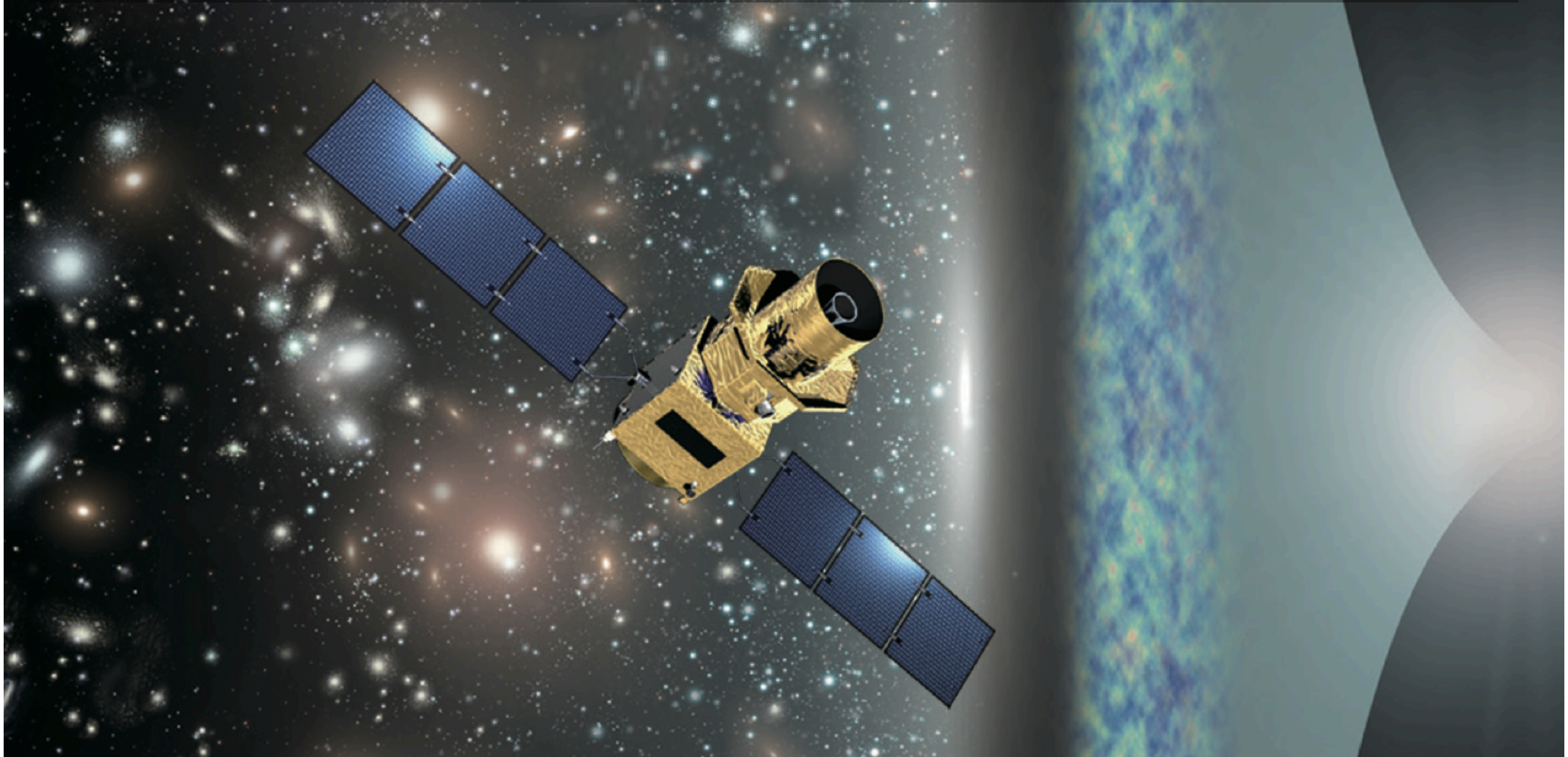
LiteBIRD

Lite(Light) satellite for the studies for ***B***-mode polarization and ***I***nflation from cosmic background ***R***adiation ***D***etection



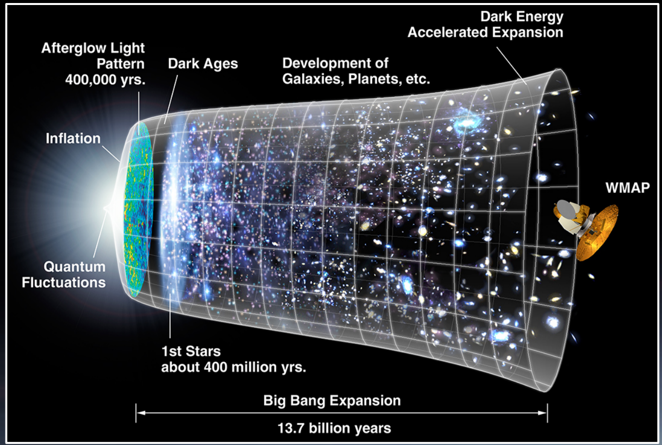
T. Matsumura (ISAS/JAXA)

2015/9/20, IPMU

Introduction

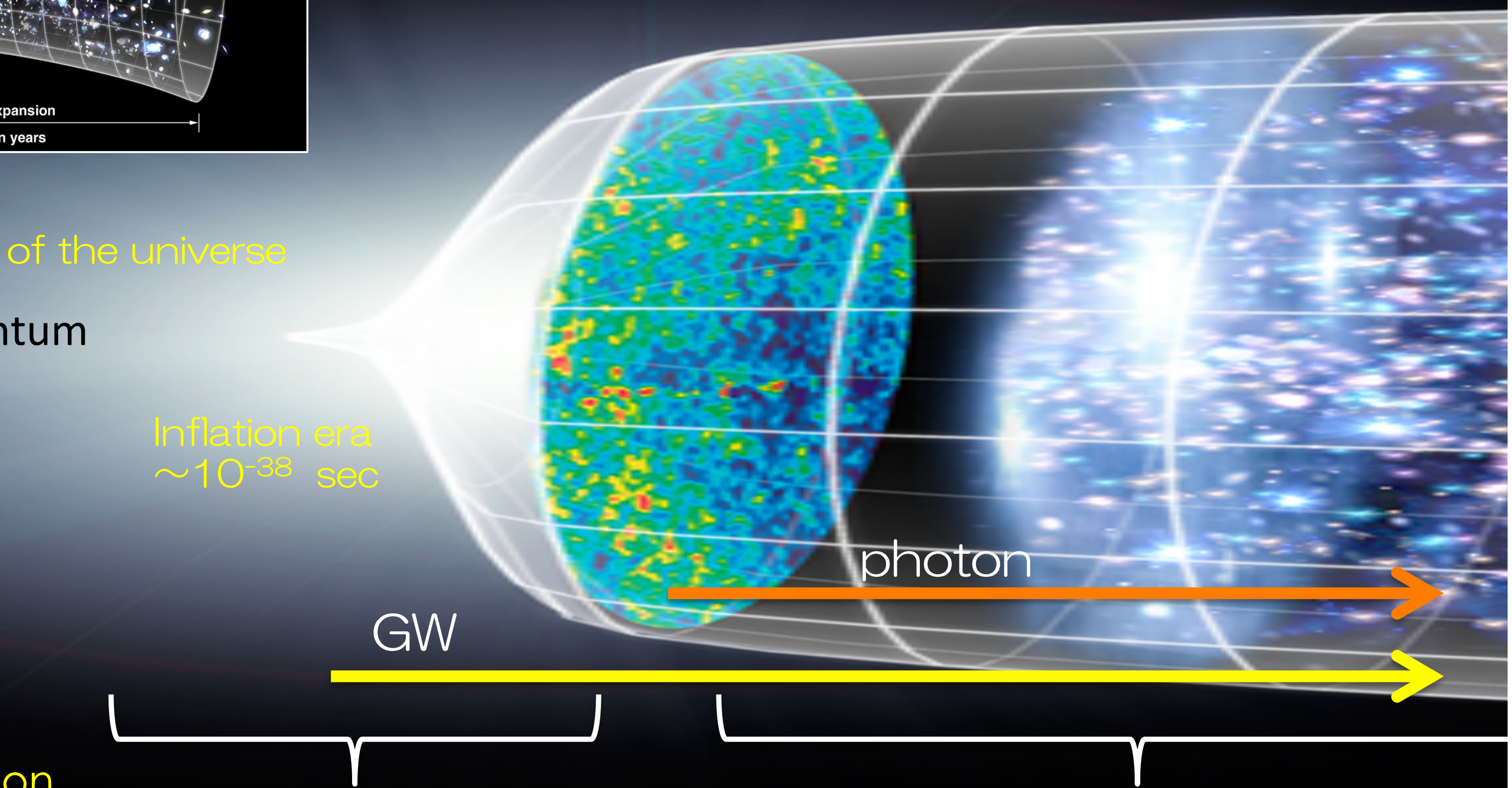
- Science motivation
- Strategy
- Overview
- Key challenges
- Current status

