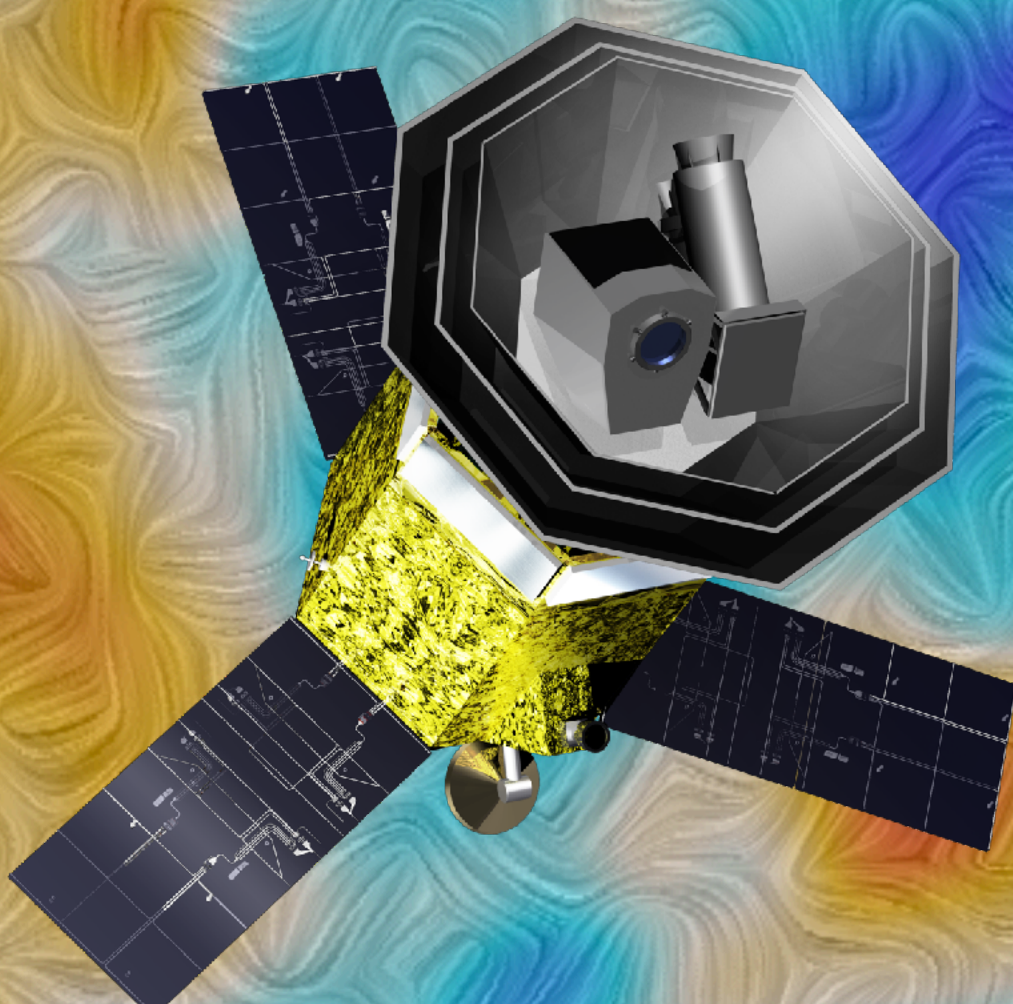
LiteBIRD

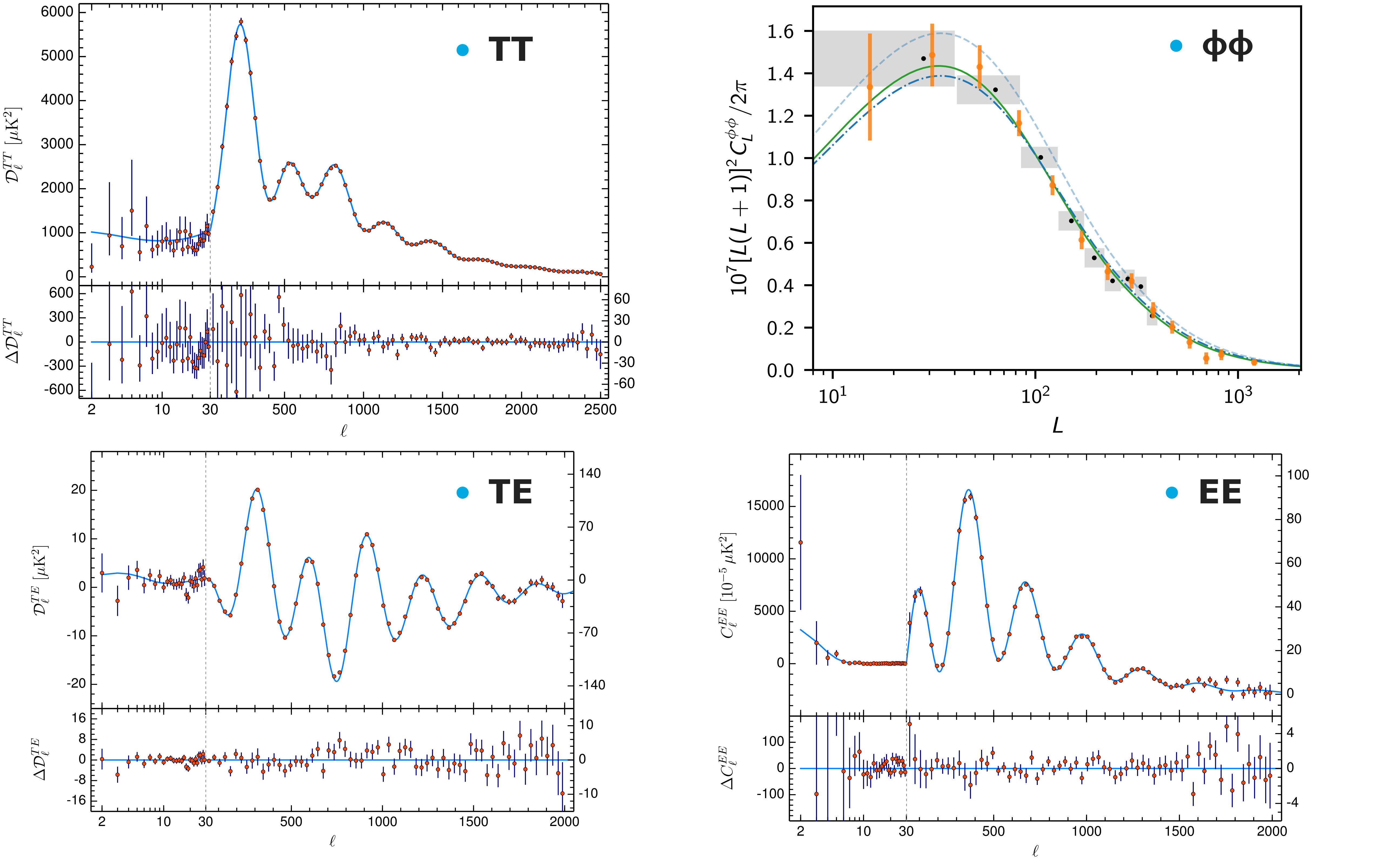


M. Tristram
on behalf of
the LiteBIRD Collaboration

TMEX2020

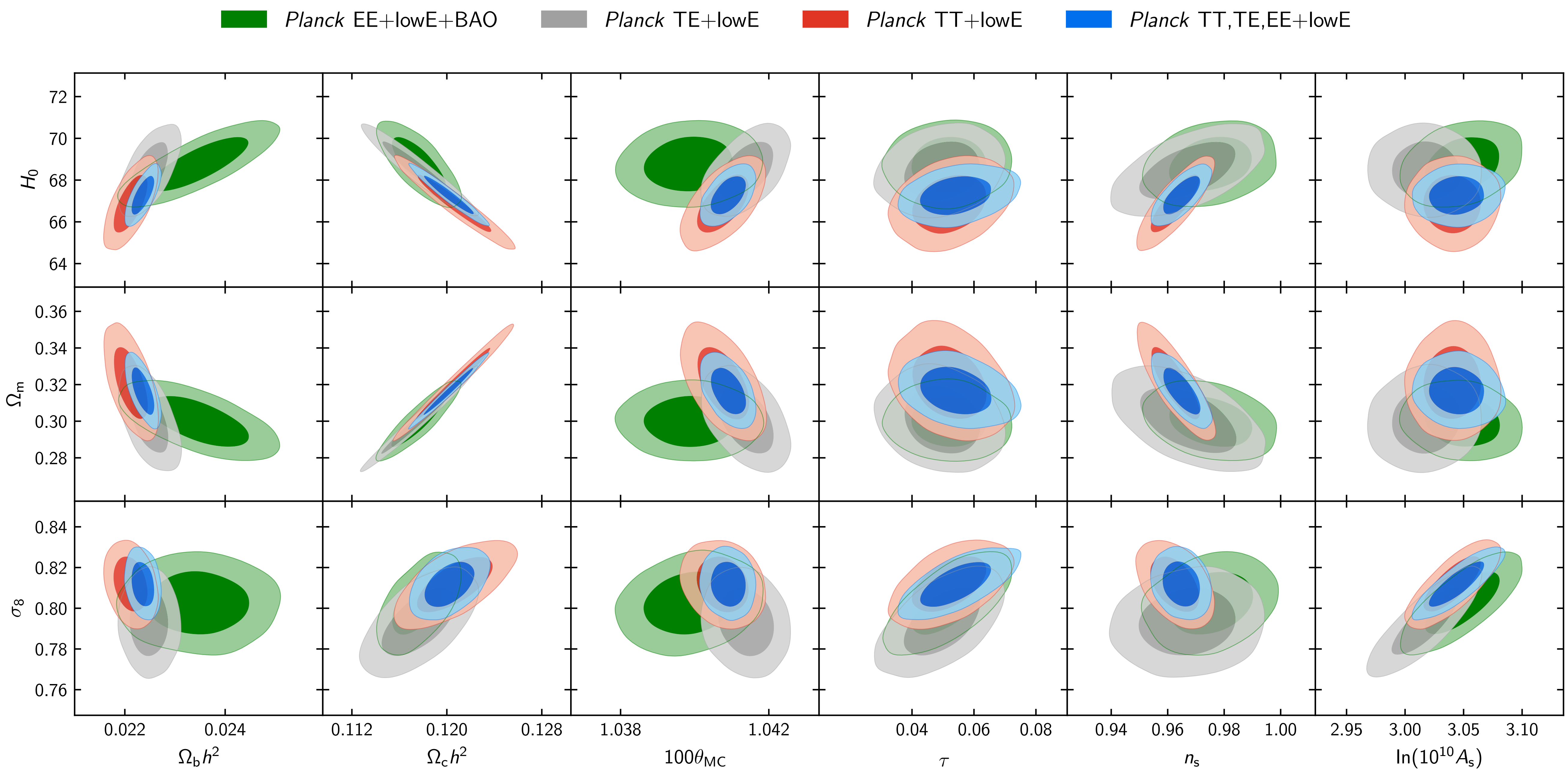
Planck

[Planck 2018 results. VI]
[Planck 2018 results. VIII]



ΛCDM

[Planck 2018 results. VI]



TE polarization spectra highly consistent with TT spectra

EE spectra also consistent but still noisier

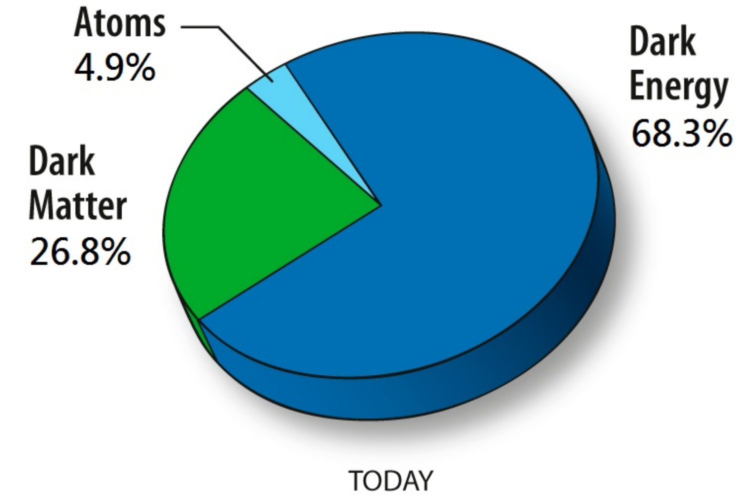
ΛCDM + extensions

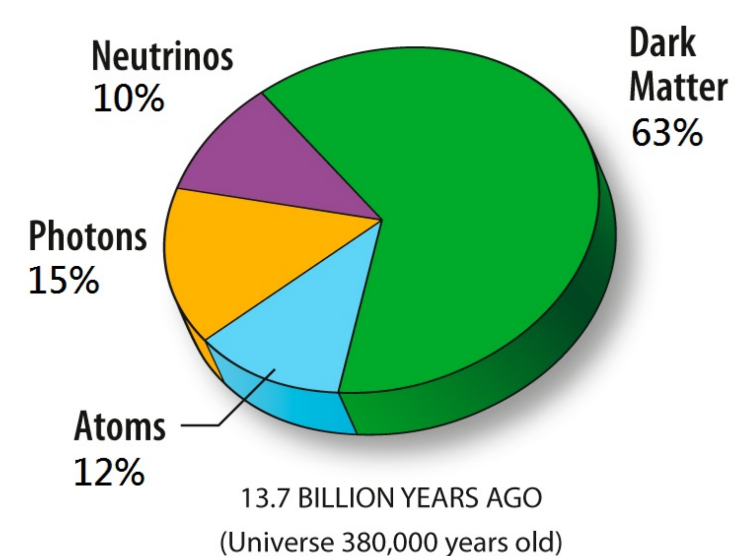
- **Consistency**
  The **CMB anisotropies** in temperature and polarisation (TT, TE, EE), **CMB lensing** ΦΦ, as well as **BAO**, **BBN**, and **SNIa** measurements are all consistent, among themselves and across experiments, within ΛCDM

- **Robustness**
  These probes allow many different checks of the robustness for the ΛCDM model and some of its extensions, including **flatness**, sum of **neutrinos masses** and **effective number**, **DM annihilation** limits, **dark energy** equation of state w(z), details of the **recombination** history ($A_{2s\to1}$, T_0, and also fundamental constants variation, or any energy input...)

