBIRD WILL ALLOW TO CLEAN GROUND BASED FROM HIGH FREQUENCY CONTAMINATION
- GROUND WILL ALLOW THE DELENSING OF THE LITEBIRD SIGNAL

SOME EXAMPLES

Photo by Thomas Couillard on Unsplash

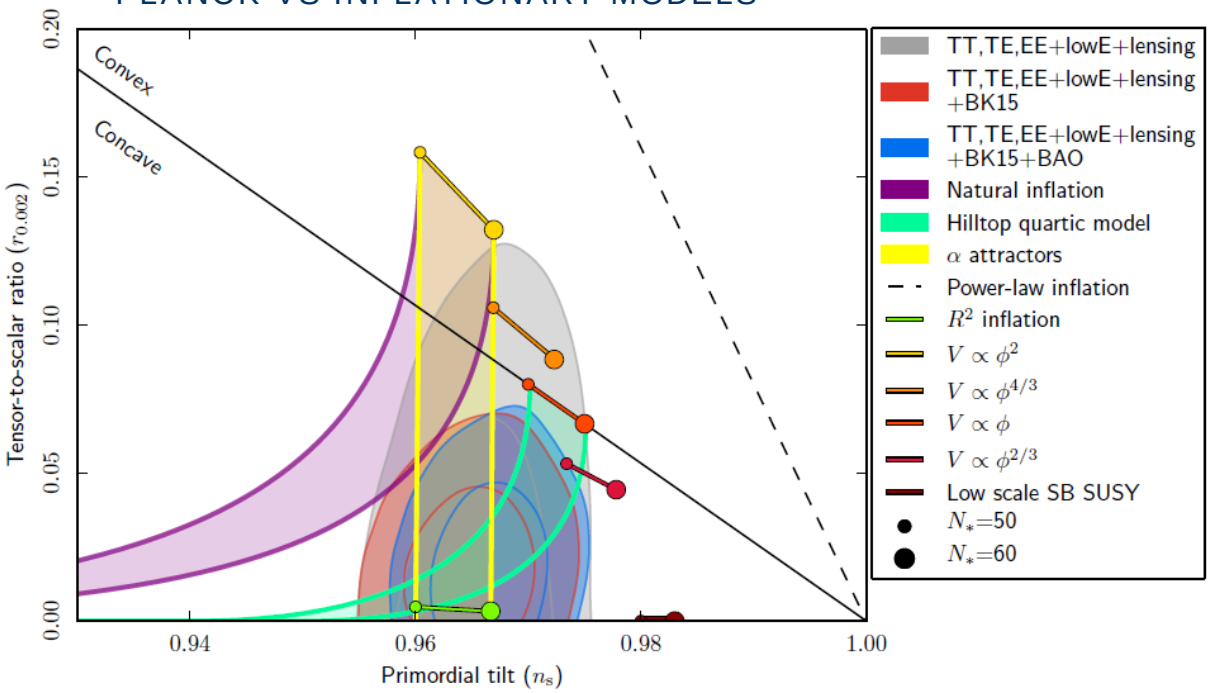
These are only few pieces of the large scenario of LiteBIRD science

SCIENCE – EARLY UNIVERSE

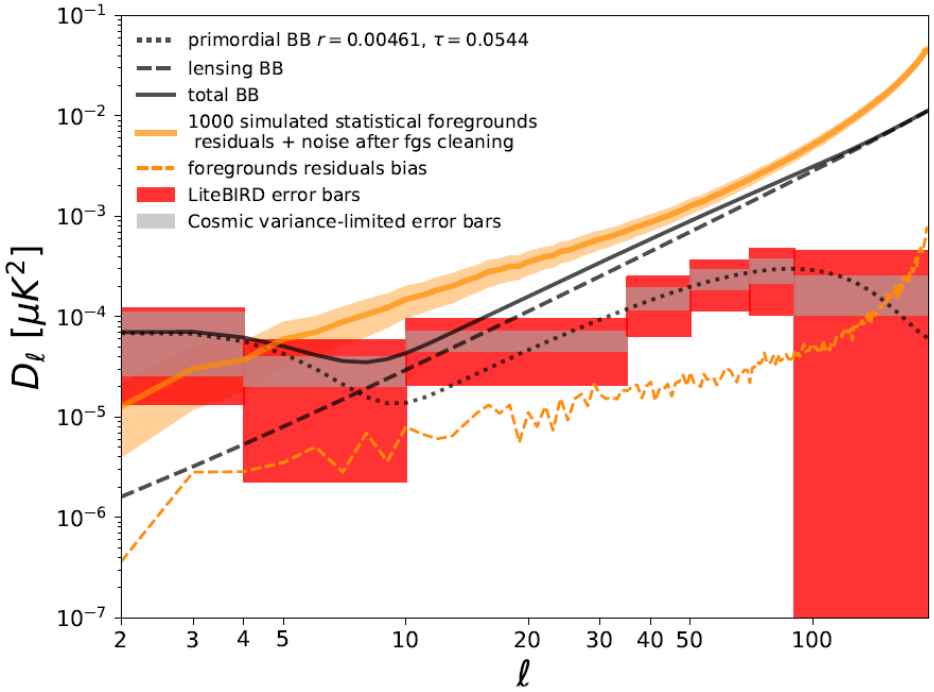
The main goal of LiteBIRD is to measure the B-mode signal from primordial gravitational waves from inflation.
The power spectrum of B-mode polarization is strictly related to the dynamics of inflation and already the simplest correlation between the scalar spectral index and the tensor to scalar ratio is able to provide information on the underlying inflationary model under slow roll assumption

$$r = \frac{\Delta_h^2(k)}{\Delta_\zeta^2(k)} \cdot \qquad V_* = \frac{3\pi^2 A_s}{2} r M_{Pl}^4 \qquad \frac{\Delta\phi}{M_P} \gtrsim \left(\frac{r}{8}\right)^{1/2} N_*$$

