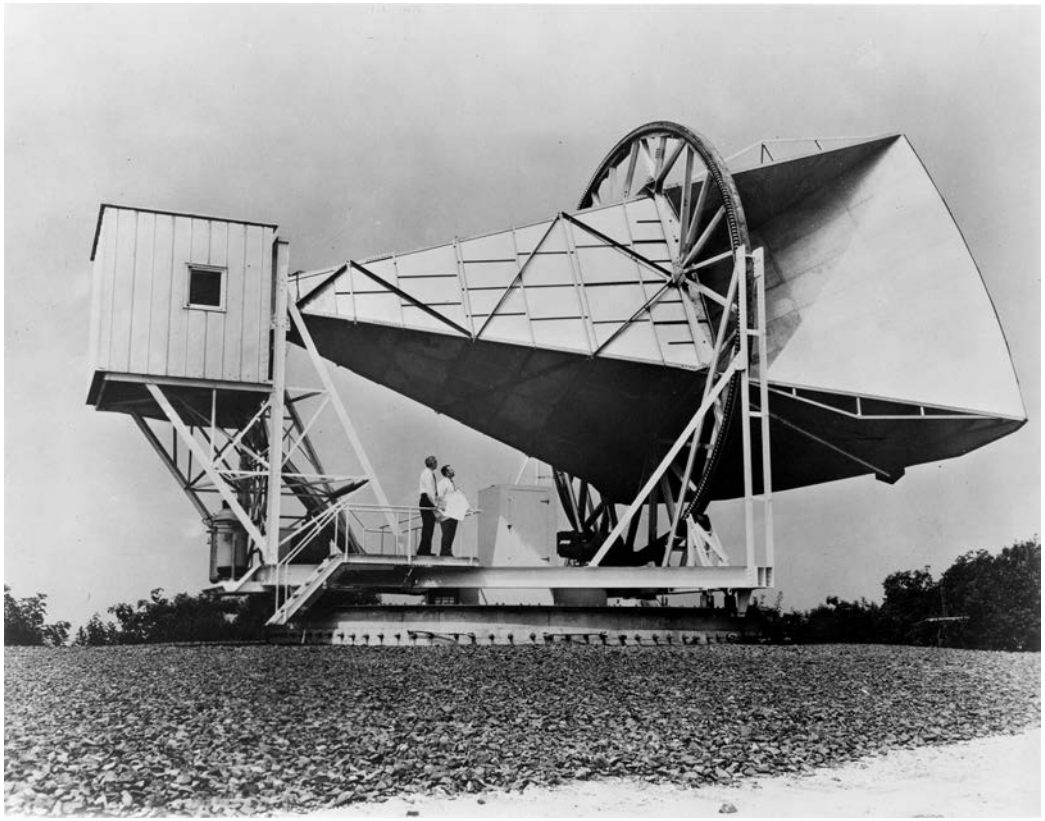
LiteBIRD

T. Matsumura, for LiteBIRD collaboration
Kavli IPMU, the University of Tokyo/ISAS JAXA

CMB@60, Torino, Italy, 2025 May 28-30

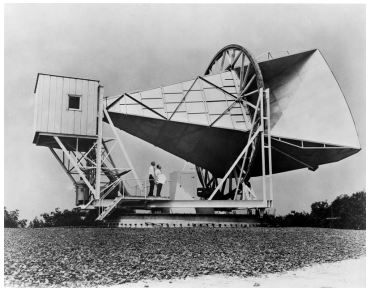
LiteBIRD in the context

Happy 60th anniversary to the discovery of the CMB by Penzias and Wilson in 1965.

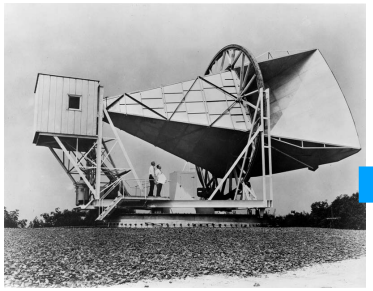


LiteBIRD in the context

Penzias and Wilson
1965



LiteBIRD as part of ground/space CMB observatories



Penzias and Wilson
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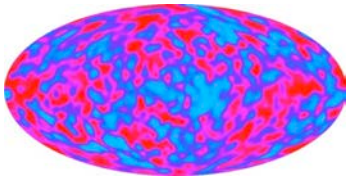
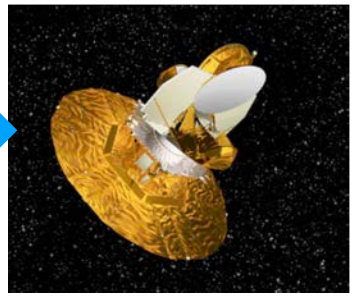
NASA COBE
1989





NASA WMAP
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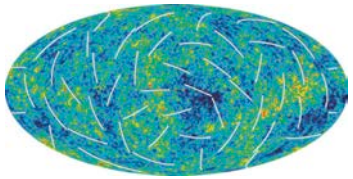

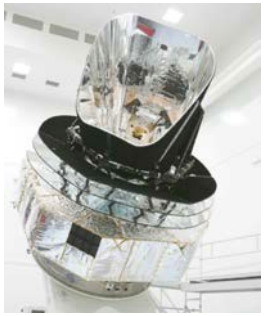

ESA Planck
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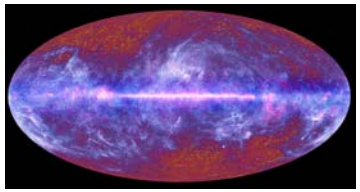

Many ground and balloon telescopes play vital roles in parallel.