- **Precision**
  This network of consistency tests is passed with **per cent** level precision but for relative **tensions** (including A_L, H_0, S_8)

Parameter	TT,TE,EE+lowE+lensing 68% limits	
$\Omega_b h^2$	0.02237 ± 0.00015	**0.7%**
$\Omega_c h^2$	0.1200 ± 0.0012	**1.0%**
$100\theta_{MC}$	1.04092 ± 0.00031	**0.03%**
τ	0.0544 ± 0.0073	**13%**
$\ln(10^{10} A_s)$	3.044 ± 0.014	**0.5%**
n_s	0.9649 ± 0.0042	**0.4%**





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what's next ?

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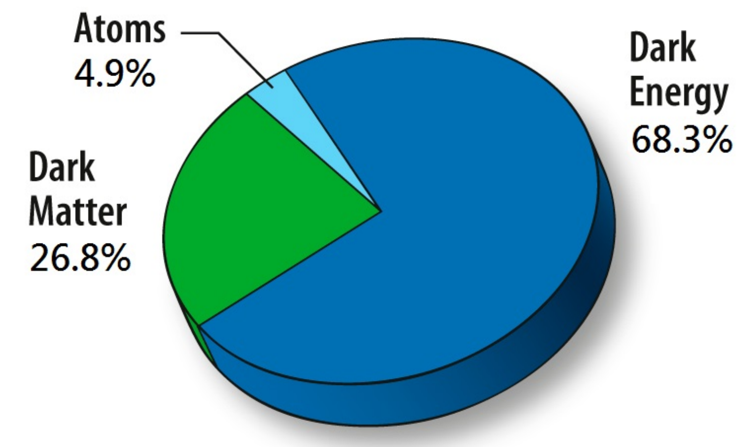
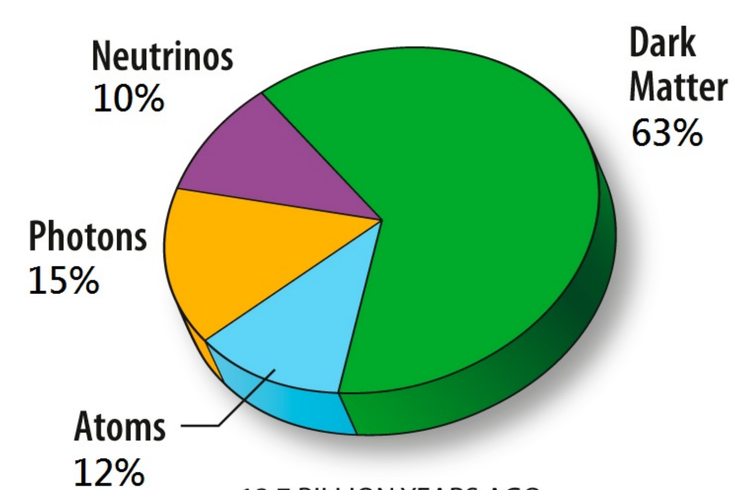


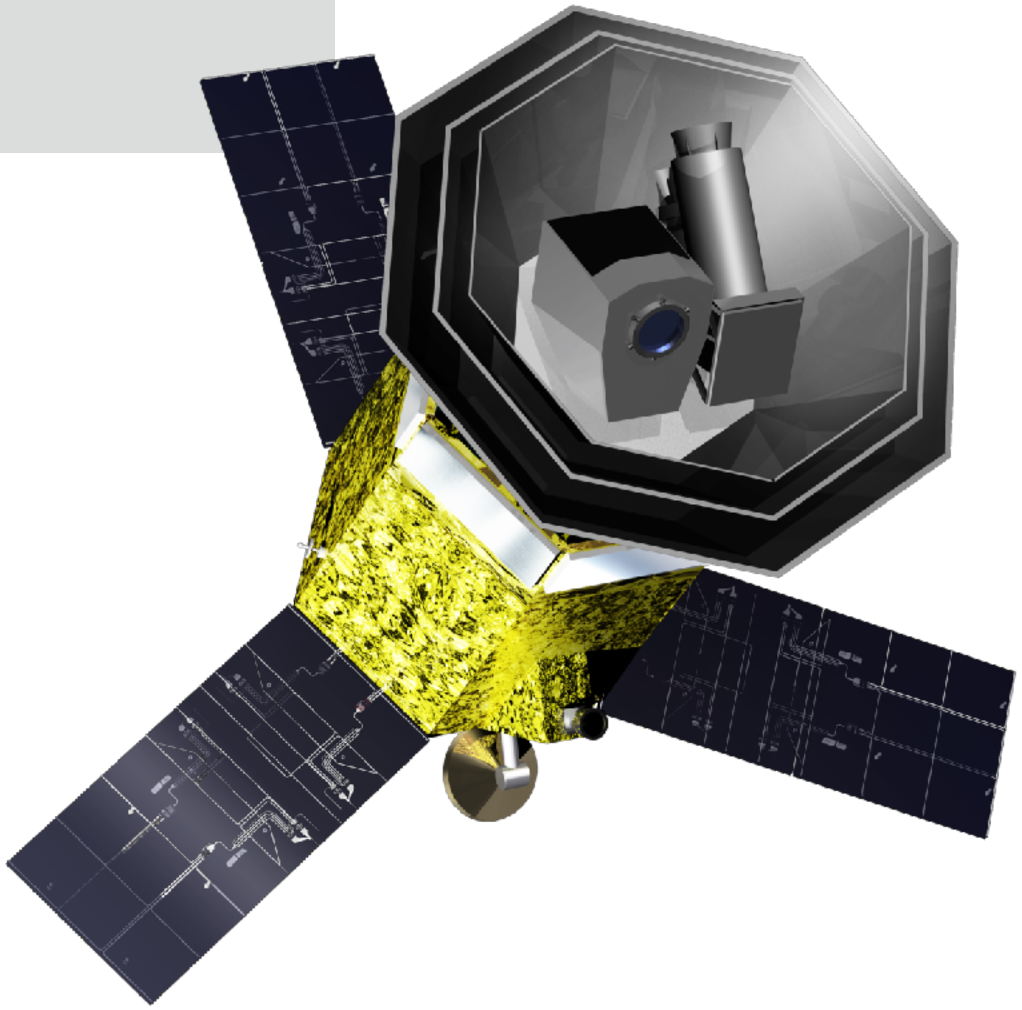
TODAY



13.7 BILLION YEARS AGO
(Universe 380,000 years old)

LiteBIRD Science outcomes

- Primordial gravitational waves from inflation
  - B-mode power spectrum
  - Full success
  - Extra success
  - Beyond the B-mode power spectrum

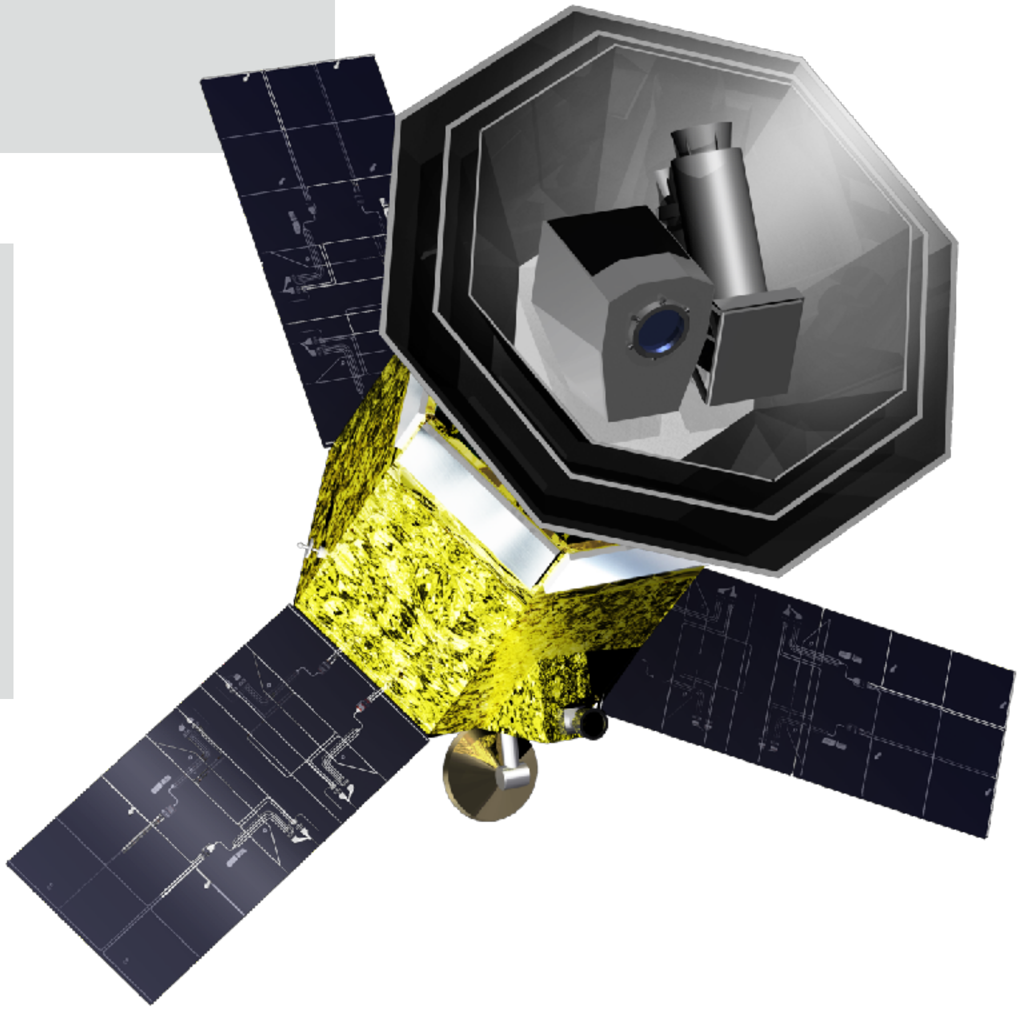


LiteBIRD Science outcomes

- Primordial gravitational waves from inflation
  - B-mode power spectrum
  - Full success
  - Extra success
  - Beyond the B-mode power spectrum

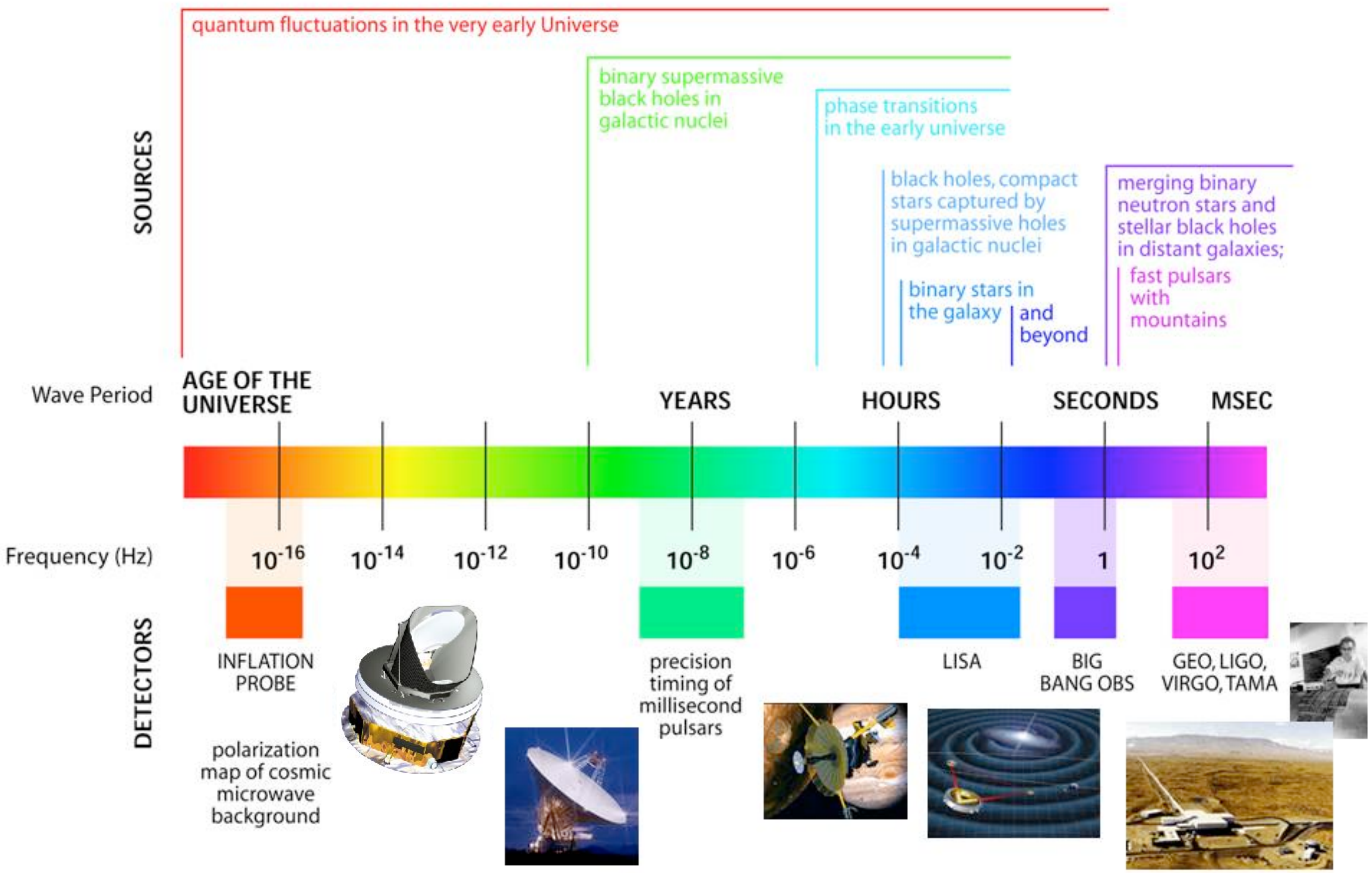
- Cosmological parameters with E polarisation
  - Optical depth and reionization of the Universe
  - Elucidating low-ℓ anomalies with polarization
- Galactic science
- Cosmic birefringence