PLANCK VS INFLATIONARY MODELS



LITEBIRD PREDICTIONS FOR B-MODES INCLUDING EVERYTHING

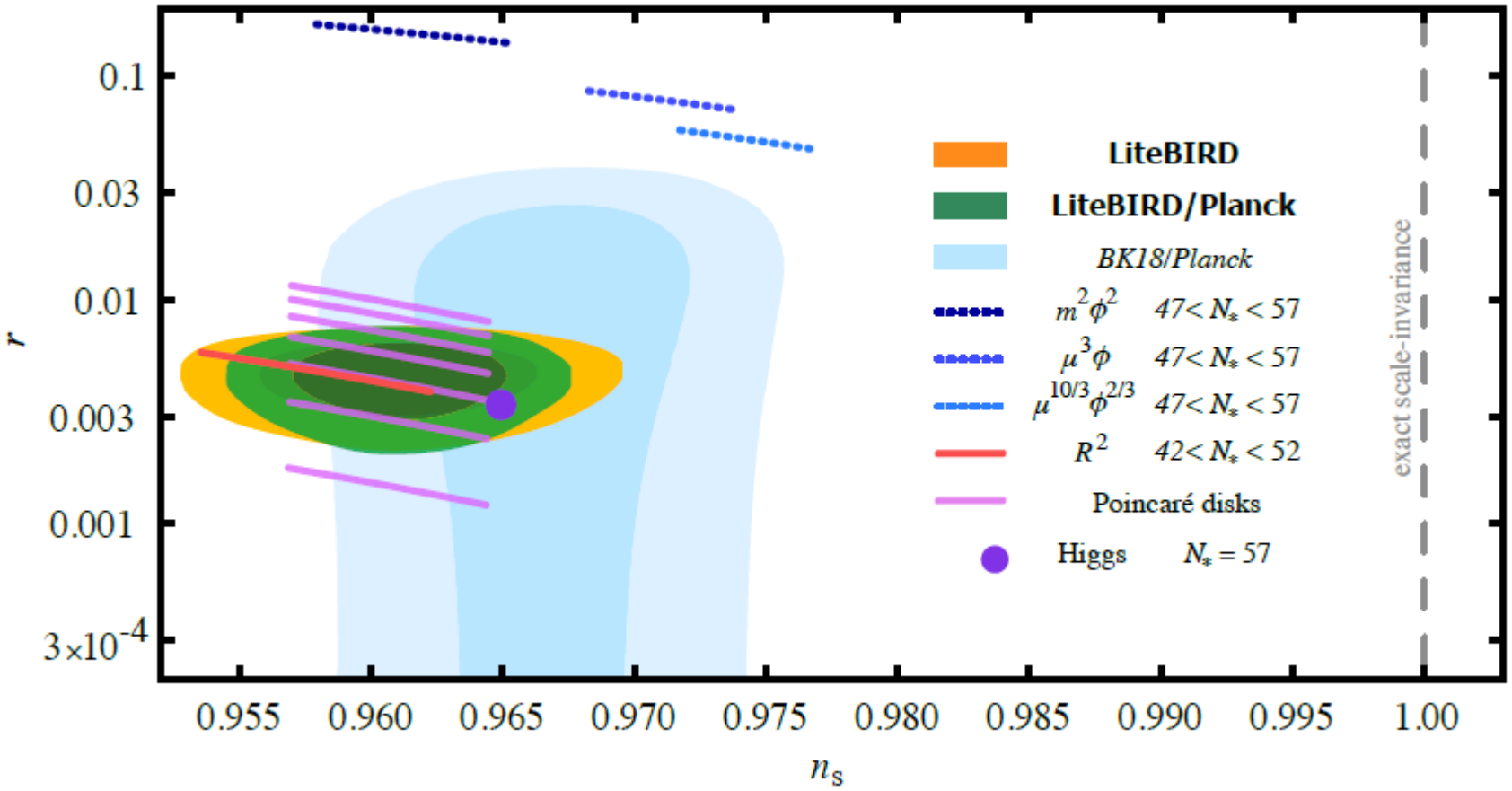


LiteBIRD Coll – PTEP- arXiv:2202.02773

SCIENCE – EARLY UNIVERSE

LiteBIRD will be able to detect a Starobinsky like model predicting r=0.00461 and ns=0.961 with N*=51 with high significance in the most optimistic case of only statistical foreground residuals.

