LiteBIRD Mission Definition

Masashi Hazumi
(KEK and Kavli IPMU)
December 12, 2015

LiteBIRD working group

121 members, international and interdisciplinary (as of June 20, 2015)

JAXA
H. Fuke
I. Kawano
H. Matsuhara
T. Matsumura
K. Mitsuda
T. Nishibori
K. Nishijo
A. Noda
A. Okamoto
S. Sakai
Y. Sato
K. Shinozaki
H. Sugita
Y. Takei
M. Utsunomiya
T. Wada
N. Yamasaki
T. Yoshida
K. Yotsumoto

Osaka U.
S. Kuromiya
M. Nakajima
S. Takakura
K. Takano

Osaka Pref. U.
M. Inoue
K. Kimura
M. Kozu
H. Ogawa
N. Okada

Okayama U.
H. Ishino
A. Kibayashi
Y. Kibe
Y. Kida
A. Okamoto
Y. Yamada

NIFS
S. Takada

Kavli IPMU
K. Hattori
N. Katayama
H. Sugai

KEK
M. Hazumi (PI)
M. Hasegawa
N. Kimura
K. Kohri
H. Morii
T. Nagasaki
R. Nagata
H. Nishino
S. Oguri
T. Okamura
N. Sato
T. Suzuki
O. Tajima
T. Tomaru
M. Yoshida

SOKENDAI
Y. Akiba
Y. Inoue
H. Ishitsuka
Y. Segawa
H. Watanabe

NAOJ
A. Dominjon
J. Inatani
K. Karatsu
S. Kashima
T. Nitta
T. Noguchi
S. Sekiguchi
Y. Sekimoto
S. Shu

Saitama U.
M. Naruse

NICT
Y. Uzawa

Konan U.
I. Ohta

U. Tokyo
N. Tomita

Kansei Gakuin U.
S. Matsuura

U. Tsukuba
M. Nagai

TIT
S. Matsuoka
R. Chendra

Tohoku U.
M. Hattori
T. Morishima

Nagoya U.
K. Ichiki

Yokohama Natl. U.
T. Fujino
F. Irie
K. Mizukami
S. Nakamura
K. Natsume
T. Yamashita

RIKEN
S. Mima
C. Otani

APC Paris
R. Stompor

CU Boulder
N. Halverson

McGill U.
M. Dobbs

MPA
E. Komatsu

NIST
G. Hilton
J. Hubmayr

Stanford U.
K. Irwin
C.-L. Kuo
T. Namikawa

UC Berkeley / LBNL
J. Borrill
Y. Chinone
A. Cukierman
T. de Haan
J. Errard
N. Goeckner-wald
P. Harvey
C. Hill
Y. Hori
W. Holzapfel
O. Jeong
A. Kusaka
A. Lee(US PI)
E. Linder
P. Richards
U. Seljak
B. Sherwin
A. Suzuki
P. Turin
B. Westbrook
N. Whitehorn

UC San Diego
K. Arnold
T. Elleot
B. Keating
G. Rebeiz

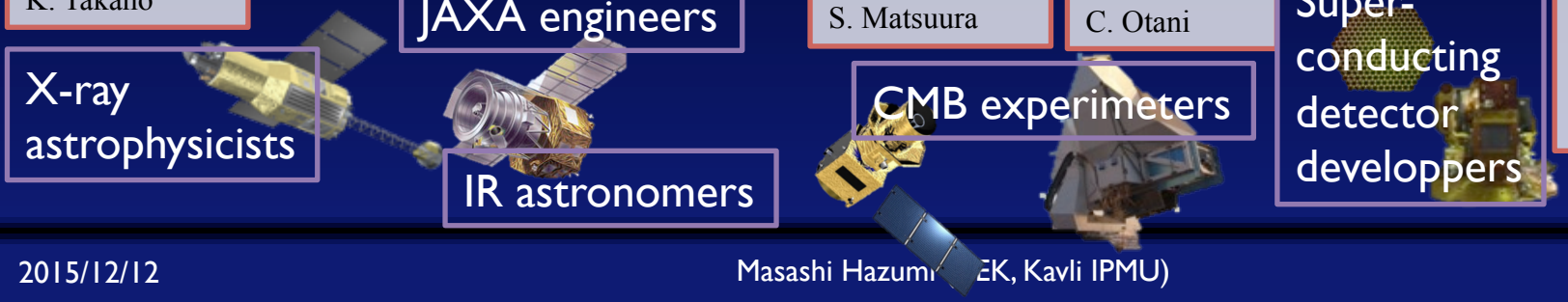
X-ray astrophysicists

JAXA engineers

IR astronomers

CMB experimeters

Super-conducting detector developpers



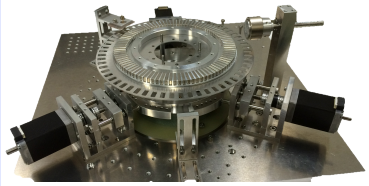
Outline

1. Introduction to
   JAXA Space Science Programs
2. LiteBIRD Mission Overview
3. LiteBIRD Global Baseline for Phase A Studies