- Mapping the hot gas in the Universe
- Anisotropic CMB spectral distortions
- Correlation with other data sets

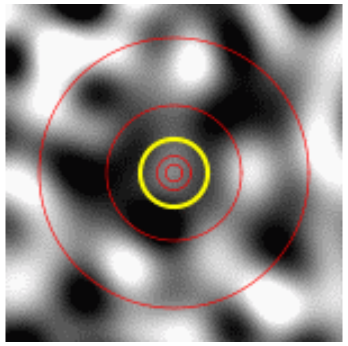


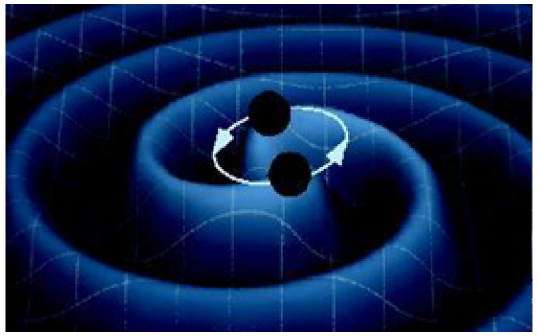
Primordial Gravitational Waves

Big leap between LISA and LiteBIRD



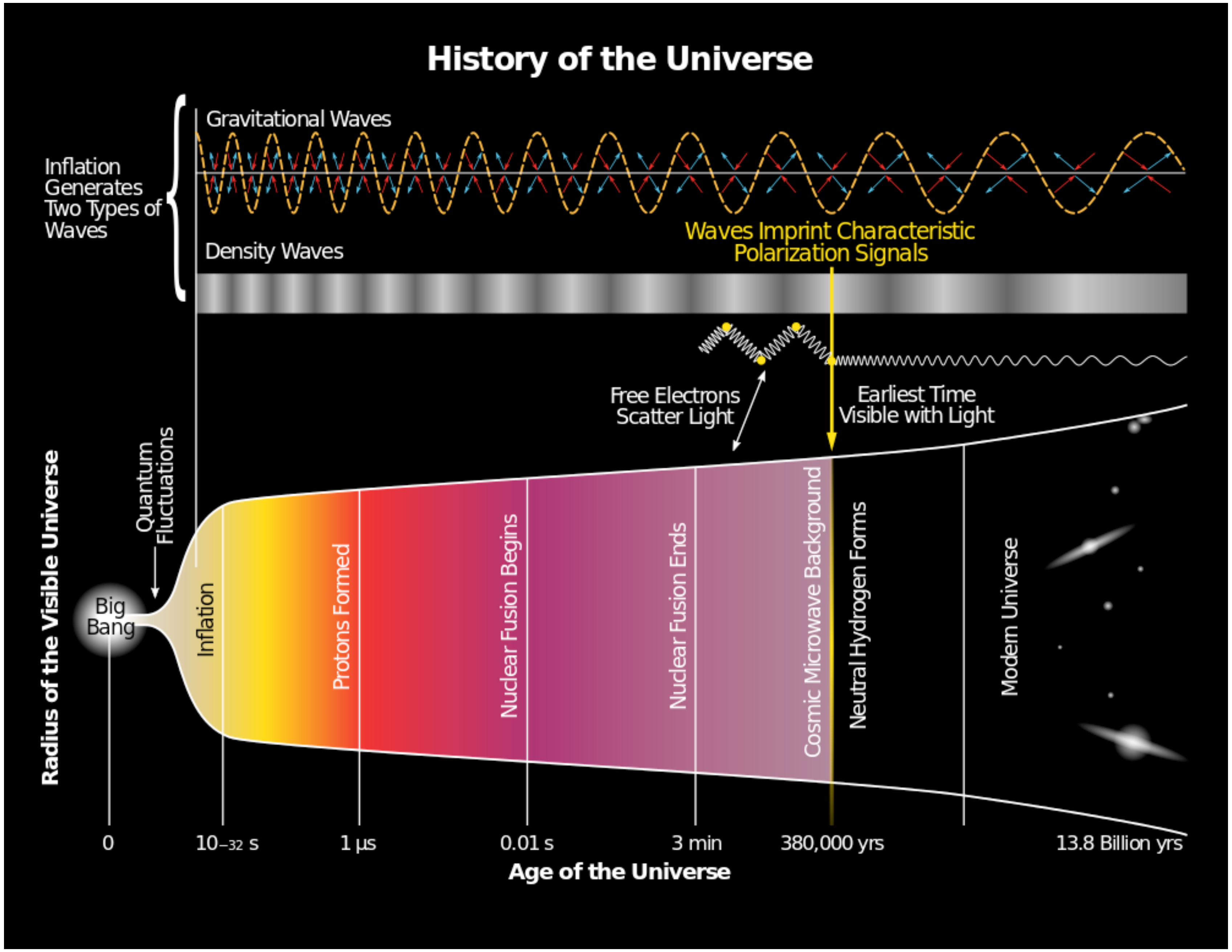
LiteBIRD
Gravitational waves with quantum origin





LISA
Gravitational waves with classical origin

Primordial Gravitational Waves



Inflation

↓

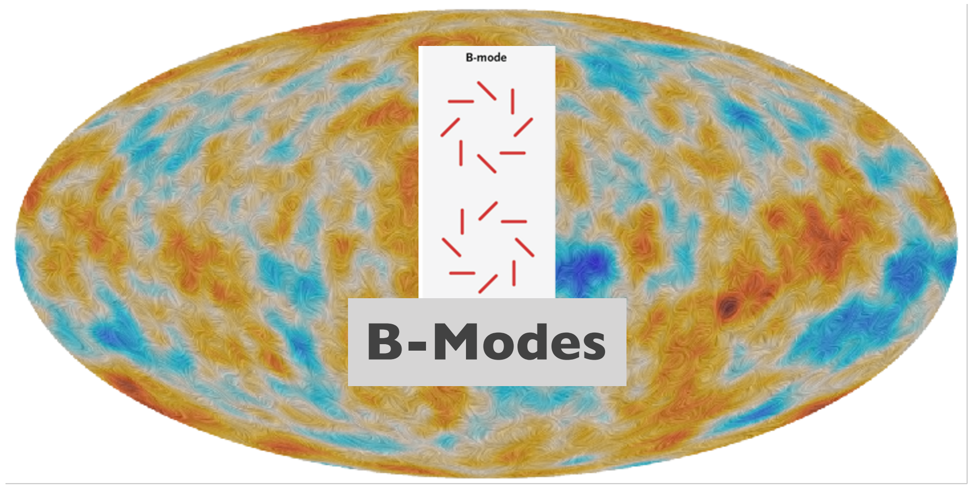
Quantum fluctuation of spacetime

↓

Primordial gravitational waves

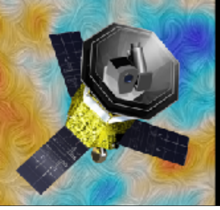
↓

"vortex"es in the CMB polarization map (called "B-mode")



Opportunity to probe the Cosmic Inflation but also to shed light on GUT-scale physics

Observational test of quantum gravity



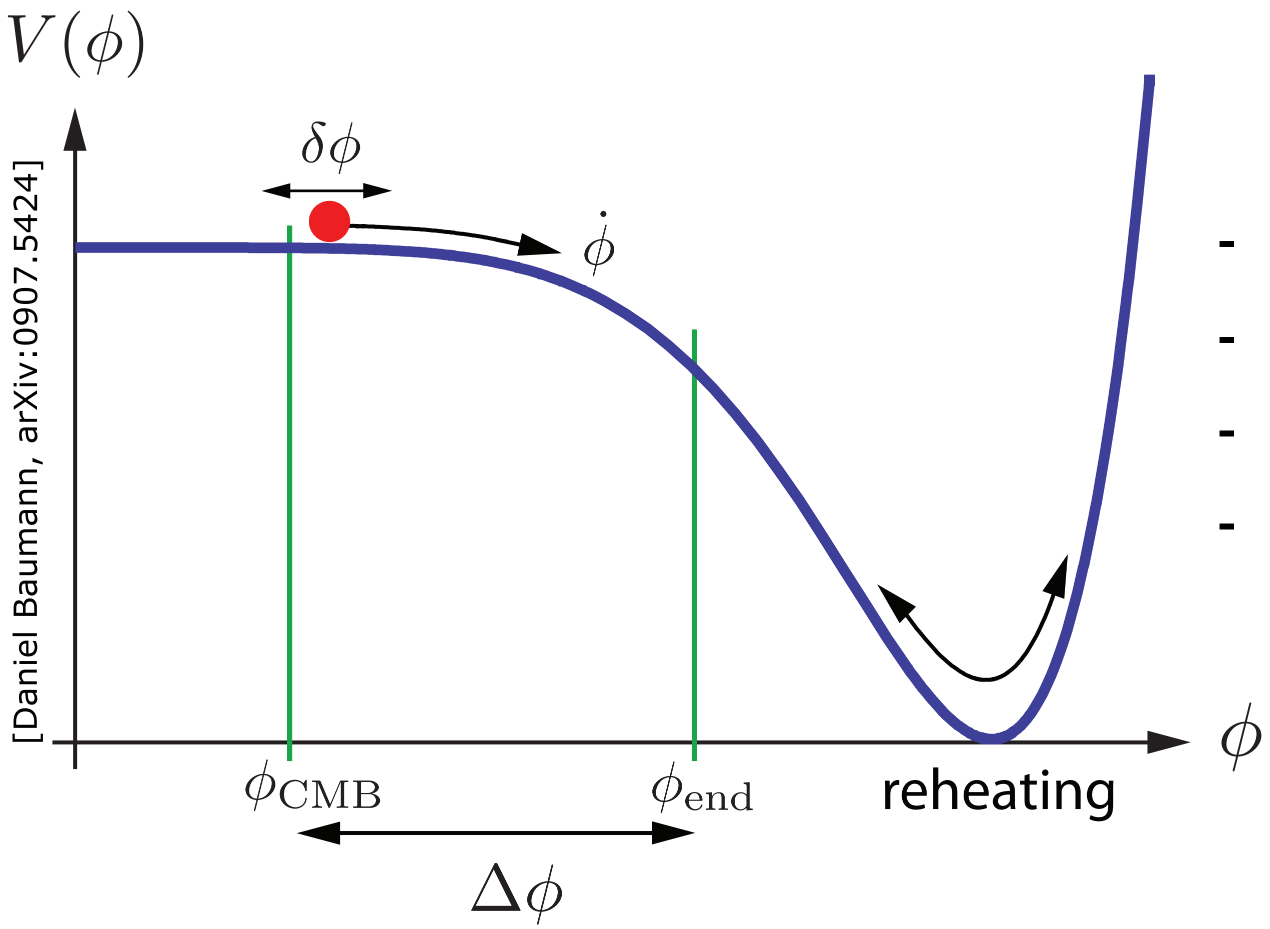
Primordial Gravitational Waves

inflation ϕ

- **dynamics of an homogeneous scalar field in a FRW geometry is given by**

$$\ddot{\phi} + 3H\dot{\phi} + V_{,\phi} = 0 \qquad \text{and} \qquad H^2 = \frac{1}{3}\left(\frac{1}{2}\dot{\phi}^2 + V(\phi)\right)$$

- **inflation happen when potential dominates over kinetic energy (slow-roll)**



- where did **V(Φ) comes from** ?
- why did the field start in **slow-roll** ?
- why is the potential so **flat** ?
- how do we convert the field energy into **particules** ?

Primordial Gravitational Waves

matter

- **According to single field, slow-roll inflationary scenario, quantum vacuum fluctuations excite cosmological scalar and tensor perturbations**

$$\mathcal{P}_{\mathcal{R}}(k) = A_s \left(\frac{k}{k_0}\right)^{n_s - 1} \quad \text{scalar}$$

$$\mathcal{P}_{\mathcal{T}}(k) = A_t \left(\frac{k}{k_0}\right)^{n_t} \quad \text{tensor}$$

- **with the definition of the tensor-to-scalar ratio "r"** $r = A_t / A_s$

Primordial Gravitational Waves

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- **with the definition of the tensor-to-scalar ratio "r"** $r = A_t / A_s$