For LiteBIRD sensitivity we have to switch to Logarithmic scale for r figures



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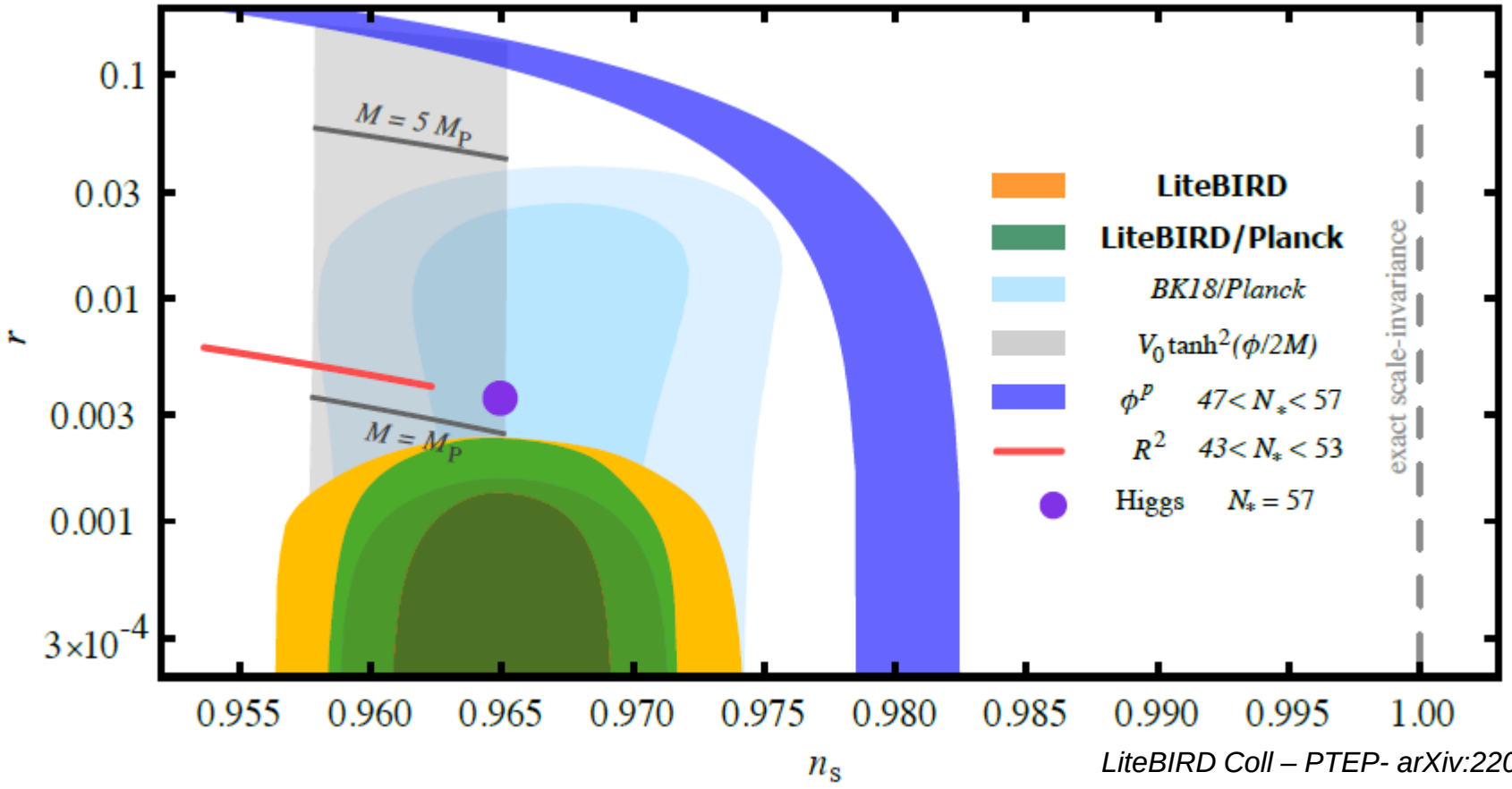
SCIENCE – EARLY UNIVERSE

Even in a case of non-detection we would be able to clearly exclude several models as the Starobinsky itself together with Higgs inflation and all the power law