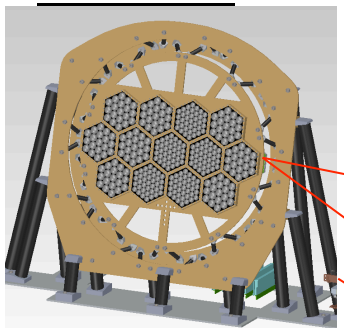
This talk will be followed by the
System Definition talk Monday Dec. 14.

LiteBIRD Instrument

- Mission module benefits from heritages of other missions (e.g. ASTRO-H) and ground-based experiments (e.g. POLARBEAR).
- Bus module based on high TRL components



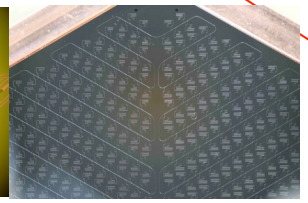
Multi-chroic focal plane detectors



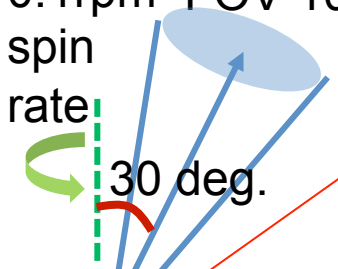
Lenslet

TES

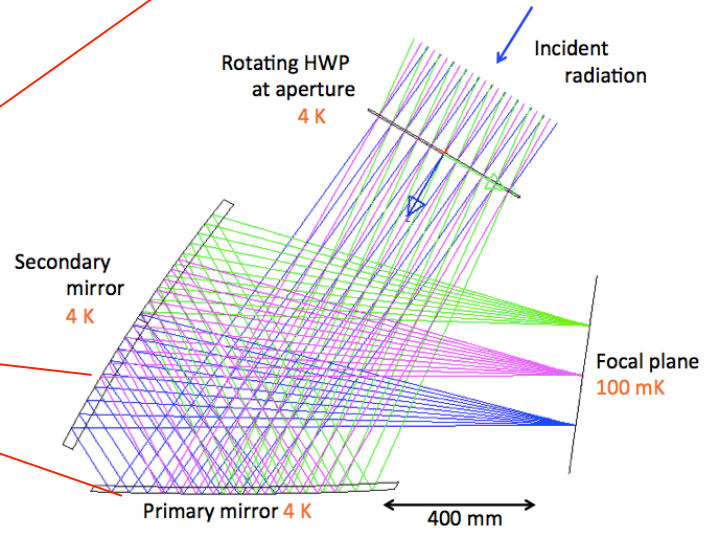
MKID



Continuously-rotating half wave plate (HWP)



Line of sight
FOV 10 x 20 deg.



Mirrors at 4K

Mission module

slip ring

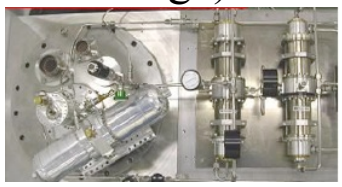
Solar array paddle

Bus module

HGA : X band data transfer to the ground

Cryogenics

- JT/ST and ADR (ASTRO-H heritage)



1. Introduction to JAXA Space Science Programs

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

LiteBIRD

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

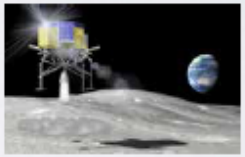
Feb. 12, 2016

ASTRO-H

Two launches in 2021~2025

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

ERG (#2)



SLIM(#3)