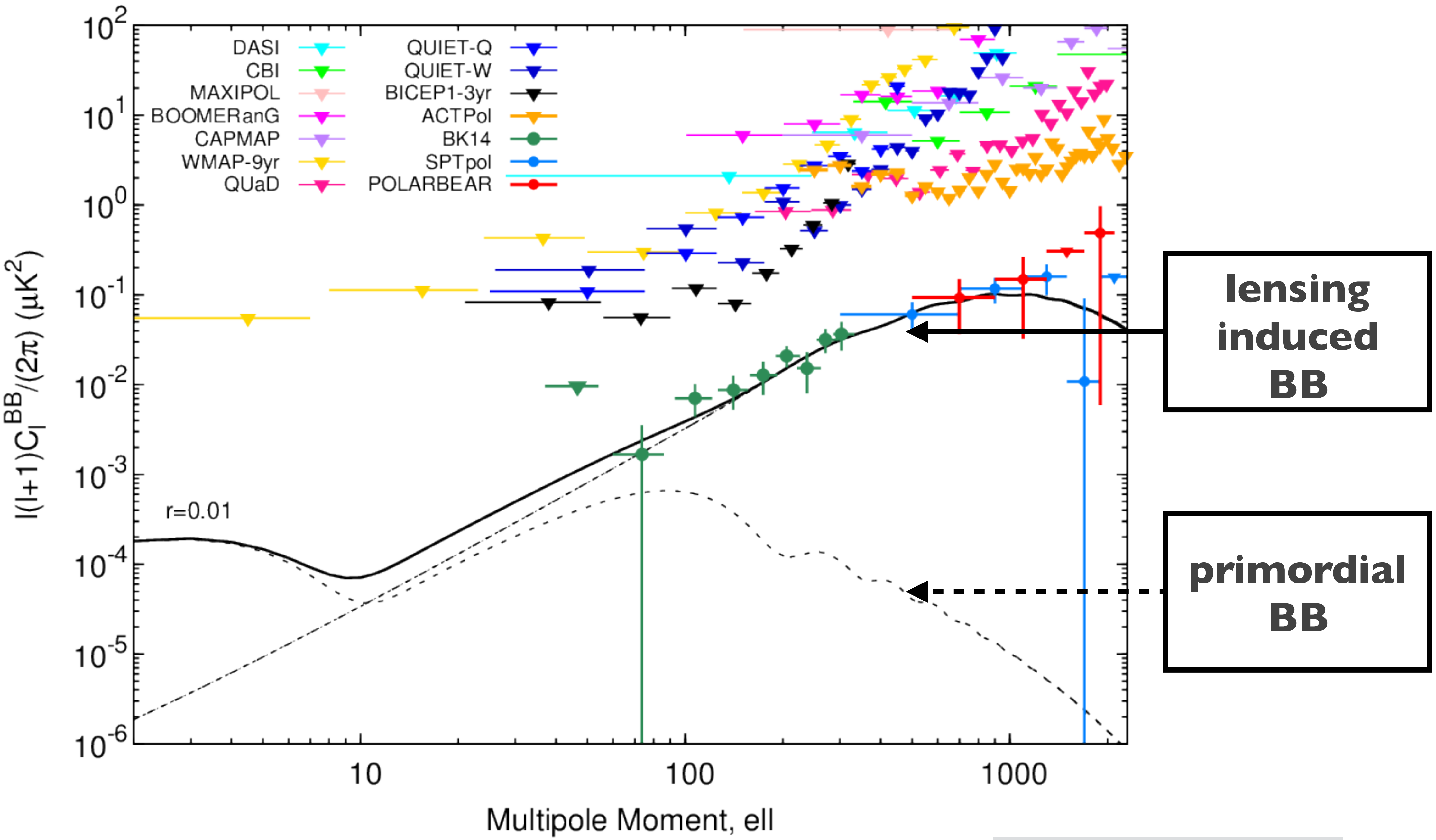
which characterises the amplitude of GW and gives direct constraints on the shape of the potential

- **energy scale of inflation** $V^{1/4}(\phi) \simeq 10^{16}\,\mathrm{GeV}\left(\frac{r}{0.01}\right)^{1/4}$
- **inflaton field excursion** $\frac{\Delta\phi}{M_P} \simeq \mathcal{N}_* \left(\frac{r_*}{8}\right)^{1/2} \simeq \left(\frac{r}{0.001}\right)^{1/2}$
- **derivative of the potential**

$$r = 8M_{\mathrm{Pl}}^2 \left(\frac{V_\phi}{V}\right)^2$$

$$n_{\mathrm{s}} - 1 \equiv \frac{\mathrm{d}\ln \mathcal{P}_\zeta}{\mathrm{d}\ln k} \simeq -3M_{\mathrm{Pl}}^2 \left(\frac{V_\phi}{V}\right)^2 + 2M_{\mathrm{Pl}}^2 \frac{V_{\phi\phi}}{V}$$

Current status of the B-mode measurements

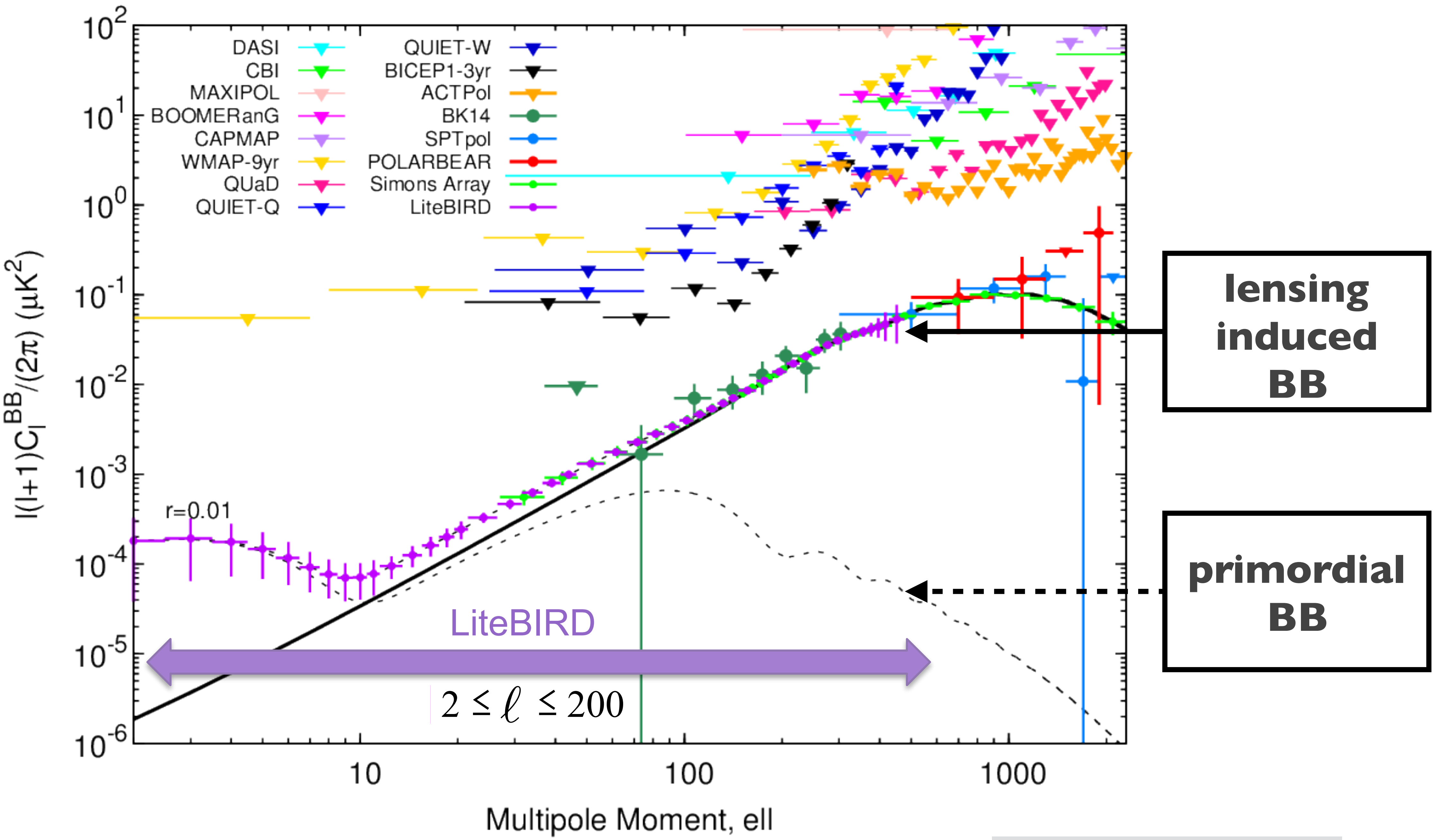


$r < 0.07$ (95% CL)

BICEP2

Primordial Gravitational Waves

LiteBIRD Expectation



$\sigma_r < 0.001$ (for r=0)

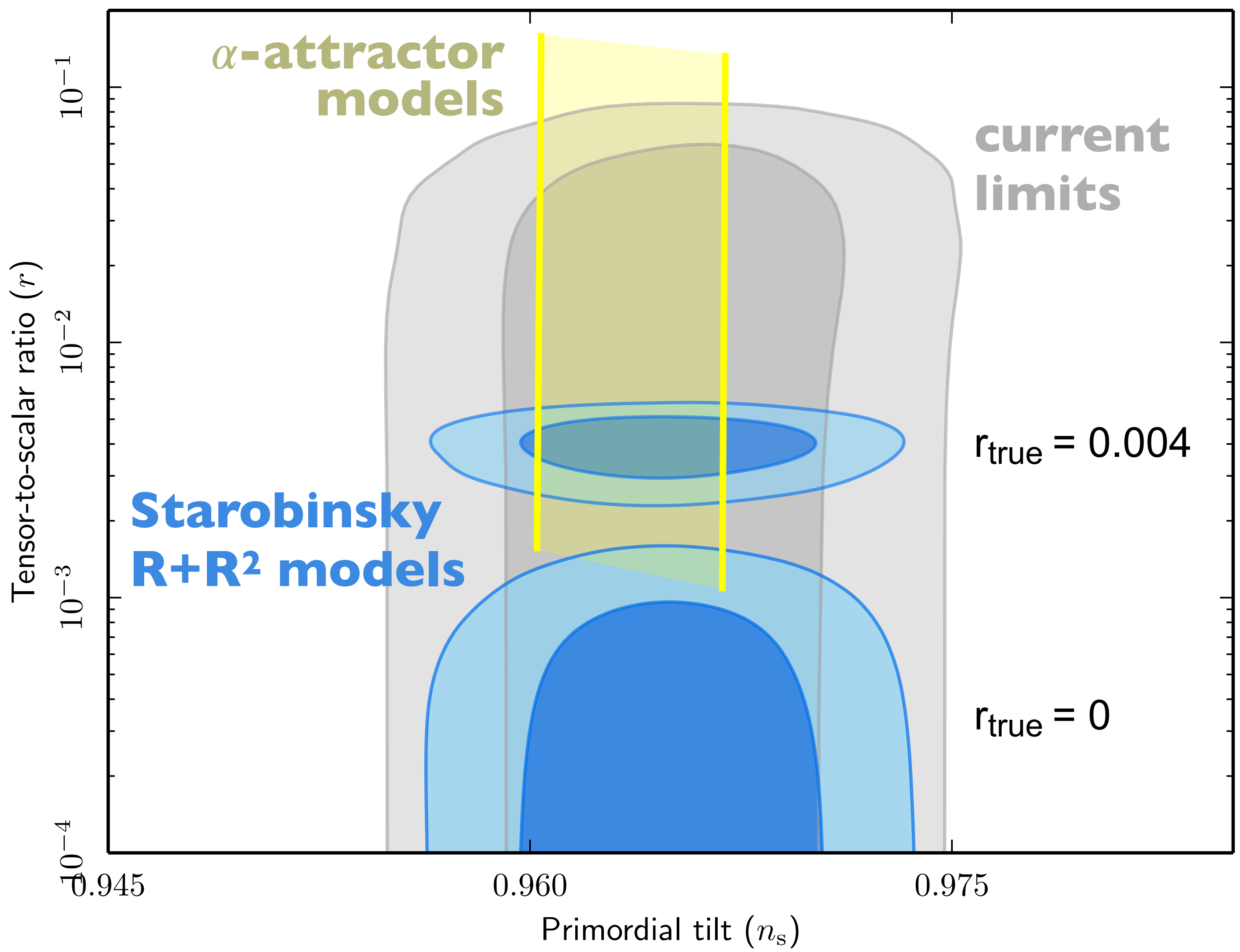
LiteBIRD only (no delensing)

Full Success

- $\sigma(r) < 10^{-3}$ (for r=0, no delensing)
- >5σ observation for each bump (for r≥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]*



Primordial Gravitational Waves

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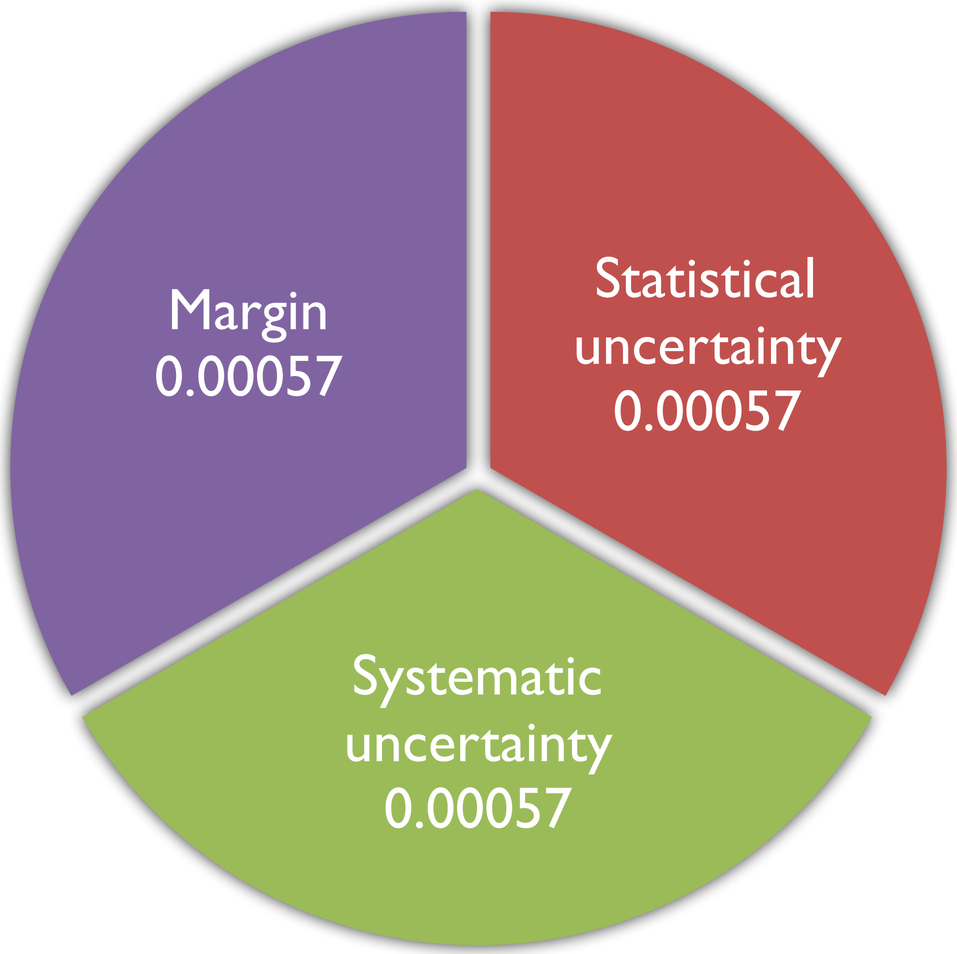