Reminder: Science motivation



Beginning of the universe

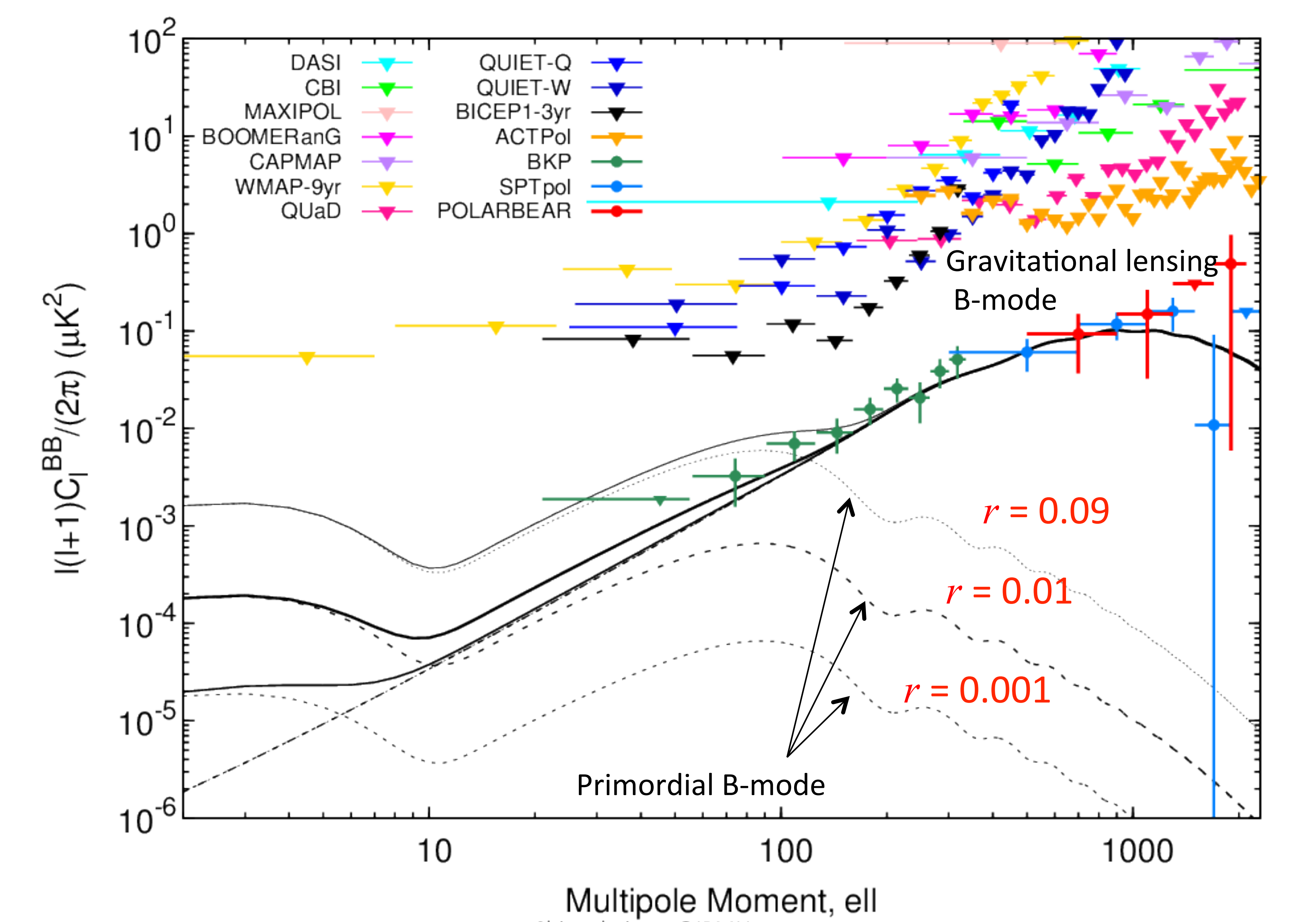
Gravity + Quantum



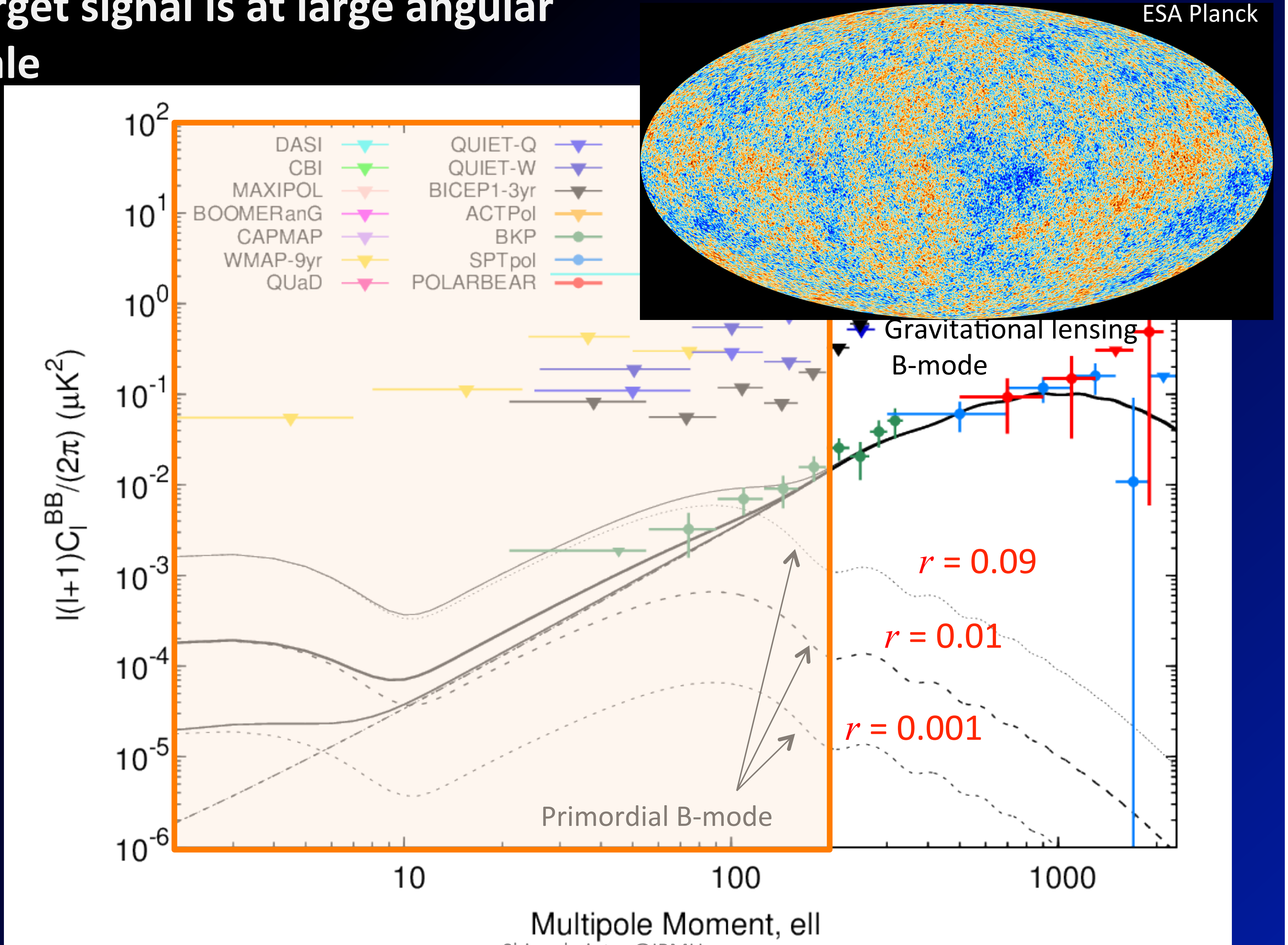
Probing inflation
If inflation exists, the primordial gravitational wave has imprinted the particular CMB polarization pattern, called B-mode.

Probing the gravitational potential of the large scale structure
The CMB polarization (E-mode) is lensed and this effect produces B-mode pattern.

Current status



Target signal is at large angular scale



Strategy

Benefits of observing from space:

- No atmosphere
  - Higher detector sensitivity
  - Broader observing frequency coverage
- Full sky coverage

But is the space mission feasible?