LiteBIRD as part of ground/space CMB observatories

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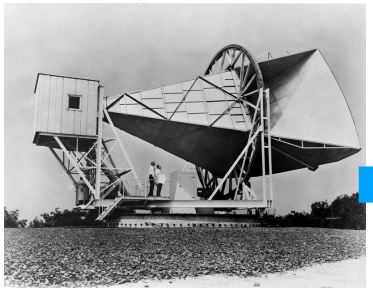

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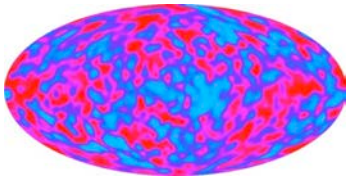

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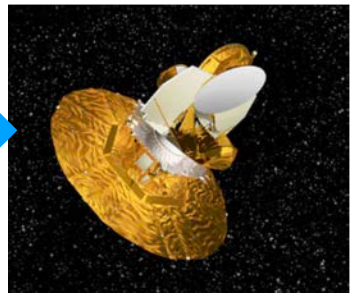

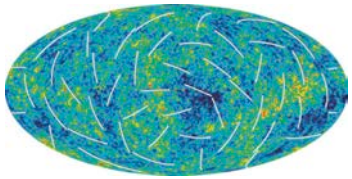

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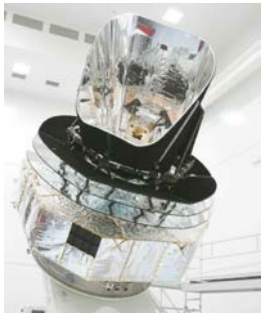
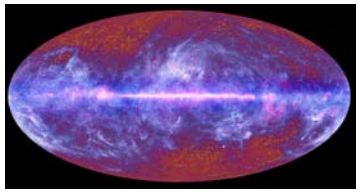
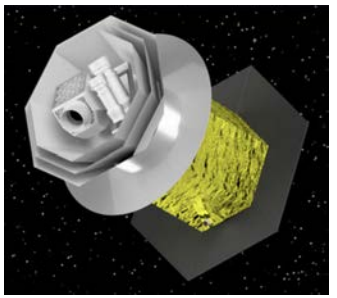
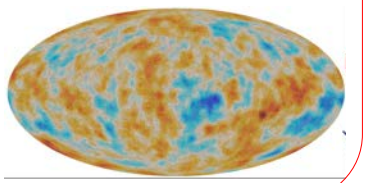




JAXA LiteBIRD early 2030s





Many ground and balloon telescopes play vital roles in parallel.


LiteBIRD

LiteBIRD Joint Study Group

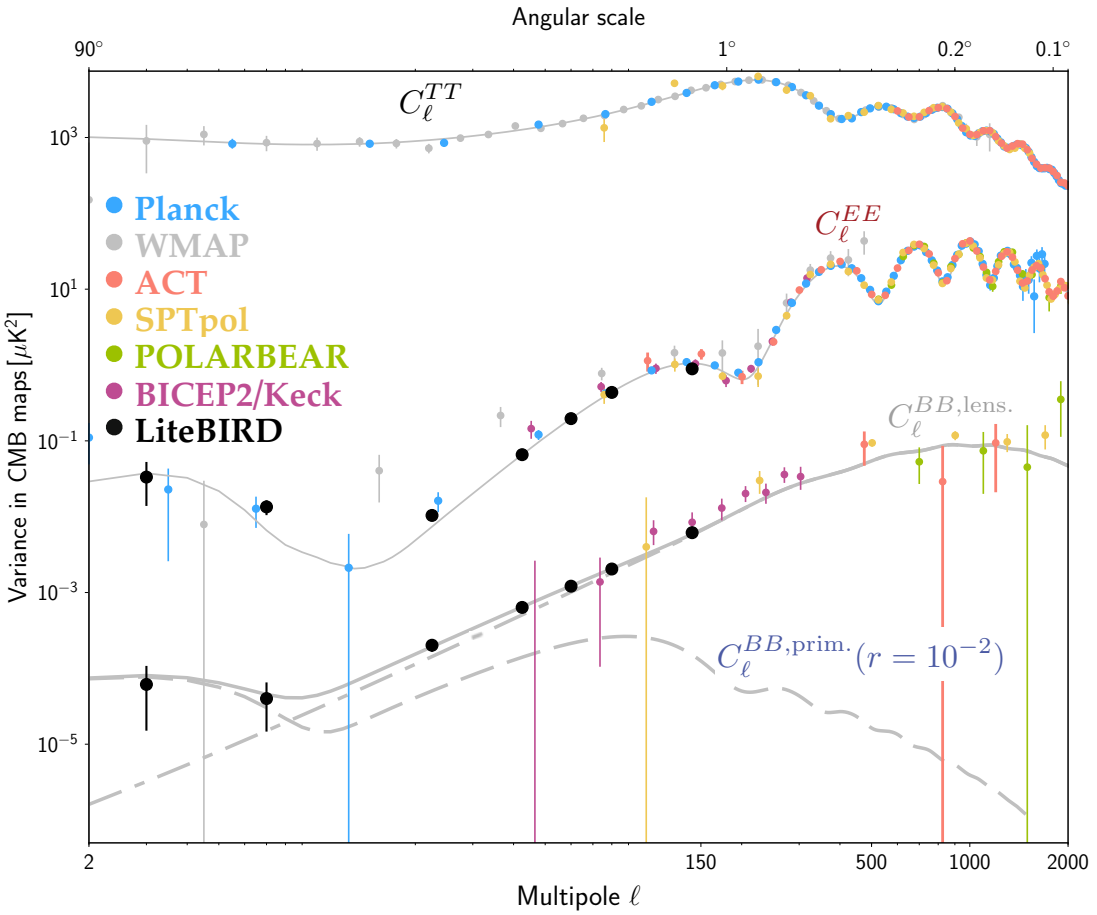
Close to 400 researchers from **Japan**, **North America,** and **Europe**