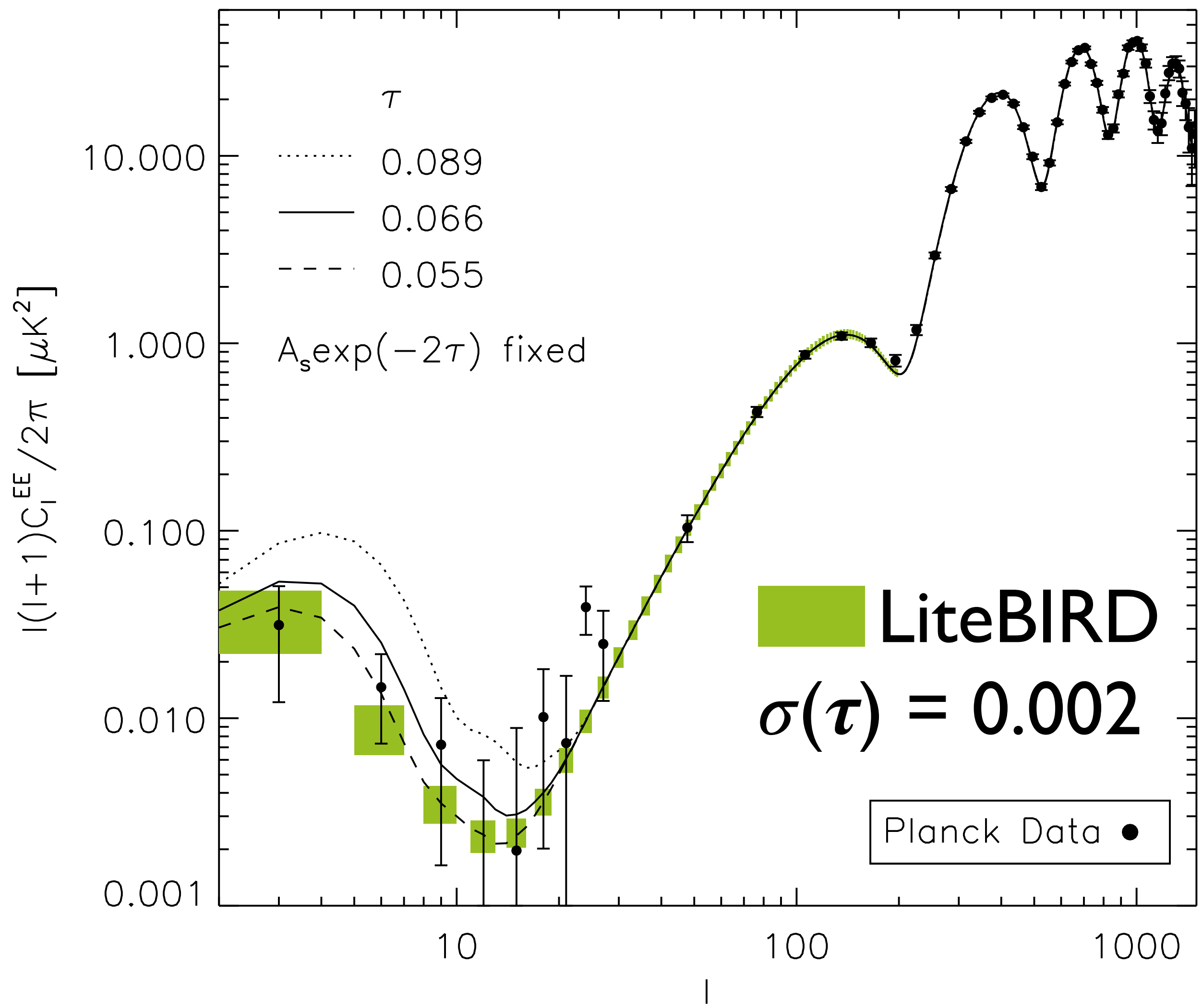
Statistical uncertainty

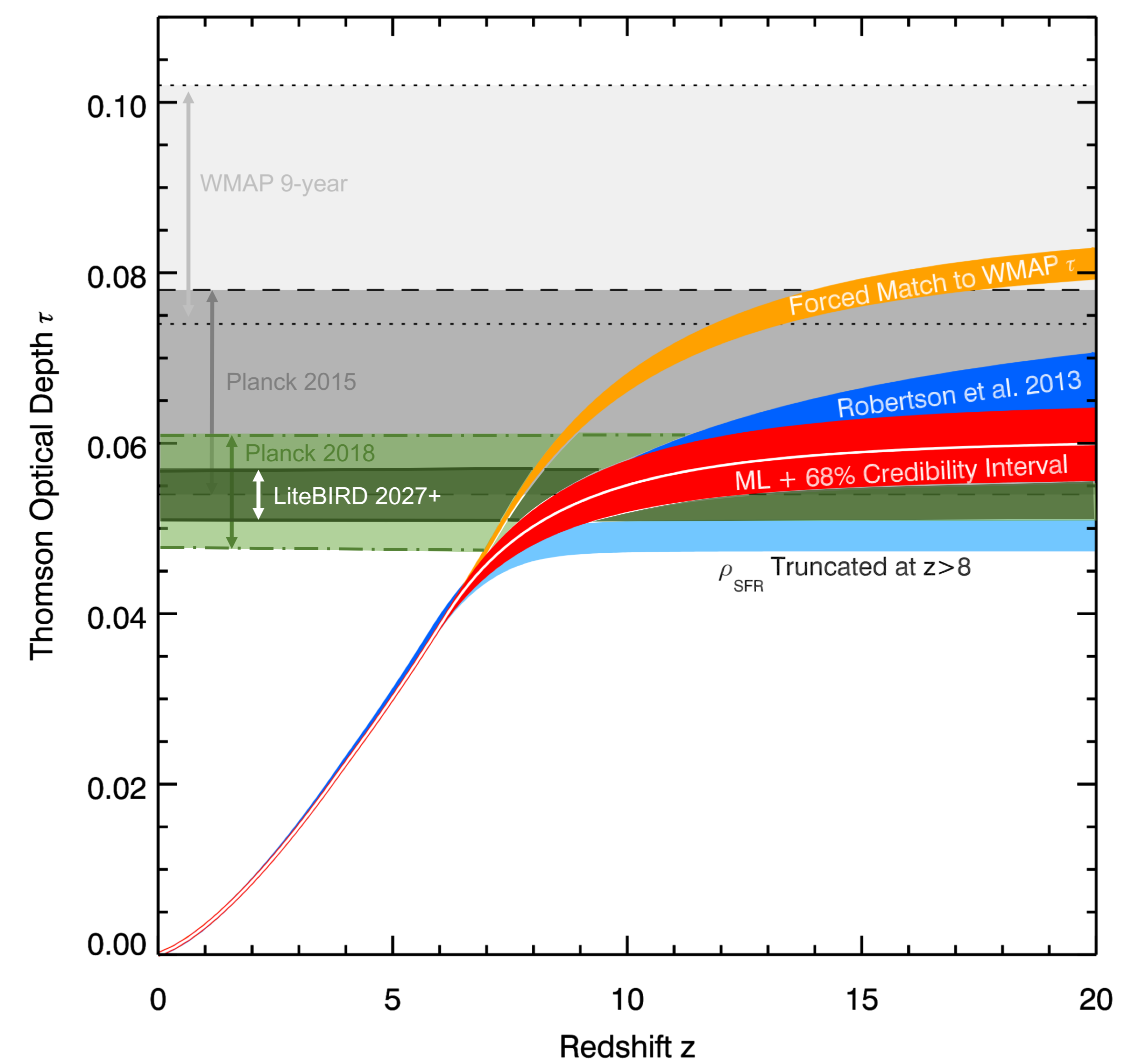
- foreground cleaning residuals
- lensing B-mode power
- 1/f noise

Systematic uncertainty

- Bias from 1/f noise
- Polarization efficiency & knowledge
- Disturbance to instrument
- Off-boresight pick up
- Calibration accuracy

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



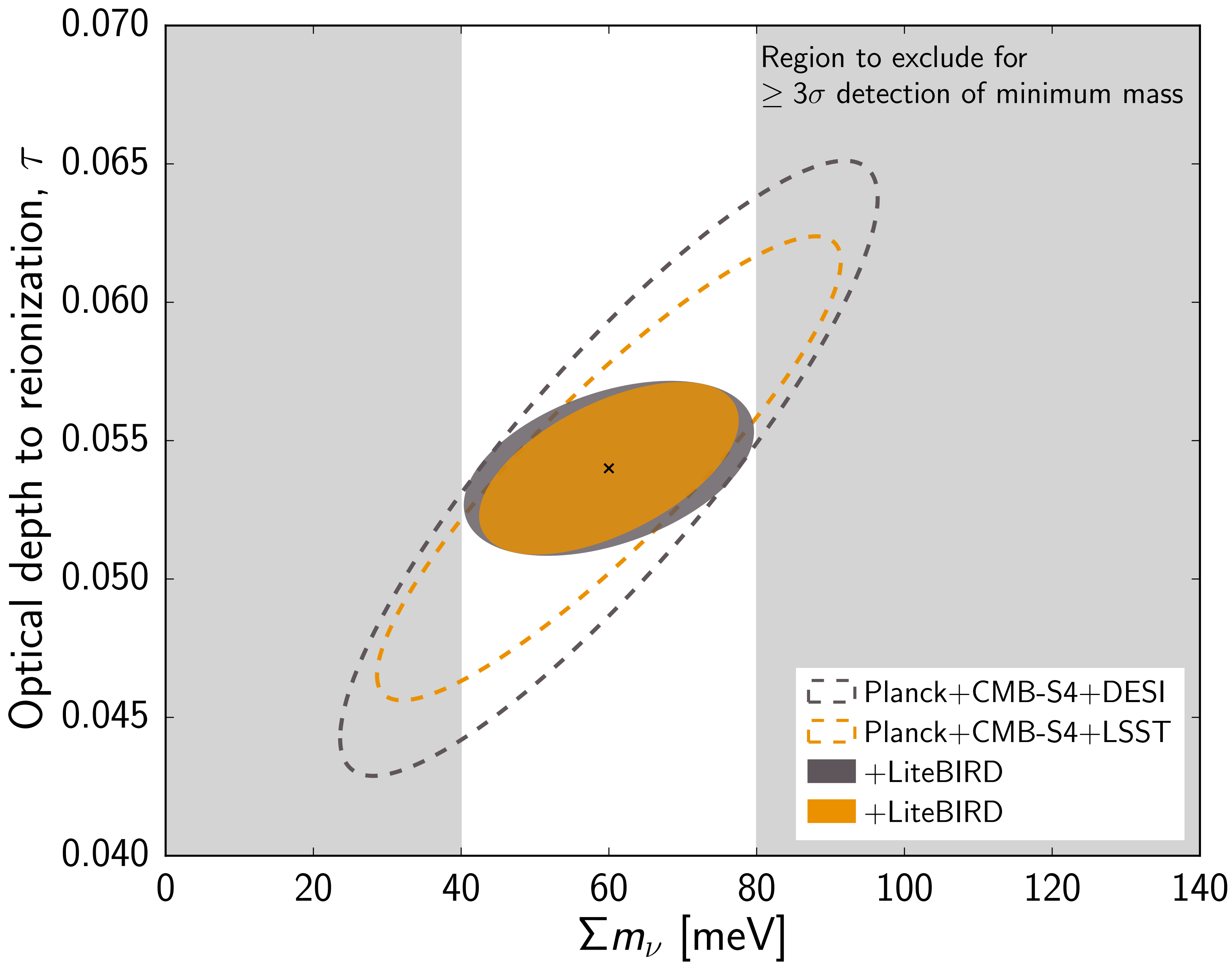


$\sigma(\tau)$ better than current Planck constraints by a factor 2

Neutrino sector

- Improvement in reionization optical depth measurement implies:

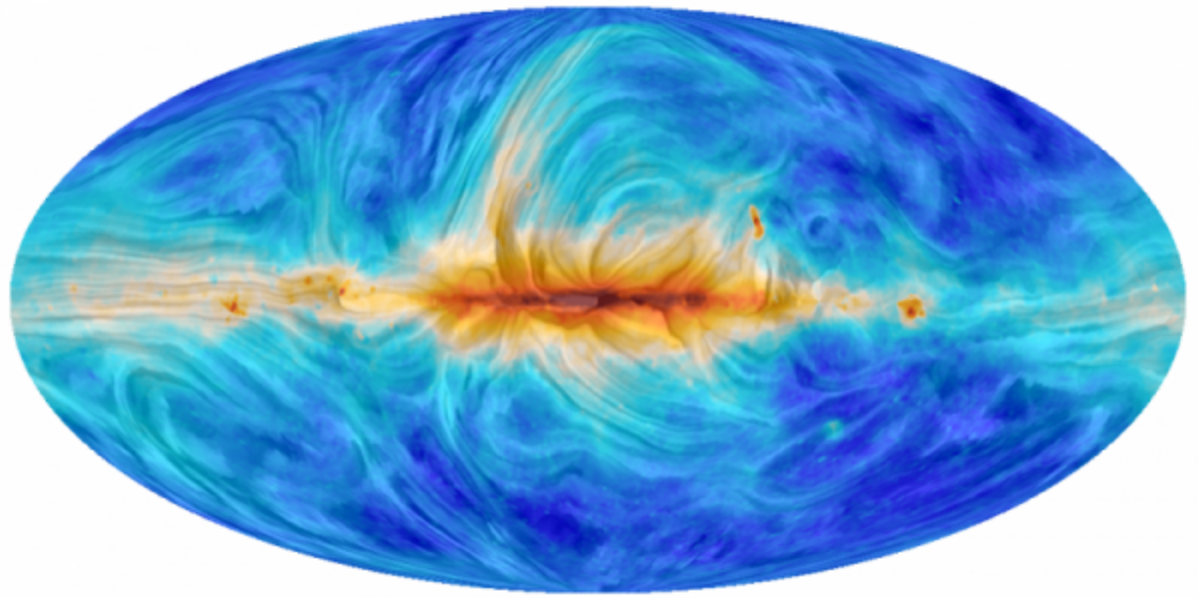
- $\sigma(\Sigma m_\nu)$ = 15 meV
- determine neutrino hierarchy (normal v.s. inverted)
- measurement of minimum mass ($\geq 3\sigma$ detection NH, $\geq 5\sigma$ detection for IH)