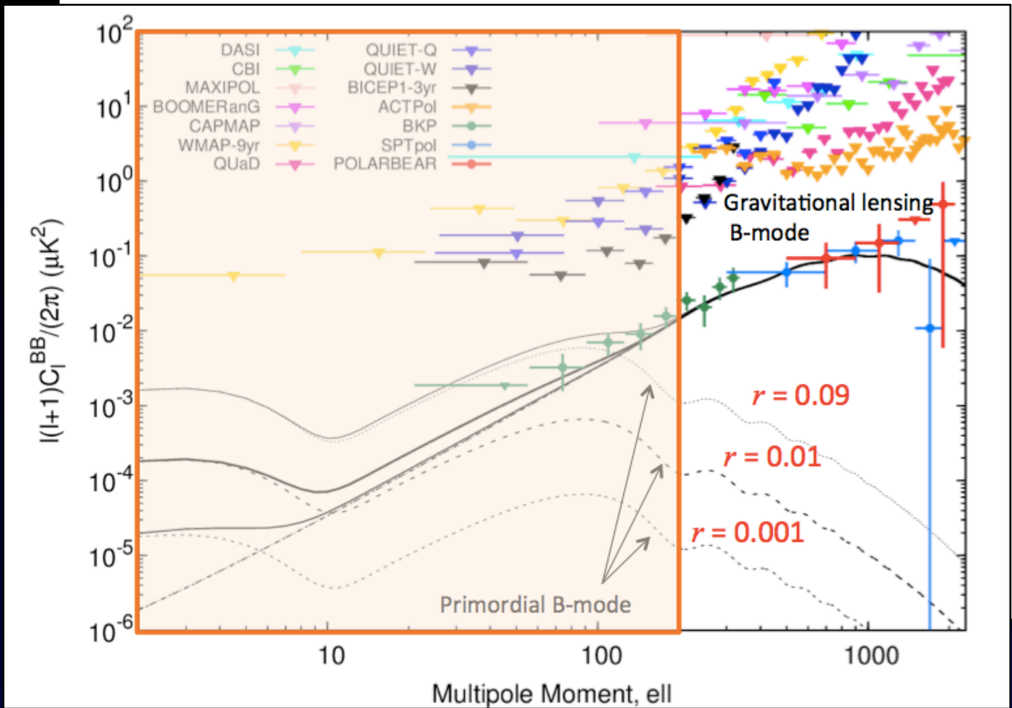
Strategy

The physics tells you

$$A\Omega = \lambda^2$$

(Aperture size) (Angular resolution) = (wavelength)^2

Full sky ∼1 deg



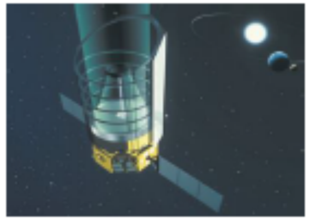
1. CMB is at millimeter wave.
2. The required solution to go after only the inflationary signal is about a degree.
3. The required aperture size is < 1 m.

ISAS/JAXA mission categories

Space Policy Commission under cabinet office intends to guarantee predetermined ***steady annual budget*** for space science and exploration for ISAS/JAXA to maintain its excellent scientific activities

Strategic Large Missions (300M$ class) for JAXA-led flagship science mission with HIIA vehicle (3 in ten years)

ASTRO-H



SPICA

Competitively-chosen medium-sized focused missions (<150M$ class) with Epsilon rocket (every 2 year)

ERG

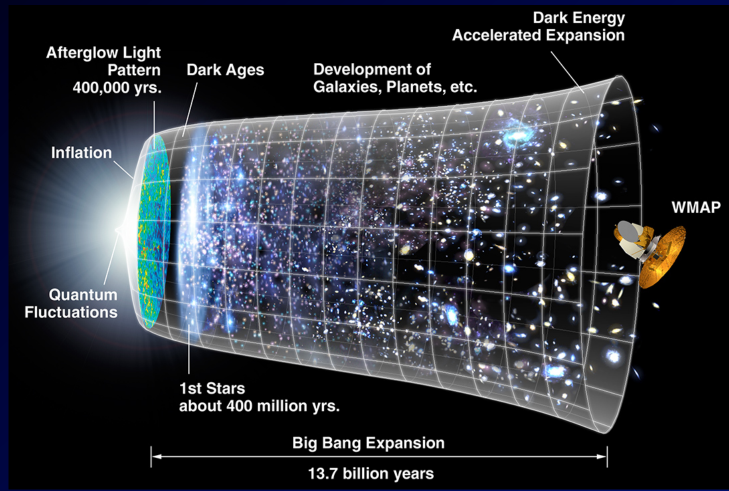
#3 Under selection

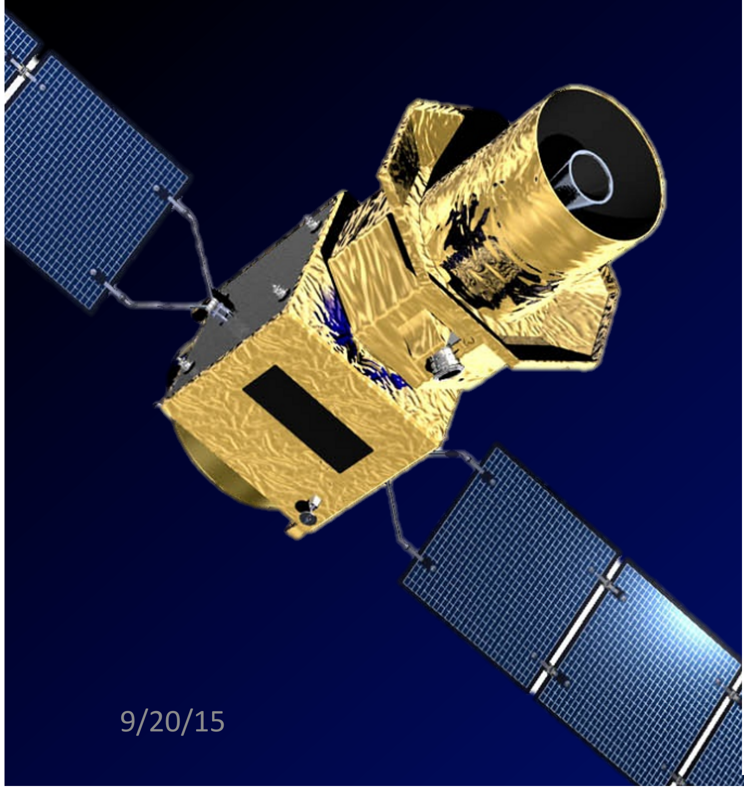
Missions of opportunity (10M$ per year) for foreign agency-led mission, sounding rocket, ISS