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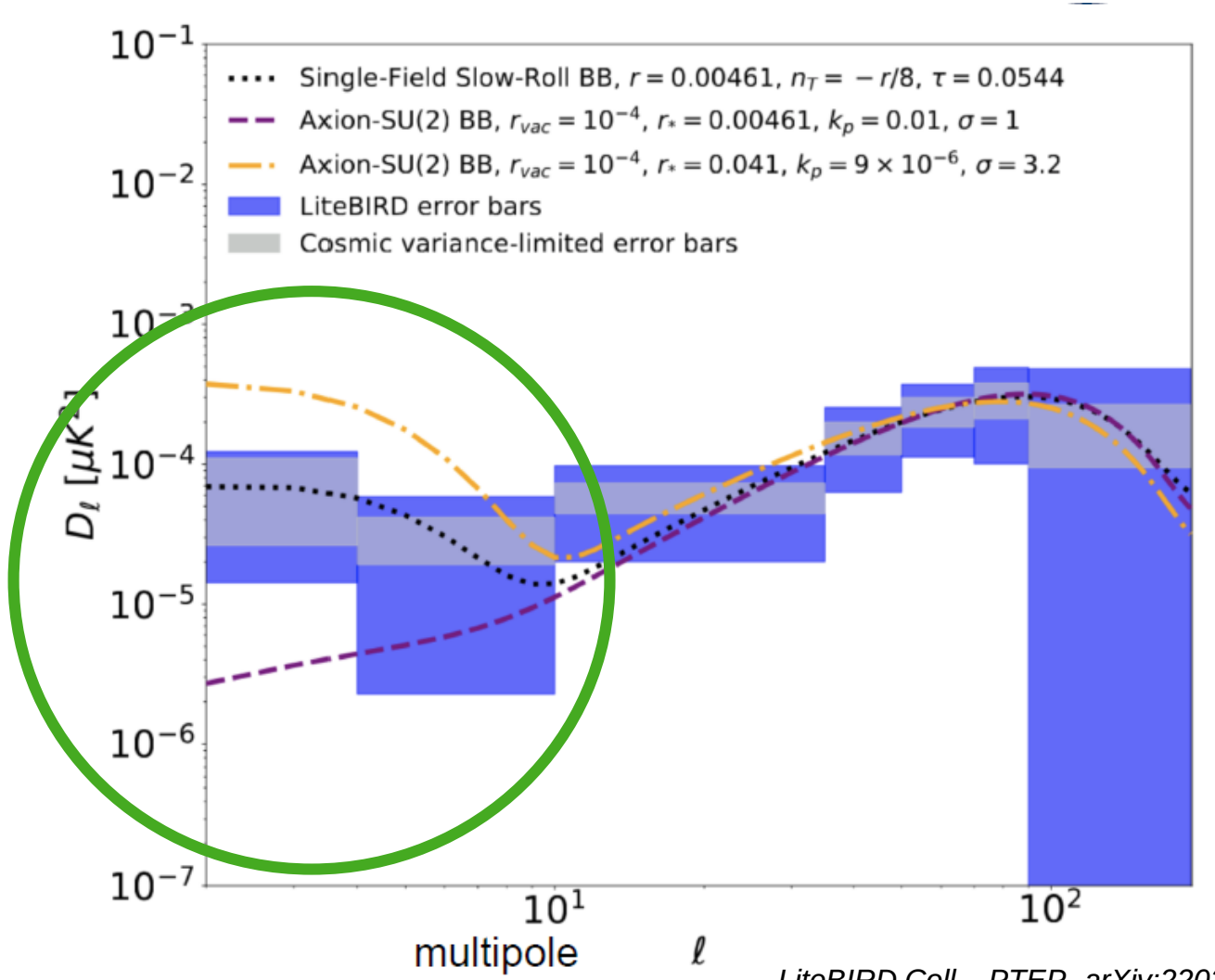
SCIENCE – EARLY UNIVERSE

Beyond standard single field model – Axion-SU(2) inflation
Inflaton+Axion+SU(2) gauge fields.
Axion and gauge fields are coupled with a Chern-Simons term and the inflaton always dominates the energy density -> Chiral GW with TB and EB Cross correlator



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SCIENCE – B-Beyond inflation

COSMIC BIREFRINGENCE

If we suppose the existence of a pseudoscalar field with a Chern Simons term, it induces a rotation of the polarization plane of CMB photons

$$-\frac{1}{4}g_{\varphi\gamma}\varphi F_{\mu\nu}\tilde{F}^{\mu\nu} \longrightarrow \beta = \frac{1}{2}g_{\varphi\gamma}\int_{t_L}^{t_0} dt\ \dot{\varphi}$$

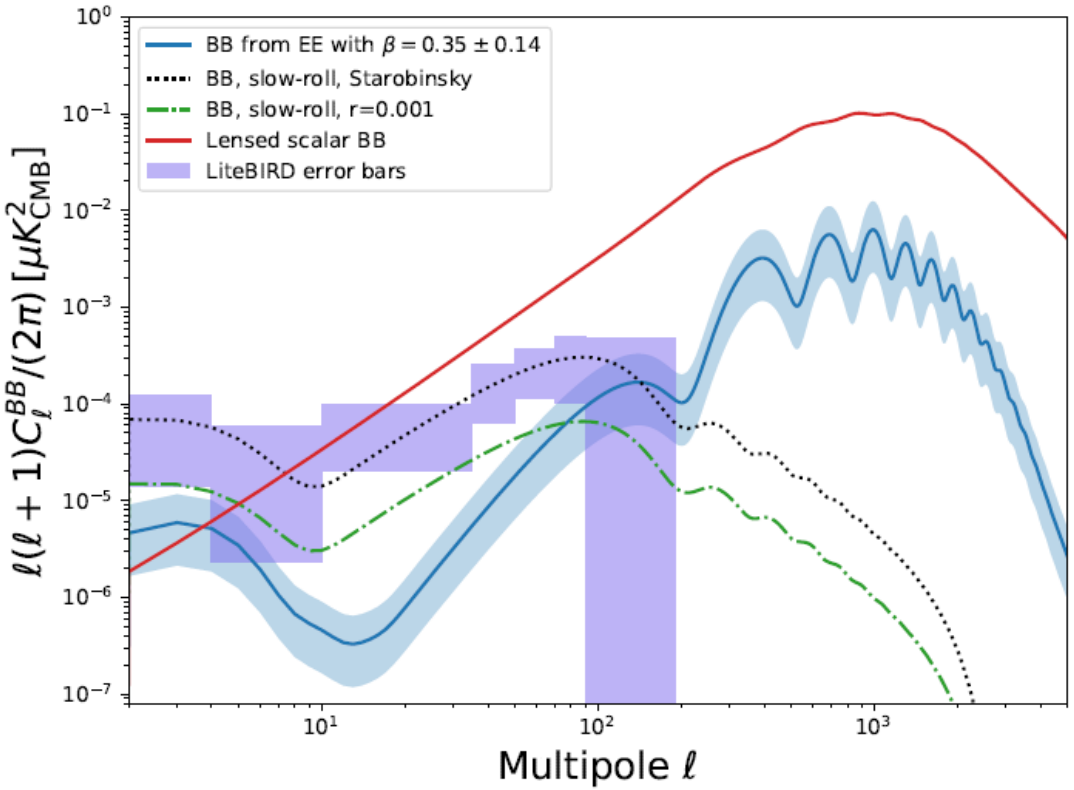
$$a_{\ell m}^{E,\mathrm{CMB,o}} = a_{\ell m}^{E,\mathrm{CMB}}\cos(2\beta) - a_{\ell m}^{B,\mathrm{CMB}}\sin(2\beta)$$
$$a_{\ell m}^{B,\mathrm{CMB,o}} = a_{\ell m}^{E,\mathrm{CMB}}\sin(2\beta) + a_{\ell m}^{B,\mathrm{CMB}}\cos(2\beta)$$