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

LiteBIRD Global F2F meeting
January 2025 at Kashiwa Japan

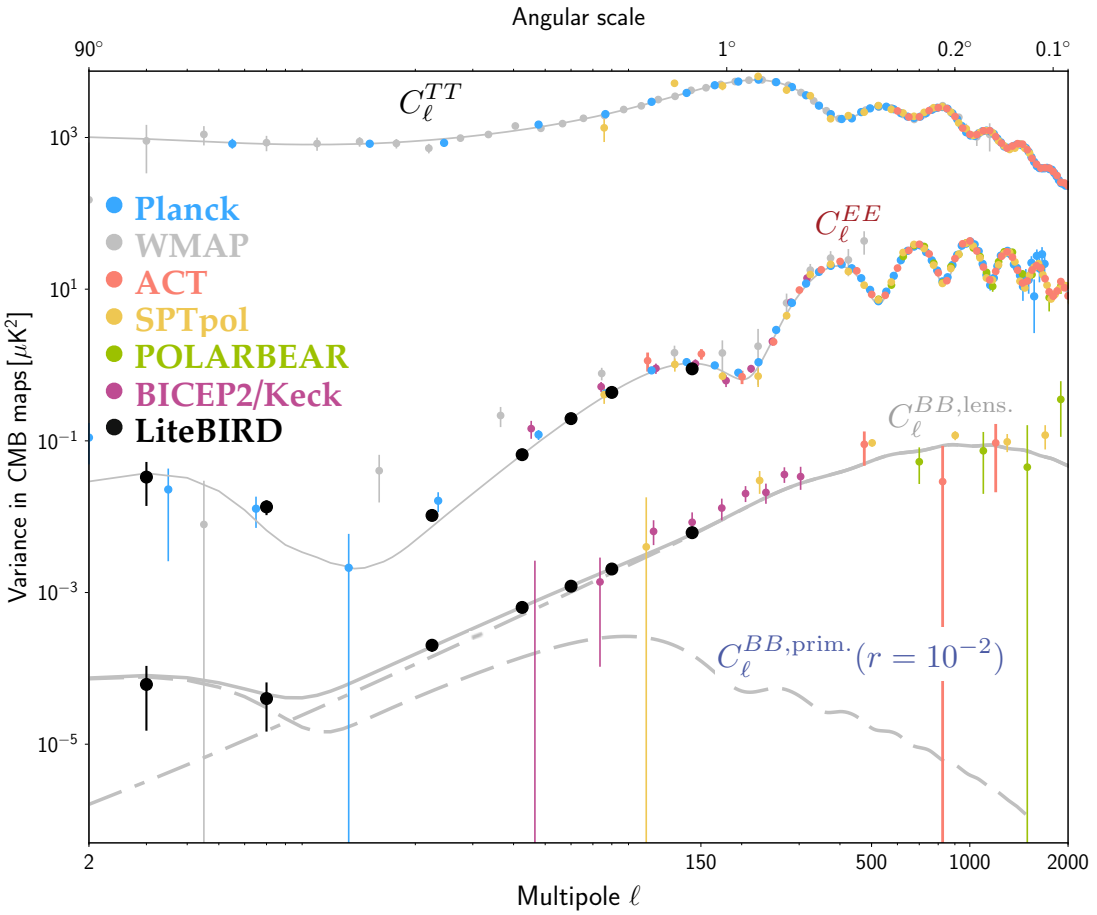
LiteBIRD main scientific objectives

- 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)