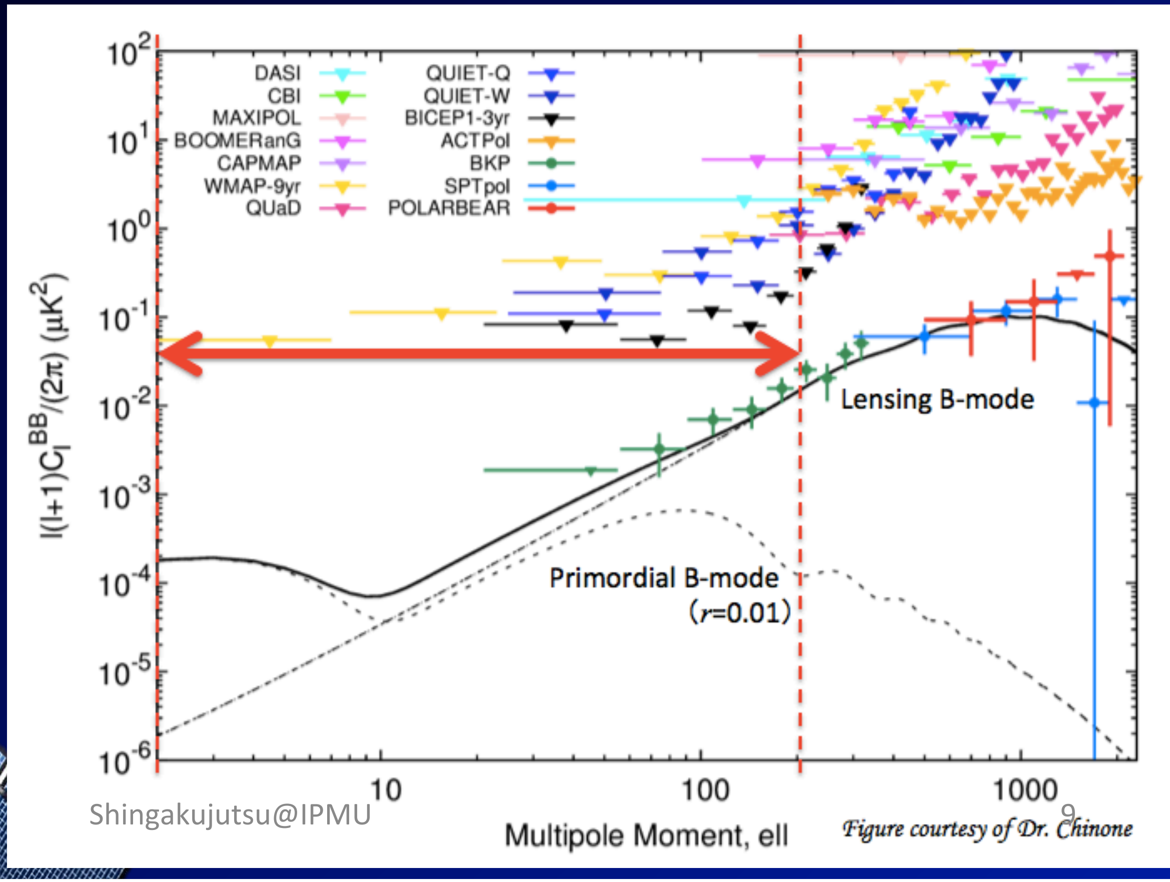
JUICE

LiteBIRD

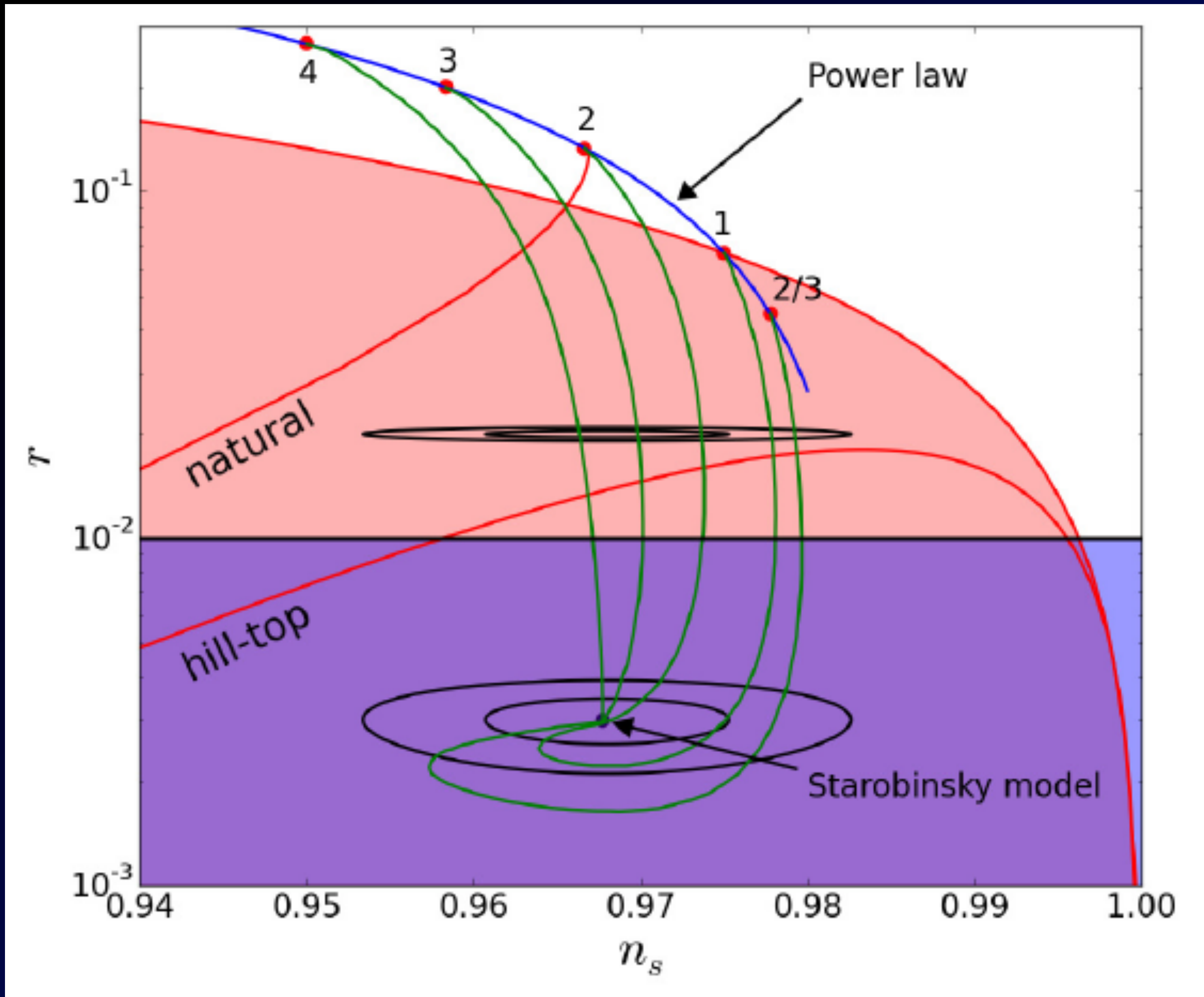
LiteBIRD is a next generation CMB polarization satellite that is dedicated to probe the inflationary B-mode. The science goal of LiteBIRD is to measure the tensor-to-scalar ratio with the sensitivity of $\sigma_r = 0.001$. In this way, we test the major large-single-field slow-roll inflation models.





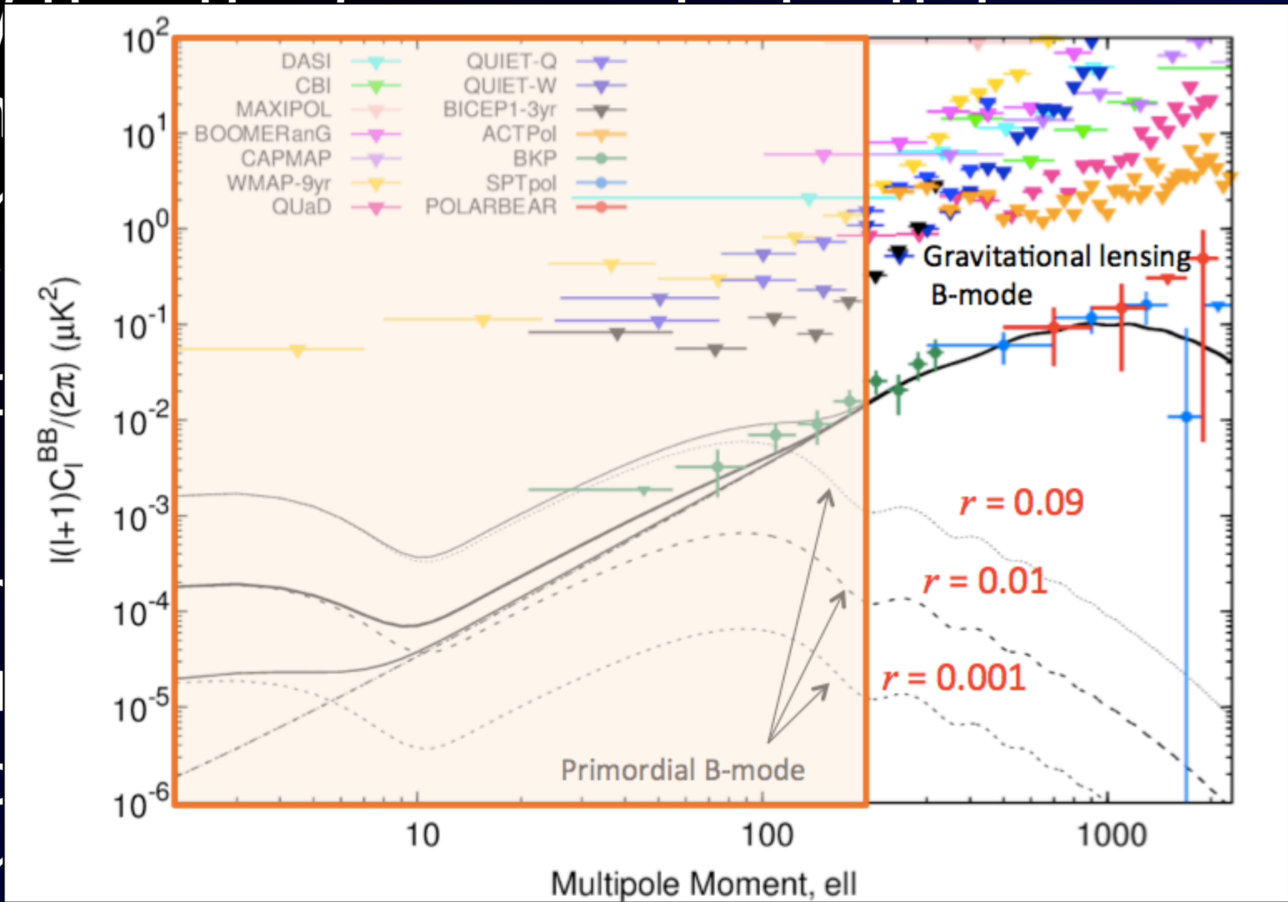


LiteBIRD constraints on r vs. n_s plane



Experimentalist point of views

- W… digm, th… pr… eed 1 bi… But do yo…
- If … the sh… um. Ar… on sp… v ph…



More than inflation?

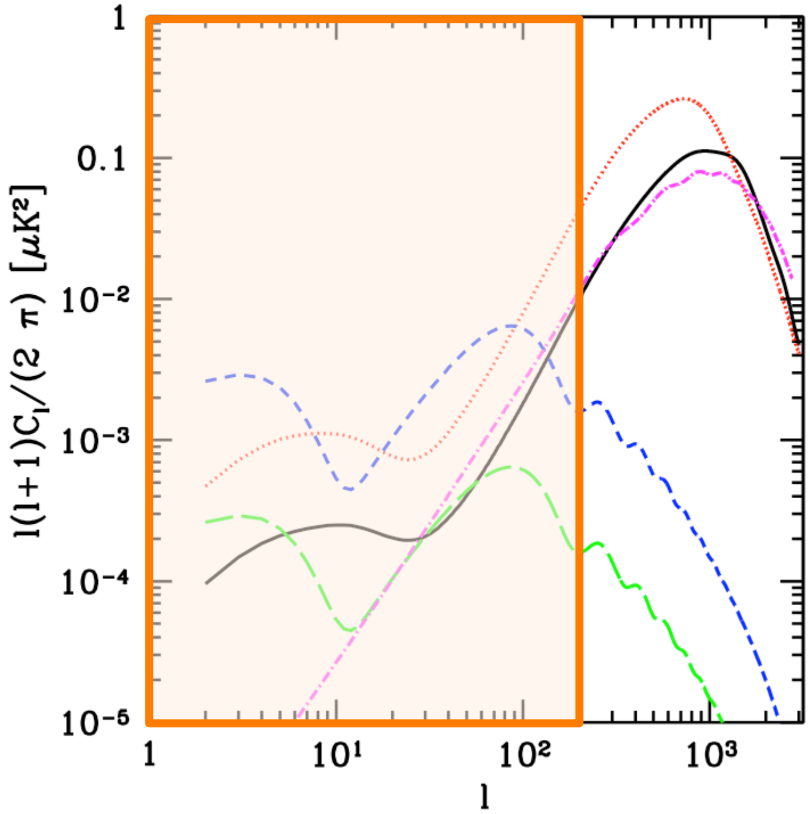


Figure 9: $B-$mode polarization power spectra from strings, tensors and gravitational lensing presented in ref. [62]. For the string spectra, we use values of $G\mu/c^2$ corresponding to the 2σ upper limit from CMB+SDSS data, that is. $G\mu/c^2 = 2.6 \times 10^{-7}$ for the USM Nambu model (solid) and 6.4×10^{-7} for the USM AH case (dotted). We also show the inflationary primordial tensor spectrum with $r = 0.1$ at $k = 0.05\,\mathrm{Mpc}^{-1}$ (short dashed) and $r = 0.01$ (long dashed). Finally, we show the gravitational lensing spectrum generated from $E-$mode mixing (dot-dash) expected in the inflationary model.