The parity violation allows for odd cross correlators to switch on:

- non negligible TB and EB

We can apply also the Minami and Komatsu (2020) estimator using the foreground to estimate the miscalibration angle together with the birefringence one

Estimates for LiteBIRD see the stat. uncertainty below 0.1°



$$\langle C_\ell^{EB,\mathrm{o}}\rangle = \frac{\tan(4\alpha)}{2}\left(\langle C_\ell^{EE,\mathrm{o}}\rangle - \langle C_\ell^{BB,\mathrm{o}}\rangle\right) + \frac{\sin(4\beta)}{2\cos(4\alpha)}\left(\langle C_\ell^{EE,\mathrm{CMB}}\rangle - \langle C_\ell^{BB,\mathrm{CMB}}\rangle\right) + \frac{1}{\cos(4\alpha)}\langle C_\ell^{EB,\mathrm{fg}}\rangle + \frac{\cos(4\beta)}{\cos(4\alpha)}\langle C_\ell^{EB,\mathrm{CMB}}\rangle\,.$$

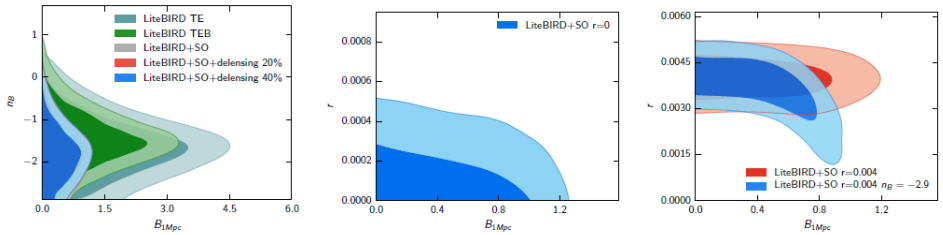
LiteBIRD Coll – PTEP- arXiv:2202.02773

SCIENCE – B-Beyond inflation

PRIMORDIAL MAGNETIC FIELDS

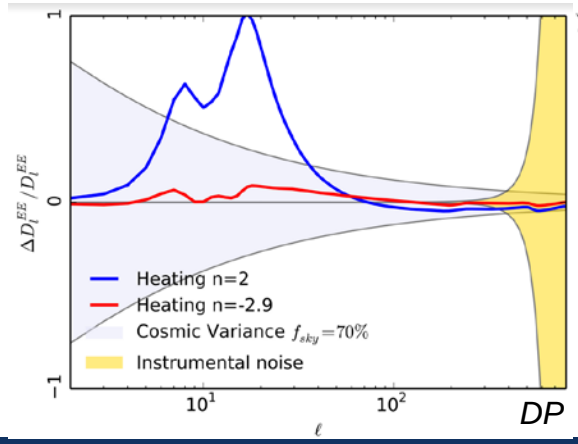
The origin of cosmic magnetism observed in the LSS may lay in magnetic fields generated in the early universe PMF.

PMF represent an unconventional window on the physics of the early Universe and leave imprints in all CMB observables and can mimic B-mode inflationary signal!