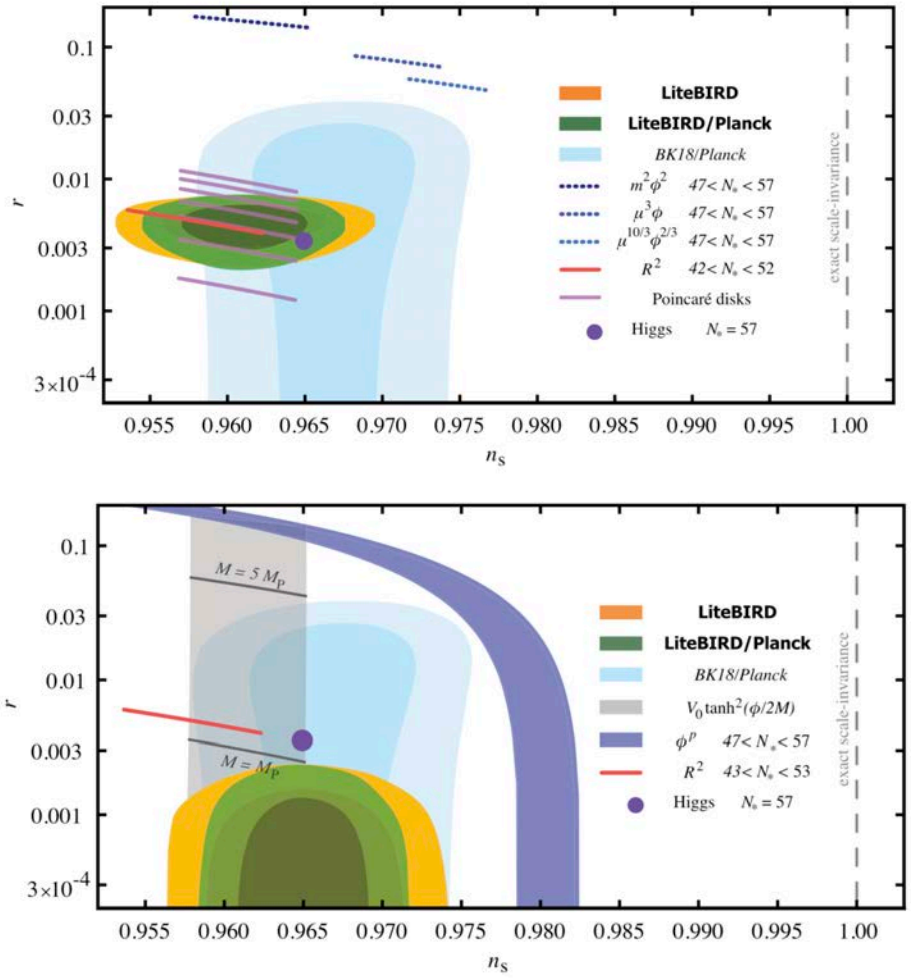
LiteBIRD main scientific objectives

- L1-requirements (no external data):
  - For $r = 0$, **the total uncertainty of $\delta r < 0.001$**
  - For $r = 0.01$, 5-σ detection of the reionization ($2 < \ell < 10$) and recombination ($11 < \ell < 200$) peaks independently



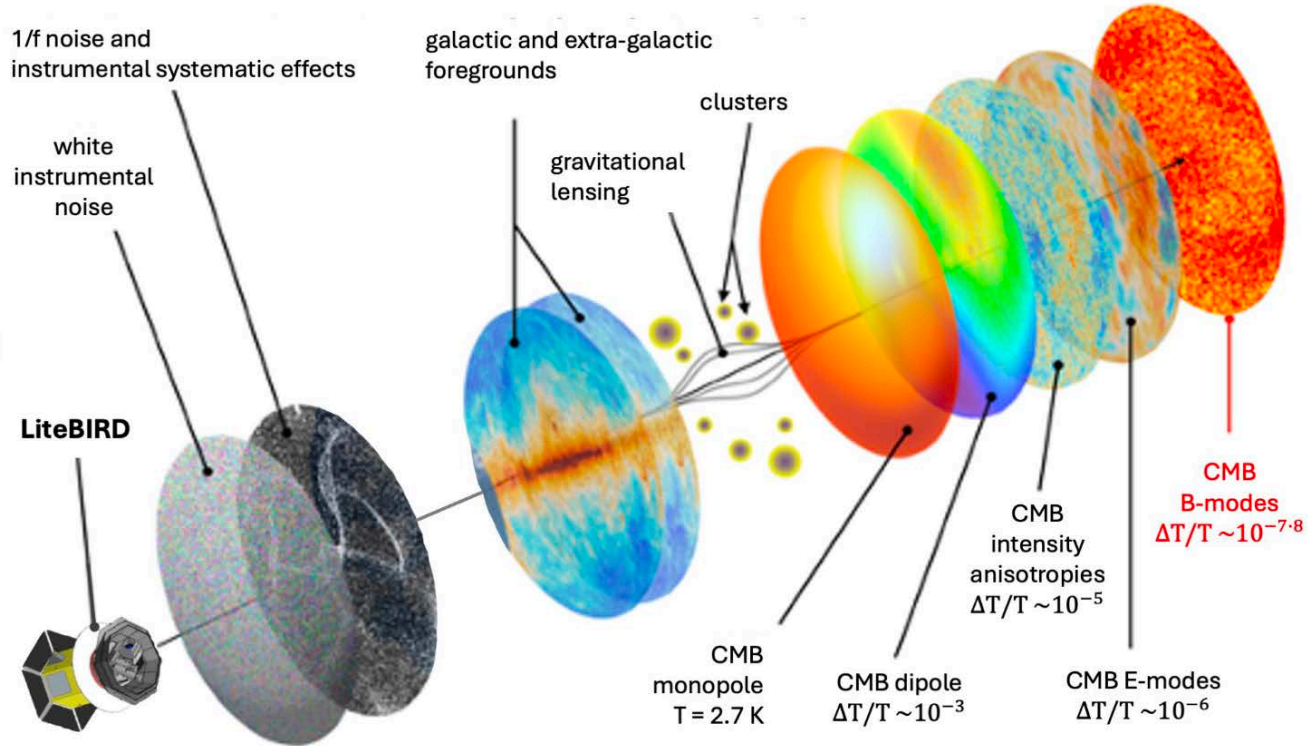
LiteBIRD constraints on inflation

- 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 $\mathcal{M} > M_p$
  - 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



The challenge of B-modes detection

- The *B*-mode signal is expected to have an amplitude at least 3 orders of magnitude below the CMB temperature anisotropies
- LiteBIRD is targeting a sensitivity level in polarization ~30 times better than Planck
- This extremely good statistical uncertainty must go in parallel with exquisite control of:
  1. **Instrument systematic** uncertainties
  2. **Galactic foreground** contamination
  3. **"Lensing B-mode signal"** induced by gravitational lensing