The main target for LiteBIRD is inflationary gravitational wave B-mode but there might be something unexpected…

COrE white paper

LiteBIRD working group

122 members, international and interdisciplinary.

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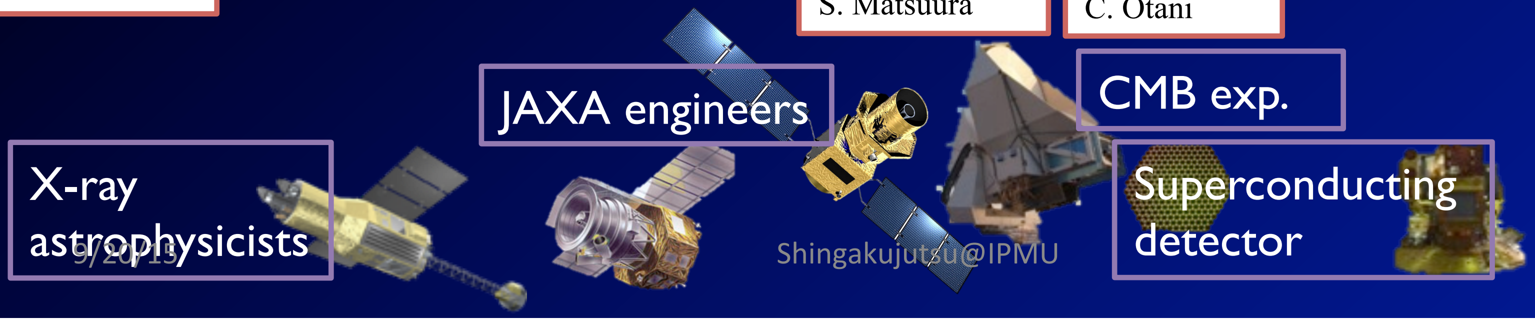
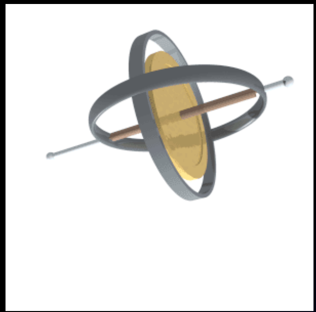
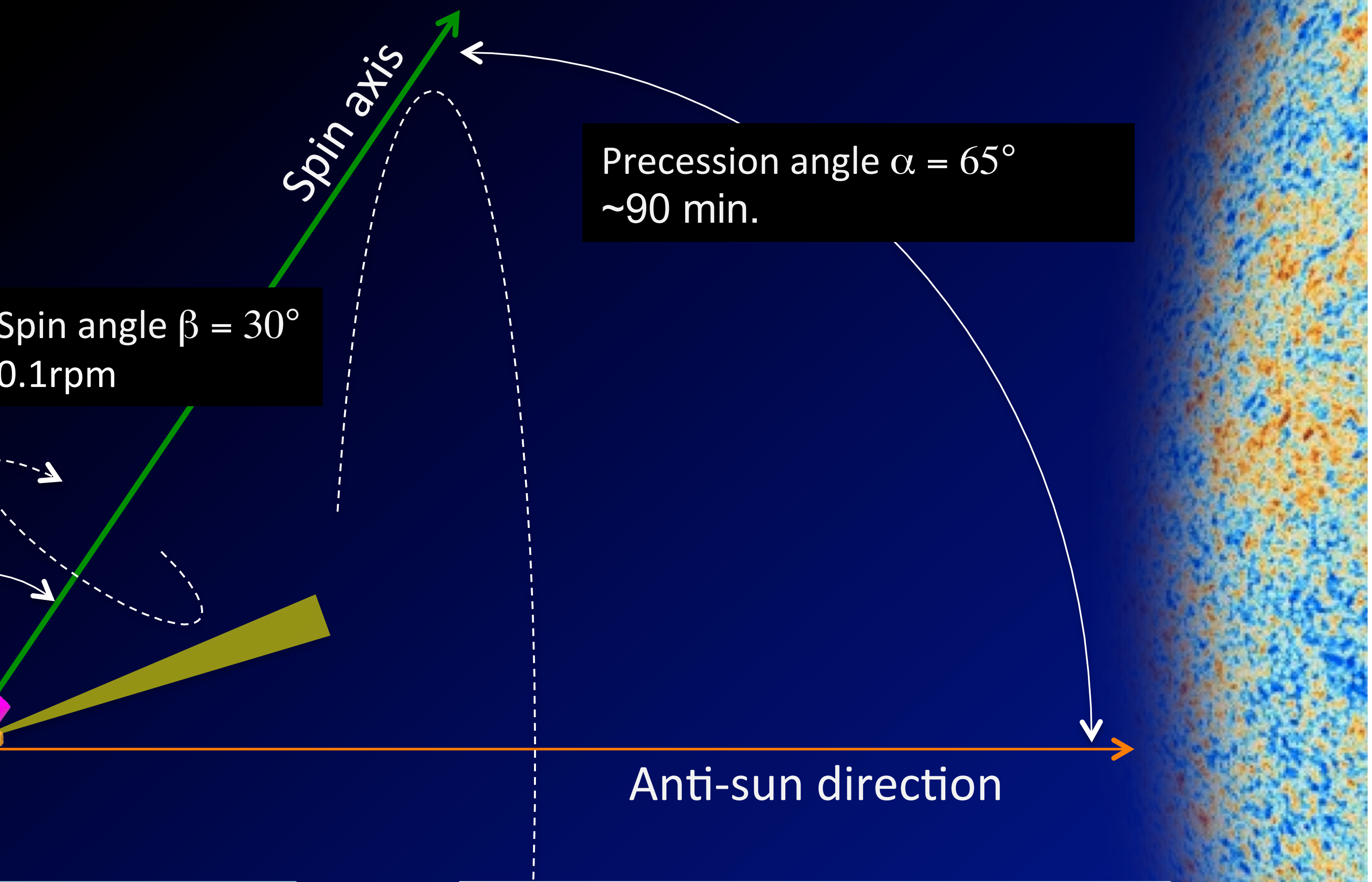


Scan strategy at *L2*





Major Specifications

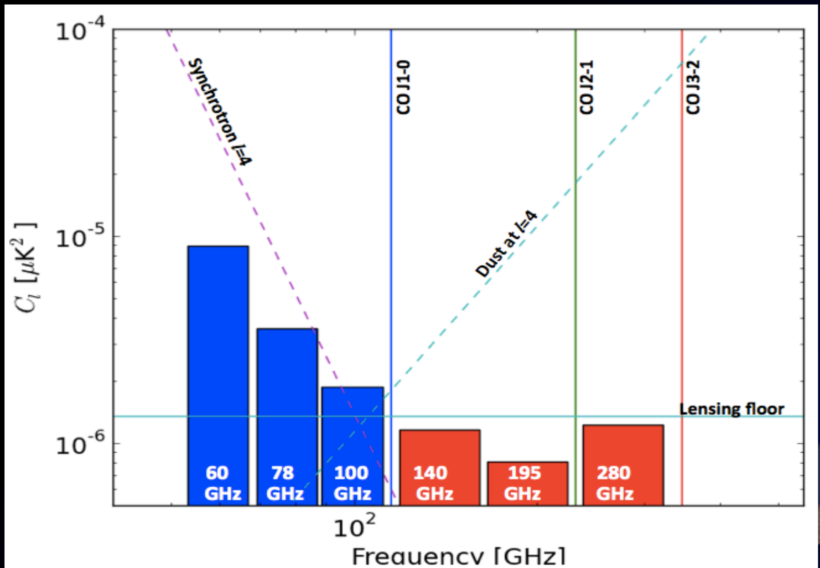
- Weight: ~1300kg
- Power: ~2000W
- Observing time: ≥3 years
- Spin rate: ~0.1rpm (=1.6mHz)

Signal modulation

The signal is modulated by the scan strategy and the rotating HWP to mitigate the $1/f$ noise and the systematics.