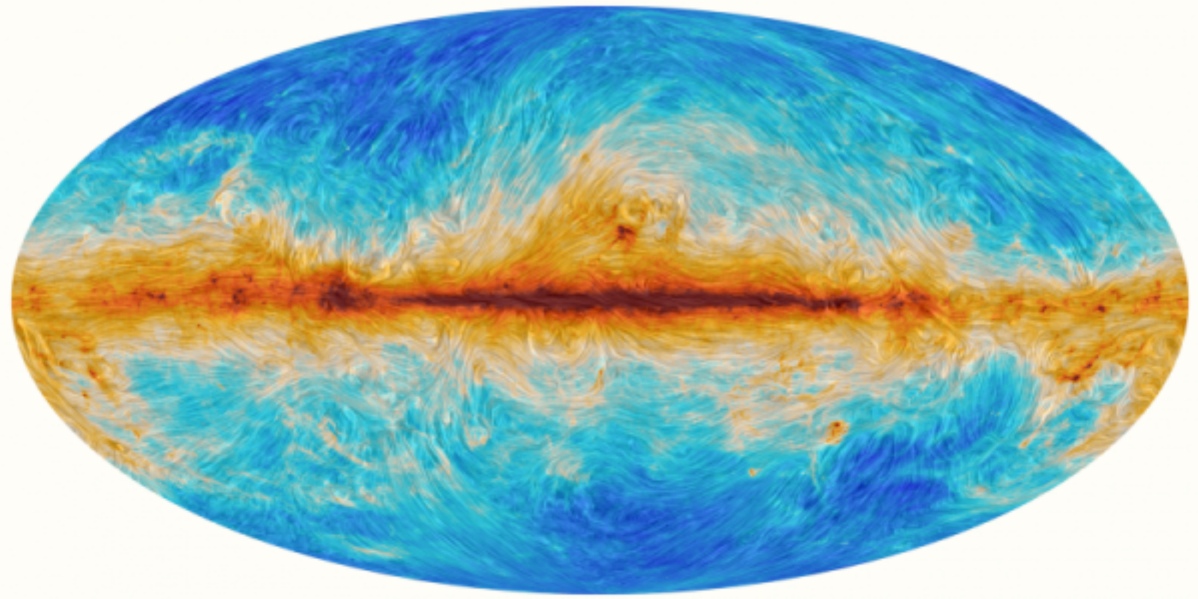
Galactic science

- 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

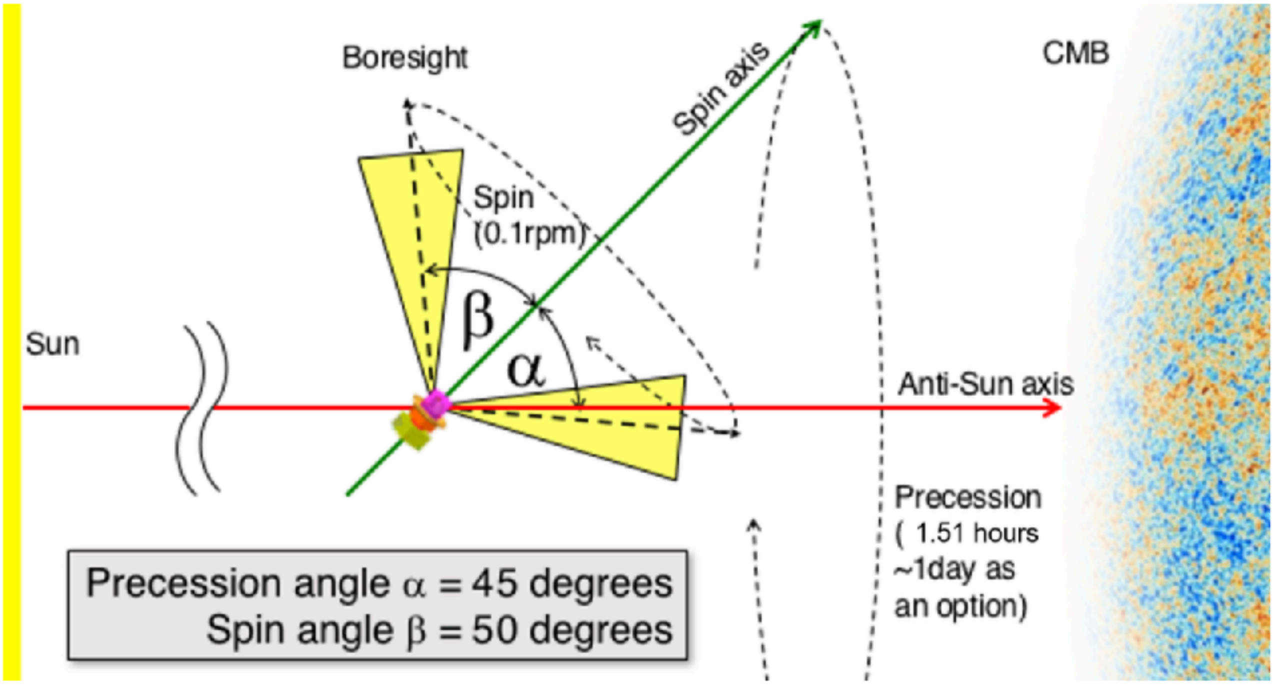


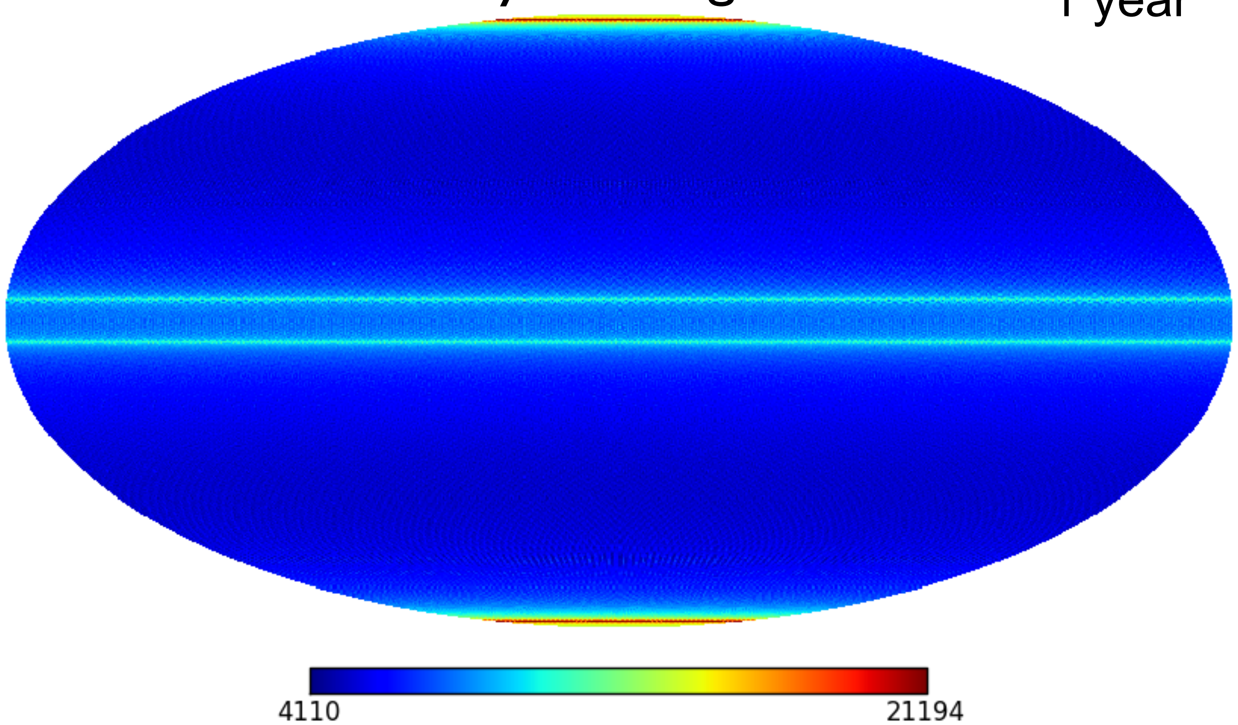
Synchrotron



Dust

LiteBIRD in a nutshell





L-Class JAXA Mission

Selected by JAXA May 2019

Launch 2028

L2 orbit

All-sky Survey during 3 years

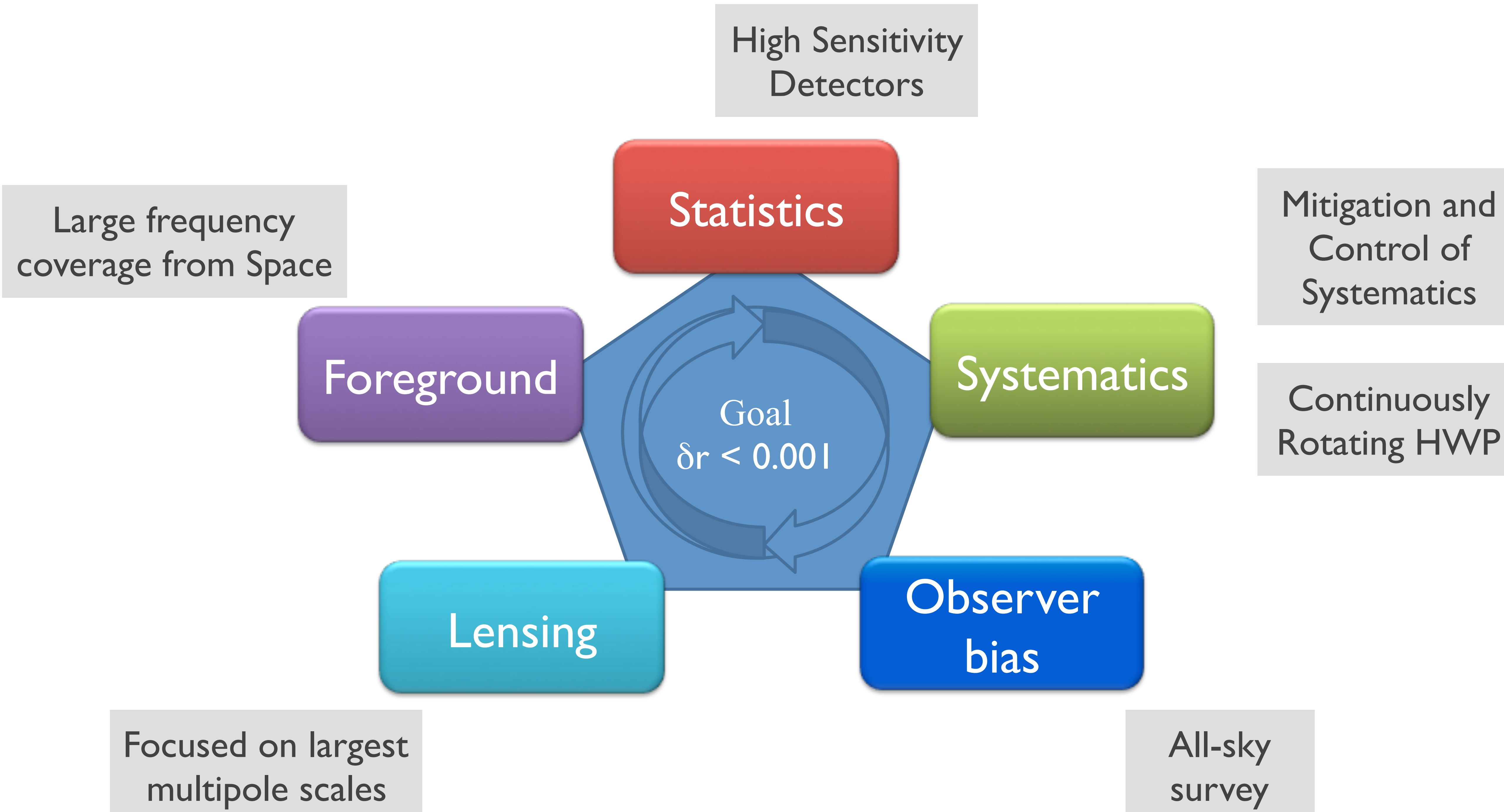
Large frequency coverage
15 bands 34 - 448 GHz