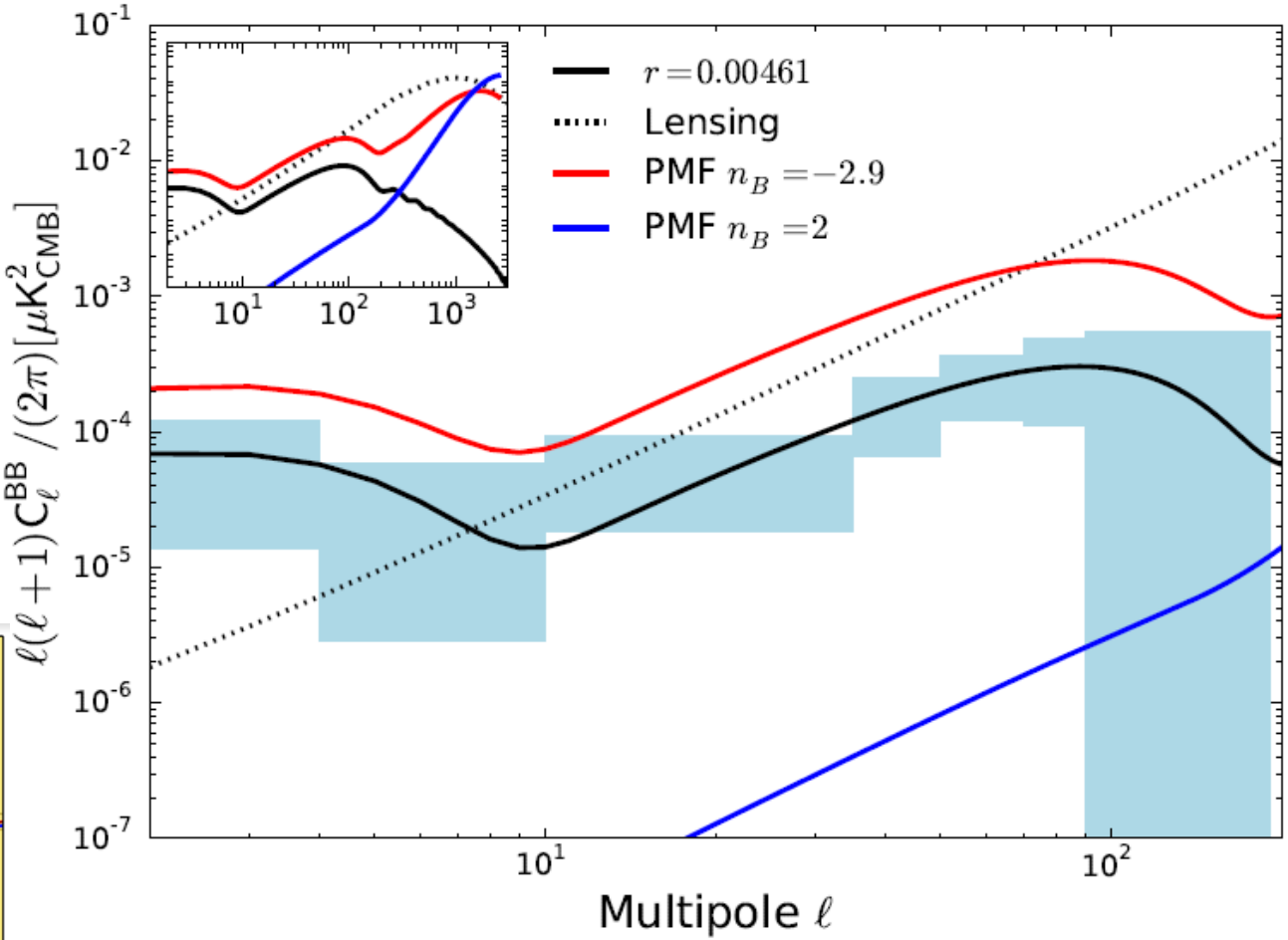


DP and Finelli 2019 – idealistic forecasts

PMF impact also E-mode polarization through the effects on the ionization history