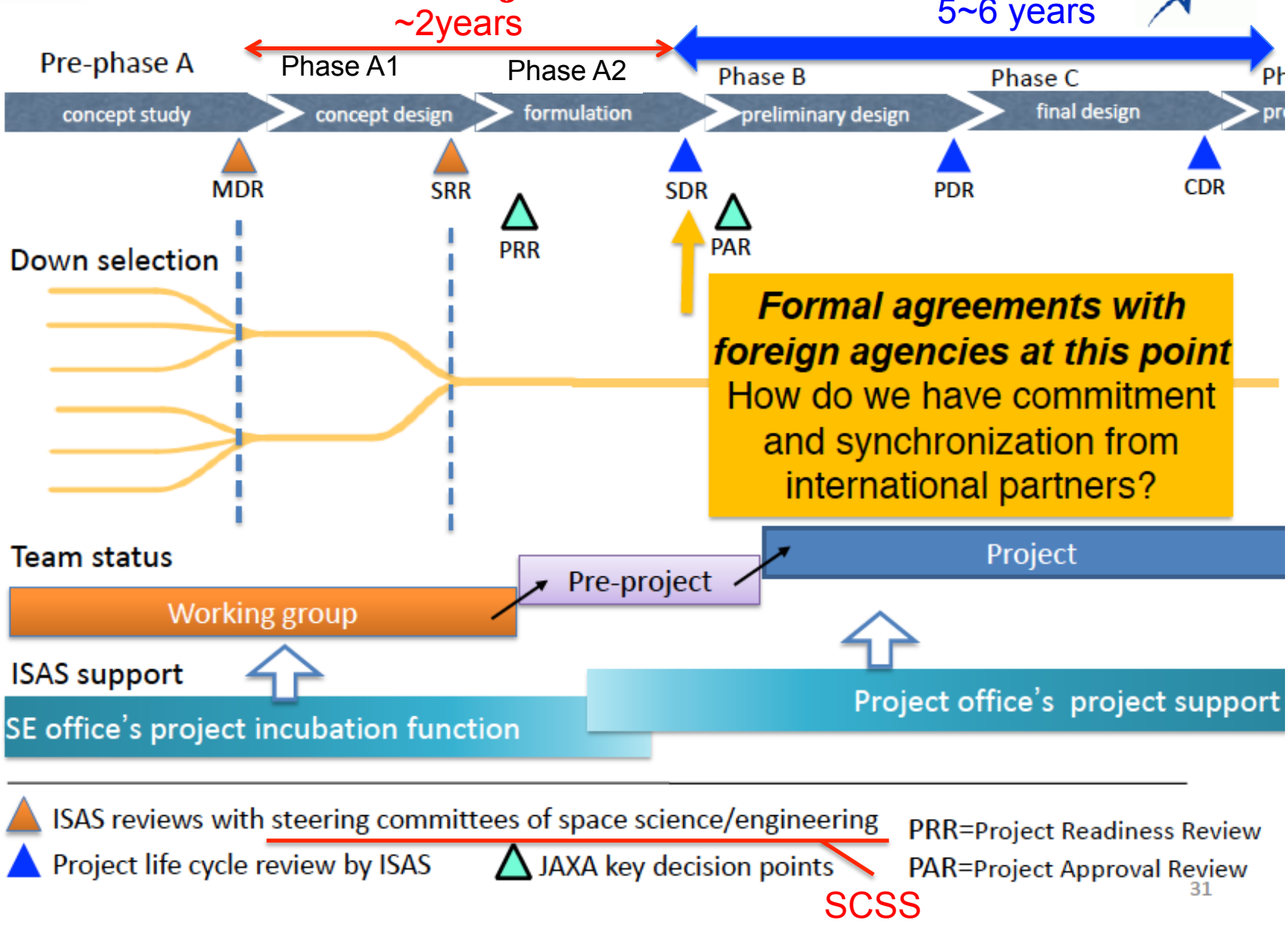
AO for #4 & #5 issued soon

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

JUICE

Original slide by Saku Tsuneta (ISAS director)

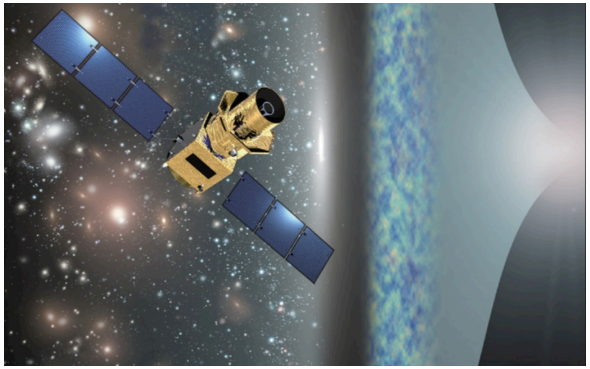
Project Timeline



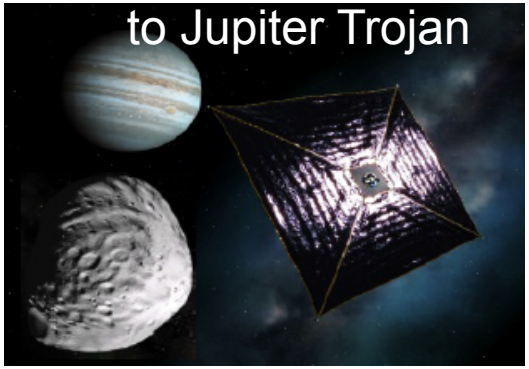
2015 Down-selection for Strategic Missions 2021-2025