Resolution

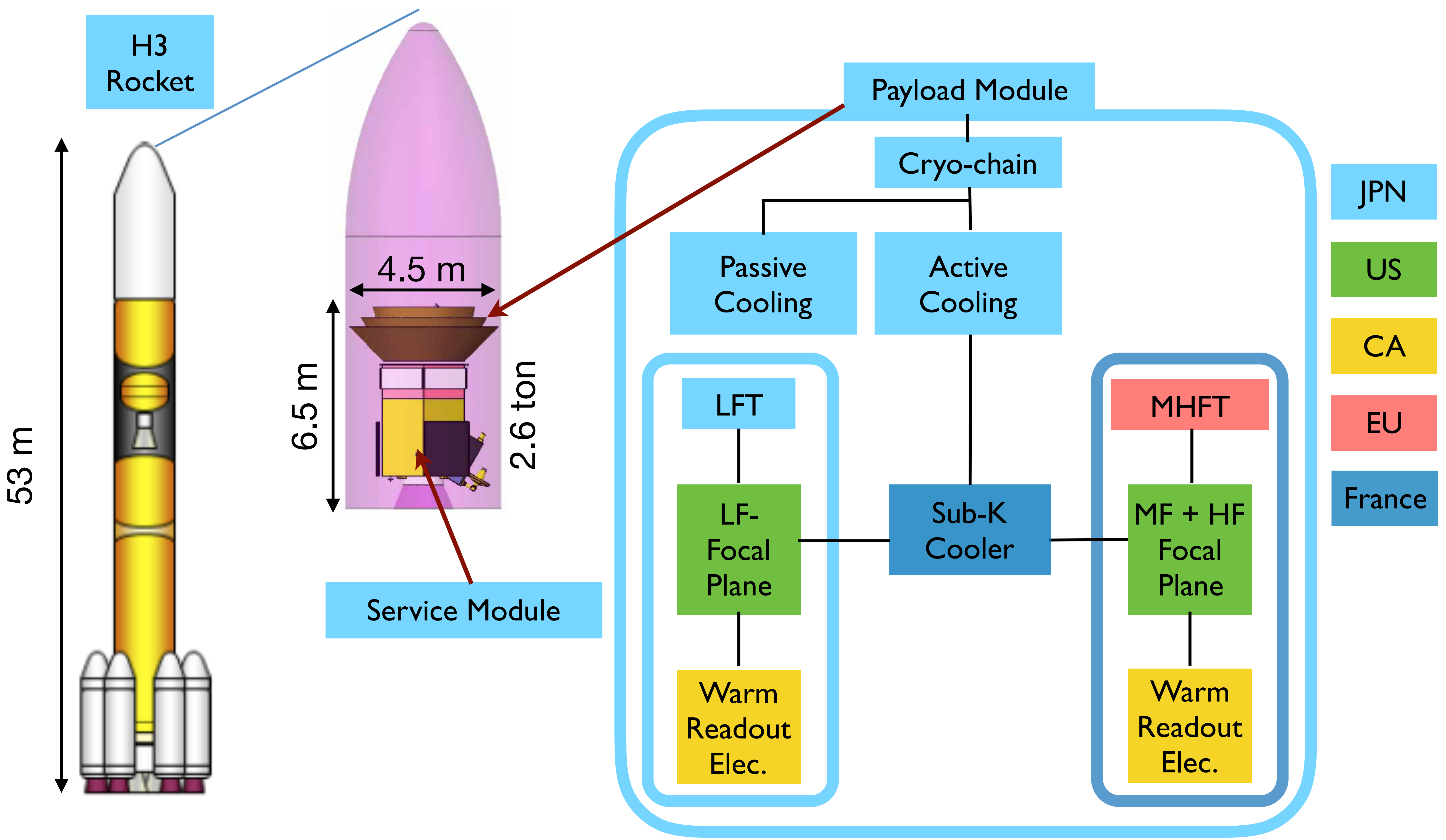
LFT	69' - 20.7'
MHFT	27.6' - 9.7'

Sensitivity
2.8 uK.arcmin
after component separation
(more than 100 times better than Planck in P)

Mission Challenges



Payload

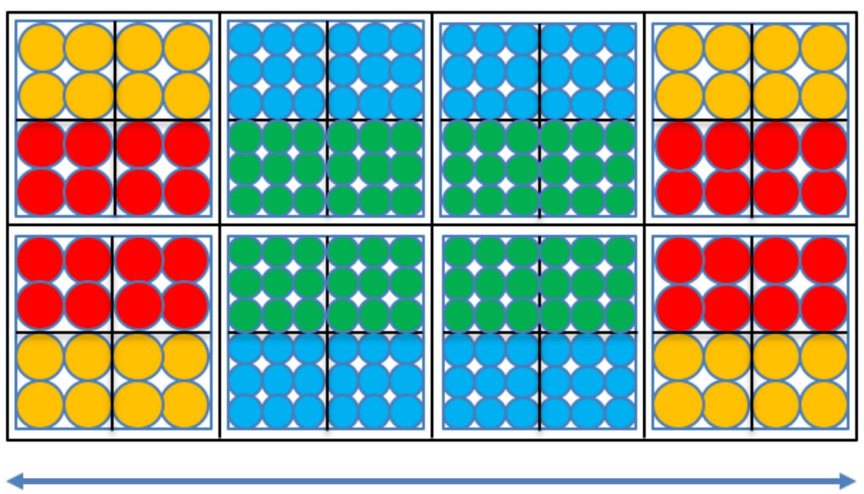

H3
Rocket
53 m
4.5 m
6.5 m
2.6 ton
Service Module
Payload Module
Cryo-chain
Passive
Cooling
Active
Cooling
LFT
LF-
Focal
Plane
Warm
Readout
Elec.
Sub-K
Cooler
MHFT
MF + HF
Focal
Plane
Warm
Readout
Elec.
JPN
US
CA
EU
France

the LiteBIRD Mission

Number of detectors: 4676
Overlap between telescopes

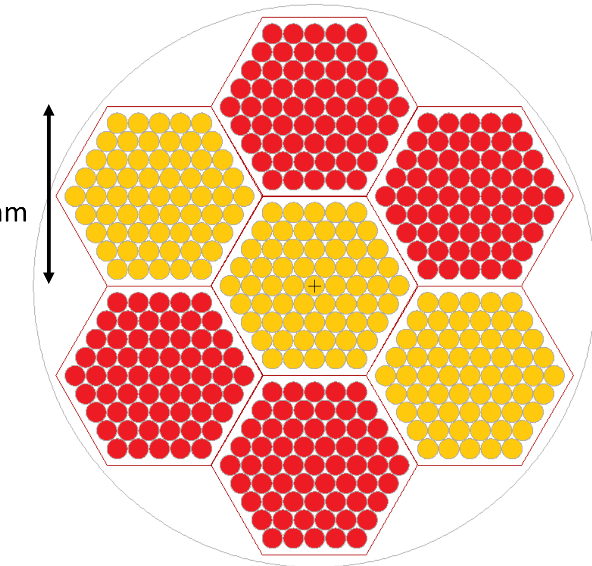
focal plane

210 mm



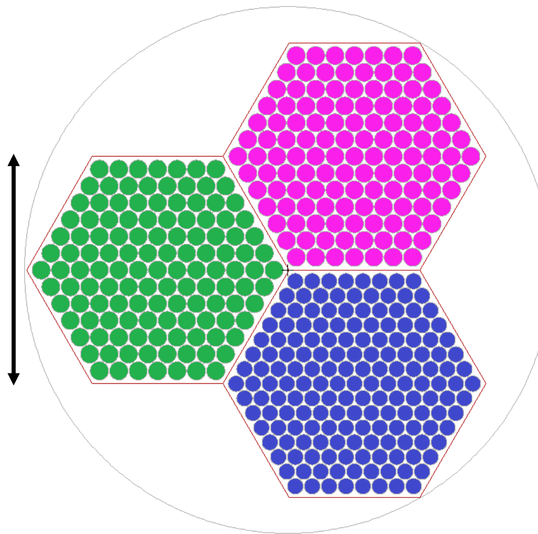
420 mm

102 mm



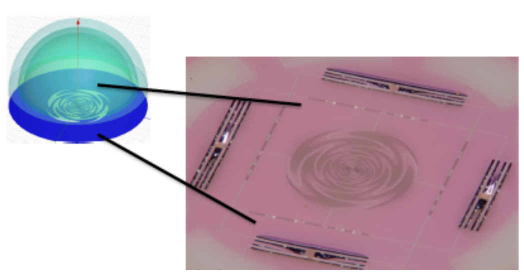
320 mm

82 mm

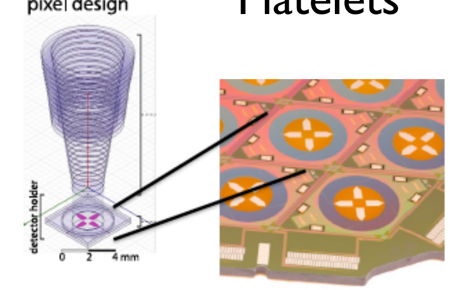


195 mm

Lenslets



Platelets



MFT (2.5:1)

89GHz — 224 GHz

2074 detectors
366 Trichroic TES
488 Dichroic TES

100	119	140	166	195

LFT (4.7:1)

40	50	60	68	78	89	100	119	140

1248 detectors
2 x (64 + 144) Trichroic TES

34GHz — 161 GHz

HFT (2.7:1)