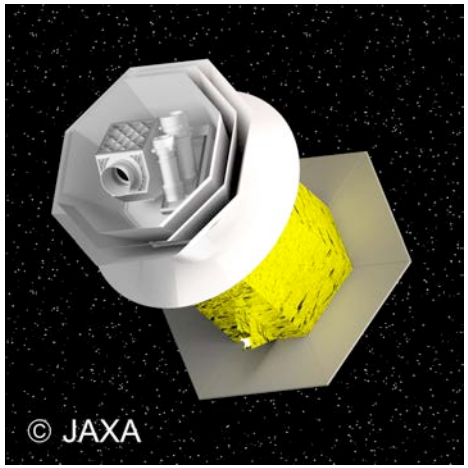


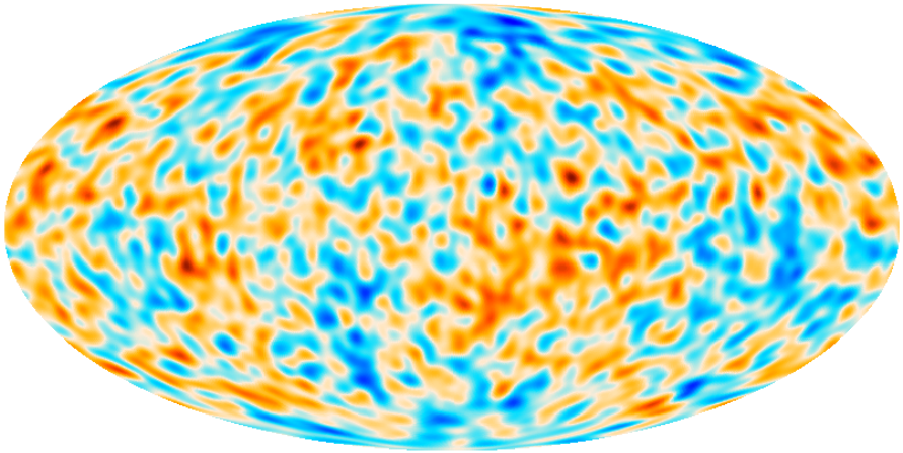
T. Ghigna et al., SPIE (2024)
(Image credit: Josquin Errard)

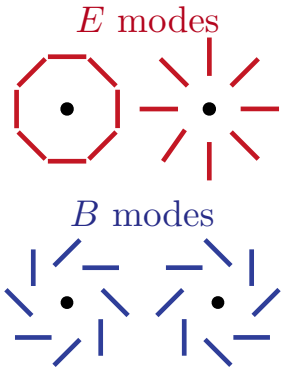
LiteBIRD overview

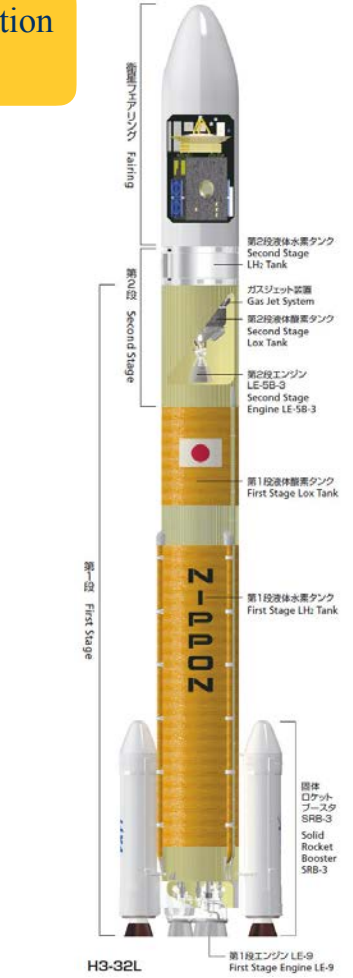
- JAXA's L-class mission was selected in May 2019 to be launched by JAXA's H3 rocket.
- **All-sky 3-year survey**, from Sun-Earth Lagrangian point L2
- Large frequency coverage (**40–402 GHz**, 15 bands) at **70–18 arcmin** angular resolution for precision measurements of the **CMB *B*-modes**
- Final combined sensitivity: **2.2 μK·arcmin**