Mission instrument overview (1/2)

Observing band



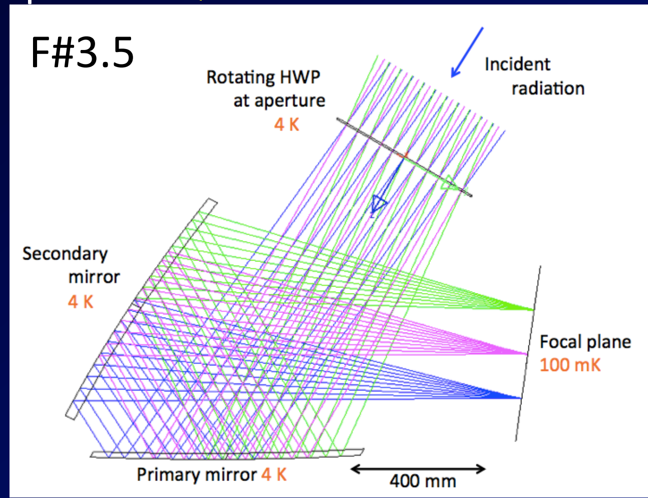
- Baseline coverage of 6 bands at
  60, 78, 100, 140, 195, 280 GHz.

and extend 40-400 GHz if necessary with further study.

- Avoid CO lines.
- In case of a need for more bands, we have an option to vary the band center for each detector and increase the number of bands effectively.

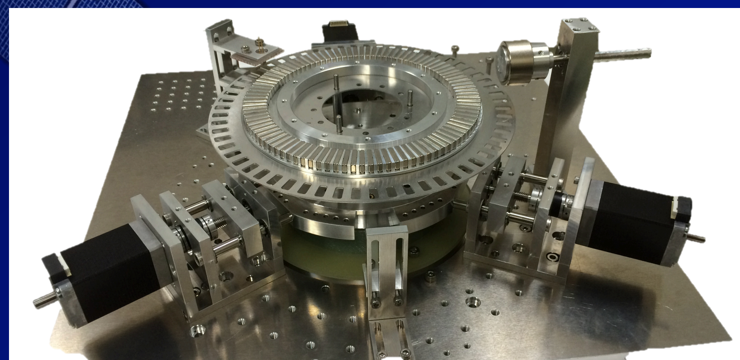
Optical system

Modified cross-Dragone optics 10x20 degrees^2 field-of-view with >99% Strehl ratio over all the observing bands. The telecentric focal plane (D=300mm w/ F#=3.5). Similar telescope from QUIET and ABS.

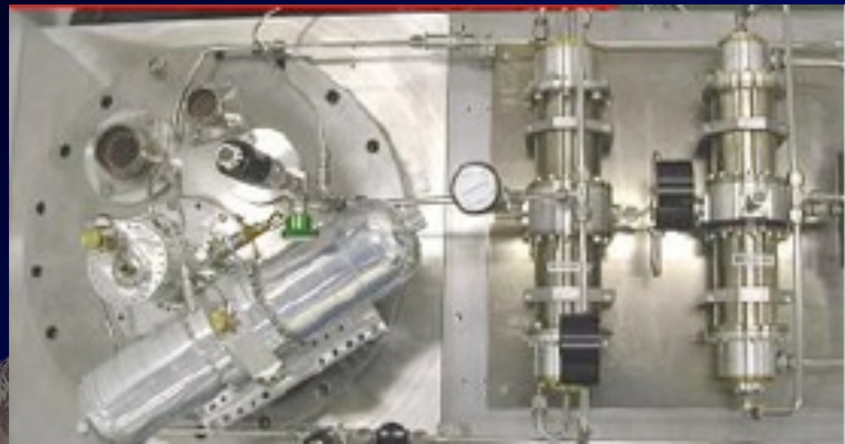


Polarization modulator

Continuously rotating achromatic HWP mechanism at cryogenic temperature. Heritage from EBEX, and ongoing observations using the continuous rotation in ABS and POLARBEAR.



Mission instrument overview (2/2)



Cryogenics

- Warm launch
- 3 years of observations
- 4K for the mission instruments (optical system)
- 100mK for the focal plane

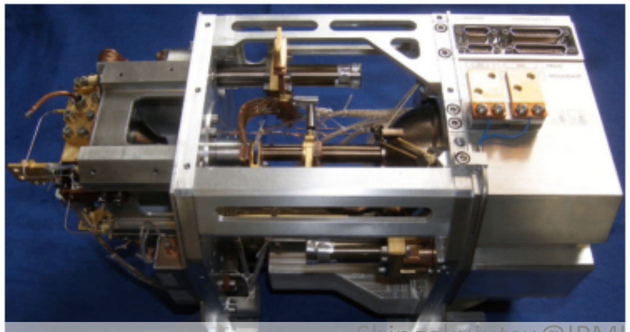
Mechanical cooler

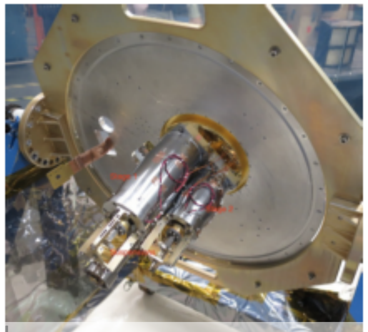
- The 2-stage Stirling cooler and 4K-JT cooler from the heritage of the JAXA satellites, Akari (Astro-F), JEM-SMILES and Astro-H.
- There is an option to employ the 1K-JT that provides the 1.7 K interface to the sub-Kelvin stage.

Sub-Kelvin cooler

- ADR has a high-TRL and extensive development toward SPICA, Astro-H, and Athena.
- Closed dilution with the Planck heritage is also under development.

	ADR + 3He sorption (CEA)	3-stage ADR (NASA/GSFC)	2-stage ADR (JAXA/SHI)
TRL	5 for SPICA 7 (sorption for Herschel)	6 for Astro-H	4
Thermal interface	1.7 K	4 K	4 K


ADR from CEA


ADR from GSFC


ADR from JAXA/SHI

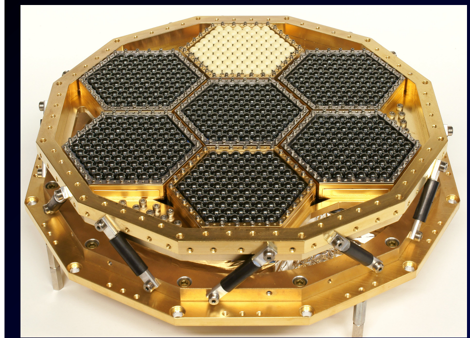
Detector and readout

Requirements

- Sensitivity : Optical NEP ～ aW/√Hz
- Broad frequency coverage : 50 – 300 GHz
- Multi-pixel array: ~2000
- Stability
- High yield
- Low power consumption (< 100W total)
- Controlled sidelobe at a feed
- High TRL

Transition edge sensor (TES) bolometer

Ongoing effort toward Simons array (previous talk).



Z. Kermish Ph.D. thesis
UC Berkeley

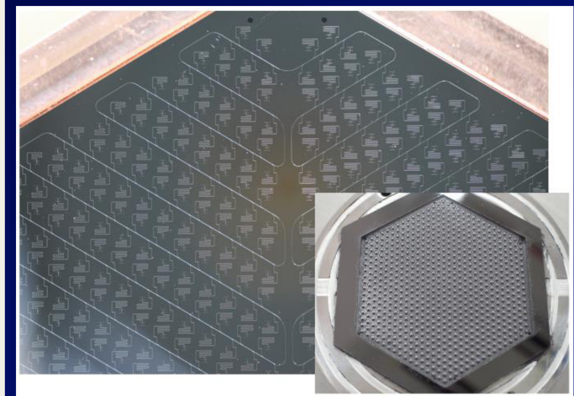
PB-1
1274 TESs with 80% yield.
NET per array: 23 μK√s

PB-2
2 bands/pixel（95,150GHz）
7588 TESs (1897×2pol×2band)
Readout is DfMUX with
MUX=32(+) by McGill Univ.

Matured technology used by the various CMB experiments. Need space qualified low loading TES and low power consumption readout.

Microwave kinetic inductance detector (MKID)

Example of MKID from NAOJ.



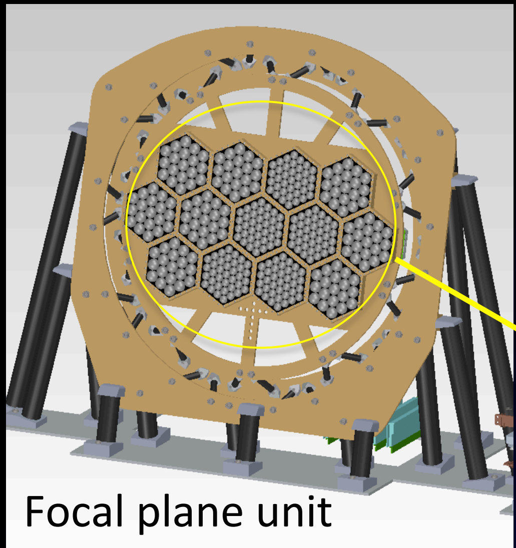
K. Karatsu et al. 2013

NEP ～ 6×10^{-18} W/√Hz
Single band at 200GHz
MUX=600

More examples from
JPL, SRON and others.

