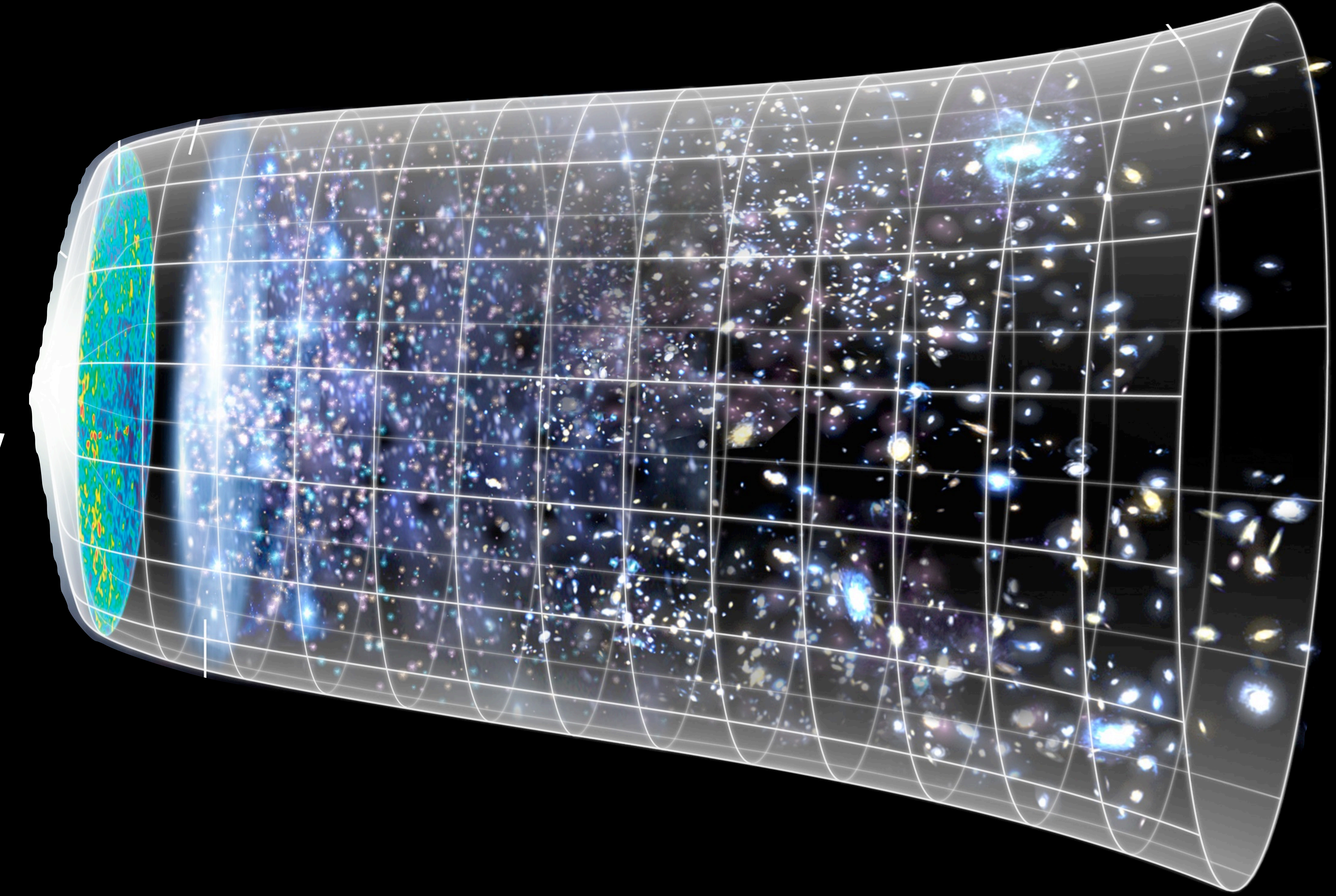
Overview and news from the *LiteBIRD* mission

Léo Vacher
For the *LiteBIRD* collaboration

IJCLab
Irène Joliot-Curie
Laboratoire de Physique des 2 Infinis

Primordial B-modes and inflation



Inflation?

$t \simeq 10^{-35}$s

Primordial *B*-modes and inflation

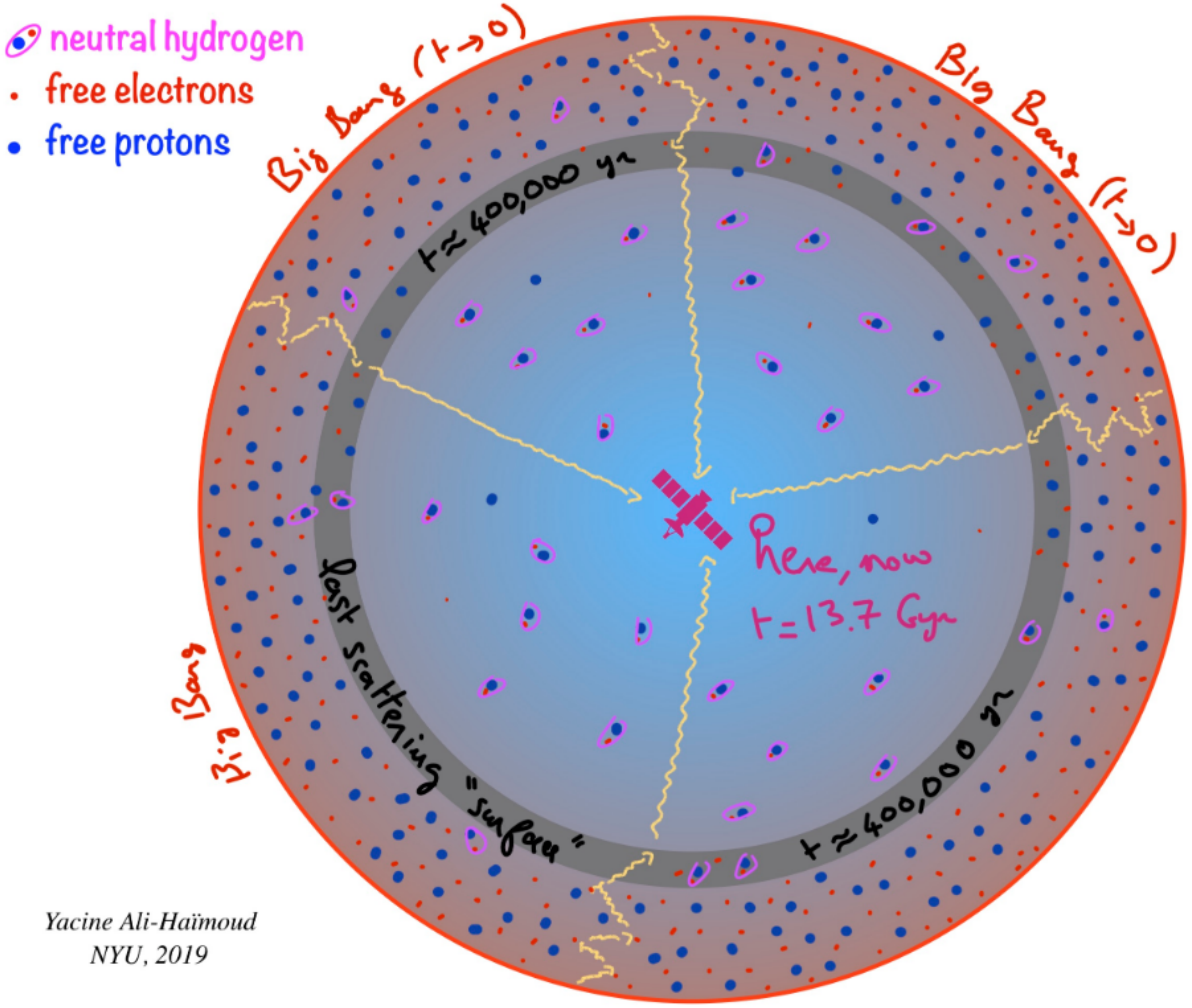
Inflation?

$t \simeq 10^{-35}$s

Cosmic microwave background (CMB)

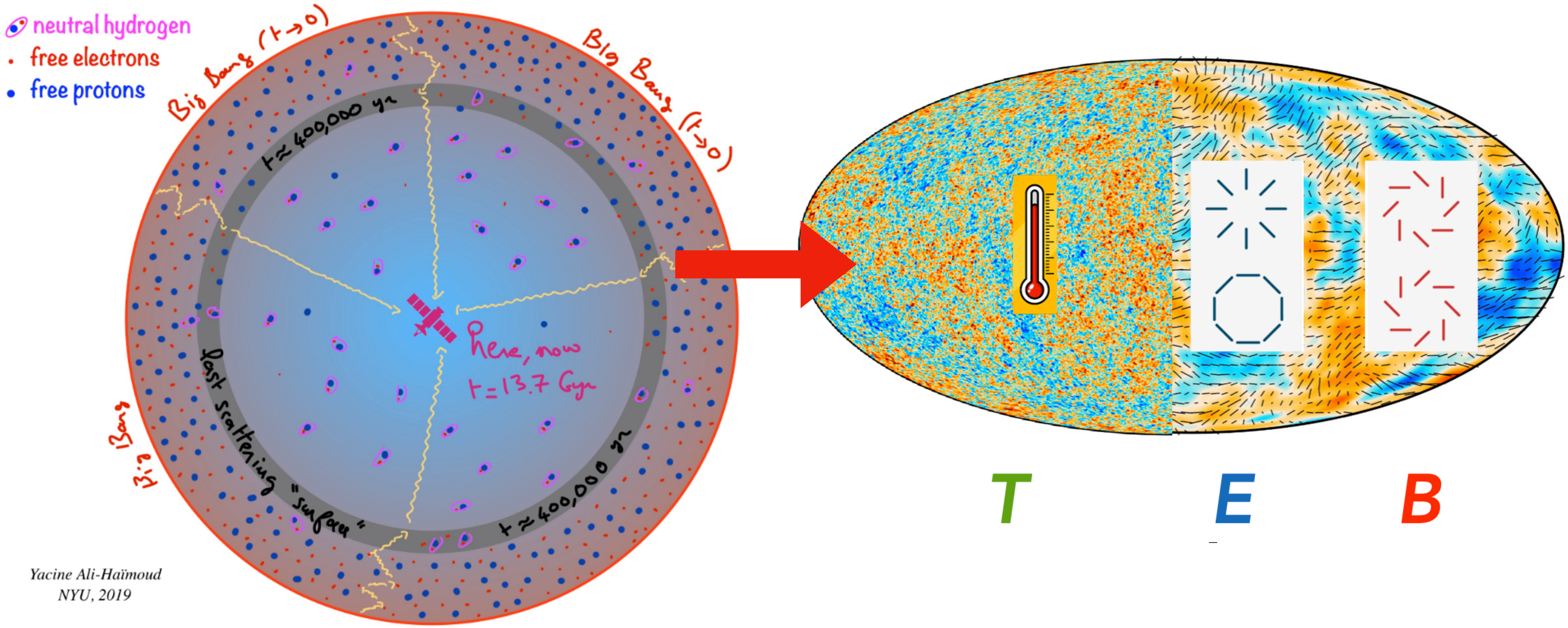
$t \simeq 380000$ yrs

Primordial *B*-modes and inflation



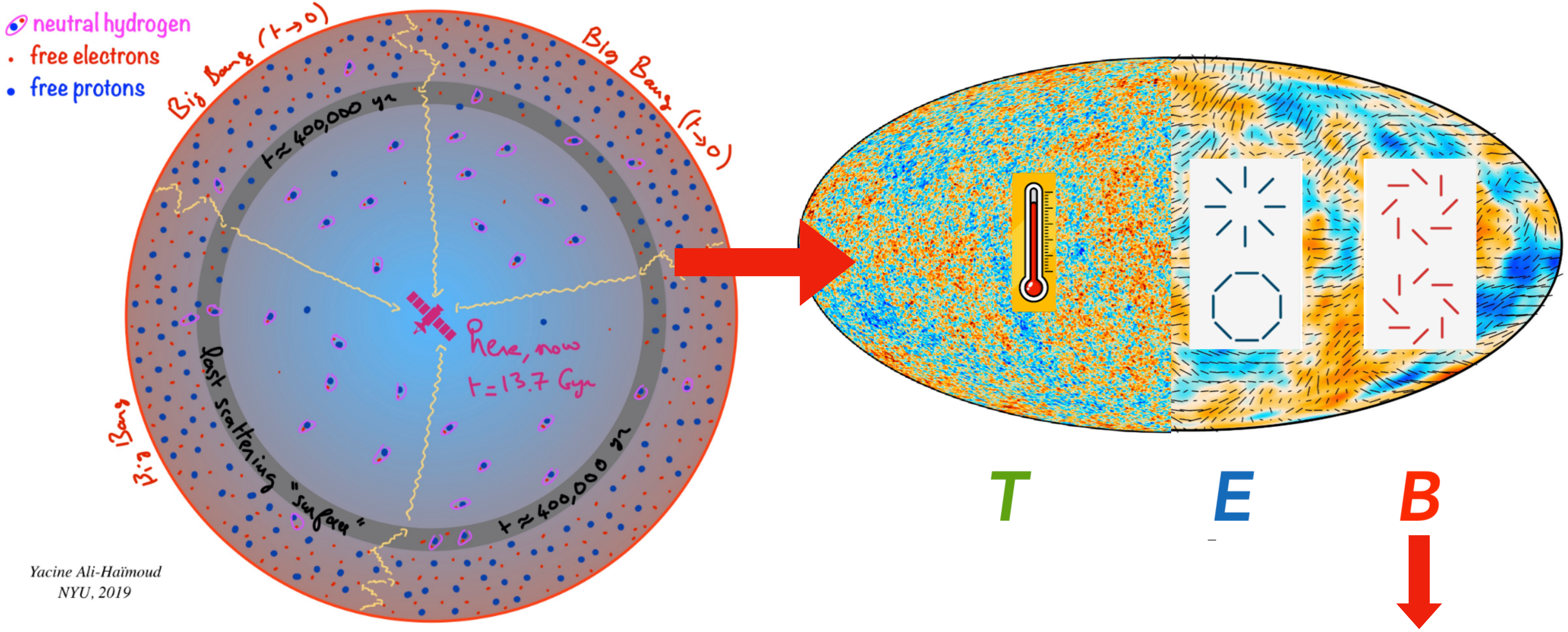
Yacine Ali-Haïmoud
NYU, 2019

Primordial *B*-modes and inflation



Yacine Ali-Haïmoud
NYU, 2019

Primordial *B*-modes and inflation



Yacine Ali-Haïmoud
NYU, 2019

Primordial *B*-modes = signature of inflation!

Primordial *B*-modes and inflation

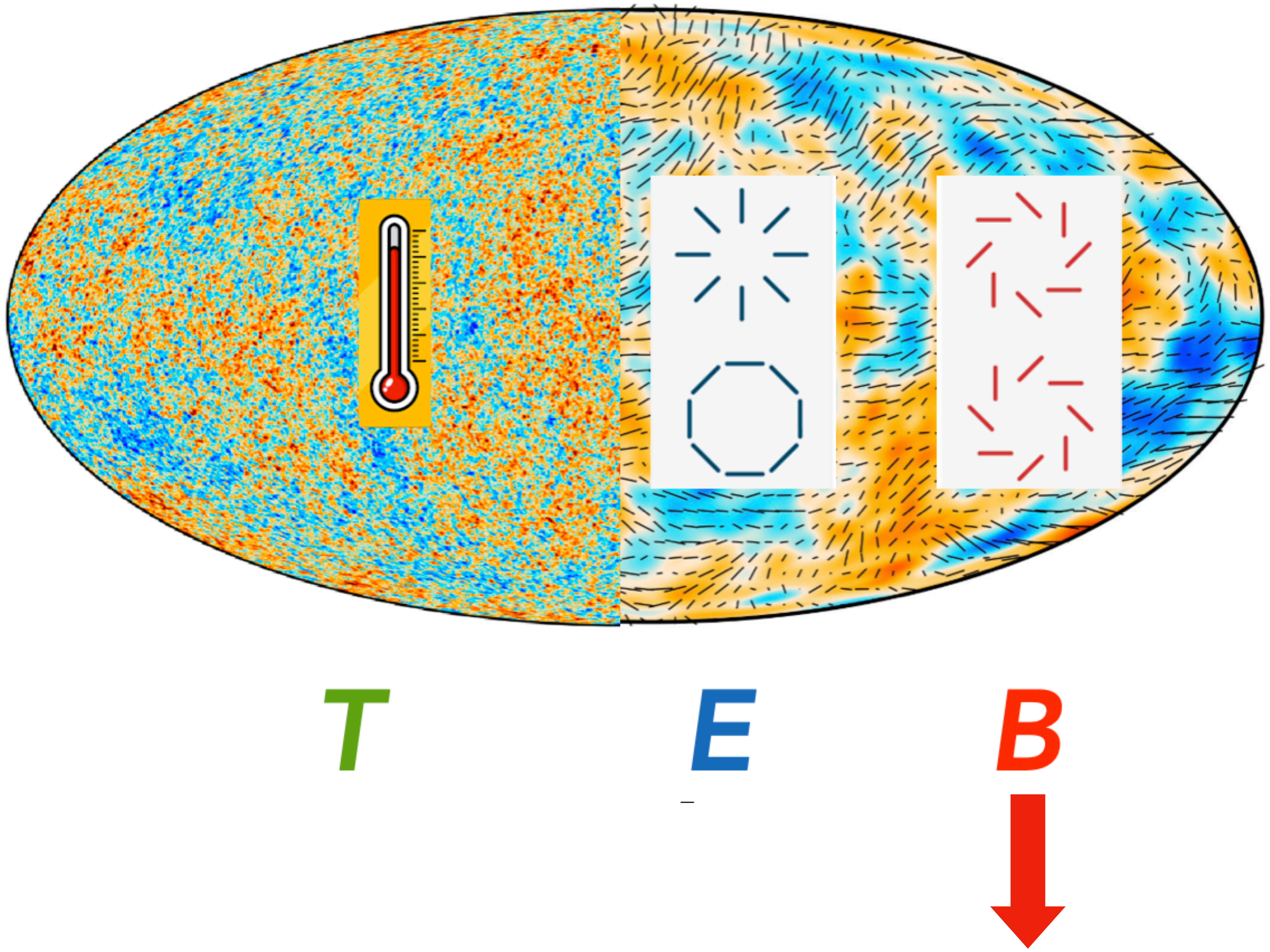
- The amplitude of the primordial *B*-modes is the **tensor-to-scalar ratio *r*.**
  It is proportional to the **energy scale of inflation**

- Current best constraint: **$r < 0.032$ (95% C.L.)**

  (📖 Tristram et al. 2022, combining BK18 and Planck PR4)

- The final goal of future generation of CMB mission as *LiteBIRD* to reach **a statistical uncertainty of $\sigma(r) \lesssim 0.001$ for $r=0$**

- This would confirm or rule out many of the **simplest inflationary models** and give us insights on the **quantum nature of gravity**



Primordial *B*-modes = signature of inflation!