📖 LiteBIRD collaboration PTEP 2023







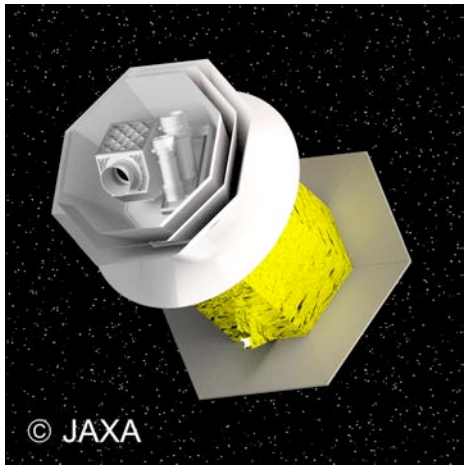


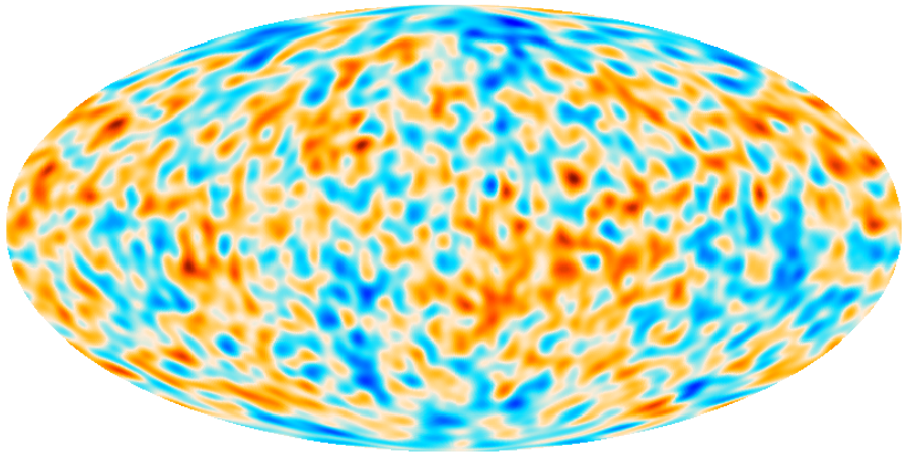
LiteBIRD overview

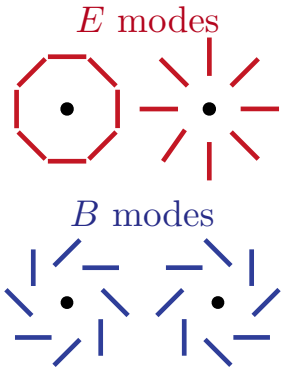
LiteBIRD reformation phase

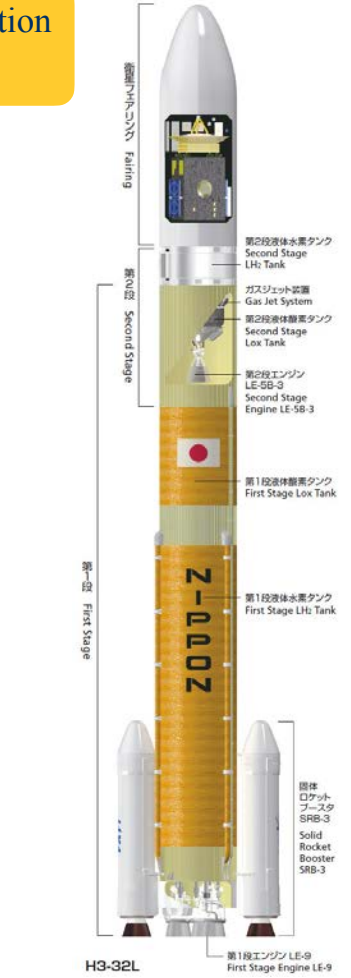
- After the ISAS/JAXA mission definition review, LiteBIRD is under rescope studies to consolidate the mission's feasibility with the same scientific objectives.
- The LiteBIRD collaboration will spend approximately one year (~ late 2025) on the studies of the reformation plan.

📖 LiteBIRD collaboration PTEP 2023







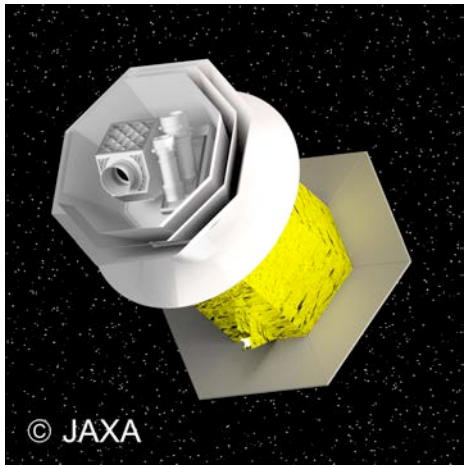


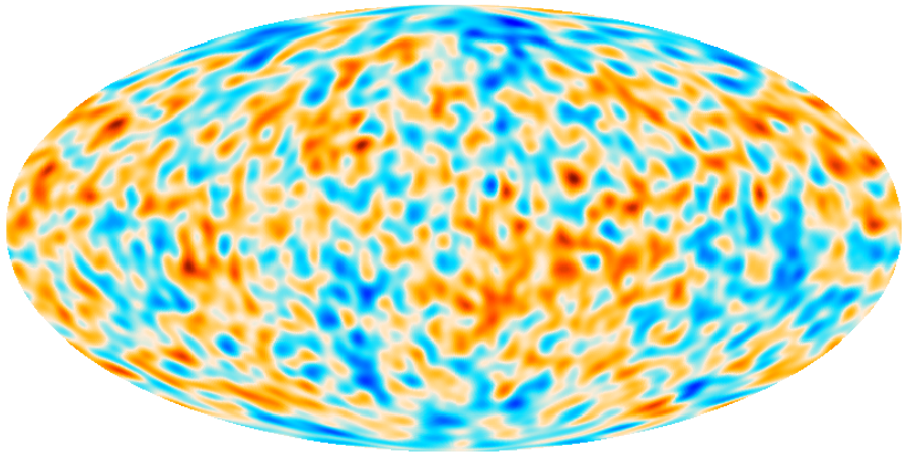
LiteBIRD main scientific objectives

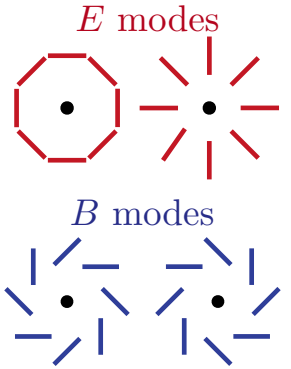
LiteBIRD delivers the full-sky polarization maps at millimeter bands.