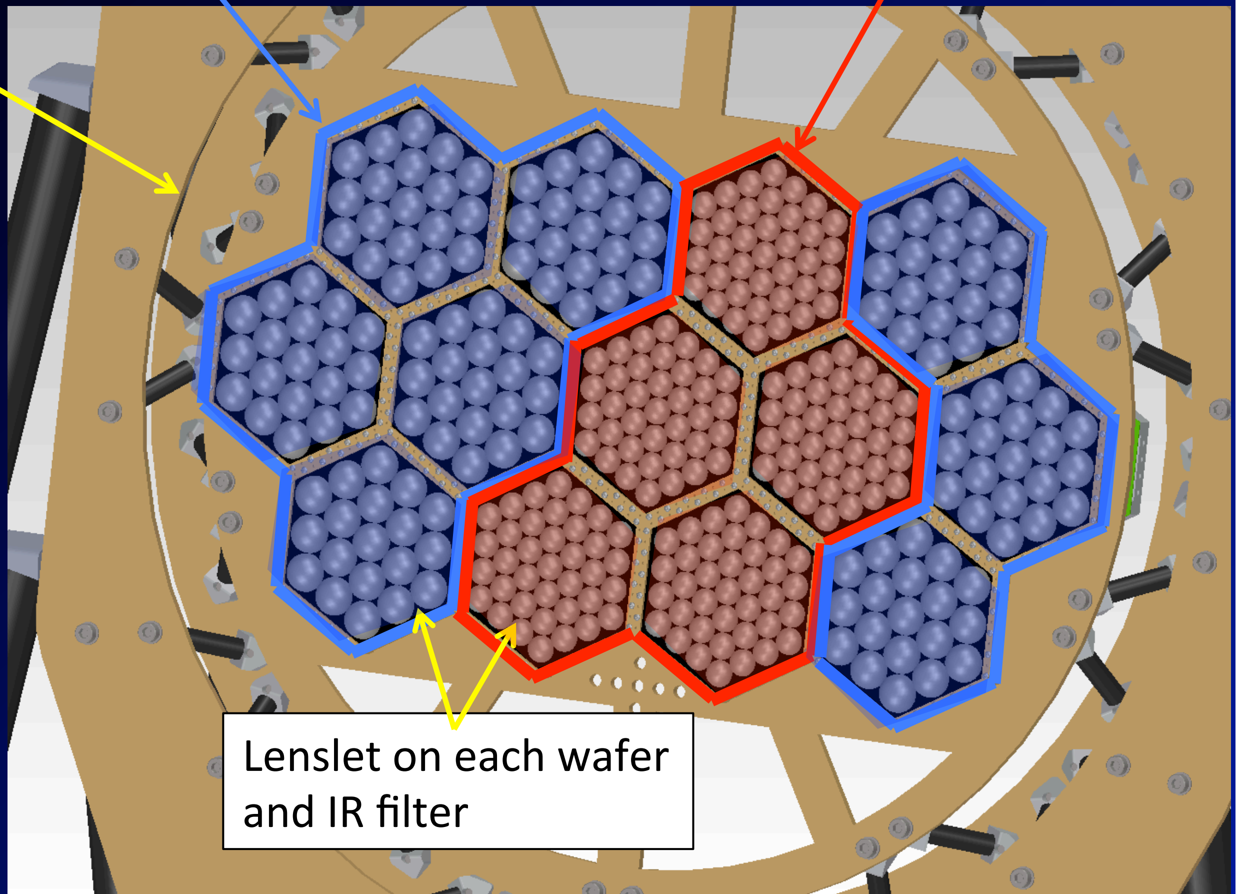
Attractive features and rapid progress in the MKID development. Potential candidate for a future mission in next a few years.

Baseline design for TES option using tri-chroic pixel



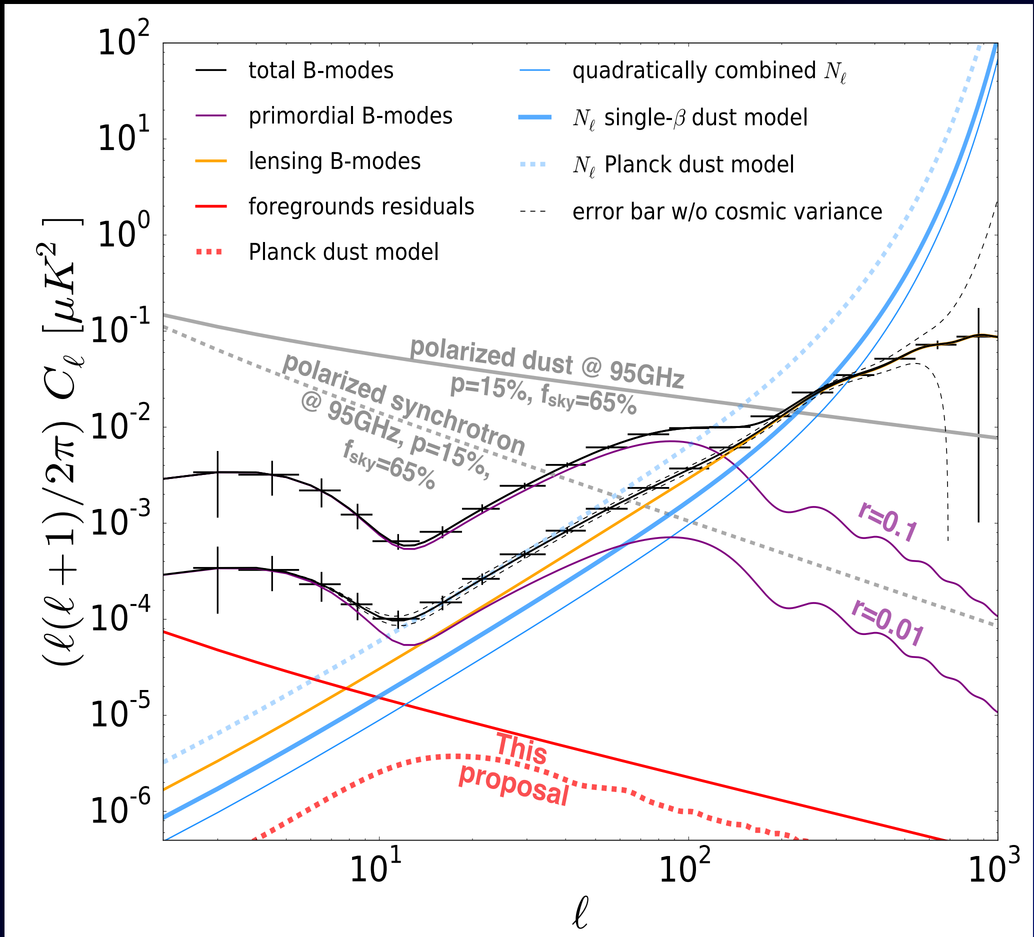
- Low Frequency Wafer (×8) with (60/78/100) GHz
- 185 pixels with 18 mm Si-lens diameter.
- IR filter < 140GHz

- High Frequency Wafer (×5) with (140/195/280) GHz
- 152 pixels with 12 mm Si-lens diameter
- IR filter < 350 GHz



- All the detectors are within the Strehl ratio > 99 %.
- The IR low-pass filters are placed at each wafer to minimize the thermal load to the 100mK stage.
- The corresponding readout is based on the SQUID/DfMUX with the mux factor of 64. We keep the total power consumption by the readout is less than 100W.
- The corresponding date rate is 1.4 GB/day.

Sensitivity w/ foreground subtraction



σ(r) = 0.45 x 10^{-3}

for r = 0.01, including foreground removal and cosmic variance

r < 0.4 x 10^{-3}
(95% C.L.)

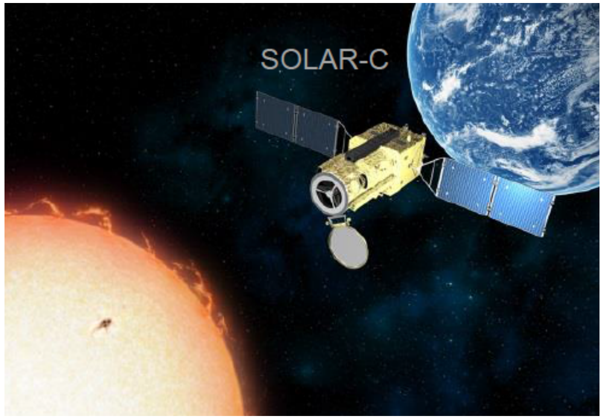
for undetectably small r

Residual computation method: Errard et al. 2011, Phys. Rev. D 84, 063005 and another paper in preparation

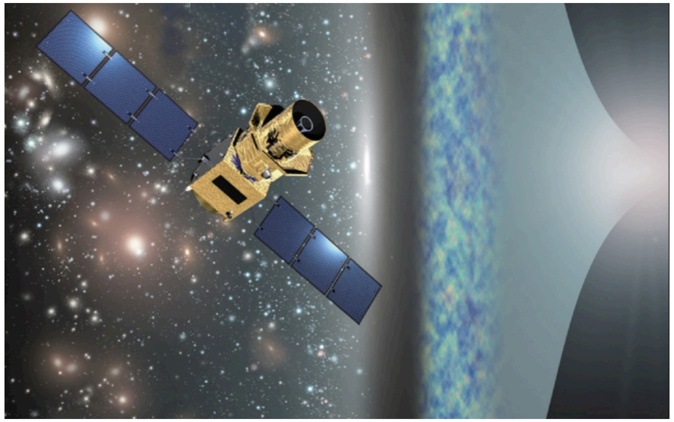
2015 Down-selection for Strategic Missions 2021-2025

- Three missions passed MDR down-selection

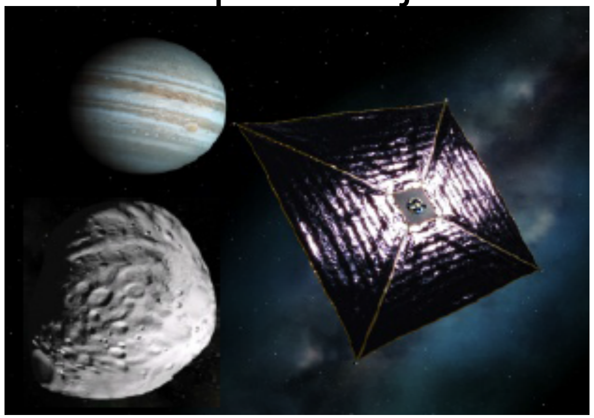
SOLAR-C



LiteBIRD
Proposed for early 2020s launch.