Challenges …

Looking for primordial *B*-modes is a **major challenge**:

- The *B*-mode signal is expected to have an amplitude at least 3 orders of magnitude below the CMB temperature anisotropies
- Looking for such a faint signal requires exquisite control of:
    1. **Instrument systematic** uncertainties
    2. **Galactic foreground** contamination (**component separation**)
    3. **"Lensing *B*-mode signal"** induced by gravitational lensing
    4. …

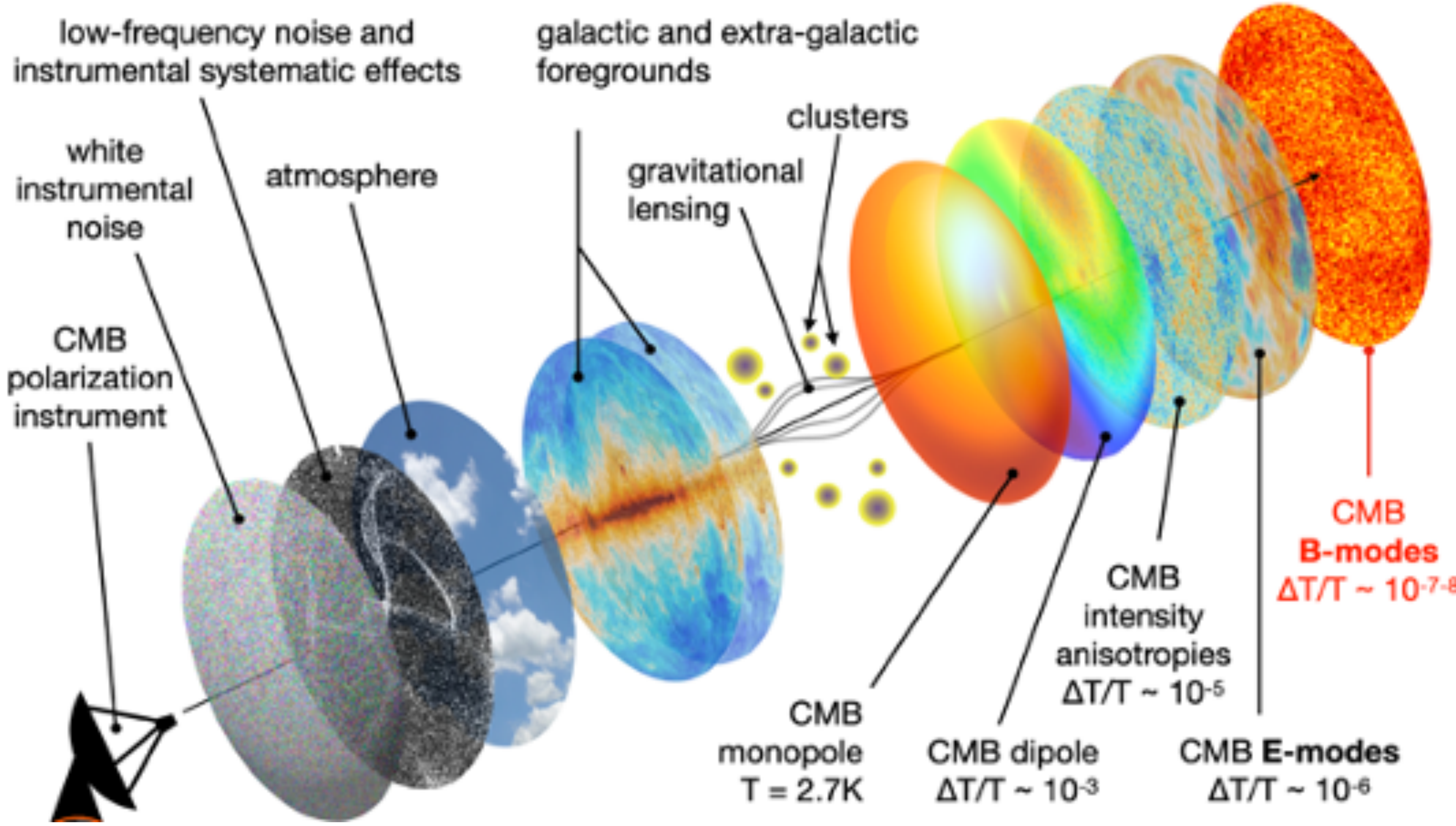


Image credit: Josquin Errard

… and opportunities

But the fine characterisation of CMB polarisation on large scales comes with **multiple scientific outcomes**:

- New high energy-physics in the primordial universe: **inflatons, axions, primordial magnetic fields …**
- Cosmological principle and **anomalies**
- **Lensing** and mass distribution on large scales
- **Reionisation** (optical depth)
- **neutrino masses** and ordering
- **Cluster physics:** SZ effects
- New Energy injection: **CMB spectral distortions**
- **Galactic science** (magnetic fields, dust, turbulence …)
- Polarised **point sources**

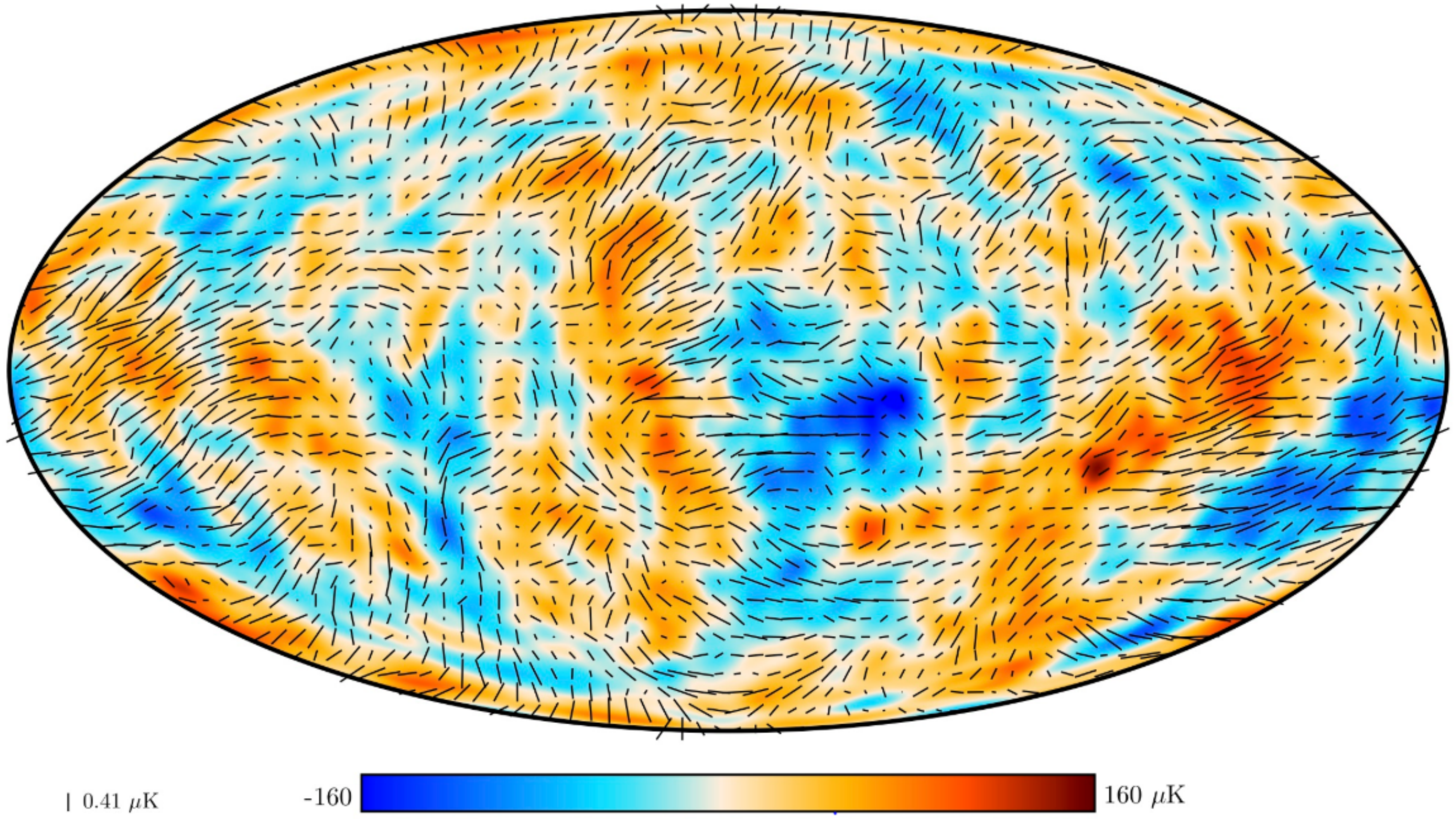
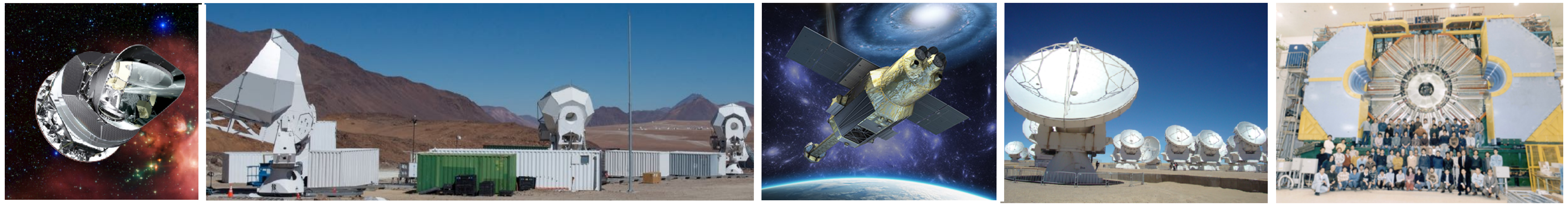


Image credit: Planck team

LiteBIRD Joint Study Group

Around 400 researchers from **Japan**, **Europe** and **North America**

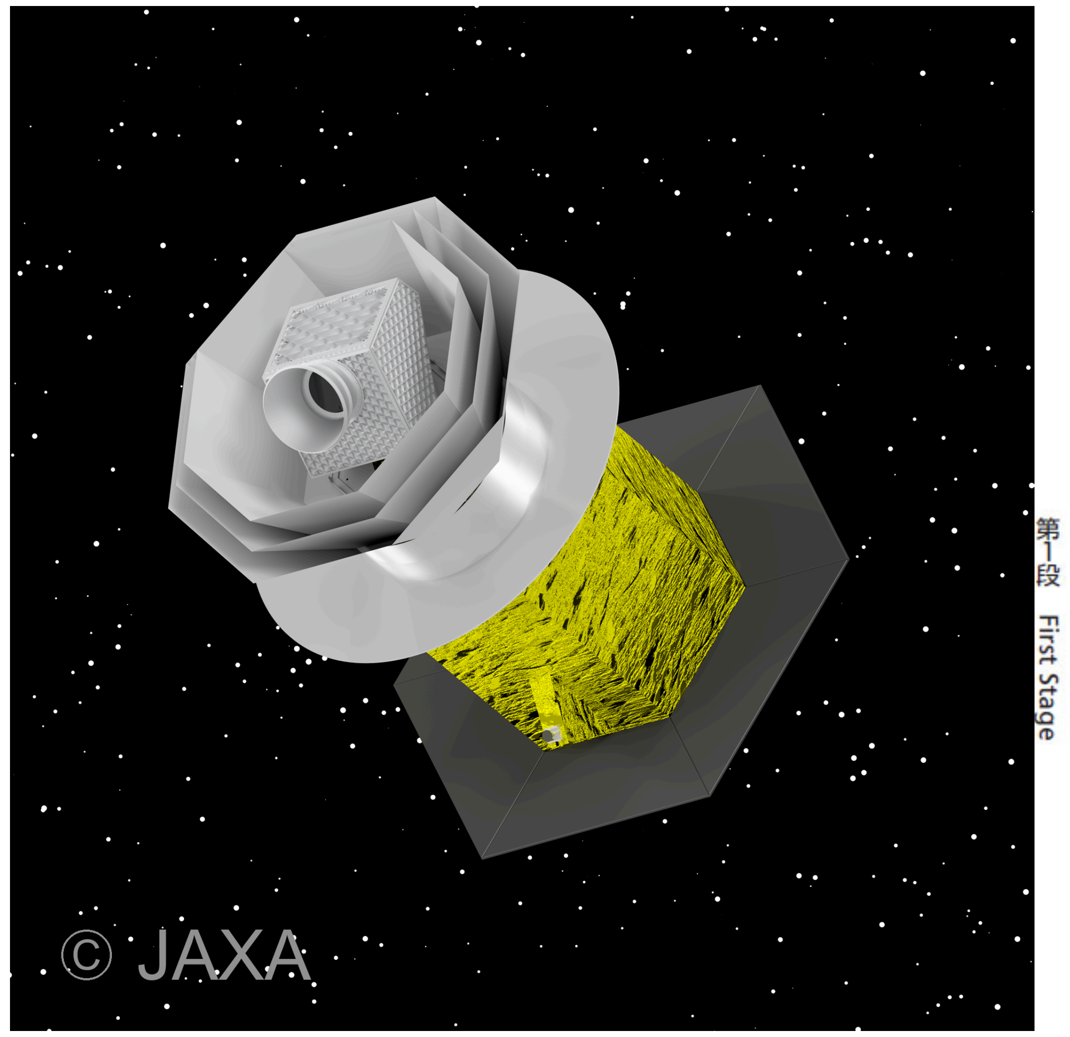
Team experience in CMB experiments, X-ray satellites and other large projects (ALMA, HEP experiments, …)

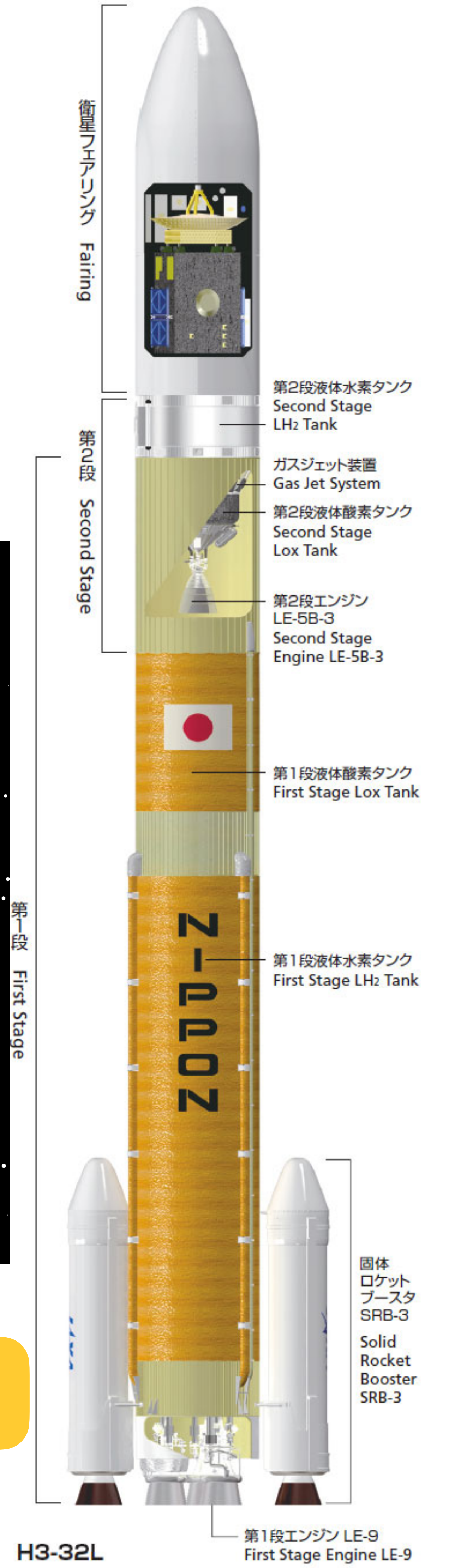


LiteBIRD Global F2F meeting
Jan 26 - 30, 2026 at Kavli IPMU (Tokyo)

LiteBIRD **overview**

- Lite (Light) spacecraft for the study of *B*-mode polarization and Inflation from cosmic background Radiation Detection
- JAXA's L-class mission was selected in May 2019 to be launched by JAXA's H3 rocket on **JFY2037**
- **All-sky 3-year survey**, from Sun-Earth Lagrangian point L2
- Large frequency coverage (**40–402/570 GHz**) at **53/6 arcmin** angular resolution for precision measurements of the **CMB *B*-modes**
- Final combined sensitivity: **2.2 μK·arcmin.** Sensitivity level in polarization **~30 times** better than Planck





📖 LiteBIRD collaboration PTEP 2023

LiteBIRD reformation phase

- *LiteBIRD* has been under **rescope studies to consolidate the mission's feasibility while keeping the same scientific objectives**
  - Revisit the error budget
  - **Simplify the mission configuration** (one single telescope instead of three; try to use existing technologies)
  - **Simplify the cryogenic chain**
  - Detectors to be procured by Europe
  - New HWP design based on stacking 6 plates in Pancharatnam configuration, providing large bandwidth

Two different configuration options now being considered, both based on single Crossed-Dragone reflective telescope:

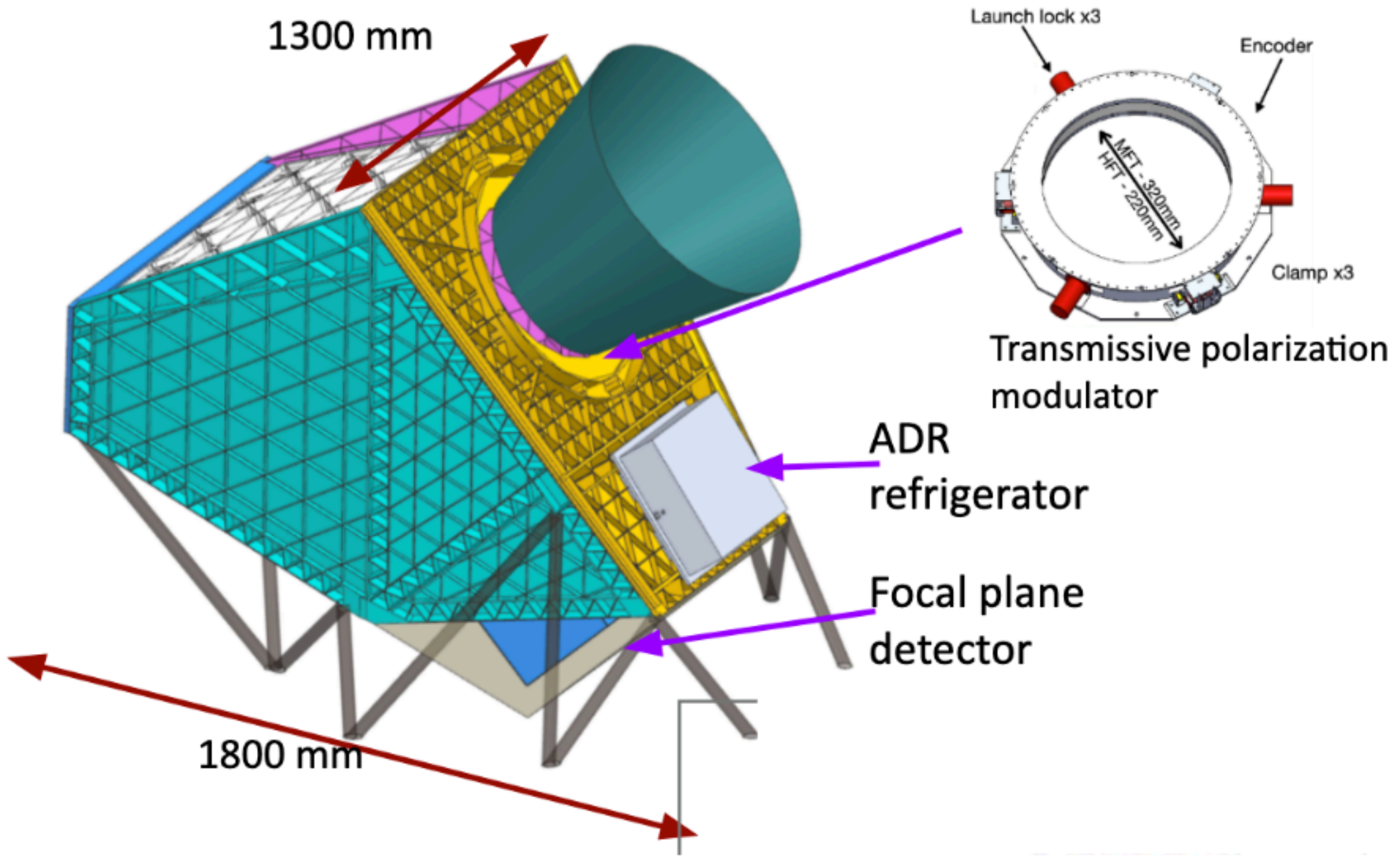
- Option 1 (no HWP) requires a faster spin rate to minimize 1/f noise
- Option 2 is based on the possibility of using a wider-band HWP

Option 1

- Aperture 500 mm
- 40-570 GHz
- No HWP
- Spin rate 0.3 rpm

Option 2

- Aperture 500 mm
- 40-402 GHz
- Transmissive HWP
- Spin rate 0.05 rpm



LiteBIRD reformation phase

- *LiteBIRD* has been under **rescope studies to consolidate the mission's feasibility while keeping the same scientific objectives**
  - Revisit the error budget
  - **Simplify the mission configuration** (one single telescope instead of three; try to use existing technologies)
  - **Simplify the cryogenic chain**
  - Detectors to be procured by Europe
  - New HWP design based on stacking 6 plates in Pancharatnam configuration, providing large bandwidth

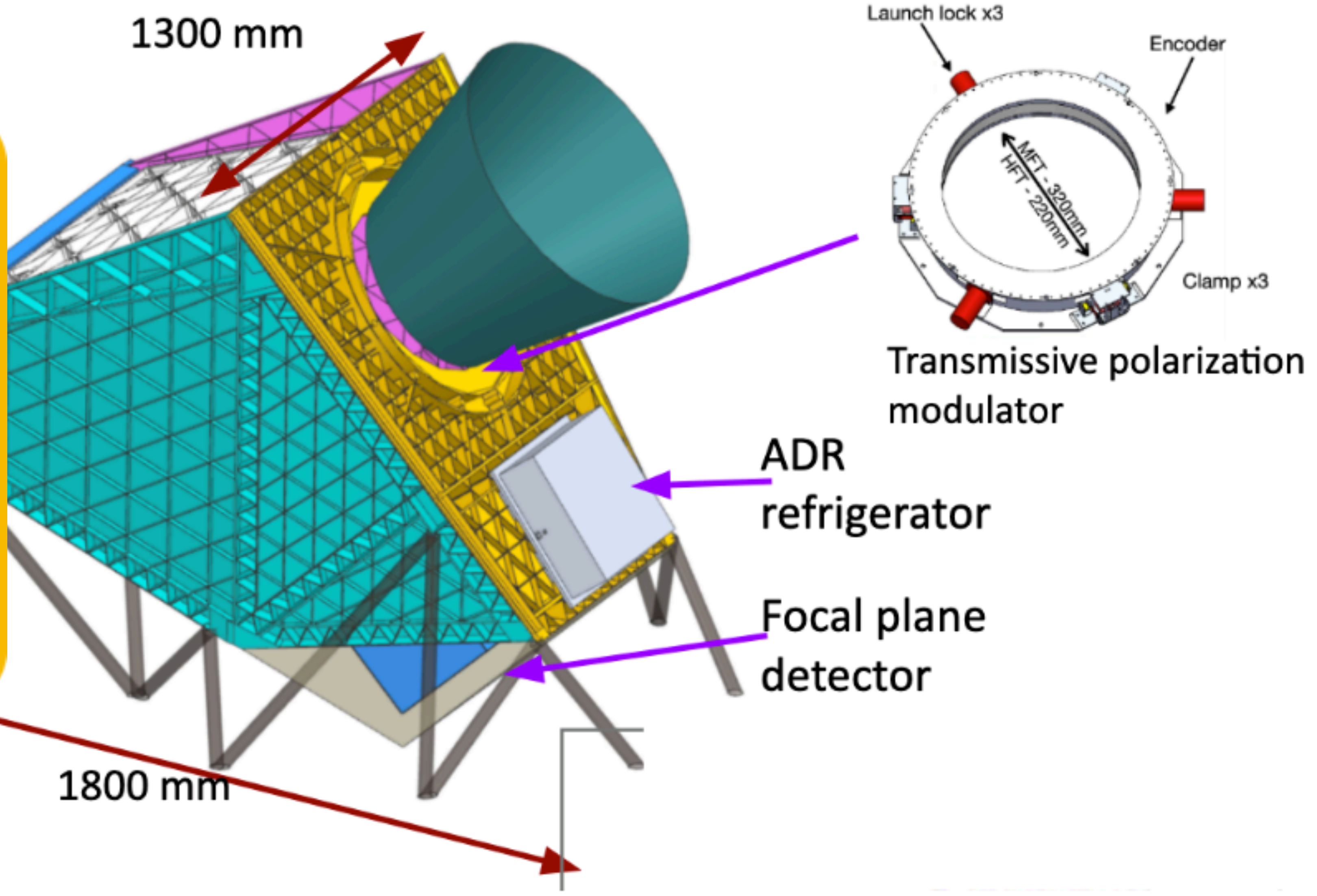
Two different configuration options now being considered, both based on s
Dragone reflective telescope:

- Option 1 (no HWP) requires a f
  to minimize 1/f noise
- Option 2 is based on the possib
  wider-band HWP

Key Decision point #2 passed in Sep. 2025
This month: Mission definition review (MDR #2)
If passed, design is fixed and start of phase A of JAXA (« Project phase »)

Opti

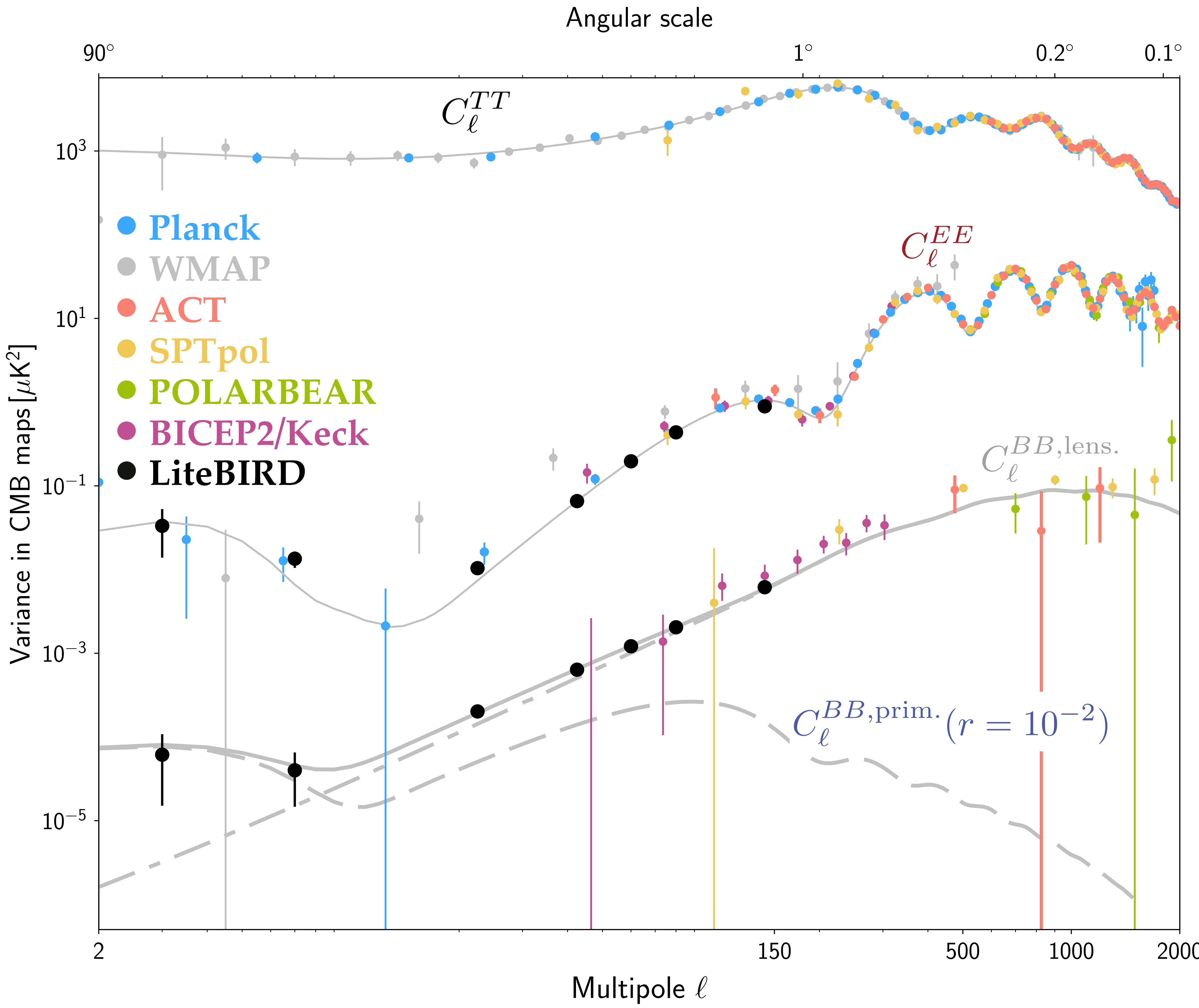
- Transmissive HWP
- Spin rate 0.05 rpm



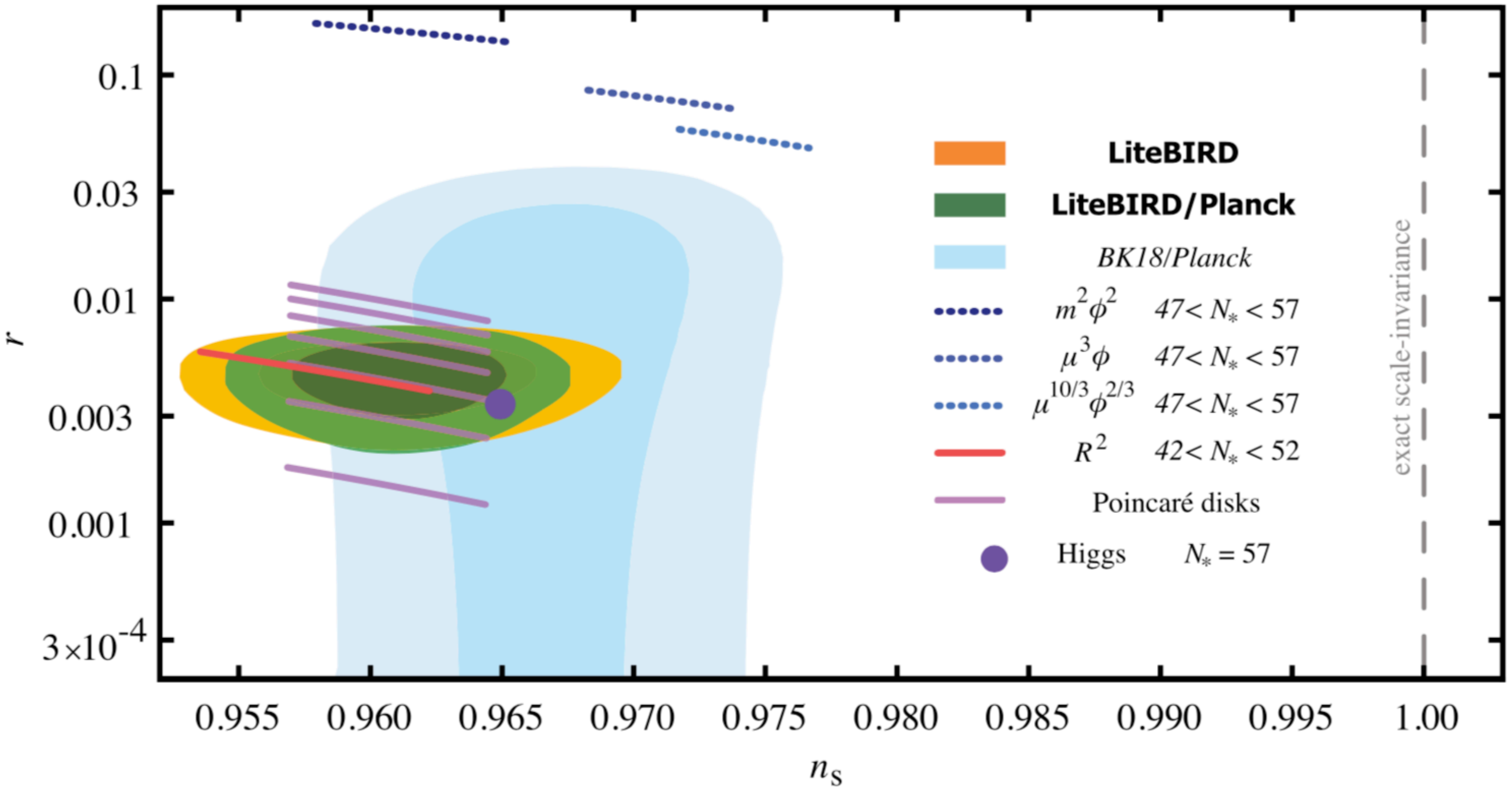
LiteBIRD overview of scientific targets

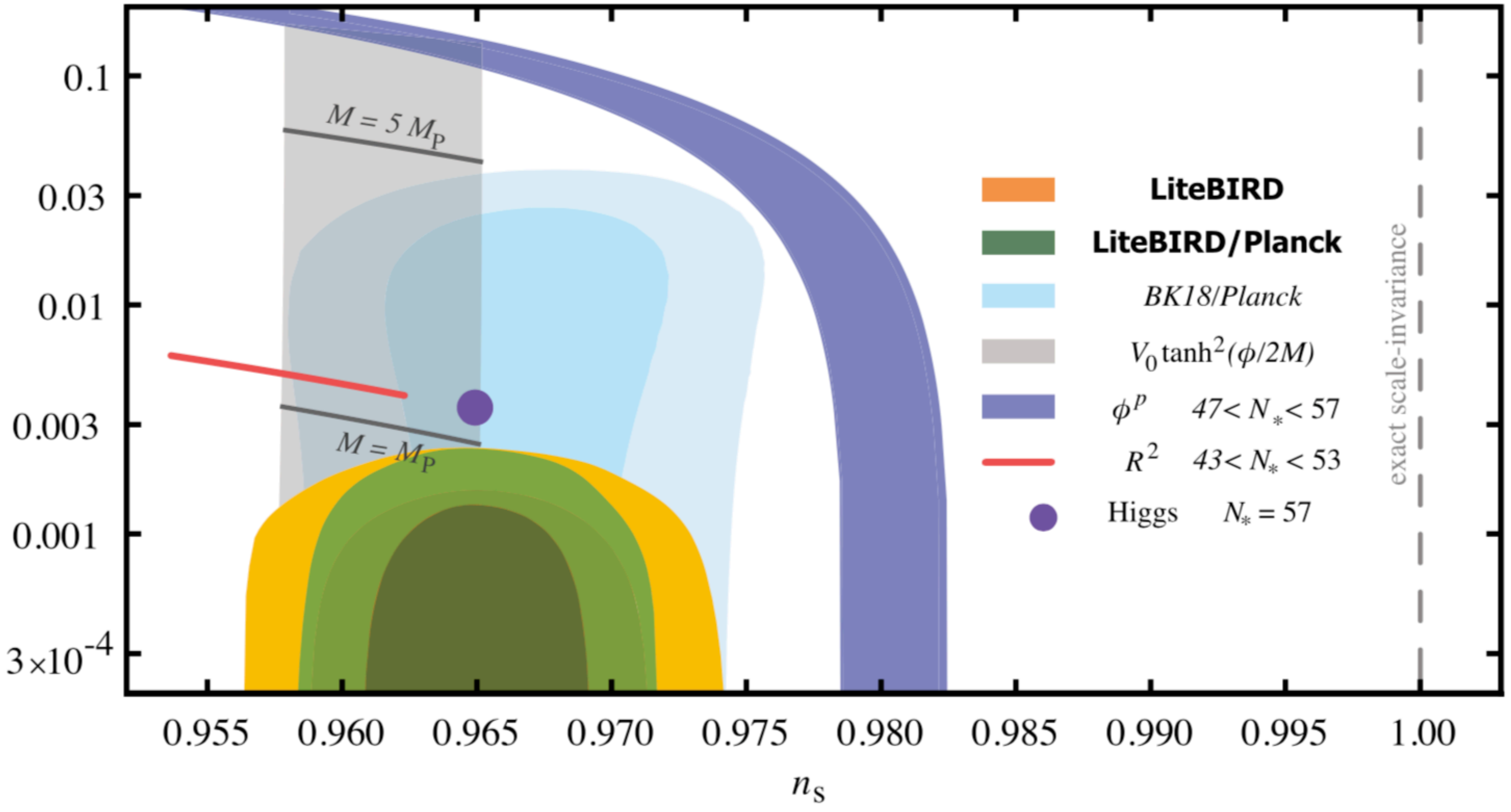
Some of the key scientific outcomes of *LiteBIRD*:

- 5σ **detection of primordial *B*-modes** if $r > 0.01$, else $\delta_r \leq 2 \times 10^{-3}$.
- **Optical depth of reionisation**: $\sigma(\tau) = 0.002$ (cosmic variance limited and 3 times better than Planck).
- **Neutrino masses $\sigma(\sum m_\nu) \approx 18$ meV (LB + SO + BAO)** 5σ detection for $\sum m_\nu = 60$ meV (minimum mass in normal ordering)
- **5 to 13σ detection of a 0.3° cosmic birefringence angle** depending on method for detector angle miscalibration and *EB* signal from Galactic foregrounds (📖 de la Hoz et al. 2025)



LiteBIRD overview of scientific targets





📖 LiteBIRD collaboration PTEP 2023

LiteBIRD overview of scientific targets

Multiple papers already out or incoming on your favorite scientific topic!

- Hot gas and SZ: *Remazeilles+ 2024* (x10 less noise on SZ maps wrt to Planck)
- Cosmic birefringence: *de la Hoz+ 2025*
- Anomalies: *Banday+ 2025*
- Primordial magnetic fields: *Paoletti+ 2024* (x3 wrt to Planck, nG level)
- Inflation models: *Campeti+2024, LB collab (in prep)*
- Lensing reconstruction and delensing: (x2 Planck sensi. on lensing maps and S_8 *Namikawa+ 2023, Lonappan +2024, Ruiz-Granda+ 2025*
- Galactic science: *Vynzl+ (in prep)*
- Neutrino masses and reionisation : *LB collab (in prep)*
- …

LiteBIRD overview of scientific targets

As well as systematic effects and data analysis problems:

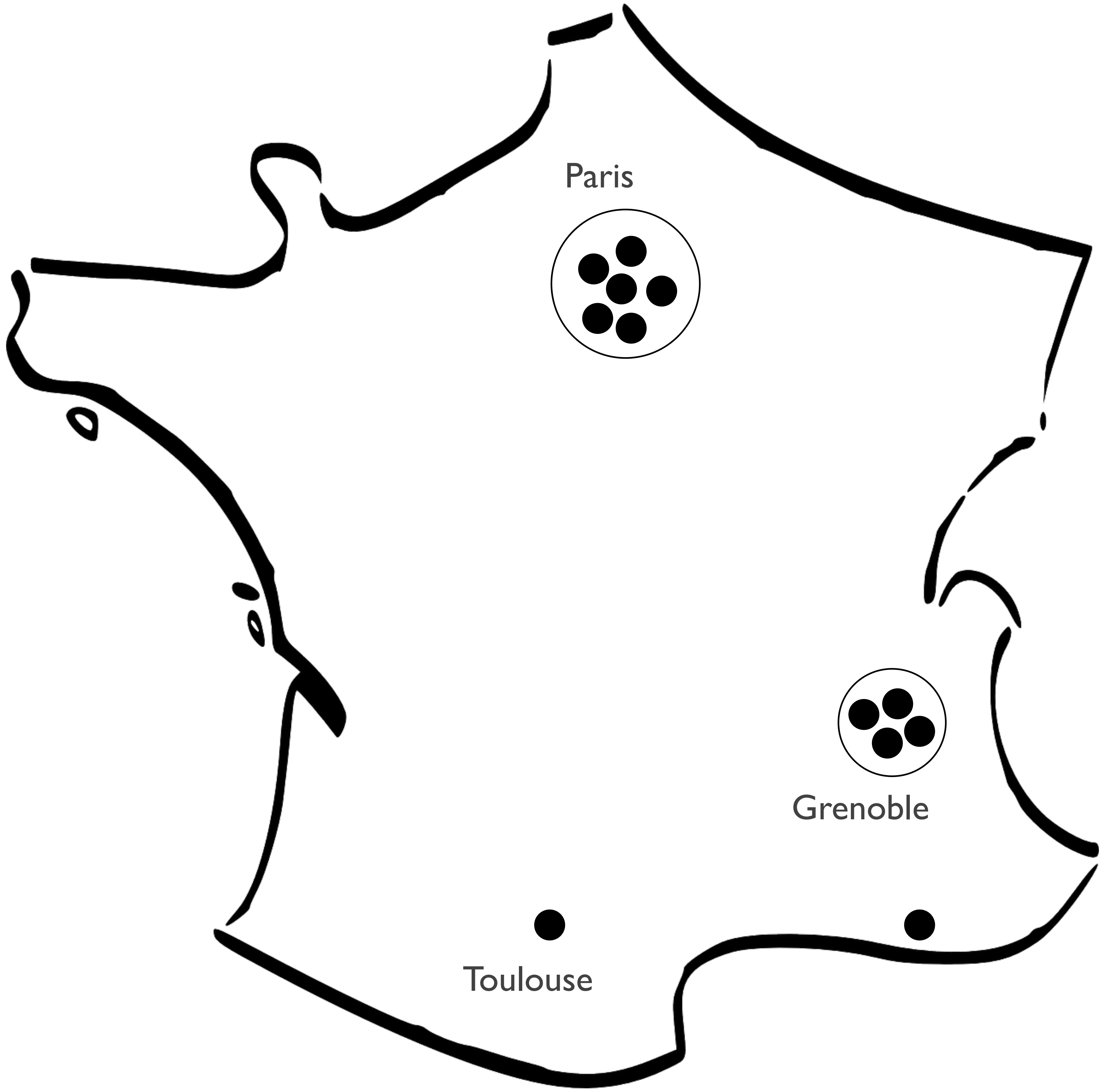
- Bandpass integration: Giardiello+ 2025
- Half-wave plate: Micheli+ 2024
- Scanning strategy: Takase+ 2023
- Simulations: Tomasi+ 2025, Bortolami+ 2025
- Gain calibration: Carralot+2025
- Far side lobes and beams: Leloup+2023
- In flight calibration: Krachmalnicoff+ 2022
- Component separation: Vacher+ 2022, Puglisi+ 2022, Carones+ 2023, LB PTEP 2023, Rizzieri+2025… (+ two major papers in prep for *E* and *B*-modes)
- …

LiteBIRD in France

Strong French **involvement** with multiple **expertises**:

- Component separation
- Systematic effects
- Data analysis and reduction
- Instrument and detectors
- Galactic astrophysics
- Phenomenology and theory
- …

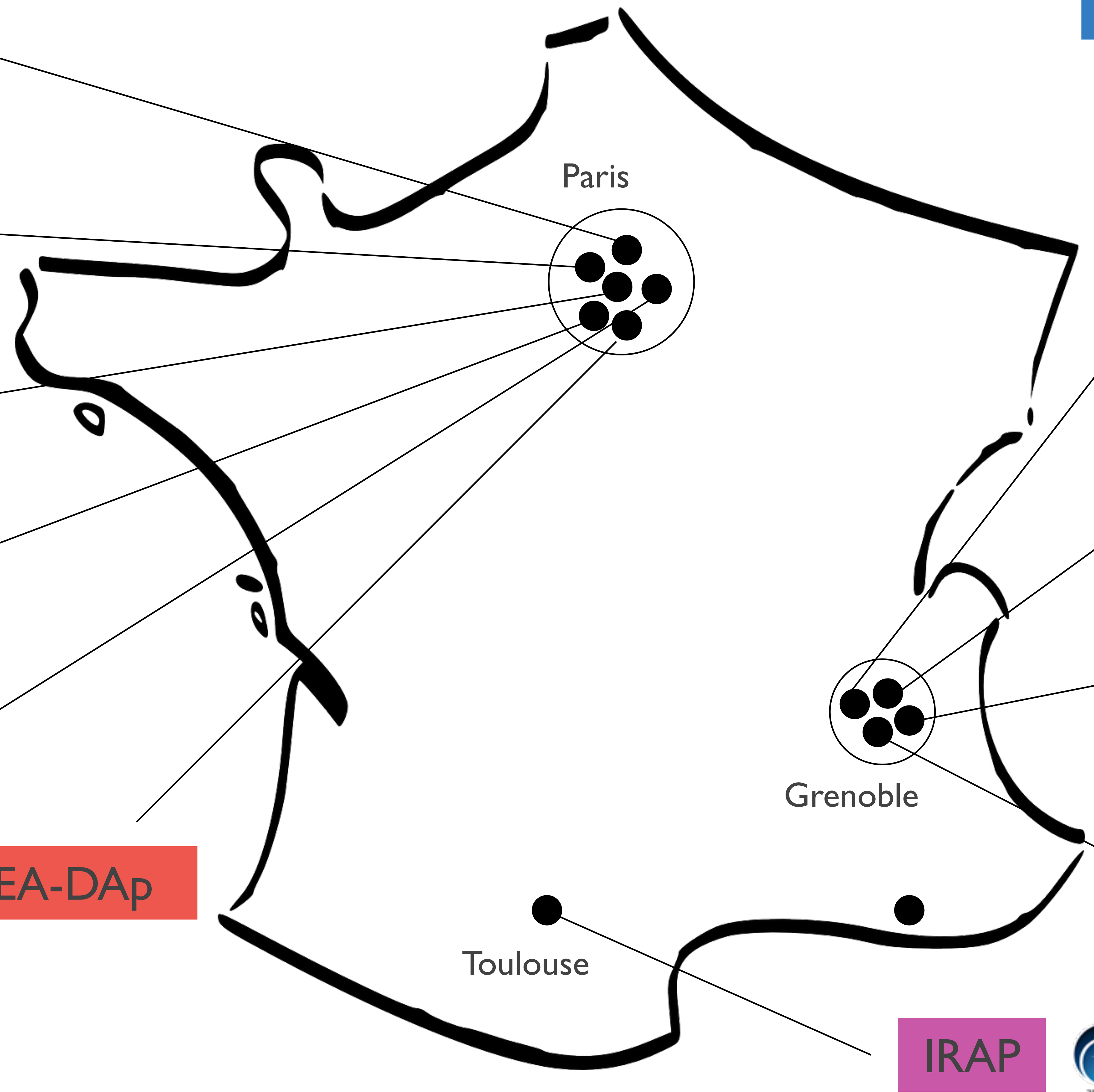
37 Scientists
18 Engineers



LiteBIRD in France

37 Scientists
18 Engineers
12+ labs

🟧 IN2P3
🟥 CEA
🟪 INSU
⬜ ENS
🟦 INP



- APC
- IAP
- IJCLab
- IAS
- ENS
- CEA-DAp
- LPSC
- IPAG
- I. Neel
- CEA-SBT
- IRAP

Some recent good news

- We are about to enter **Phase A/Project Phase of JAXA** soon! After **Mission Definition Review** held this month.