195	235	280	337	402

1354 detectors
2 x 254 Dichroic TES
338 Monochromatic TES

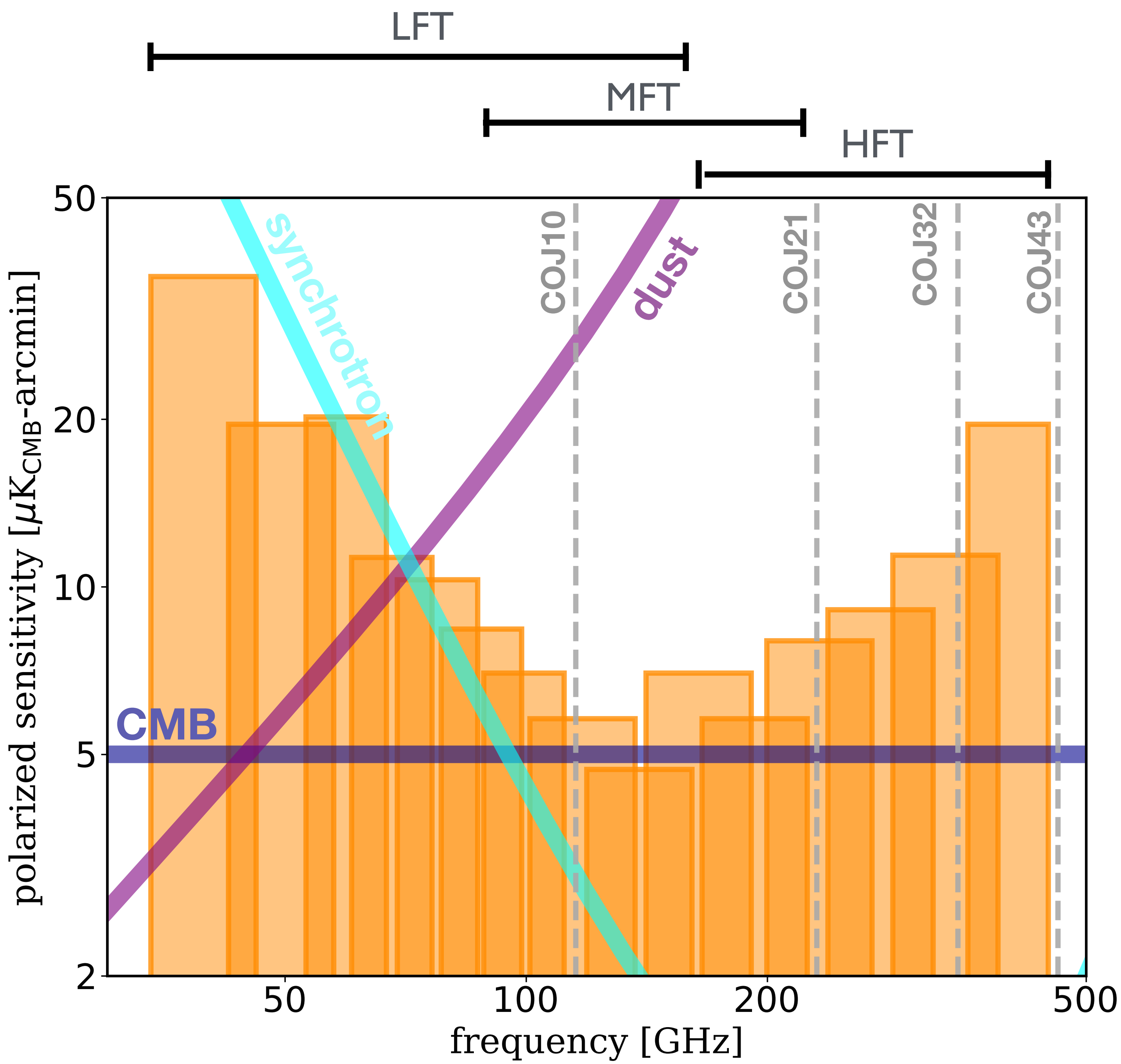
166 GHz — 448 GHz

the LiteBIRD Mission

Frequency coverage

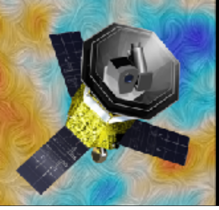
15 bands
from 34GHz
to 448GHz

4676
detectors



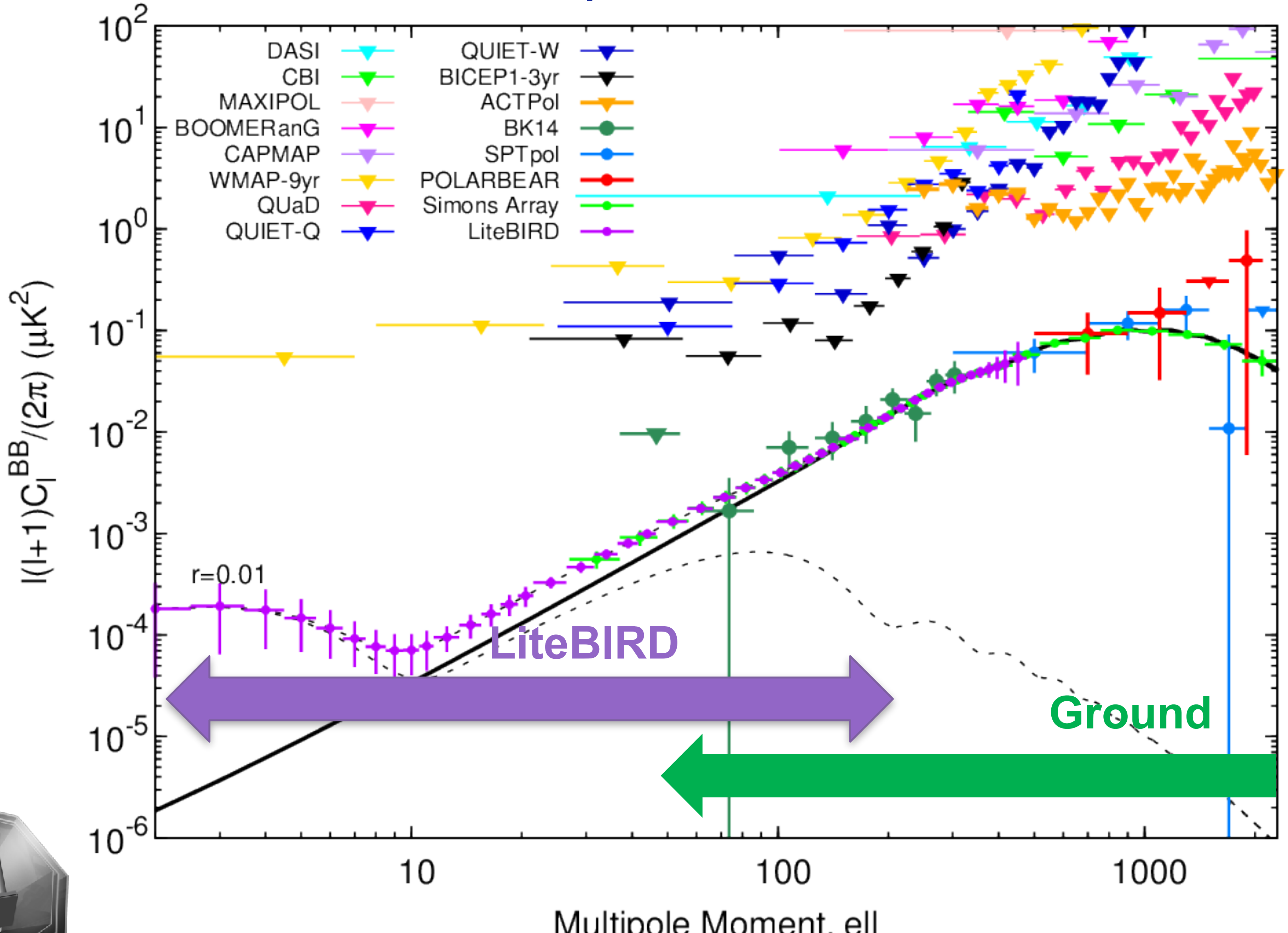
9 bands LFT
5 bands MFT
5 bands HFT

with 4 overlapping bands



CMB from space and ground

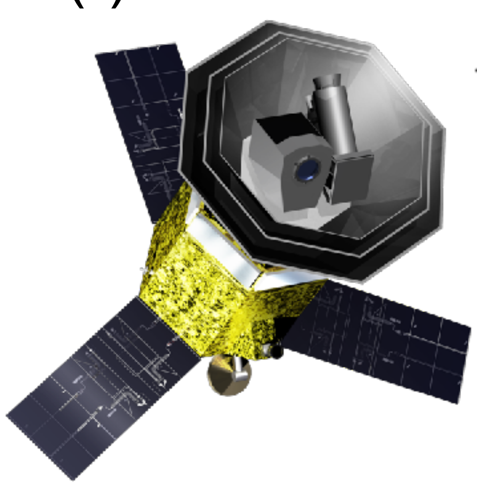
a powerful duo



LiteBIRD

$2 \leq \ell \leq 200$

$\sigma(r) < 0.001$



Ground telescopes

$30 \leq \ell \leq 8000$

SIMONS OBSERVATORY

CMB from space and ground

Extra Success

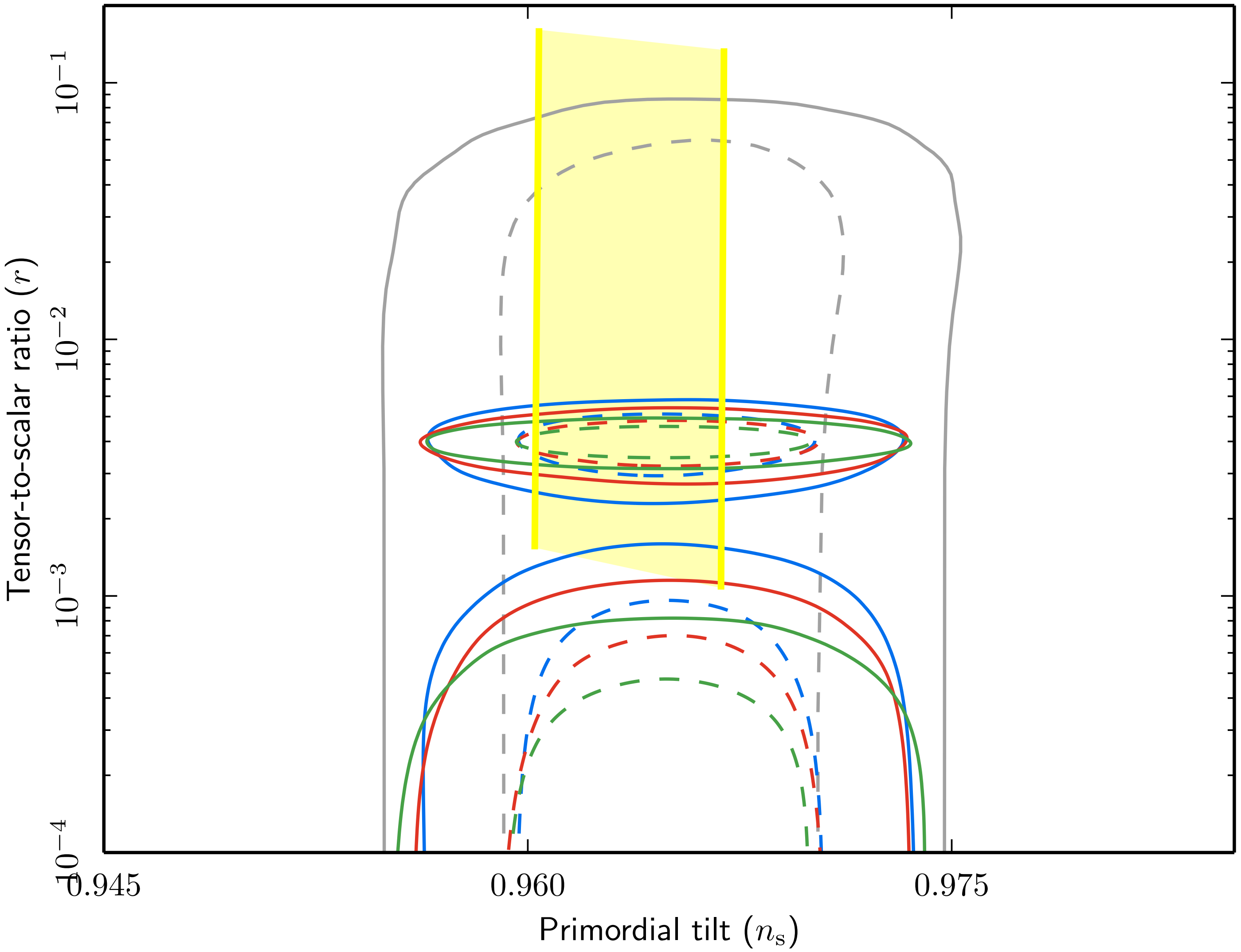
- improve σ(r) with external observations
- delensing improvement to σ(r) can be a factor ≥ 2

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

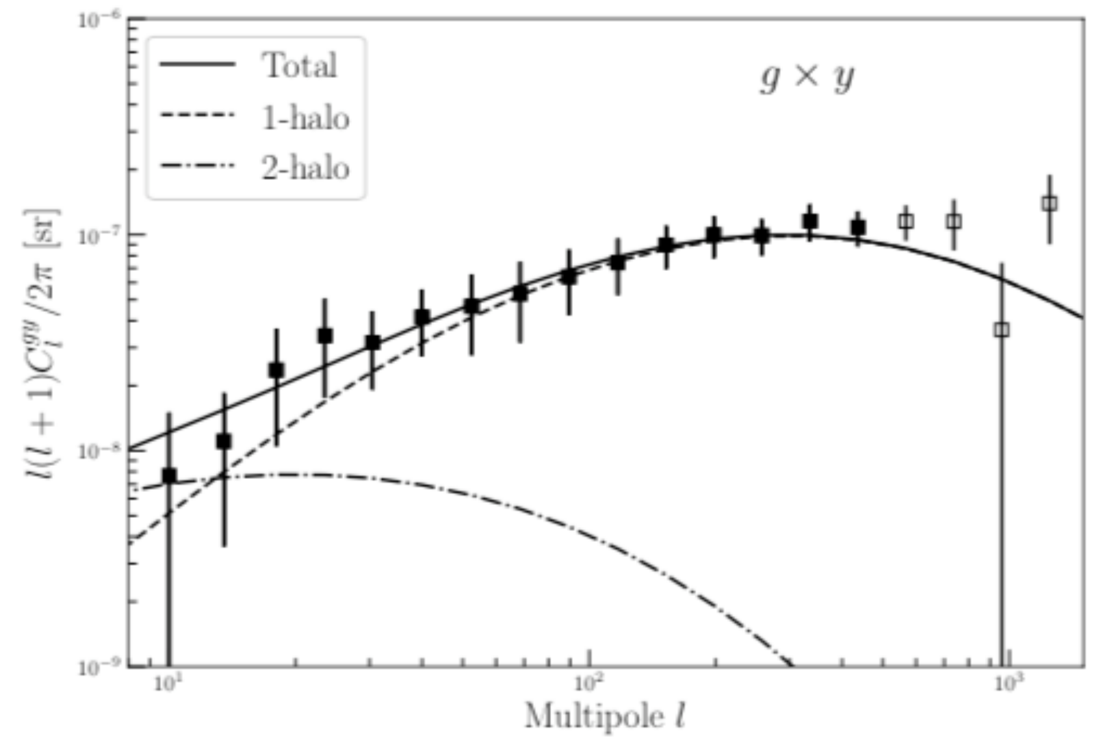


Synergy with other probes

- Galaxy surveys

full-sky map of hot gas
(thermal SZE)
⊗
3D distribution of the matter
(galaxy survey)

how gas traces the matter in the Universe



- Integrated Sachs-Wolf effect

improvement on ISW signal (~20%)

- Lensing

LiteBIRD E-modes
+
CMB-S4 high-resolution

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

LiteBIRD Collaboration

An international collaboration

More than 200 researchers from Japan, Europe & North America

Y. Sekimoto[14,37] , P. Ade[2], K. Arnold[49], J. Aumont[12], J. Austermann[29], C. Baccigalupi[11], A. Banday[12], R. Banerji[56], S. Basak[7,11], S. Beckman[49], M. Bersanelli[44], J. Borrill[20], F. Boulanger[4], M.L. Brown[53], M. Bucher[1], E. Calabrese[2], F.J. Casas[10], A. Challinor[50,60,64], Y. Chinone[16,47], F. Columbro[46], A. Cukierman[47,36], D. Curtis[47], P. de Bernardis[46], M. de Petris[46], M. Dobbs[23], T. Dotani[14,37], L. Duband[3], JM. Duval[3], A. Ducout[16], K. Ebisawa[14], T. Elleflot[49], H. Eriksen[56], J. Errand[1], R. Flauger[49], C. Franceschet[54], U. Fuskeland[56], K. Ganga[1], J.R. Gao[35], T. Ghigna[16,57], J. Grain[9], A. Gruppuso[6], N. Halverson[51], P. Hargrave[2], T. Hasebe[14], M. Hasegawa[5,37], M. Hattori[42], M. Hazumi[5,14,16,37], S. Henrot-Versille[19], C. Hill[21,47], Y. Hirota[38], E. Hivon[61], D.T. Hoang[1,63], J. Hubmayr[29], K. Ichiki[24], H. Imada[19], H. Ishino[30], G. Jaehnig[51], H. Kanai[59], S. Kashima[25], K. Kataoka[30], N. Katayama[16], T. Kawasaki[17], R. Keskitalo[20,48], A. Kibayashi[30], T. Kikuchi[14], K. Kimura[31], T. Kisner[20,48], Y. Kobayashi[39], N. Kogiso[31], K. Kohri[5], E. Komatsu[22], K. Komatsu[30], K. Konishi[39], N. Krachmalnicoff[11], C.L. Kuo[34,36], N. Kurinsky[34,36], A. Kushino[18], L. Lamagna[46], A.T. Lee[21,47], E. Linder[21,48], B. Maffei[9], M. Maki[5], A. Mangilli[12], E. Martinez-Gonzalez[10], S. Masi[46], T. Matsumura[16], A. Mennella[54], Y. Minami[5], K. Mistuda[14], D. Molinari[52,6], L. Montier[12], G. Morgante[6], B. Mot[12], Y. Murata[14], A. Murphy[28], M. Nagai[25], R. Nagata[5], S. Nakamura[59], T. Namikawa[27], P. Natoli[52], T. Nishibori[15], H. Nishino[5], C. O'Sullivan[28], H. Ochi[59], H. Ogawa[31], H. Ogawa[14], H. Ohsaki[38], I. Ohta[58], N. Okada[31], G. Patanchon[1], F. Piacentini[46], G. Pisano[2], G. Polenta[13], D. Poletti[11], G. Puglisi[36], C. Raum[47], S. Realini[54], M. Remazeilles[53], H. Sakurai[38], Y. Sakurai[16], G. Savini[43], B. Sherwin[50,65,21], K. Shinozaki[15], M. Shiraishi[26], G. Signorelli[8], G. Smecher[41], R. Stompor[1], H. Sugai[16], S. Sugiyama[32], A. Suzuki[21], J. Suzuki[5], R. Takaku[14,40], H. Takakura[14,39], S. Takakura[16], E. Taylor[48], Y. Terao[38], K.L. Thompson[34,36], B. Thorne[57], M. Tomasi[44], H. Tomida[14], N. Trappe[28], M. Tristram[19], M. Tsuji[26], M. Tsujimoto[14], S. Uozumi[30], S. Utsunomiya[16], N. Vittorio[45], N. Watanabe[17], I. Wehus[56], B. Westbrook[47], B. Winter[62], R. Yamamoto[14], N.Y. Yamasaki[14], M. Yanagisawa[30], T. Yoshida[14], J. Yumoto[38], M. Zannoni[55], A. Zonca[33],