DP



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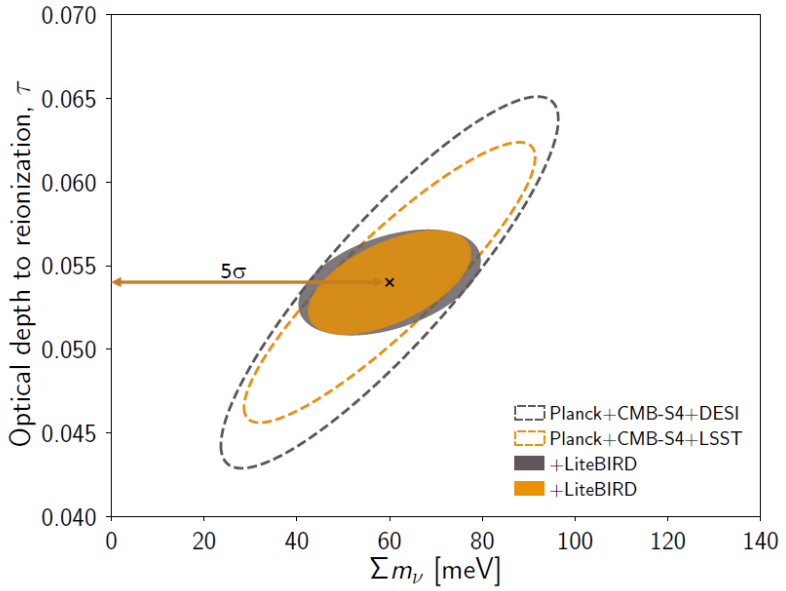
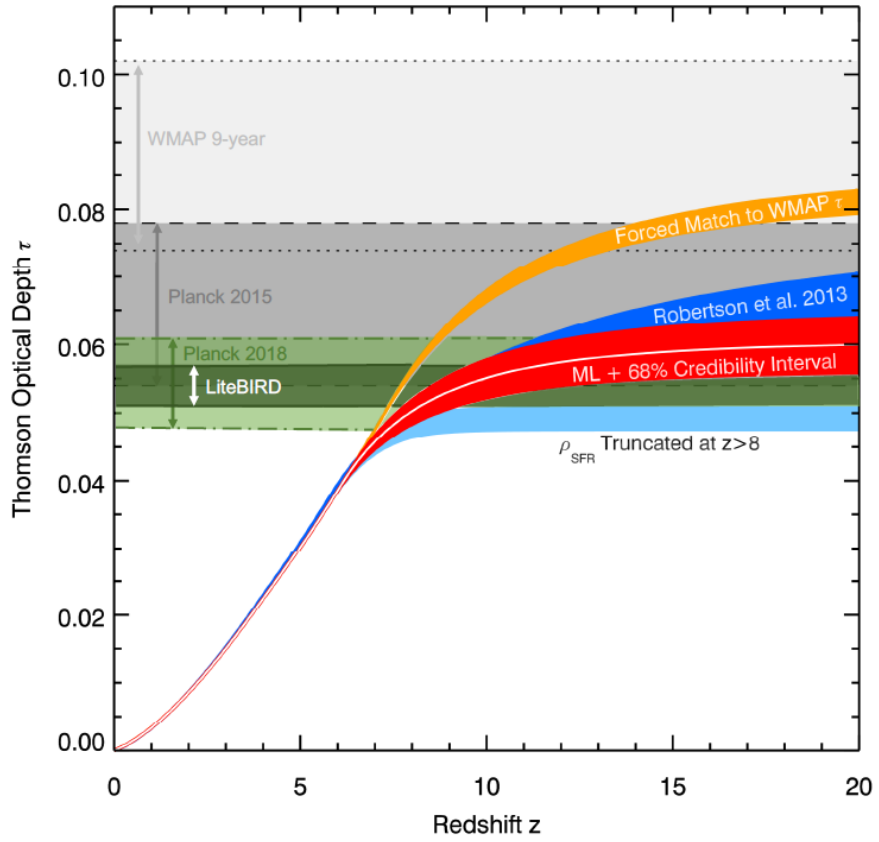
SCIENCE – E-modes

REIONIZATION

Reionization represents one of the greatest uncertainties in CMB cosmology with the optical depth being the only parameter still over the 1% precision.

The CV limited E-mode polarization will allow to remove good part of the degeneracies with the extensions to the standard cosmological model and improve our knowledge of the epoch of reionization itself.