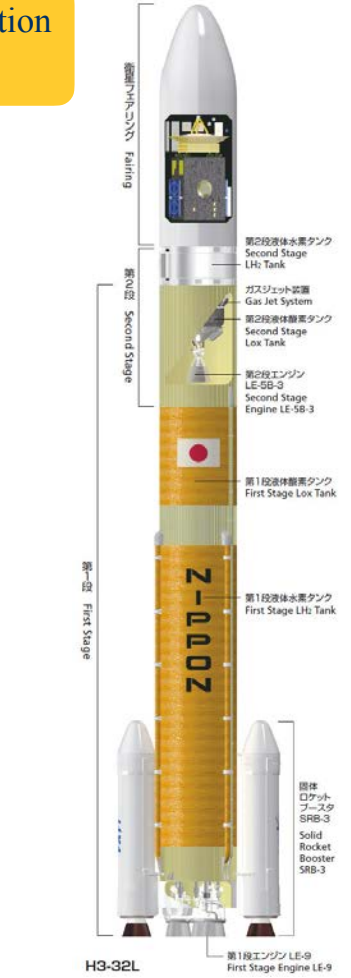
📖 LiteBIRD collaboration PTEP 2023

They provide rich science outcomes as we have witnessed in COBE, WMAP, and Planck in the community.









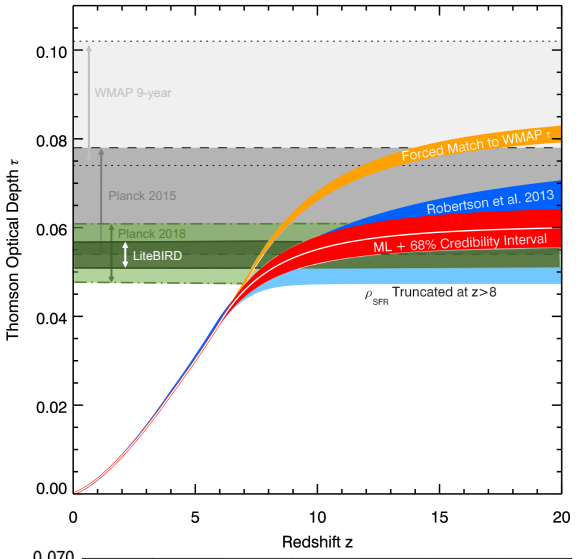
LiteBIRD broad science outcomes

- The mission specifications are driven by the required sensitivity on r
- Meeting those sensitivity requirements would allow to address other important scientific outcomes, e.g.

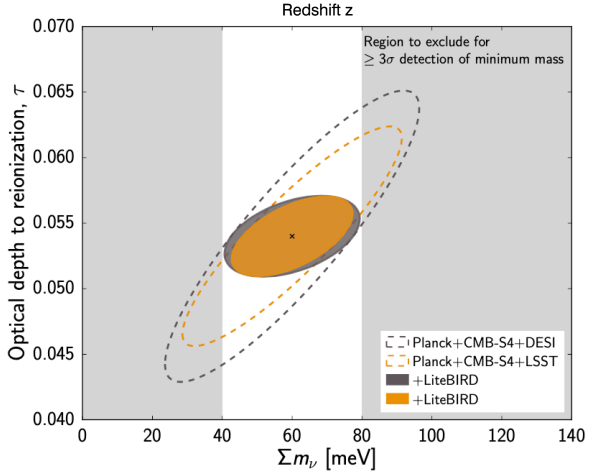
1. Characterize the B-mode power spectrum and search for source fields (e.g. scale-invariance, non-Gaussianity, parity violation, …)
2. Power spectrum features in polarization
   - Large-scale ***E*-modes**
   - **Reionization** (improve $\sigma(\tau)$ by a factor of 3)
   - **Neutrino mass** ($\sigma(\sum m_\nu) = 12$ meV)
3. Constraints on **cosmic birefringence**
4. **SZ effect** (thermal, diffuse, relativistic corrections)
5. Constraints on **primordial magnetic fields**
6. Elucidating **anomalies**
7. **Galactic science**
   - Characterizing the foreground SED
   - Large-scale Galactic magnetic field
   - Models of dust polarization
   - Polarized compact/point sources

Optical depth, reionization and neutrino masses

- LiteBIRD will provide a cosmic-variance limited measurement of the ***E*-mode** power spectrum at large scales ($2 < \ell < 200$)
- This will lead to improved constraints on:
  - **Reionization**
    - Cosmic-variance measurement of the **optical depth** to reionization $\Rightarrow \sigma(\tau) \approx 0.002 \Rightarrow \times 3$ improvement with respect to Planck (📖 Planck Int.Res. LVII, 2020)
    - Improved constraints on reionization history models: 35% improvement on the uncertainty of $\Delta(z_{\rm reion})$
  - **Neutrino masses**
    - $\times 2$ improvement on $\sigma(\sum m_\nu)$
    - $\sigma(\sum m_\nu) = 12$ meV $\Rightarrow 5\sigma$ detection for a minimum value of $\sum m_\nu = 60$ meV (allowed by flavour-oscillation experiments) or larger
    - Potentially allow to distinguish between the inverted neutrino mass ordering and the normal ordering



adapted from Robertson+2015



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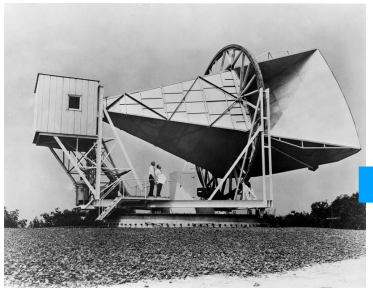