- Detectors to be developed in **Europe**: Ongoing R&D **studies for transition edge sensors (TES) at SRON** (Netherland) funded by **ESA** and lead by **INFN**.
  A **French contribution** lead by LETI (Grenoble) with CEA-DAp, APC and IRAP is currently under study.

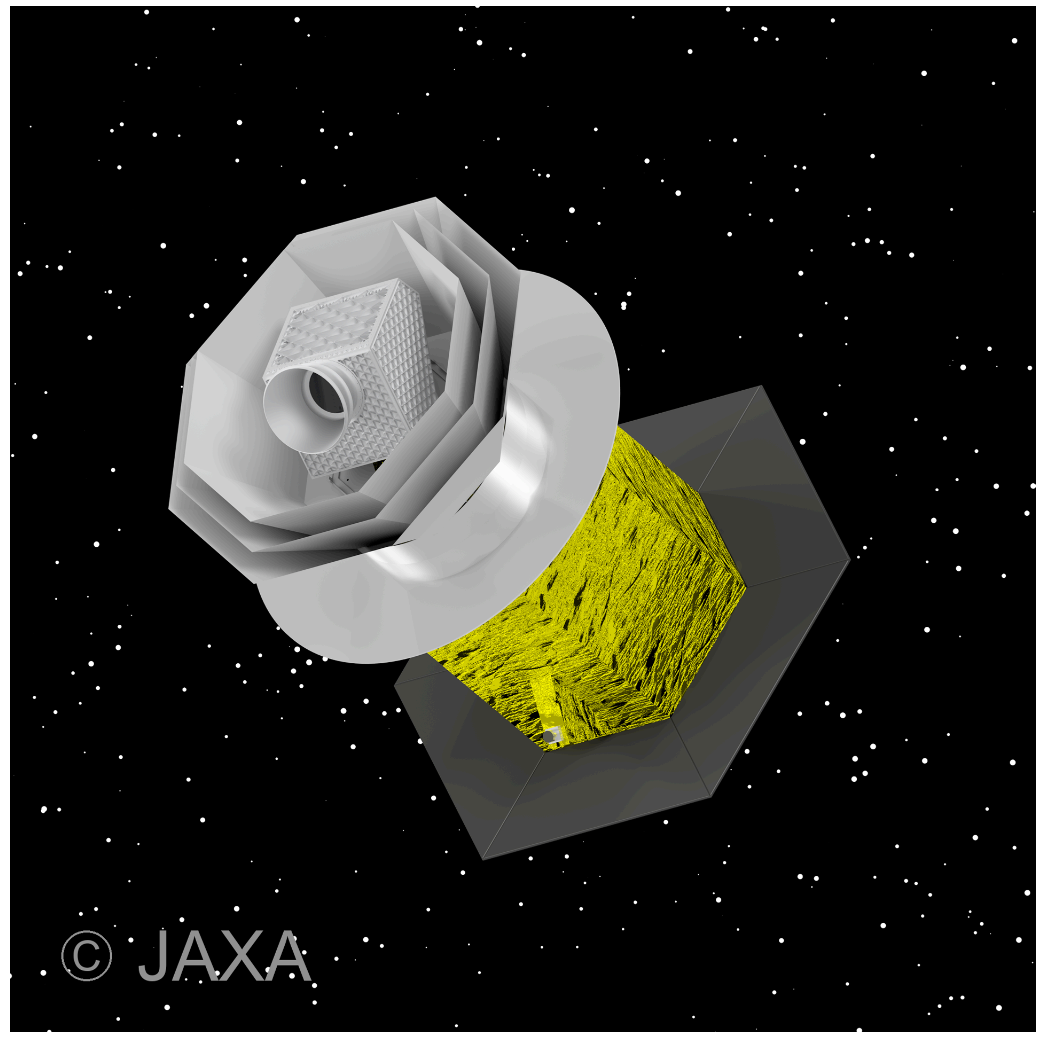
- **French contribution** is aligned with JAXA's schedule and is going as expected. In current Phase-A, **CNES** is responsible for the delivery of the unique instrument (LMHFT).

Conclusions

- *LiteBIRD* is an **ambitious project** successor of Planck and targeting **microwave polarisation** on large scales with a **broad frequency range**

- It will have multiple **scientific outcomes** beyond primordial *B*-modes

- The **French community** is strongly involved in the project.


© JAXA

APC
ASI
Berkeley
UNIVERSITY OF CALIFORNIA
BERKELEY LAB
UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA
CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD
cea
Centre Pierre Binétruy
CNRS • Berkeley
cnes
cnrs
CSA ASC
Canada

CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS
CSL
CENTRE SPATIAL DE LIÈGE
ENS | PSL
erc
European Research Council
Established by the European Commission
EXCELENCIA MARÍA DE MAEZTU
EXCELENCIA SEVERO OCHOA
FAU
FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
Forskningsrådet
The Research Council of Norway
GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

NASA
Goddard
Space Flight Center
G S
S I
GRAN SASSO SCIENCE INSTITUTE
INSTITUTO DE ASTROFISICA DE CANARIAS
IAC
IAP
IAS
Institut d'Astrophysique Spatiale
Orsay
IFCA
Instituto de Física de Cantabria
ifpU
IJCLab
Irène Joliot-Curie
Laboratoire de Physique des 2 Infinis

INFN
INAF
ISTITUTO NAZIONALE DI ASTROFISICA
IPMU
iPNS
素粒子原子核研究所
Institute of Particle and Nuclear Studies
irap
astrophysique & planétologie
JAXA
NASA
Jet Propulsion Laboratory
California Institute of Technology

NATIONAL INSTITUTE OF TECHNOLOGY KAGAWA COLLEGE
香川高専
KEK
KIPAC
KAVLI INSTITUTE FOR PARTICLE ASTROPHYSICS & COSMOLOGY
K M I
I M K
K M I
Kobayashi-Maskawa Institute
Nagoya University
LMU
LPSC
GRENOBLE | MODANE

MAX-PLANCK-INSTITUT
FÜR ASTROPHYSIK
McGill
Maynooth University
National University of Ireland Maynooth
名古屋大学
NAGOYA UNIVERSITY
NÉEL
institut
NIST

HK
Norwegian Directorate for Higher Education and Skills
OAC
岡山大学
OKAYAMA UNIVERSITY
QUP
International Center for Quantum-field Measurement Systems for Studies of the Universe and Particles
POLITÉCNICA
idr
RWTH AACHEN UNIVERSITY

LiteBIRD

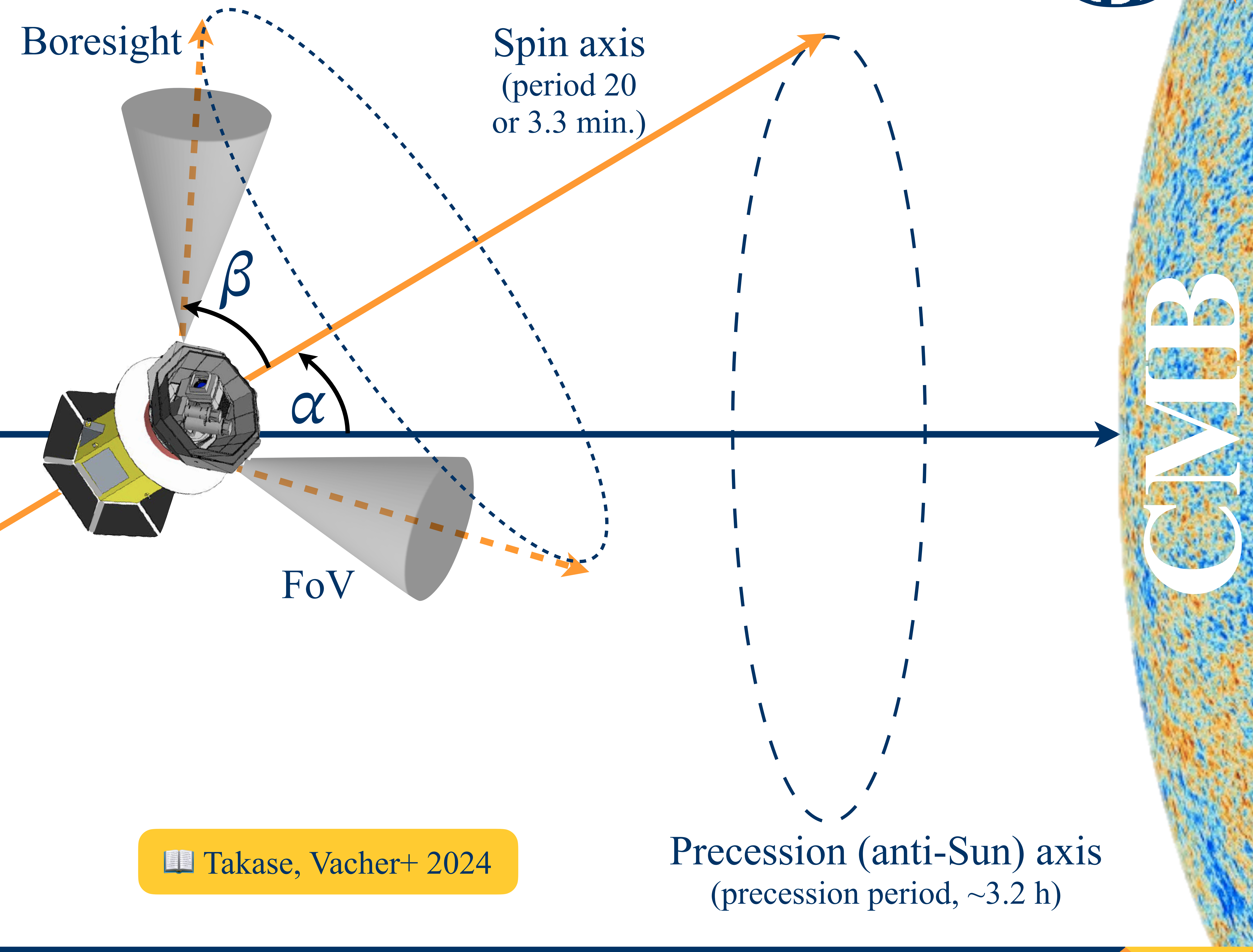
SAPIENZA
UNIVERSITÀ DI ROMA
SISSA
SORBONNE UNIVERSITÉ
SRON
SSDC
SPACE SCIENCE DATA CENTER
LELAND STANFORD JUNIOR UNIVERSITY
1891
Stockholm University
公立諏訪東京理科大学
Suwa University of Science
TOR VERGATA
UNIVERSITÀ DEGLI STUDI DI ROMA

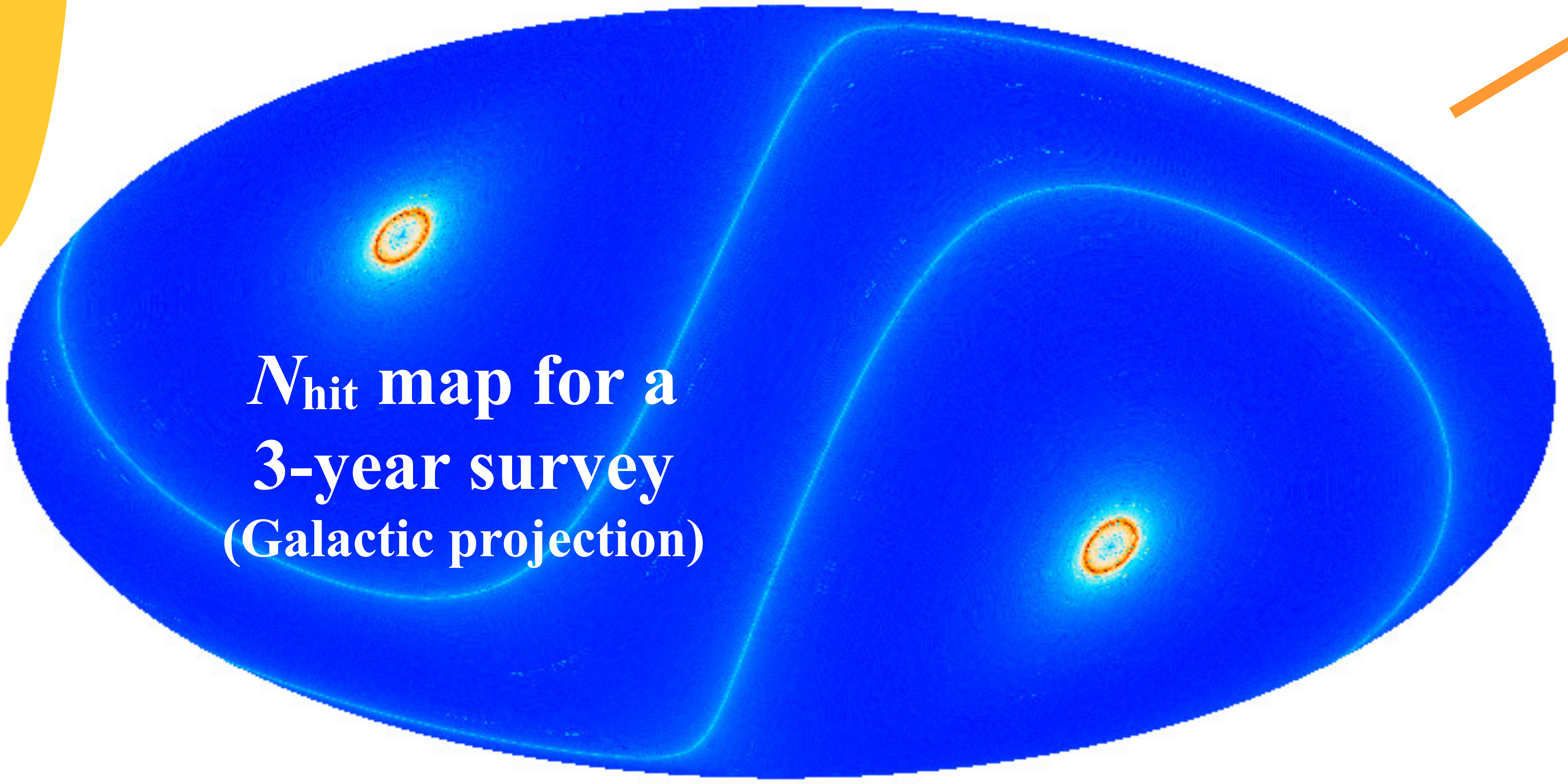
UCL
UBC
THE UNIVERSITY OF BRITISH COLUMBIA
UC
UNIVERSIDAD DE CANTABRIA
Università di Catania
University of Colorado Boulder
UKRI
Science and Technology Facilities Council
ULB
UNIVERSITÉ LIBRE DE BRUXELLES
Universidad de La Laguna

MANCHESTER 1824
The University of Manchester
UiO University of Oslo
UNIVERSITY OF OXFORD
UNIVERSITÀ DI PISA
Università degli Studi di Ferrara
UNIVERSITÀ DEGLI STUDI DI MILANO
UNIVERSITÀ DEGLI STUDI DI PADOVA
THE UNIVERSITY OF TOKYO
UNIVERSITY OF TORONTO

LiteBIRD scanning strategy

- 3-year survey, Sun-Earth L2 Lissajous orbit
- Precession angle: $\alpha = 37.5°$
- Spin angle: $\beta = 57.5°$





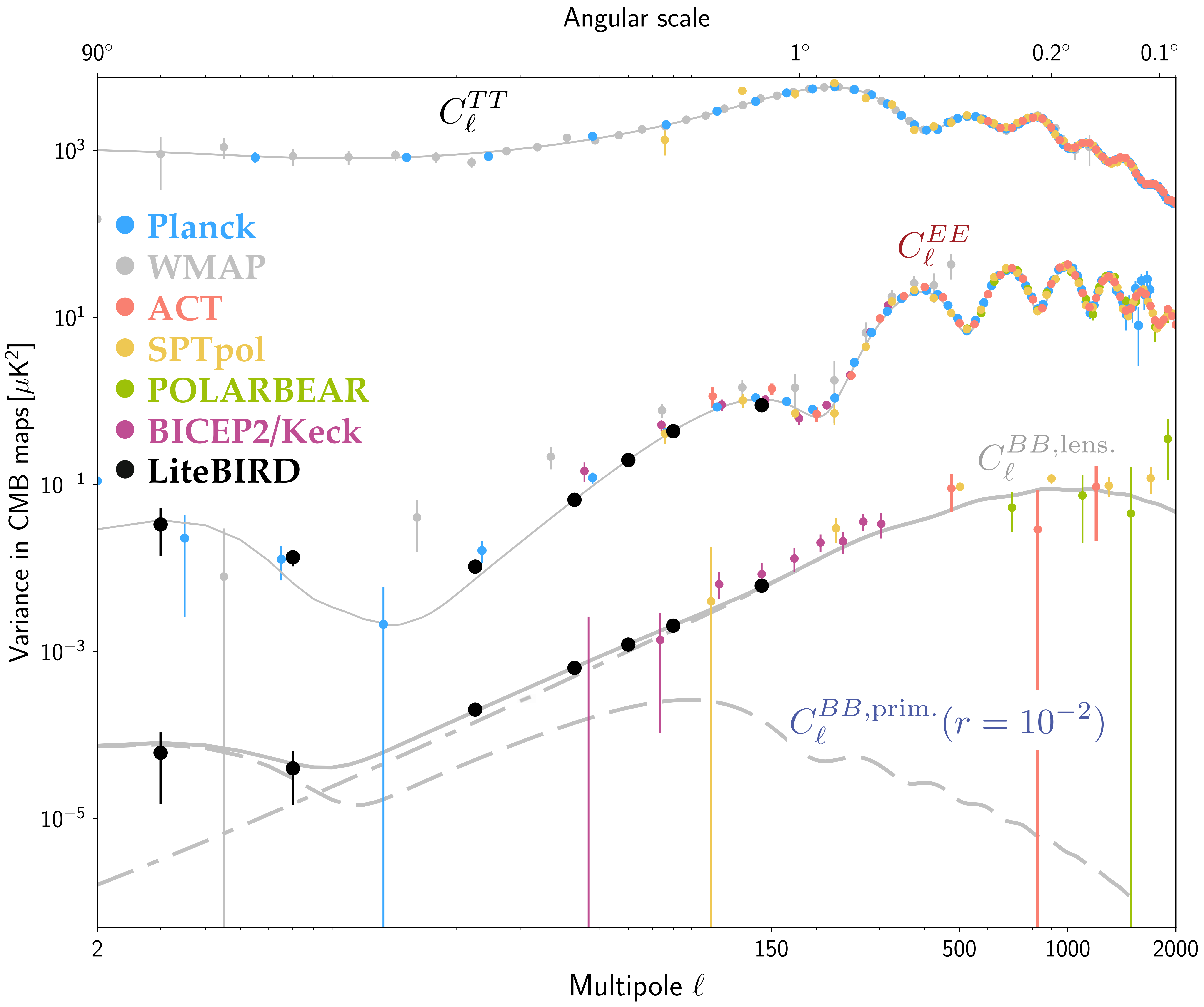
N_{hit} map for a 3-year survey
(Galactic projection)