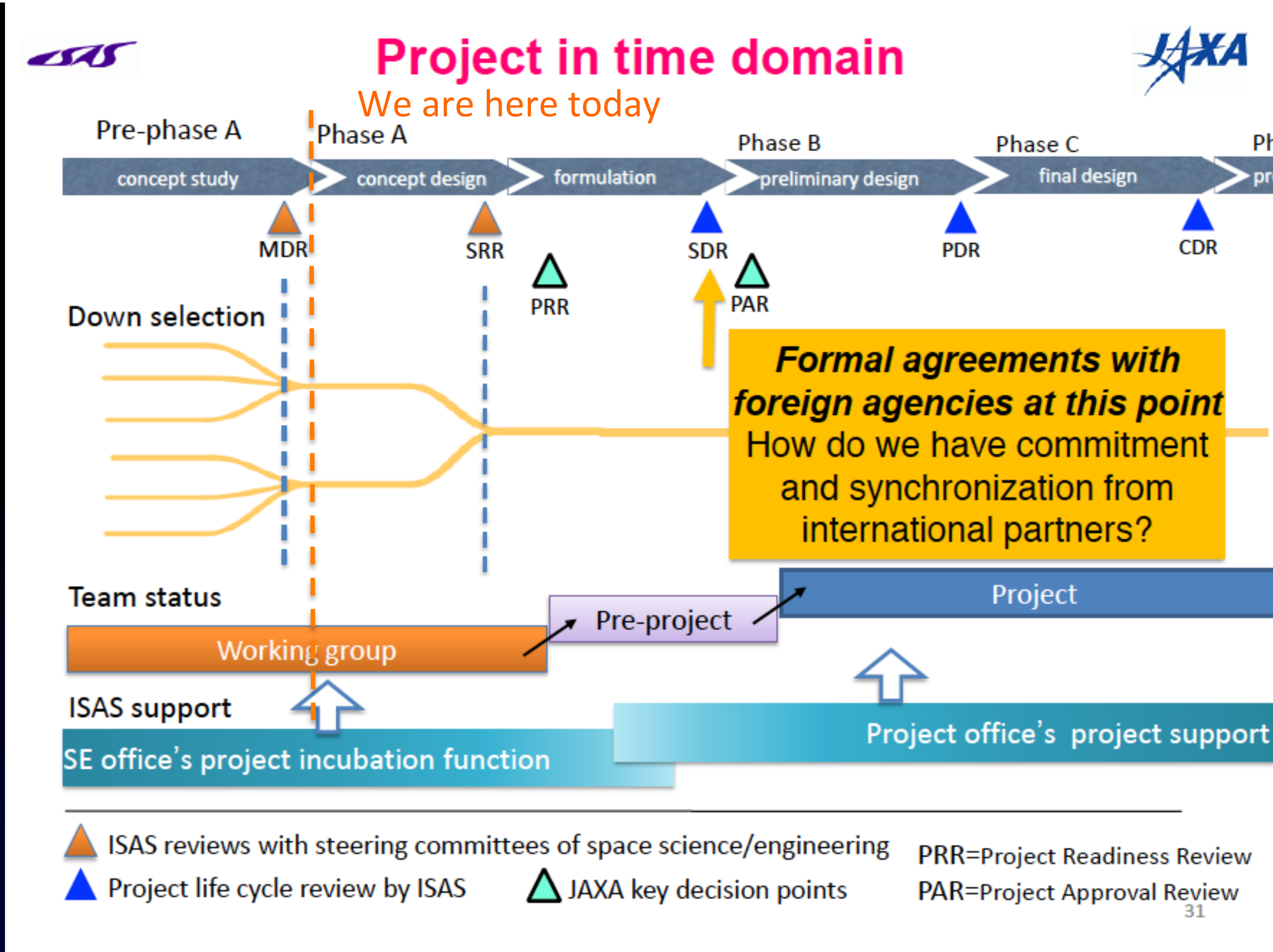


Solar Sail
to Jupiter Trojans



- Additional special mission in consideration
  - Phobos (or Deimos) Sample Return

These four missions will continue studies to pass SRR.

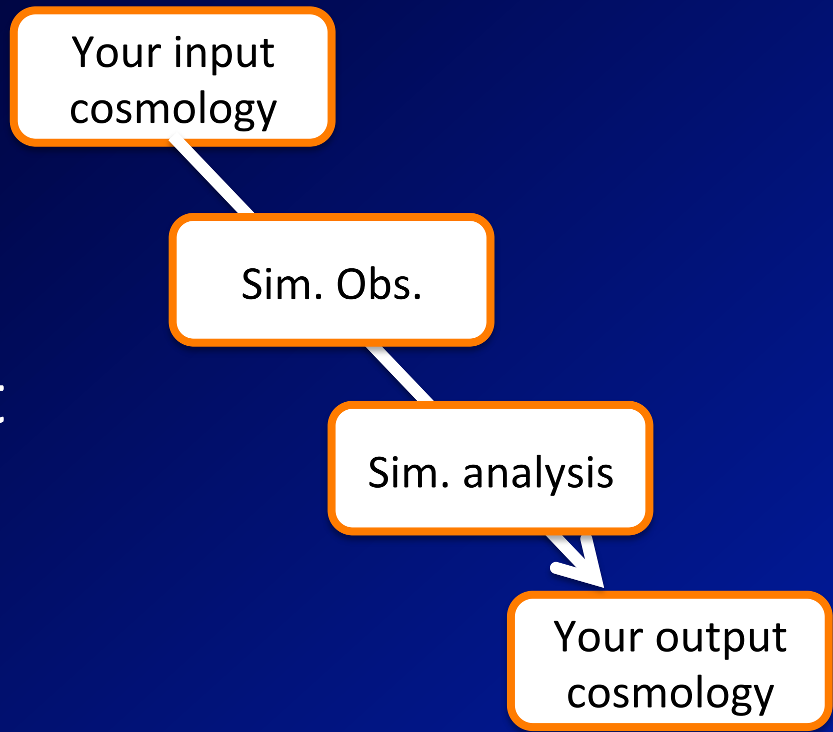


- We also proposed to the NASA missions of opportunity and the proposal is down-selected and it's in phaseA.
- US PIXIE (NASA Goddard)
- European community is putting the proposal together.

Waiting until early 2020s? No!

Many good challenges are everywhere.

- Algorithm development for analyses
  - CMB from time stream to cosmological parameters
  - Foreground removal
  - Calibration
  - Instrumental systematics
  - Validation with simulations
- Instrumental development
- Many more



Summary

- LiteBIRD is a next generation CMB polarization satellite that is dedicated to probe the inflationary B-mode. The science goal of LiteBIRD is to measure the tensor-to-scalar ratio with the sensitivity of $\sigma_r = 0.001$. In this way, we test the major large-single-field slow-roll inflation models.

- LiteBIRD is in the transition to the phase-A study for the launch year of early 2020s.

- A lot of room for young scientists to play roles!

B mode from Space -- Part 1: The cience goals, status of spaceborne projects, foregrounds (Dec 10 -12), Part 2: Mission design, technologies and challenges for the spaceborne observations (Dec 14 -16) --

10-16 December 2015
Asia/Tokyo timezone

Purpose of this Workshop:
The goal of the workshop is to discuss the science goals, status of CMB polarization projects, foregrounds and mission design, technologies and challenges for the spaceborne observations of CMB polarization to detect primordial gravitational waves and thus to prove the inflation theory. The workshop will be the first meeting where the LiteBIRD mission is focused on.

Dates: Dec 10 (Thu) - 16 (Wed), 2015

Part 1: Dec. 10 -12th: the science goals, status of spaceborne projects, foregrounds

Part 2: Dec. 14 -16th: mission design, technologies and challenges for the spaceborne observations

Venue: Lecture Hall (1F), Kavli IPMU main building

Program: not yet vailable

Organizers: M. Hasegawa (KEK), M. Hazumi (Kavli IPMU/KEK), H. Ishino (Okayama), T. Matsumura (ISAS/JAXA), Y. Sekimoto (NAOJ), H. Sugai (Kavli IPMU), N. Katayama (Kavli IPMU)

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