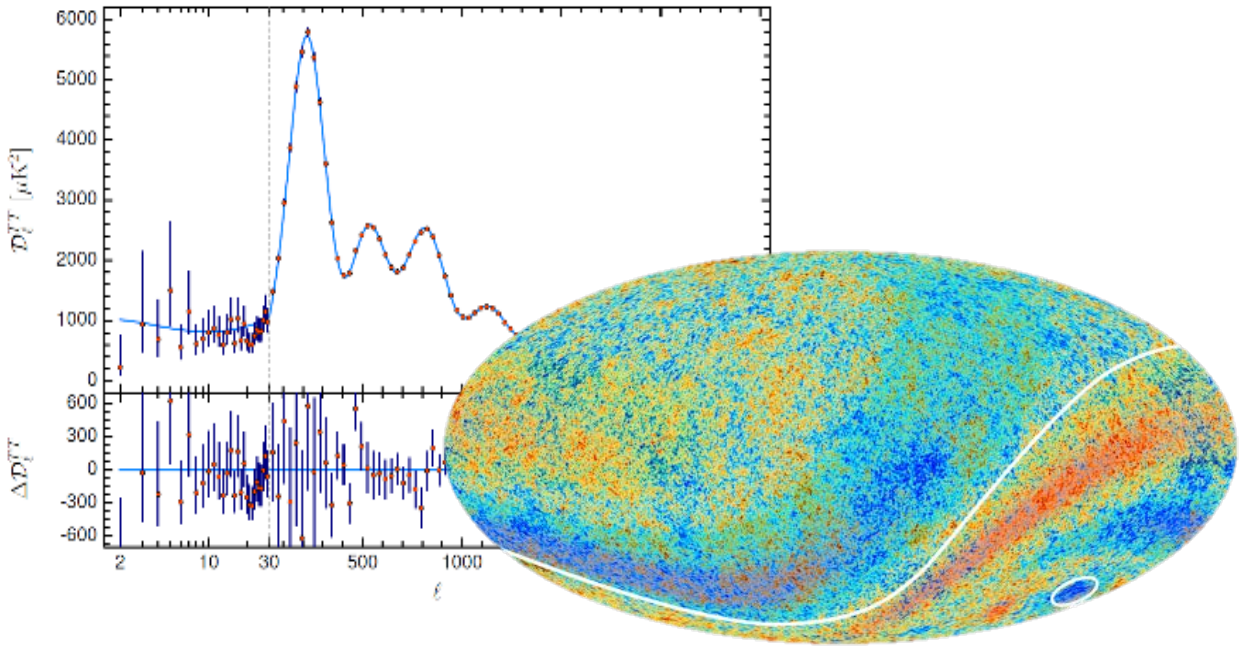
LiteBIRD Coll – PTEP- arXiv:2202.02773

SCIENCE – E-modes

ANOMALIES

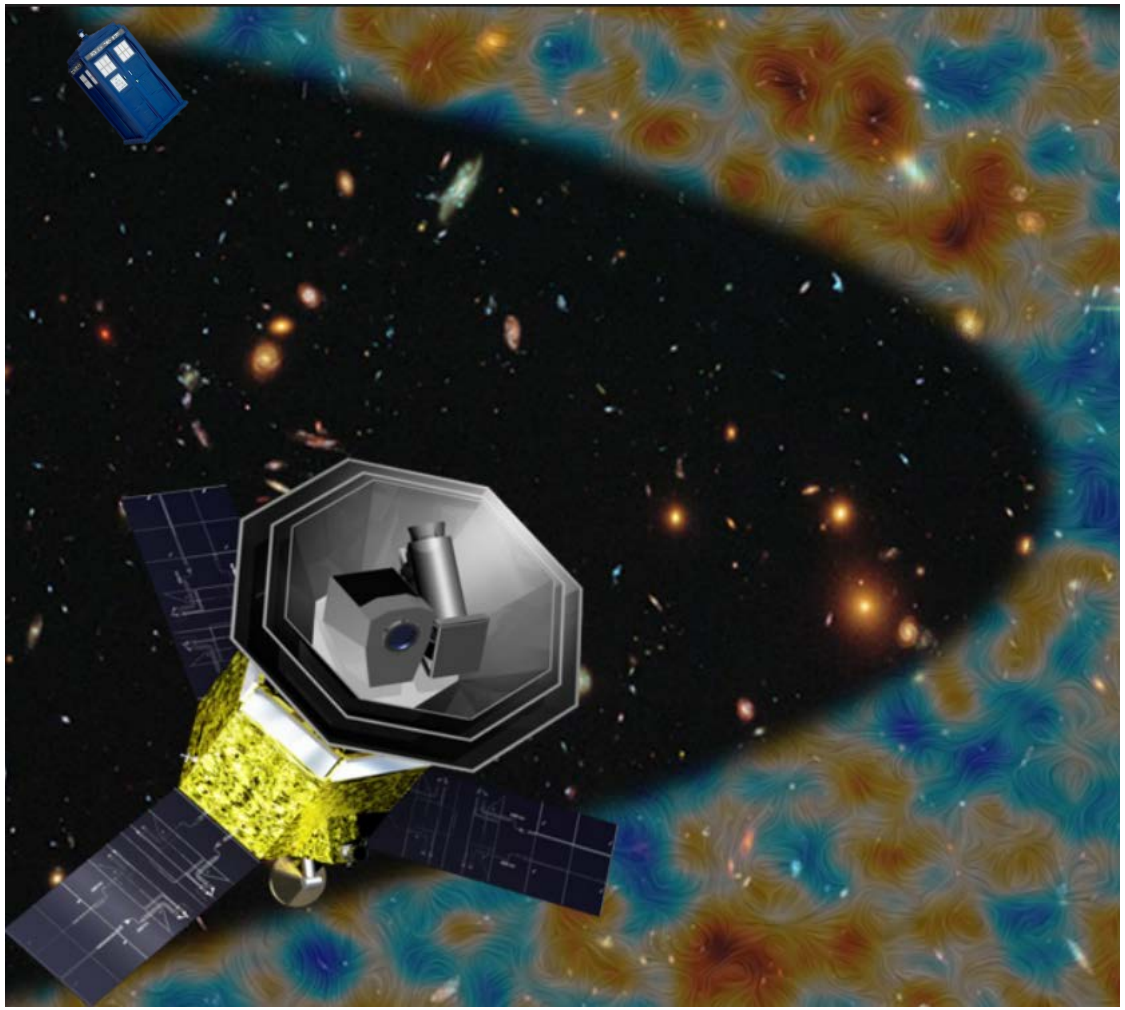
Found by WMAP and confirmed at slightly less than 2.8 sigma by Planck

- Low-l lack of power (lack of variance):can indicate a non standard inflation e.g. violations in the slow roll condition during in inflation
- Alignments of low multipole moments: quadrupole and octupole aligned though anisotropies should have random phases and be uncorrelated
- Hemispherical asymmetry or dipolar modulation: current results are all consistent with a modulation of power of around 7% between two hemispheres with the preferred direction (l, b) = (209°;-15°) with hints of extensions to small scales.



- Parity asymmetry: Universe should be parity neutral but indeed there is an evidence for odd-parity preference in the largest multipoles (20-30)
- Cold SPOT: an anomalous temperature feature on angular scales of 10', with the structure centered at Galactic coordinates (l; b) = (210°;-57°)

LiteBIRD



WE HAVE SOME OF THE MOST EXCITING TIMES AHEAD FOR COSMOLOGY
AND CMB WITH LiteBIRD WILL BE ONE OF THE MAIN ACTORS IN THE PLAY

STAY TUNED