📖 Takase, Vacher+ 2024

LiteBIRD main scientific objectives

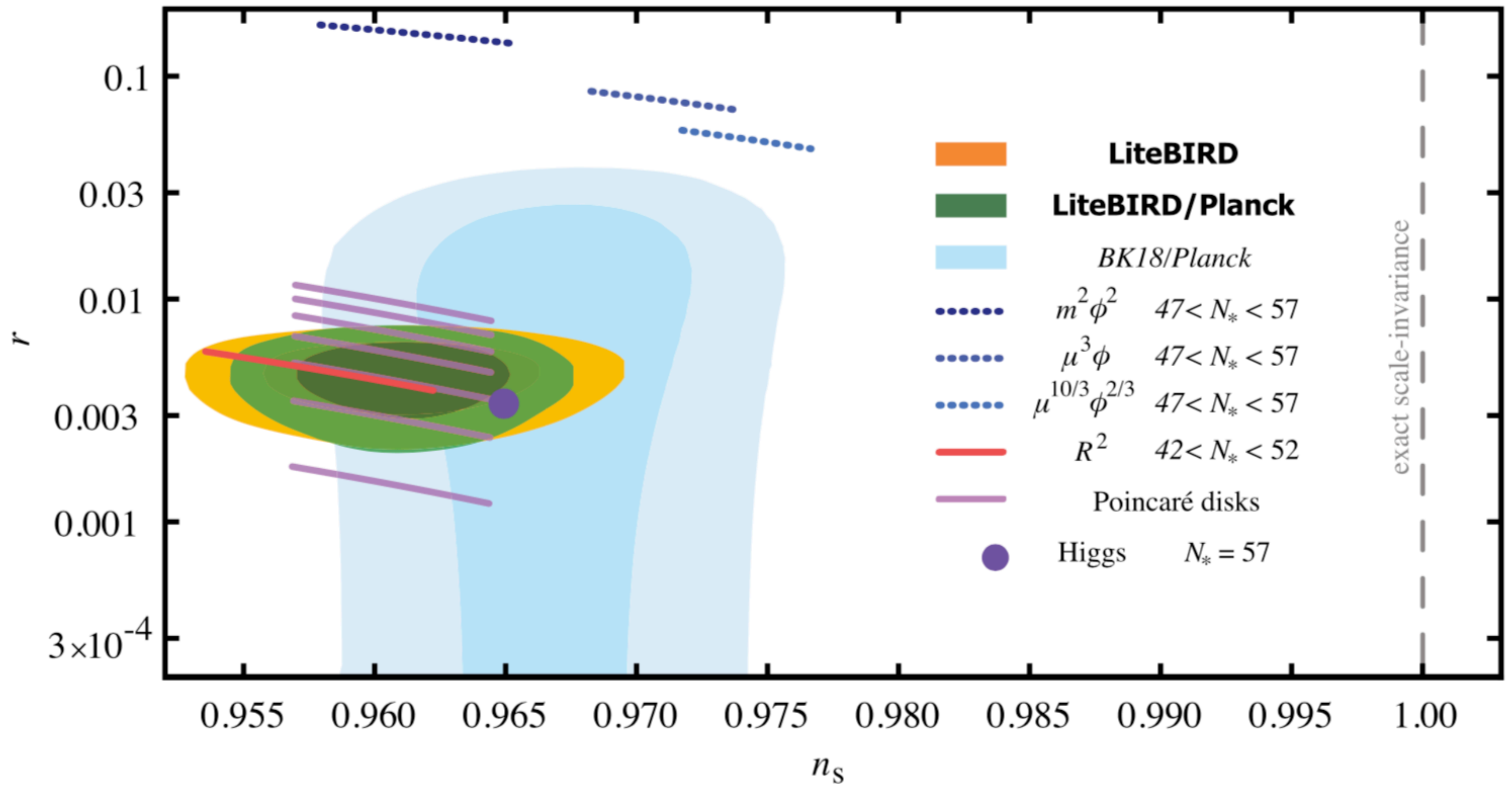
- Definitive search for the ***B*-mode signal** from **cosmic inflation** in the CMB polarization
  - Making a discovery or ruling out well-motivated inflationary models
  - Insight into the quantum nature of gravity
- The inflationary (i.e. primordial) *B*-mode power is proportional to the **tensor-to-scalar ratio, *r***
- Current best constraint: $r < 0.032$ (95% C.L.)

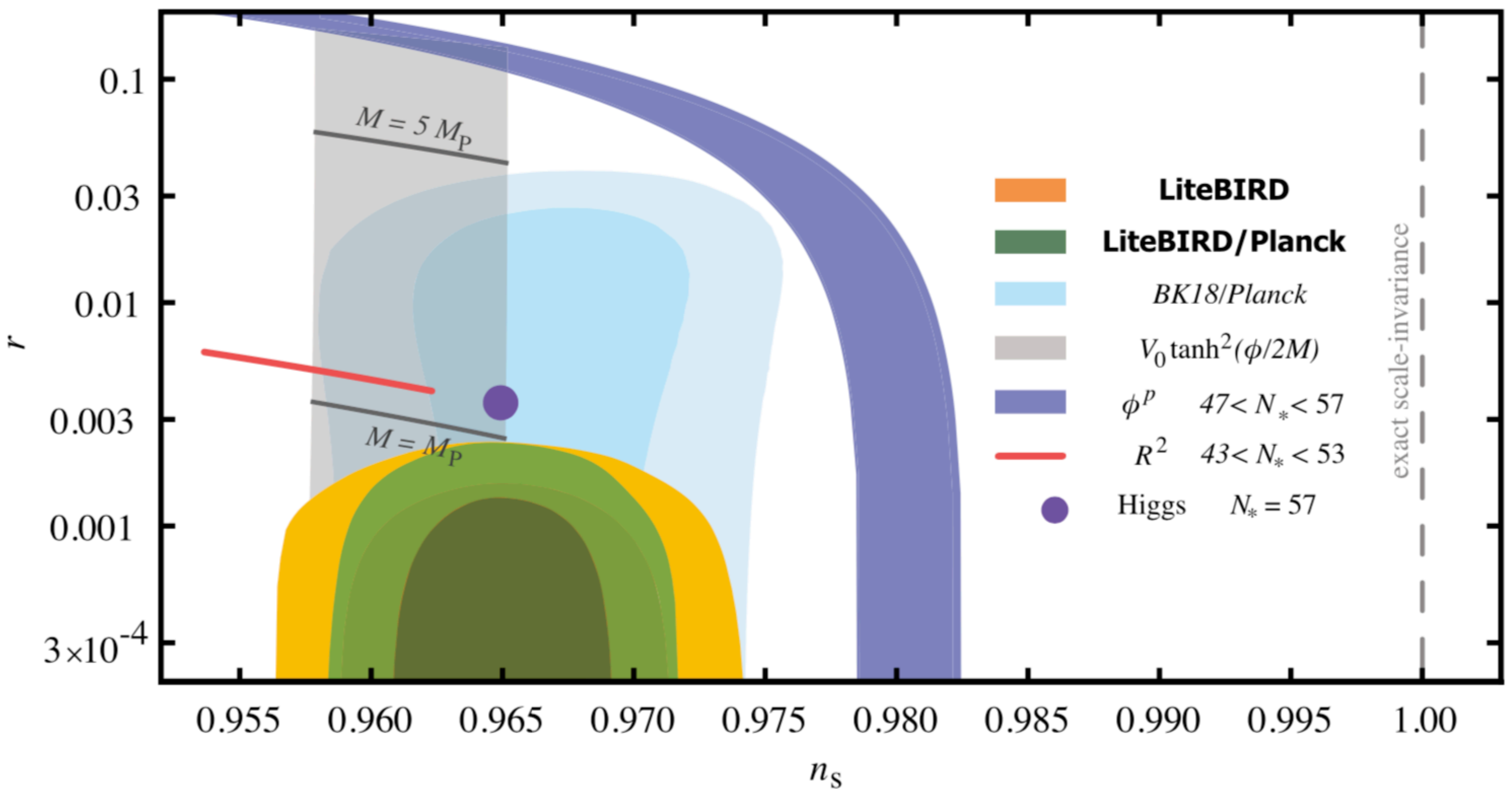
  (📖 Tristram et al. 2022, combining BK18 and Planck PR4)
- *LiteBIRD* will significantly improve the current sensitivity on r
- The final goal is to achieve **a statistical uncertainty of $\sigma(r) \lesssim 0.001$ for $r = 0$**



LiteBIRD constraints on inflation

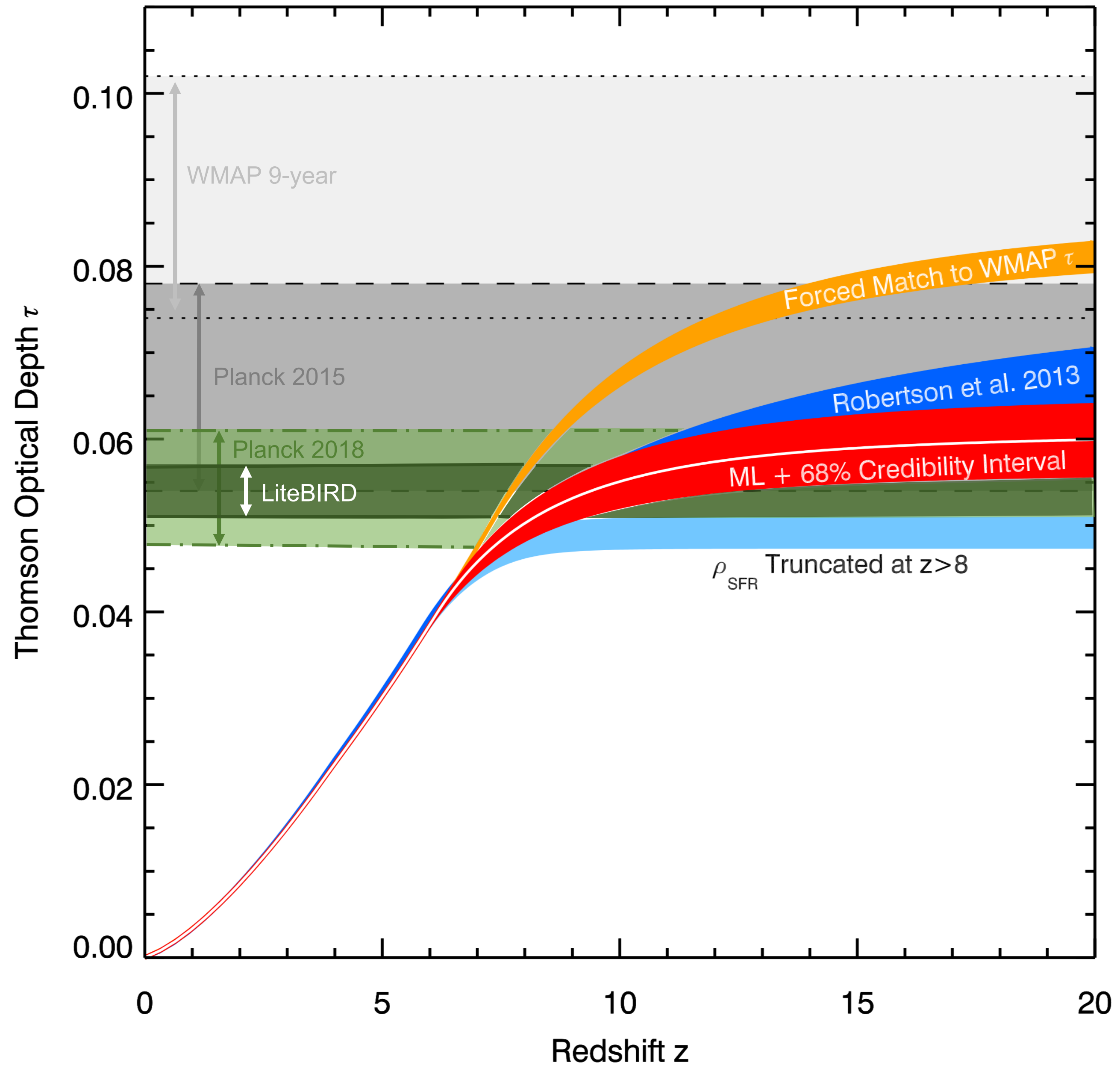
- Huge discovery impact (evidence for inflation, knowledge of its energy scale, and distance traveled by the inflaton…)
- A detection of B-modes by *LiteBIRD* with $r > 0.01$ would imply an excursion of the inflation field that exceeds the Planck mass
  - Such a detection would **constrain theories of quantum gravity** such as superstring theories
- An upper limit from *LiteBIRD* would disfavour the simplest inflationary models, with $M > M_{\rm p}$
  - This includes the monomial models, α-attractors with a super-Planckian characteristic scale, including the **Starobinsky model** and models that invoke the Higgs field as the inflaton (📖 Kallosh & Linde 2025)



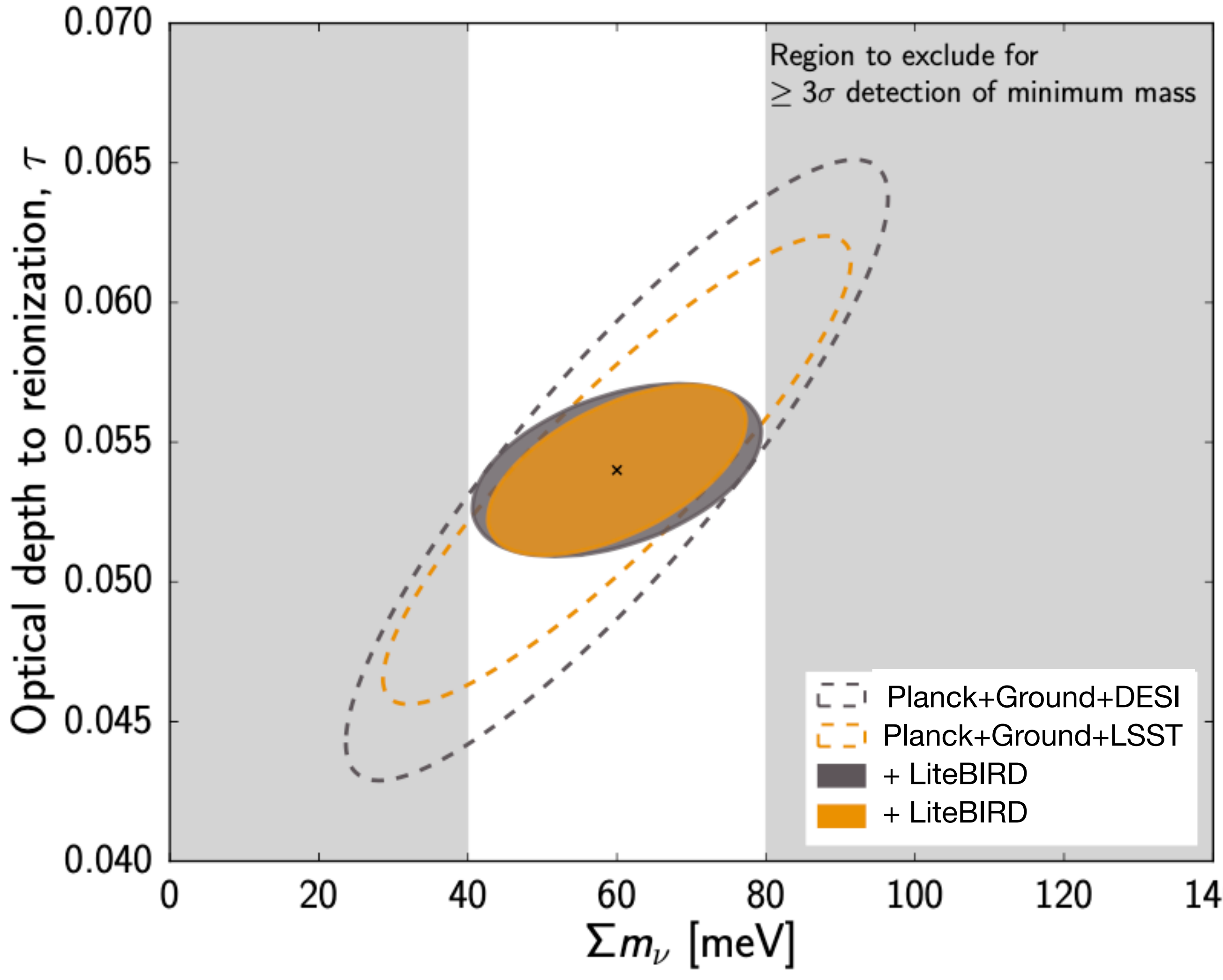


LiteBIRD other science outcomes

- The mission specifications are driven by the required sensitivity on r
- Meeting those sensitivity requirements would allow to address other important scientific topics, such as:
  1. Characterize the B-mode power spectrum and search for source fields (e.g. scale-invariance, non-Gaussianity, parity violation, …)
  2. Power spectrum features in polarization
     - Large-scale ***E*-modes**
     - **Reionization** (improve $\sigma(\tau)$ by a factor of 3)
     - **Neutrino mass** ($\sigma(\sum m_\nu) = 12$ meV) including external data
  3. Constraints on **cosmic birefringence**
  4. **Gravitational lensing**
  5. **SZ effect** (thermal, diffuse, relativistic corrections)
  6. **Anisotropic distortions** of the CMB spectrum
  7. Constraints on **primordial magnetic fields**
  8. Elucidating **anomalies**
  9. Physics of **Galactic emission** mechanisms
  10. Catalogues of polarized **point sources**