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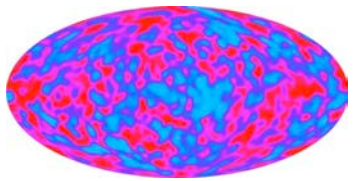

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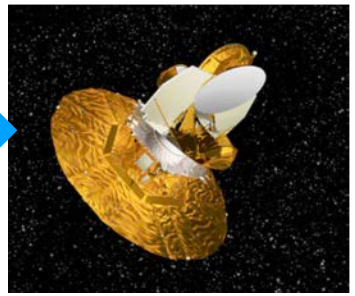

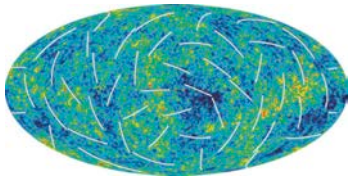

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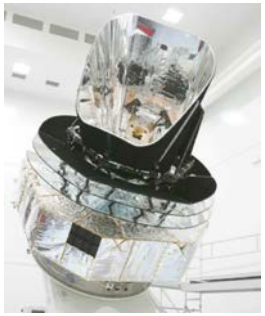
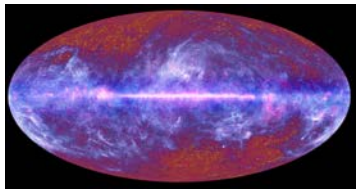
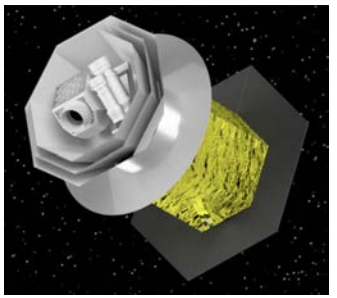
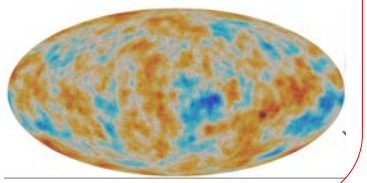




JAXA LiteBIRD
early 2030s





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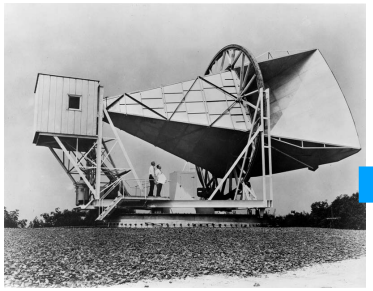

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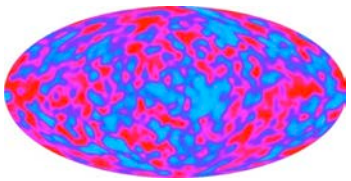

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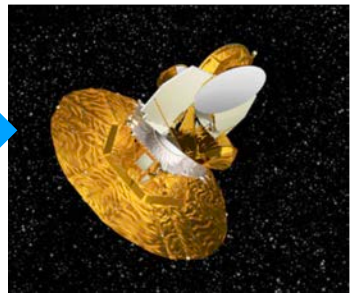

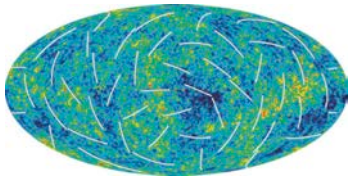

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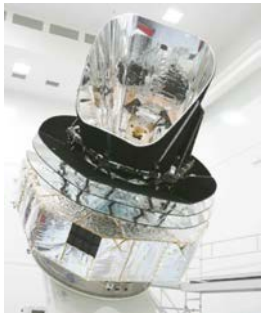

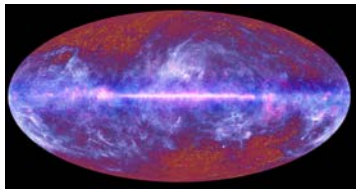

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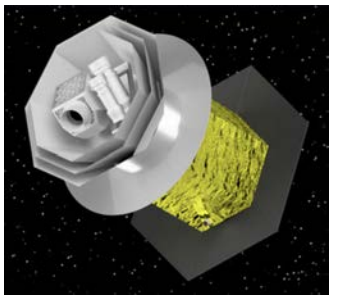
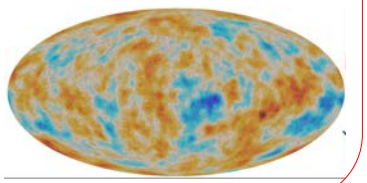
early 2030s





Many ground and balloon telescopes play vital roles in parallel.

Synergy

CMB telescopes from the ground in 2020s to 2030s

Summary

- LiteBIRD is JAXA's mission for precision measurement of the CMB B modes, under international collaboration with Europe, Canada, and the US. It is the only space CMB mission planned in the 2030s.
- It is currently under reformation until autumn 2025 to strengthen the mission in the procurement plan and its feasibility while maintaining the scientific objective.
- As a natural consequence of high-precision millimeter wave all-sky polarization maps, there are rich science outcomes on top of CMB B modes.
- We want to make LiteBIRD a meaningful step in observational cosmology. This includes enhancing the synergy with next-generation ground-based CMB telescopes and other initiatives.
- The international team is actively conducting reformation investigations so as not to lose the opportunity to conduct the CMB B-mode observations in space in the 2030s.