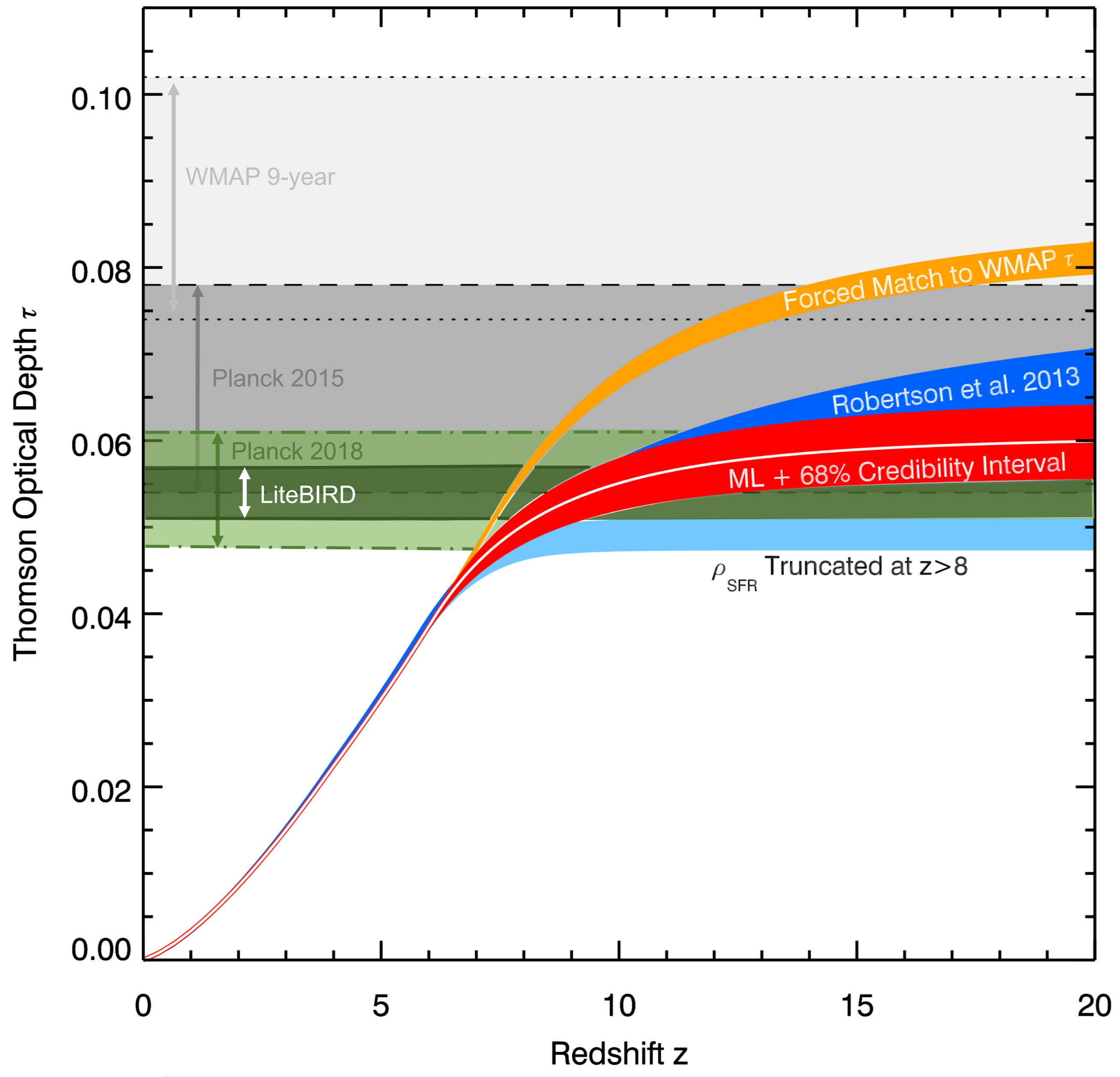
📖 Adapted from Robertson +2015



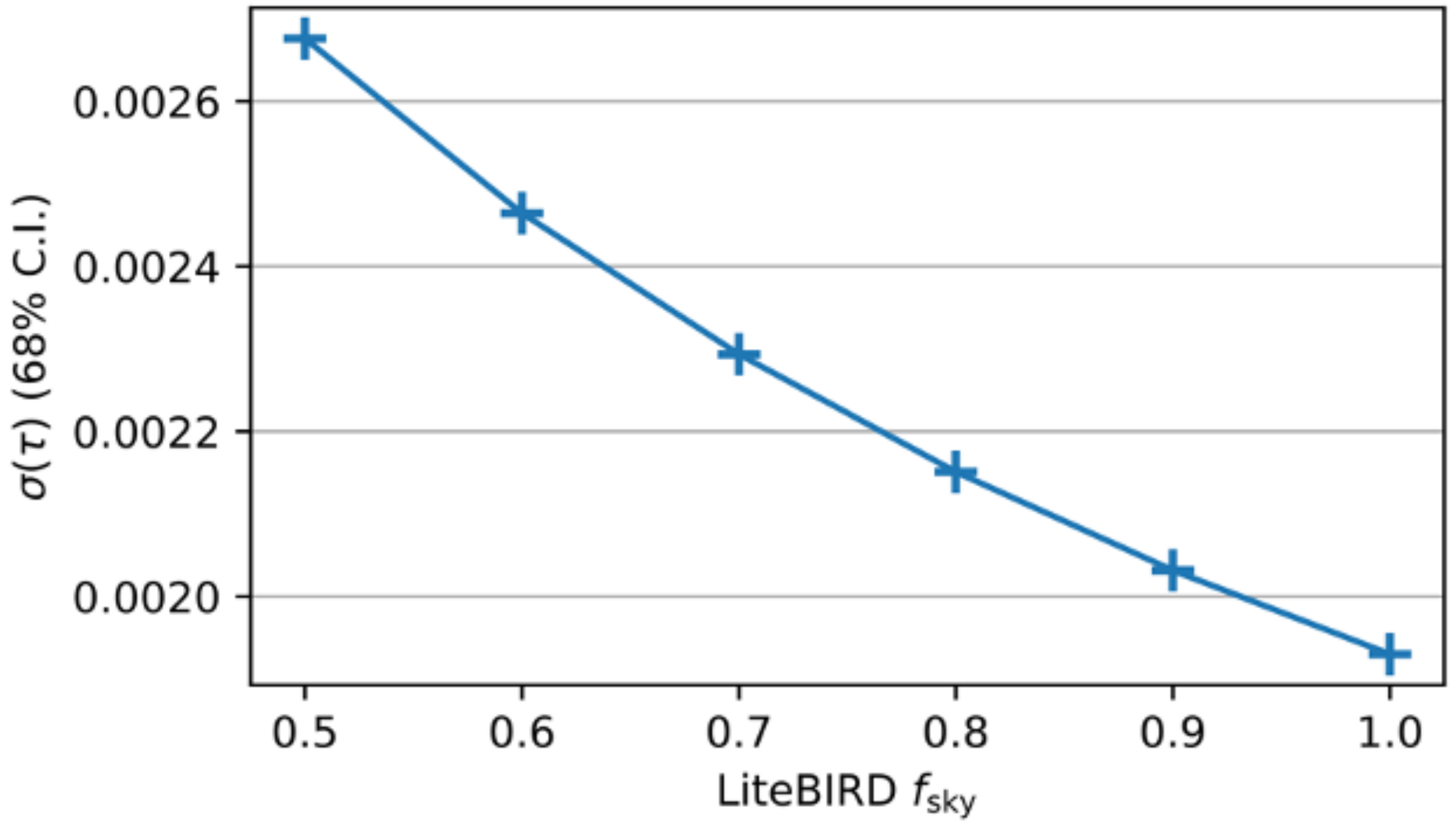
📖 LiteBIRD collaboration PTEP 2023

Optical depth, reionization and neutrino masses

- *LiteBIRD* will provide a cosmic-variance limited measurement of the ***E*-mode** power spectrum on large scales ($2 \leq \ell \leq 200$)
- This will lead to improved constraints on:
  - **Reionization**
    - Signal-dominated measurement of the **optical depth** to reionization ⇒ $\sigma(\tau) \approx \mathbf{0.002}$ ⇒ ×3 improvement w.r.t Planck
    - Only limited by the sky fraction after cleaning
    - Signal-dominated regime reached after 6 months, allowing $\sigma(\tau) \approx 0.003$. Full survey crucial to maximise $f_{\rm sky}$
    - Impact on reionization history currently under investigation

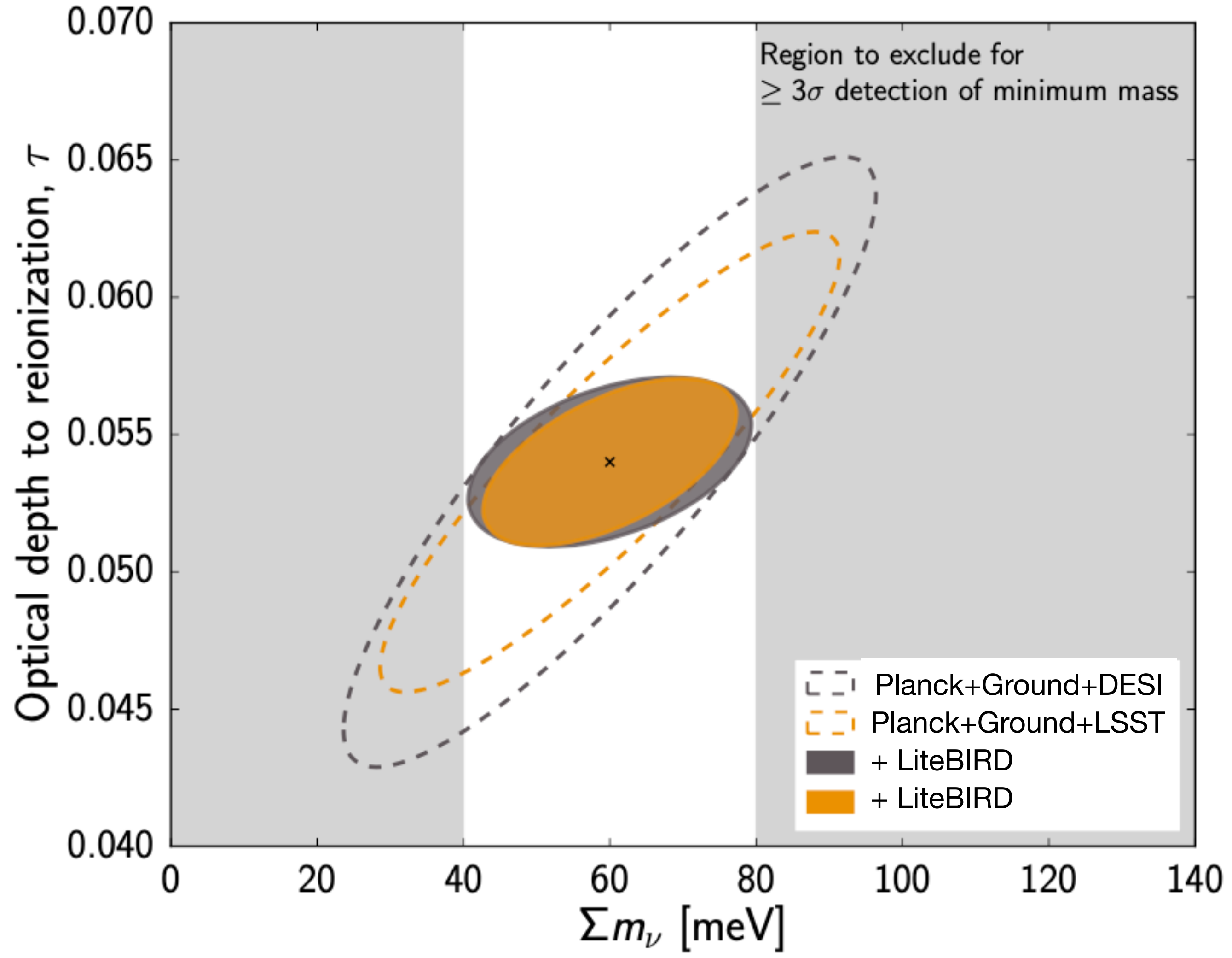


📖 Adapted from Robertson +2015

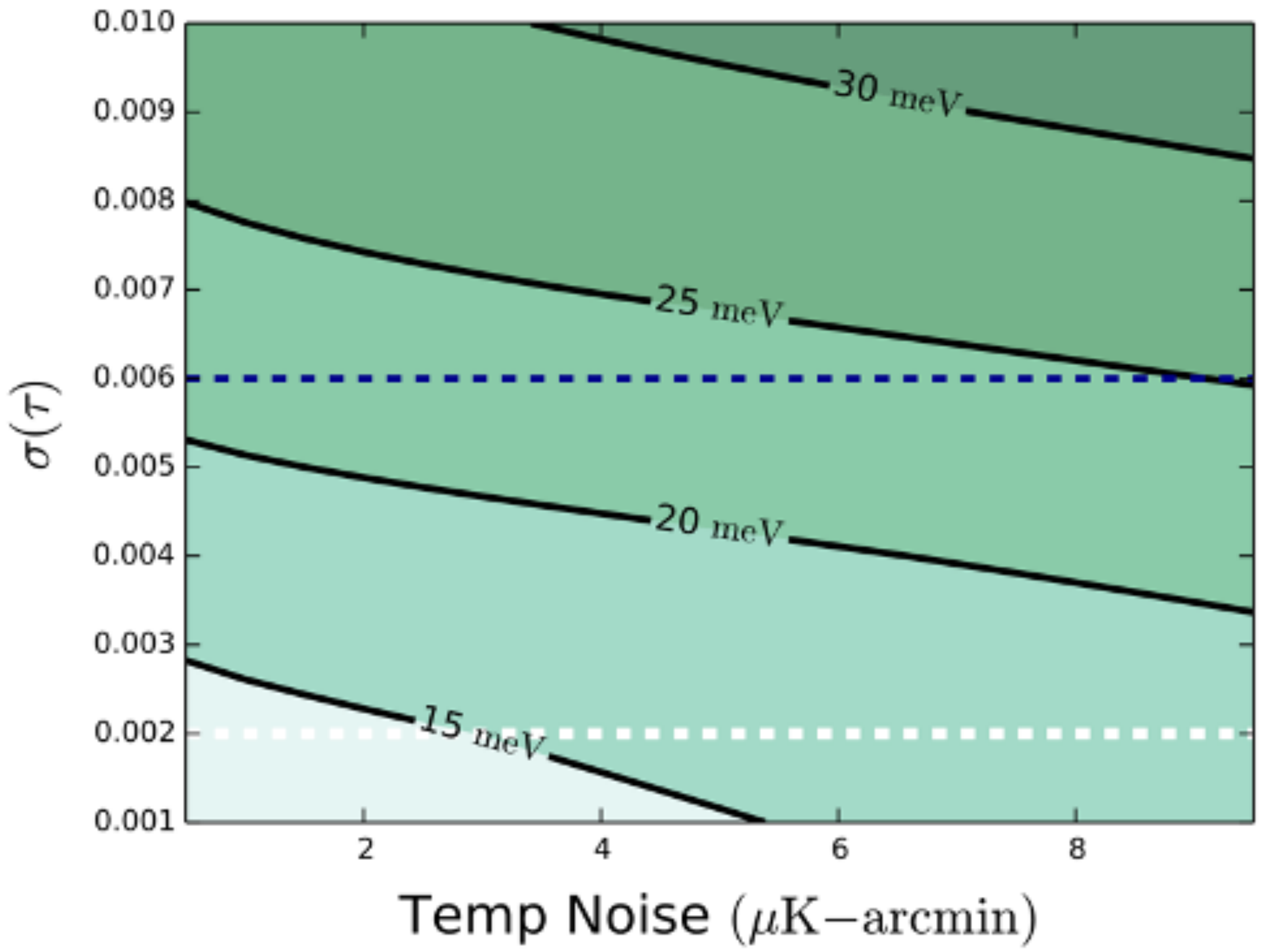


Optical depth, reionization and neutrino masses

- *LiteBIRD* will provide a cosmic-variance limited measurement of the ***E*-mode** power spectrum on large scales ($2 \leq \ell \leq 200$)
- This will lead to improved constraints on:
  - **Sum of neutrino masses**
    - The sum of neutrino masses can be constrained via combination with high-resolution CMB measurements (ground-based data)
    - The improved measurement of the optical depth provided by LiteBIRD will allow:
      - ➡ **$\sigma(\sum m_\nu) \approx 18$ meV** with CMB-ground (SO)+BAO
      - ➡ **$\sigma(\sum m_\nu) \approx 12$ meV** with CMB-ground (improved)+BAO
      - ➡ × 3-4 improvement w.r.t current constraint
    - Potentially allow to **rule out the inverted neutrino mass ordering**
    - 5σ detection for $\sum m_\nu = 60$ meV (minimum mass in normal ordering)



📖 LiteBIRD collaboration
PTEP 2023

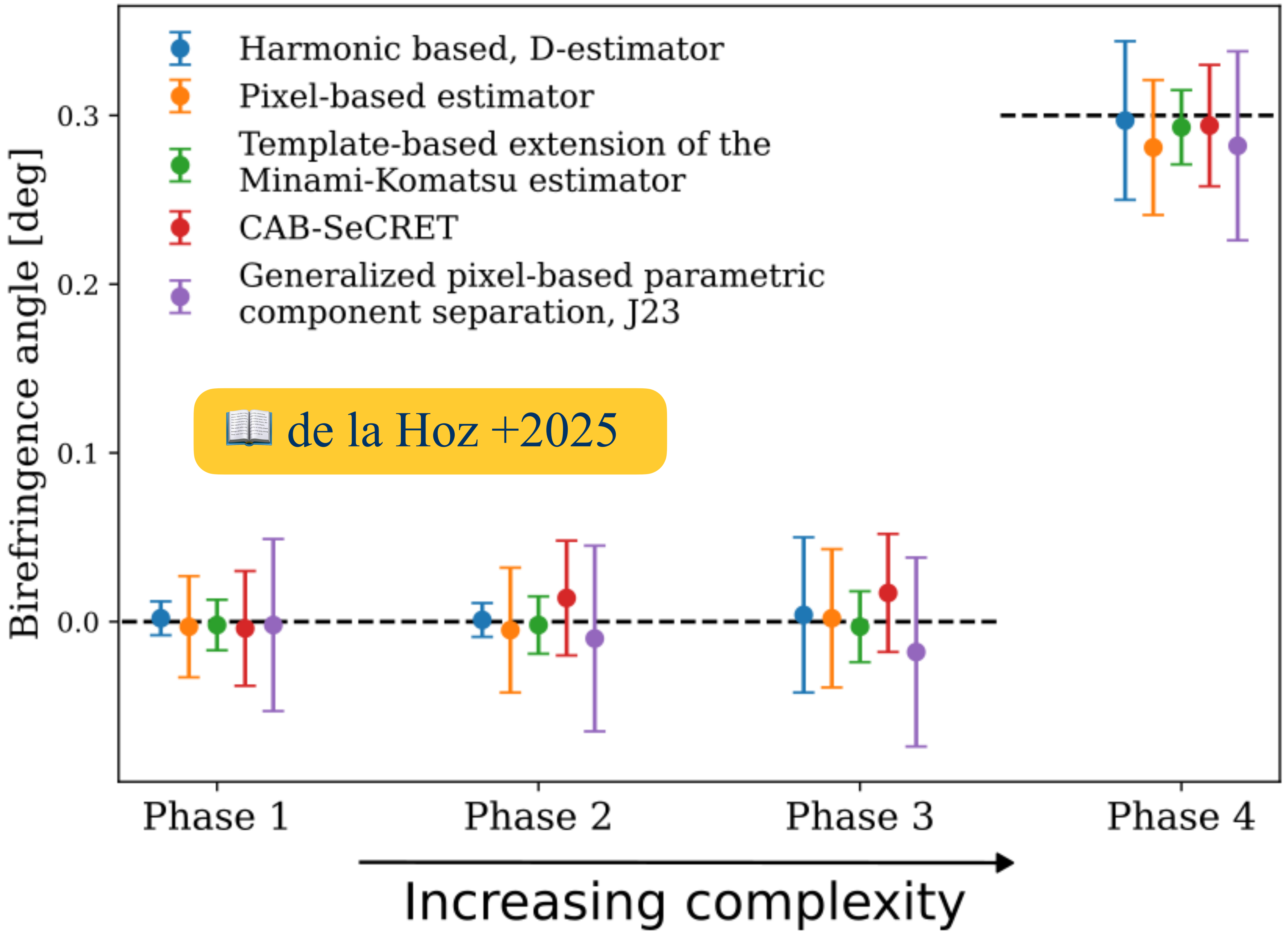


📖 CMB-S4 Science Book

Constraints on cosmic birefringence

- Dark matter or dark energy could be a parity-violating pseudo-scalar field that couples to electromagnetism and rotates the linear polarization of photons propagating through the Universe.
- This effect, known as **cosmic birefringence**, induces non-zero *TB* and *EB* correlations and also a *B*-mode signal.
- Recent measurements show tentative detections of rotations:
  - **(0.34±0.09)°** from the combined analysis of *WMAP* and *Planck* PR4 (📖 Eskilt & Komatsu 2022)
  - **(0.20±0.08)°** from ACT DR6 (📖 Louis et al. 2025)

  which are potentially compatible with cosmic birefringence.
- *LiteBIRD* has the potential to:
  - Reduce the error bar on isotropic birefringence, leading to a **5 to 13σ detection of a 0.3° angle** depending on the method used to account for possible detector angle miscalibration and the *EB* signal from Galactic foregrounds (📖 de la Hoz et al. 2025)
  - **Distinguish between dark matter and dark energy** by probing ***EB* around the reionization peak** (📖 Nakatsuka et al. 2022, 📖 Namikawa et al. 2025)
  - Produce a full-sky map of birefringence **anisotropies** to further test the **nature and origin of the field.**



📖 de la Hoz +2025

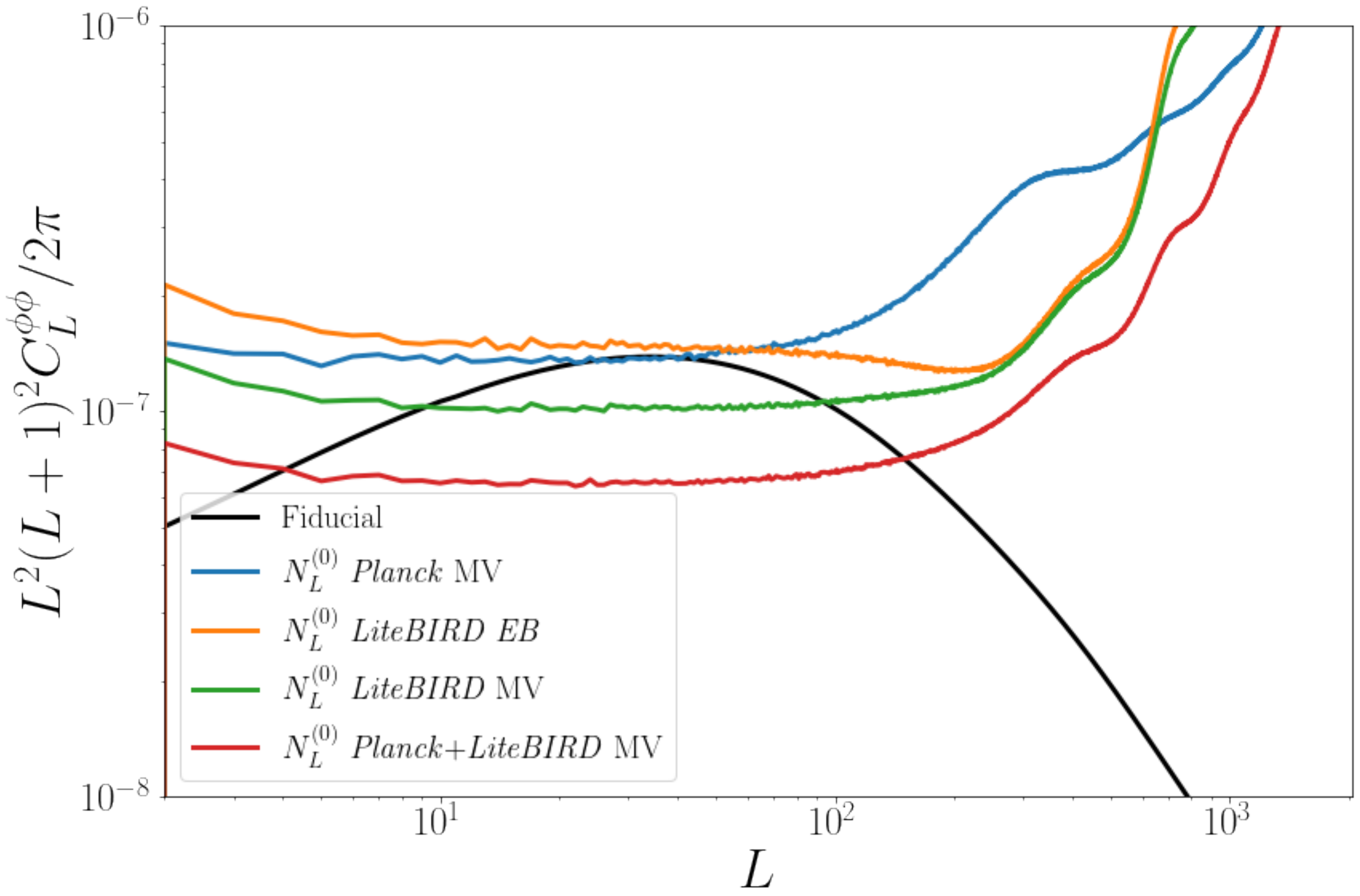
Weak gravitational lensing

- CMB photons are deflected by large-scale structure through **gravitational lensing**, which introduces higher-order correlations in CMB anisotropies.
- These higher-order correlations can be used to reconstruct the lensing deflections and map the integrated matter distribution along the line of sight, probing the growth of structure up to high redshifts.

- ***LiteBIRD* will provide a 49 to 58σ detection of the lensing power spectrum** over 80% of the sky, depending on the final complexity of polarized Galactic emission.
  - 85% of the S/N of *LiteBIRD*'s lensing reconstruction will come from polarization.

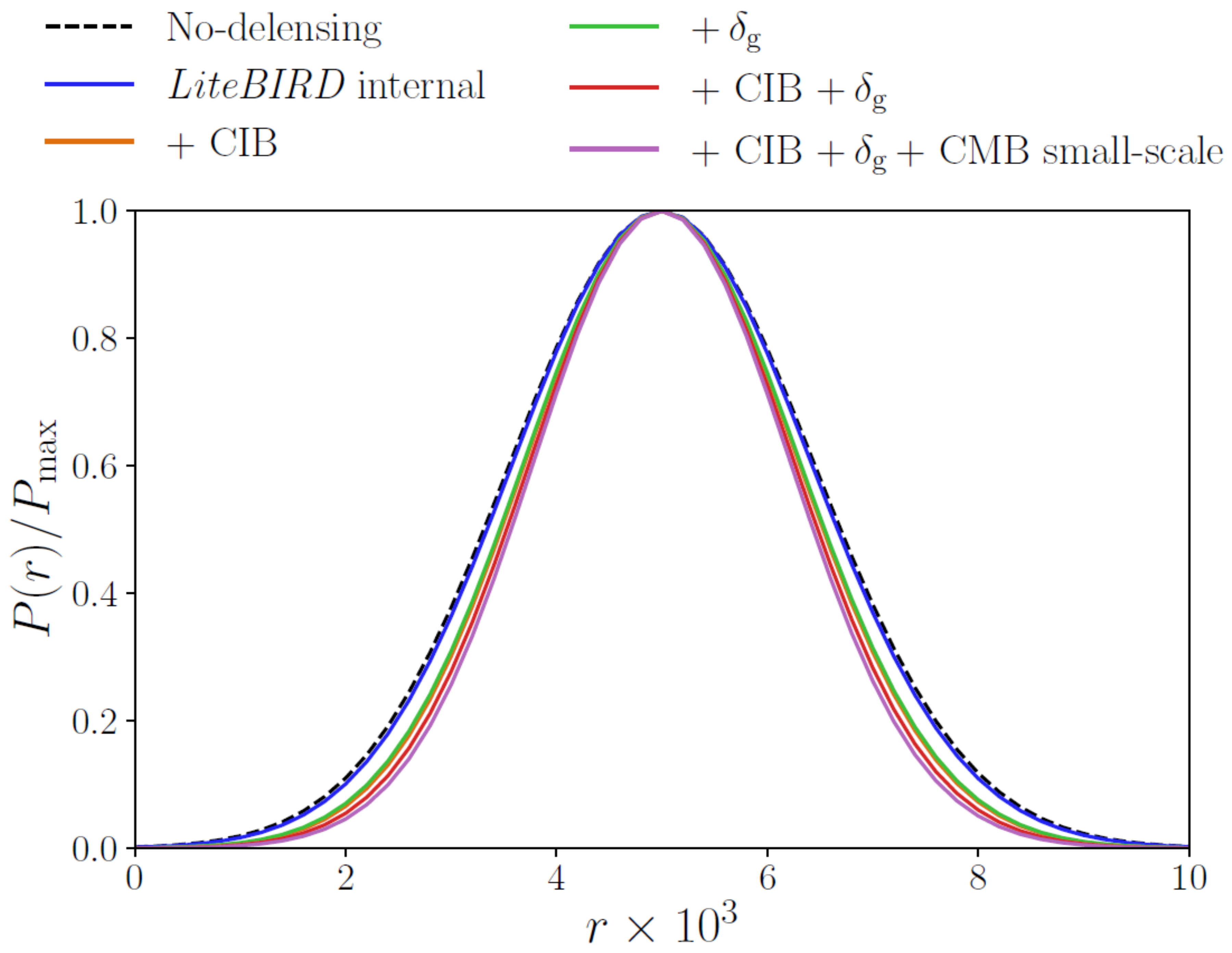
- **The combination of *Planck* and *LiteBIRD* will provide the best full-sky lensing map in the 2030s** with a 72 to 78σ detection over 80% of the sky, almost doubling *Planck*'s sensitivity.
  - These combinations will improve the constraint on S_8 by a factor 2 compared to *Planck*.

📖 Lonappan +2024, Ruiz-Granda +2025



B-mode delensing

- If the lensing potential is known, lensing deflections can be reverted to recover an undistorted view of the last scattering surface. This process is called **delensing**.



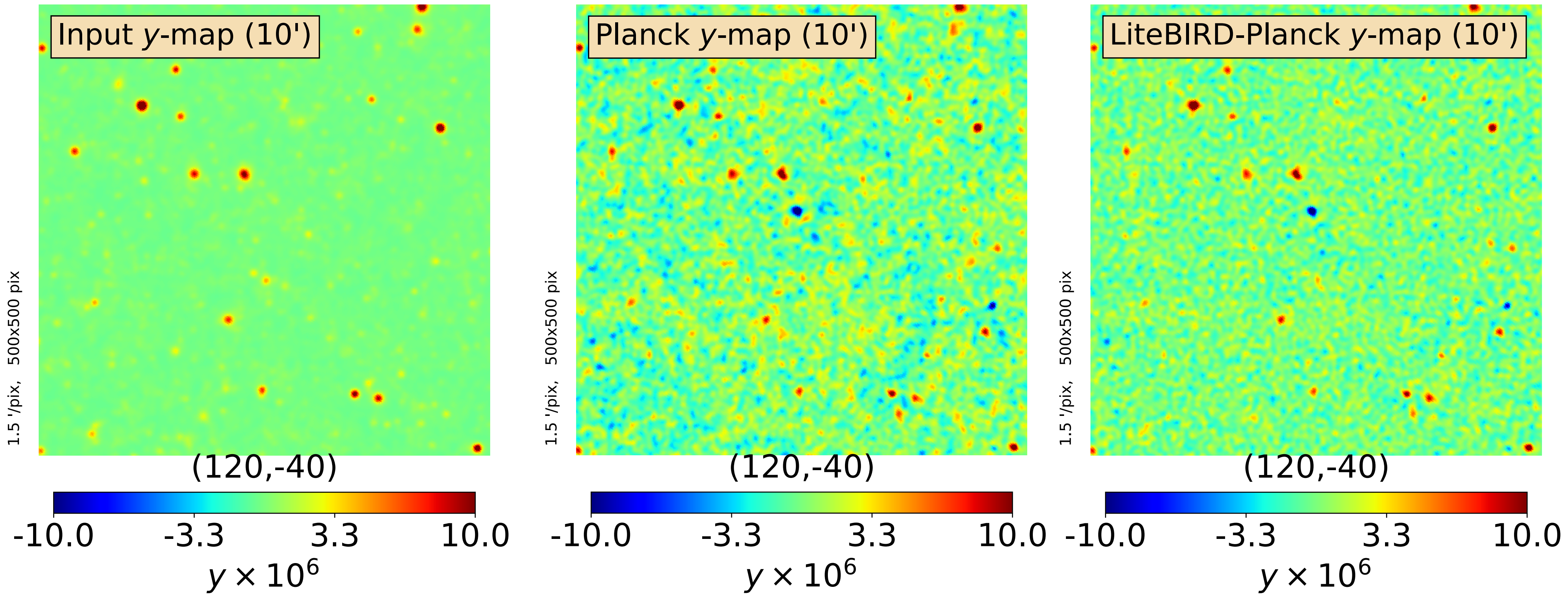
📖 Namikawa +2024

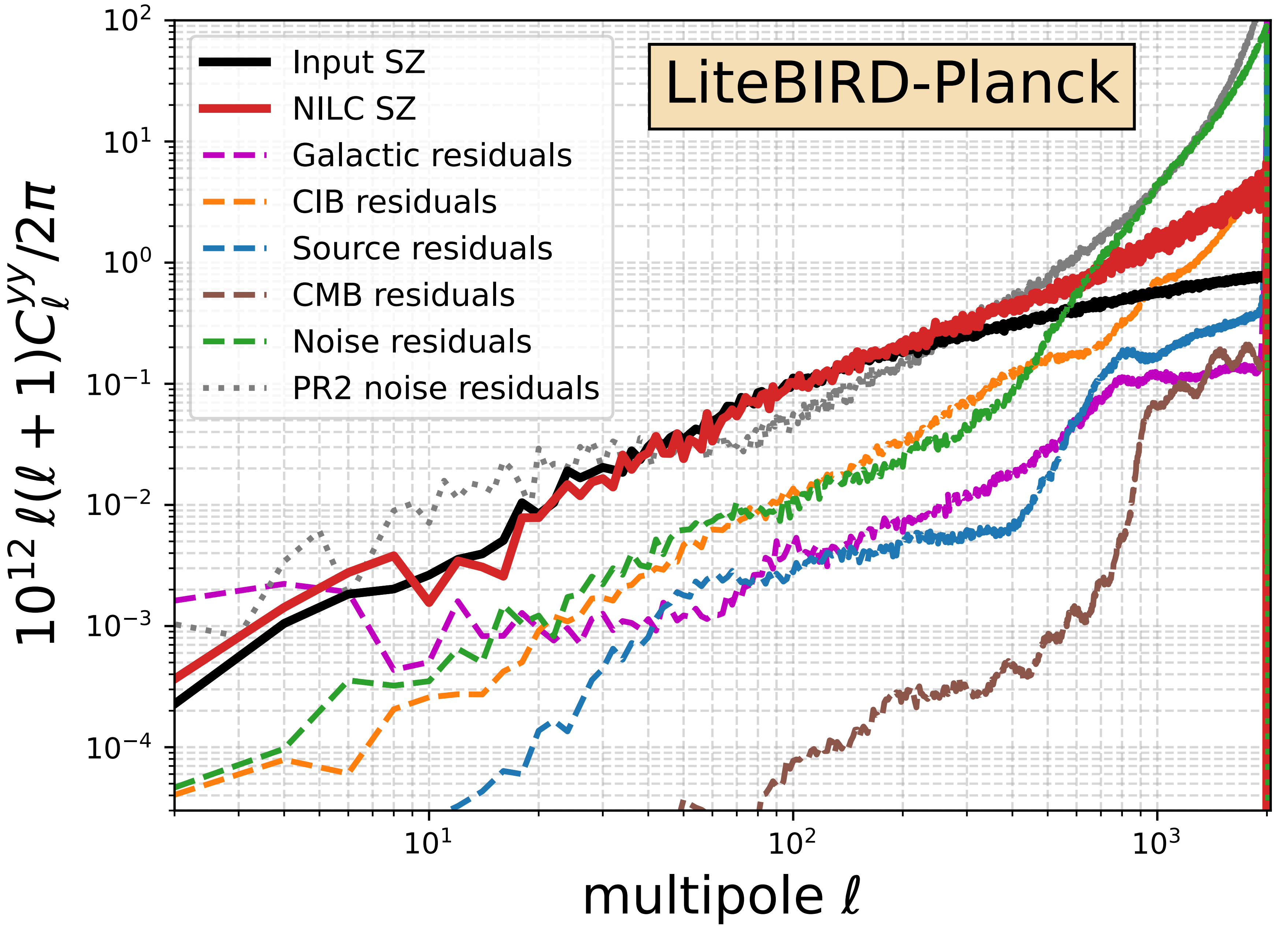
- Constraints on r will tighten by about 5% when delensing using only *LiteBIRD* data (internal delensing).
- Through the **combination of different mass tracers**, like the cosmic infrared background (CIB) or galaxy surveys such as Euclid and LSST (δ_g), and **high-resolution CMB maps**, we can achieve a more efficient delensing that **tightens constraints on r by about 20%.**

- **Synergy between *LiteBIRD* and ground-based experiments** to carry out a detailed study on how much:
  - *LiteBIRD*'s high- and low-frequency maps will improve foreground cleaning for ground-based experiments (SO, BICEP/Keck).
  - The small-scale information from ground-based experiments will improve *B*-mode delensing for *LiteBIRD*.

Mapping the hot gas in the Universe

- The **Sunyaev-Zel'dovich** effect provides a mean to map the distribution of hot electrons in the Universe
- Improved sensitivity and frequency coverage of *LiteBIRD* crucially contributes to improve these studies
- Combination with Planck adds the benefit of angular resolution
- *LiteBIRD* will **improve ×10 the noise in the SZ map** wrt Planck
- This will allow to:
  - Produce a high-fidelity SZ map over the full-sky essentially **free of contamination at $\ell < 200$**
  - Test theories of structure formation via **hot-gas tomography** from SZ × galaxy surveys correlations
  - Search for **WHIM** in filaments connecting clusters
  - Study an **inhomogeneous reionization** process via cross-correlations of SZ × CMB optical depth
  - Measure the mean gas T_e via the relativistic SZ
  - Improve constraints on $S_8 = \sigma_8(\Omega_m/0.3)^{0.5}$ by 15%

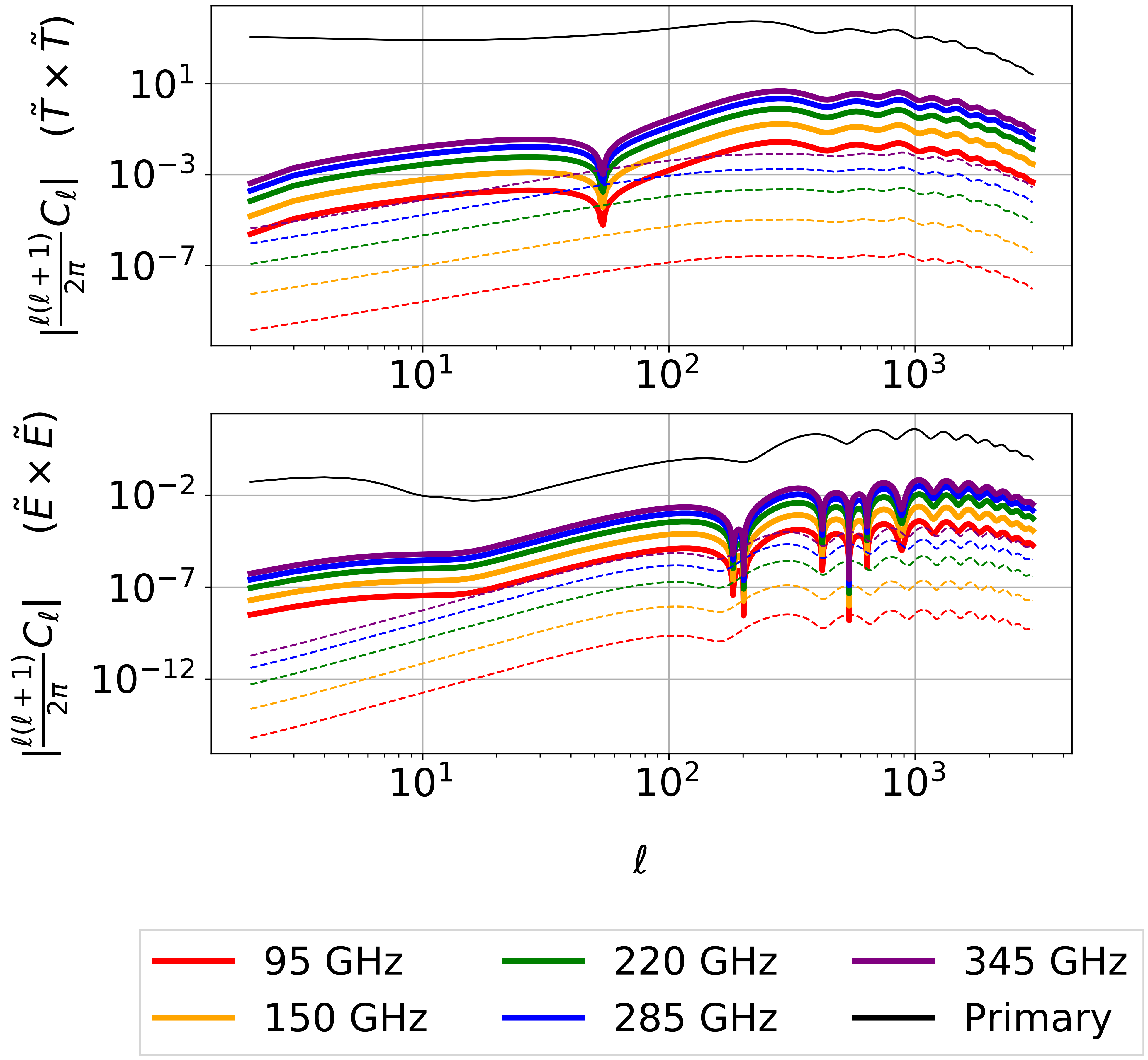




📖 Remazeilles+ JCAP 2024

Anisotropic CMB spectral distortions

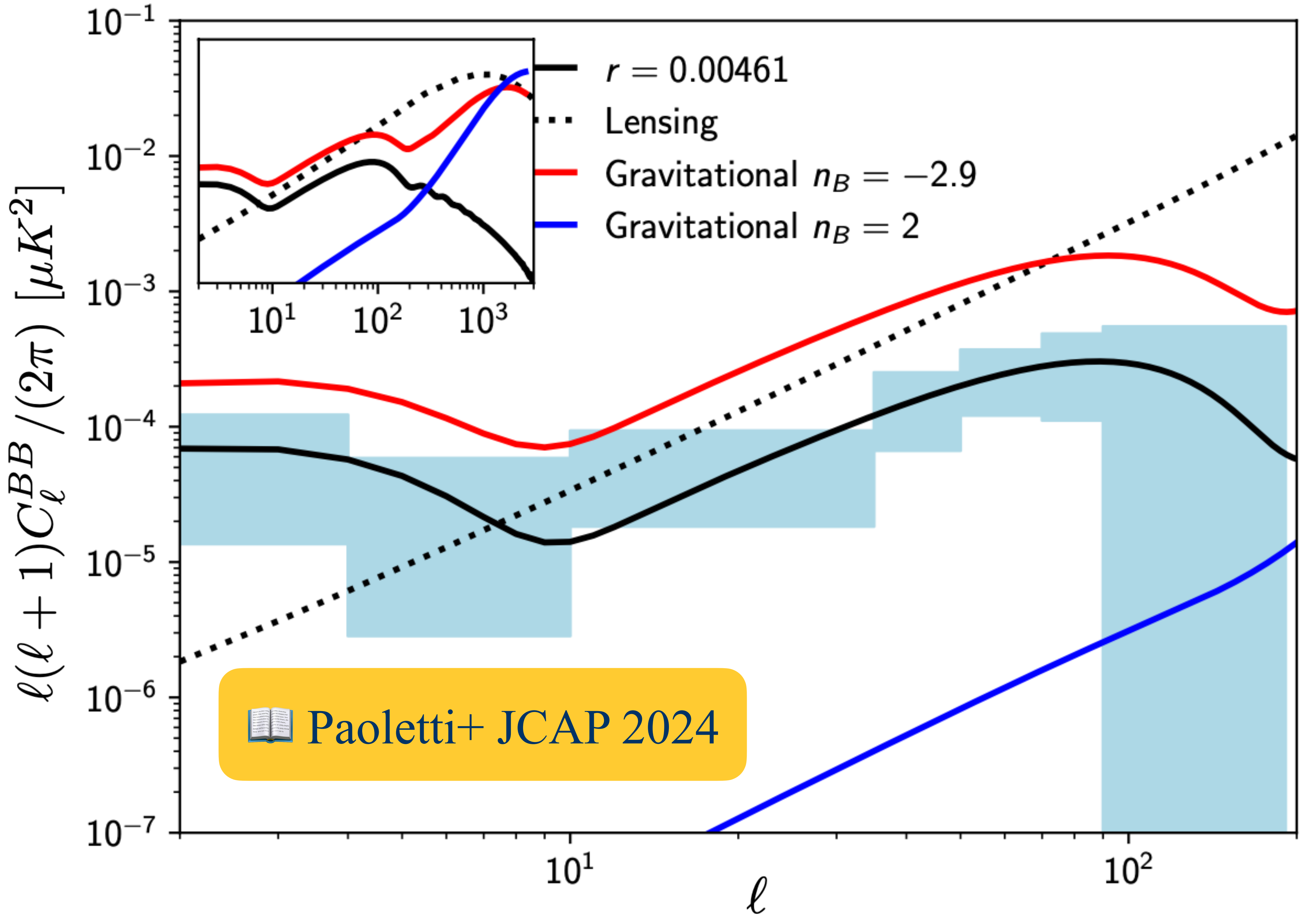
- *LiteBIRD* will be sensitive to any **spatially-varying CMB spectral distortion**, beyond the SZ effect
  - **Rayleigh scattering**. *LiteBIRD* will have sensitivity to measure at **25-sigma** (📖 Beringue et al. 2021) the frequency-dependent CMB anisotropies due to Rayleigh scattering by HI at the LSS
    - ➡ Such a detection would allow to derive improved constraints on **N_{eff}** and **$\sum m_\nu$**
  - **μ distortion**. *LiteBIRD* can detect an anisotropic μ distortion induced by non-Gaussian fluctuations induced during inflation
    - ➡ This would offer a power test of inflation at its onset
  - **Axion decay**. *LiteBIRD* can look for polarized spectral distortions produced by resonant conversion of axions into photons by the Galactic magnetic field



📖 Dibert+ PhysRevD 2022

Constraints on primordial magnetic fields

- Primordial magnetic fields (PMFs) affect the CMB via different effects:
  - **Gravitational effects** with magnetically-induced perturbations
  - Impact on the **ionization history** of the Universe due to their post-recombination dissipation
  - Induce a **Faraday rotation** of the CMB polarization
  - **Non-Gaussianity** induced in the CMB polarization anisotropies
- *LiteBIRD*:
  - Is a **sensitive probe** to PMFs through all these effects, thanks mainly to its remarkable sensitivity in polarization
  - Will **break the nG threshold** improving current upper limits by a factor of ~ 3
  - Will be able to **univocally identify the PFMs contribution to CMB** by joining all these effects together
  - Will allow a detection of **nG fields** with high significance

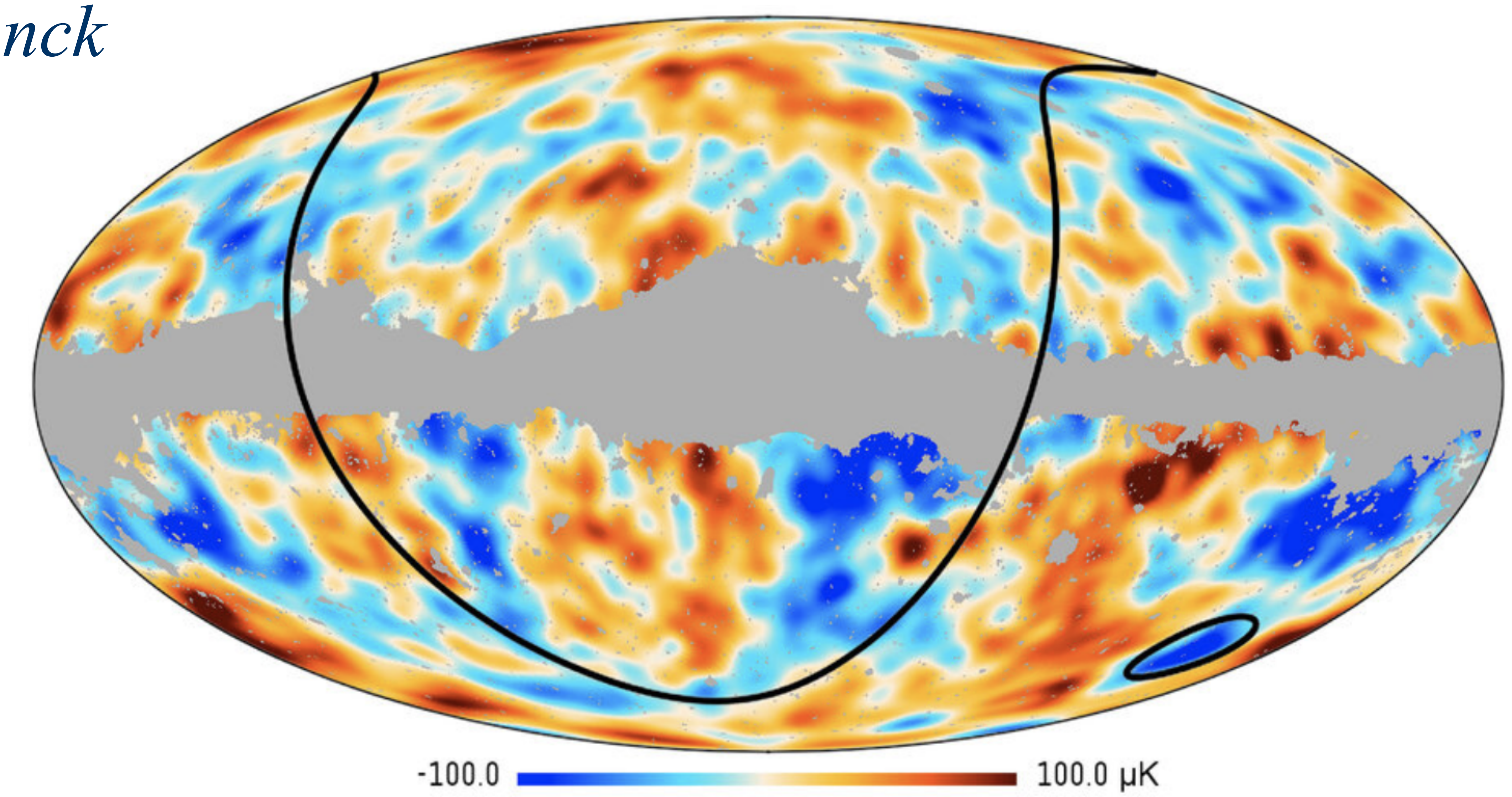


📖 Paoletti+ JCAP 2024

Upper limits on PMF amplitude for n_B = -2.9	
Gravitational effect	$B_{1\mathrm{Mpc}} < 0.8$ nG
Ionization history	$\sqrt{\langle B^2 \rangle} < 0.7$ nG
Faraday rotation	$B_{1\mathrm{Mpc}} < 3.2$ nG
Non-Gaussianities	$B_{1\mathrm{Mpc}} \lesssim 1$ nG

Confronting statistical anomalies with polarization

- Various so-called anomalies have been found in *WMAP* and *Planck* temperature data that exert a mild tension against the ΛCDM cosmological model:
  - anomalously low temperature variance
  - a lack of power on large angular scales
  - a lack of correlation at large angular scales
  - a hemispherical asymmetry in power on the sky
  - the alignment of the quadrupole and octopole moments
  - parity asymmetry in the power associated with even/odd mode
  - an anomalous "Cold Spot" on a scale of ~ 10°



Credit ESA/Planck Collaboration

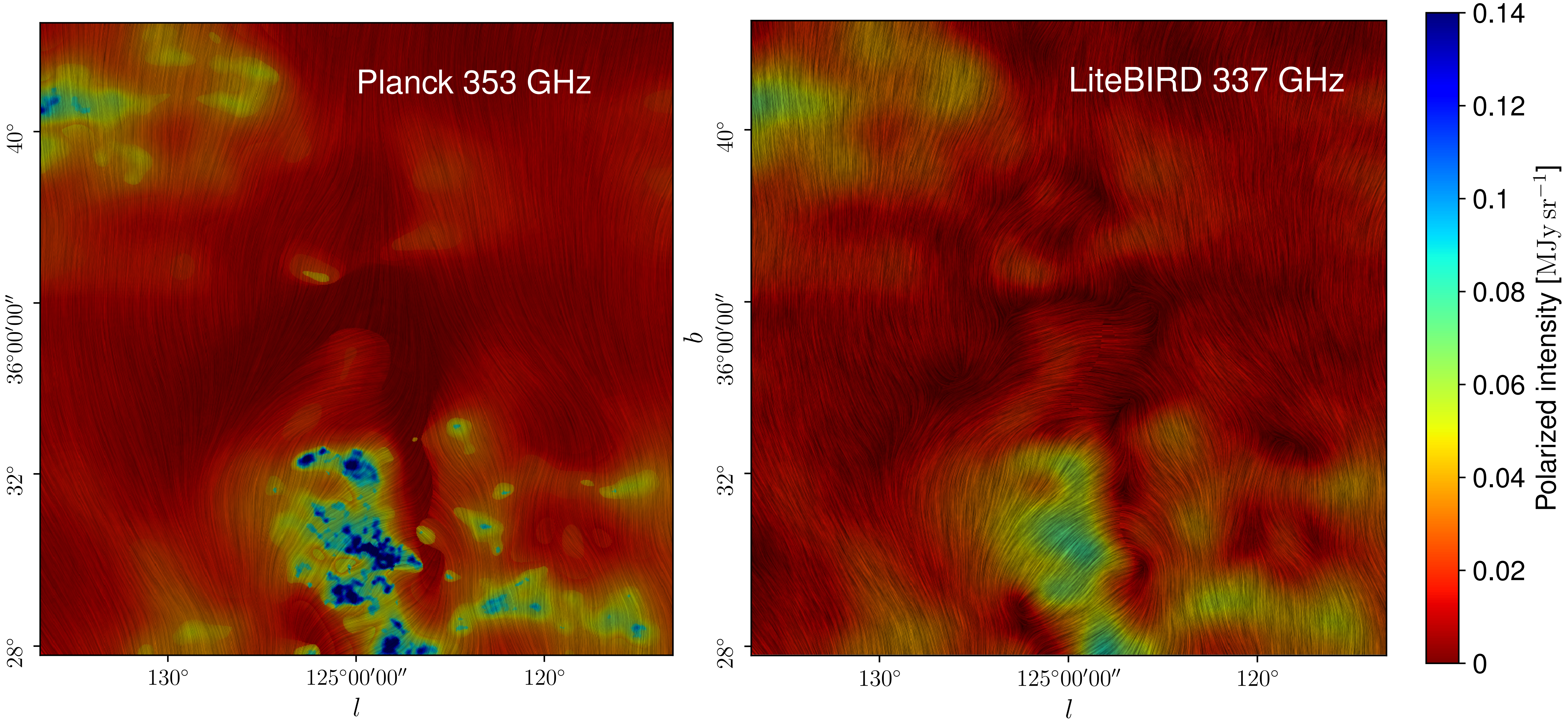
- Given their modest statistical significance, these could simply be statistical flukes. However, they may also be hints of **new physics** beyond the standard model.
- Polarized CMB anisotropies provide independent information on the fluctuations that source the temperature anisotropy and therefore a cross-check of the detected anomalies avoiding the look-elsewhere effect.
- ***LiteBIRD E*-mode polarization sky maps will allow further tests** at close to the cosmic-variance level of sensitivity. The fluke hypothesis can be assessed using temperature × *E*-mode statistics. Anomalies seen directly in *E* modes will strongly challenge the ΛCDM model.

📖 Banday+ JCAP 2025

Galactic astrophysics

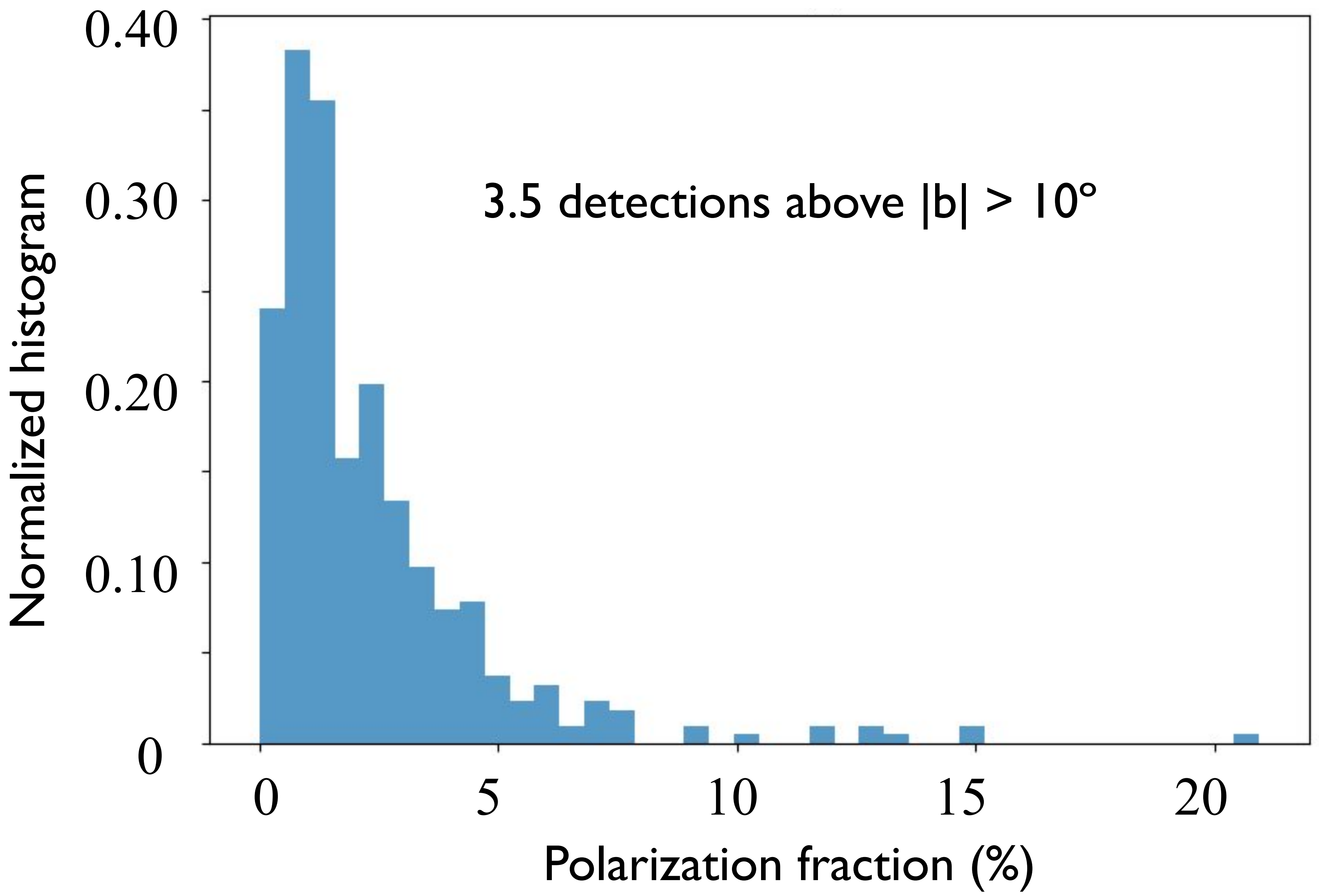
- *LiteBIRD* will provide 12 high-sensitivity polarization full-sky maps from 40 to 402 GHz
- Sensitivity improved by a factor of 5 at 40 GHz and 10 at 402, with respect to Planck
- Gain in spectral resolution

- **Wealth of Galactic science possible**:
  - Geometry of the Galactic magnetic field
  - Interstellar turbulence
  - Dust composition
  - Grain alignment
  - Cold clumps
  - Geometry of synchrotron-bright loops
  - SED of the synchrotron emission
  - Nature of AME and spectral variations...
  - … and many others!



Polarized Compact Source Catalogues

- Production of a **unique multi-frequency all-sky catalogue of polarized compact sources** significantly improving Planck catalogues
- Possibility to produce an Early (Launch+6 months) and a Full Mission catalogue
- Study the impact of resolved and unresolved polarized compact source contamination in CMB analyses
- Possible **scientific outcomes** from these source catalogues
  - Probe magnetic field structures in radio and dusty galaxies
  - Constrain AGN structure and properties through number counts
  - Measure polarization properties of faint galaxy populations via stacking
  - Trace evolution of galactic-scale magnetic fields beyond the Milky Way
  - Enable multi-wavelength studies of galaxy dust and magnetism through cross-survey correlations
  - Constrain polarization properties of the cosmic infrared background



- Support to **mission operations**
  - Monitor pointing accuracy and calibration with astrophysical sources
  - Monitor flaring transient events to minimize impact on TOD and map-making algorithms

Foreground cleaning

Foreground modelling

- **Synchrotron**: power law with spatially-varying index

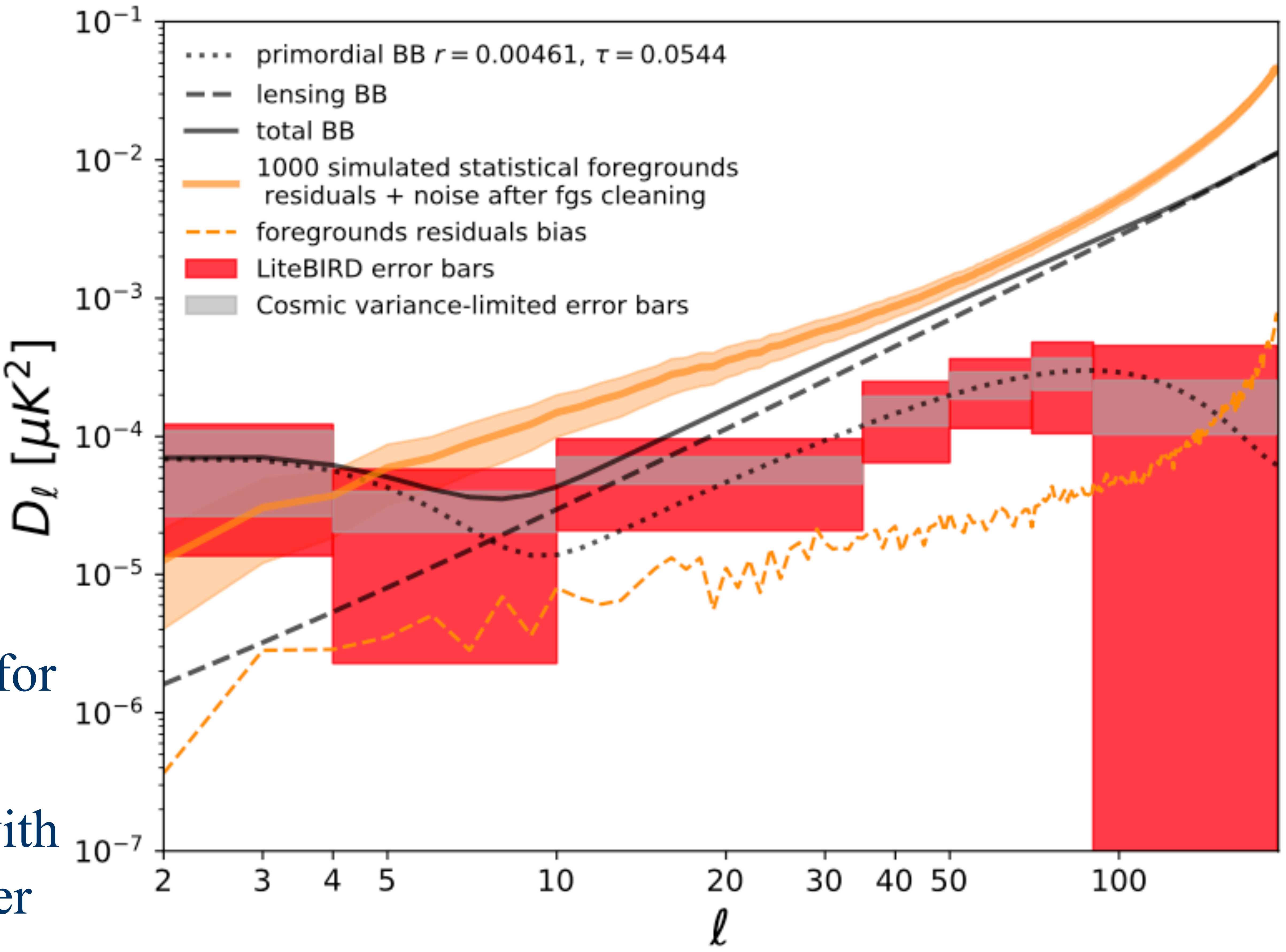
$$[Q_\mathrm{s}, U_\mathrm{s}]\,(\hat{n},\nu) = [Q_\mathrm{s}, U_\mathrm{s}]\,(\hat{n},\nu_\star)\cdot\left(\frac{\nu}{\nu_\star}\right)^{\beta_\mathrm{s}(\hat{n})}$$

- **Dust**: modified blackbody

$$[Q_\mathrm{d}, U_\mathrm{d}]\,(\hat{n},\nu) = [Q_\mathrm{d}, U_\mathrm{d}]\,(\hat{n},\nu_\star)\cdot\left(\frac{\nu}{\nu_\star}\right)^{\beta_\mathrm{d}(\hat{n})-2}\frac{B_\nu\left(T_\mathrm{d}(\hat{n})\right)}{B_{\nu_\star}\left(T_\mathrm{d}(\hat{n})\right)}$$

- **7 parameters** in each sky patch
- **Multi-Clustering** interface with foregrounds data to account for spatial variability (📖 Puglisi et al. 2022, Carones et al. 2023)
- Current baseline for fitting foregrounds: 12×(N_side)^2 patches with N_side between 8 and 64, depending on the foreground parameter
- Performance verification through FGBuster derived XForecast procedure

Impact of foreground residuals



📖 LiteBIRD collaboration PTEP 2023

Foreground cleaning

- "Multi-Clustering technique" (extension of xForecast)
- Distribution of the recovered *r* in 1000 simulations with input $r = 0$, with and without foreground residuals
- Bias from foreground (PySM `d1s1`) residuals is found to be small
- Final value: **$r = (3.3 \pm 6.2)\times10^{-4}$**