- Three missions passed Mission Definition Review (MDR) down-selection
  - SOLAR-C, LiteBIRD, and Solar Sail
- Additional review by ISAS suggested LiteBIRD and Solar Sail to proceed to Phase-A1
- Additional special mission in consideration
  - Phobos (or Deimos) Sample Return

LiteBIRD



Solar Sail



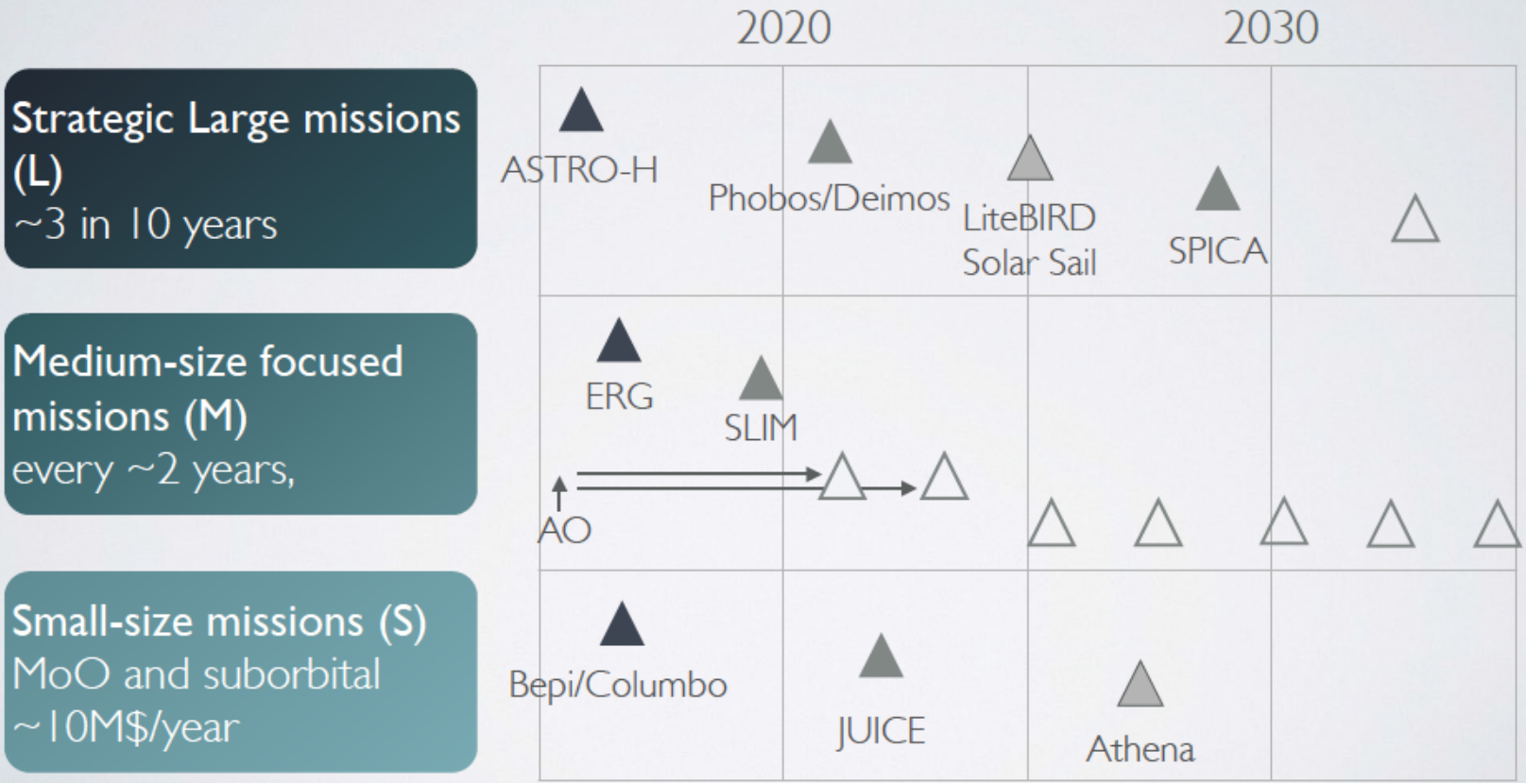
Phobos Sample Return

Studies for these three missions will continue.
Two of them will be selected for 2021-2025 launches.

Provisional Timeline

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

This does not mean the mission time lines below are guaranteed. However, they are foreseeable.



More supporting facts

- 2012: New category "missions for fundamental physics" authorized by by Steering Committee for Space Science (SCSS)
- 2013: "ISAS/JAXA Framework toward Roadmap for Space Science and Exploration" lists "tests of cosmic inflation with the CMB B-mode" as a top-priority scientific objective.

2. LiteBIRD Mission Overview

Special importance of primordial CMB B-mode

- Direct evidence for cosmic inflation
- GUT-scale physics

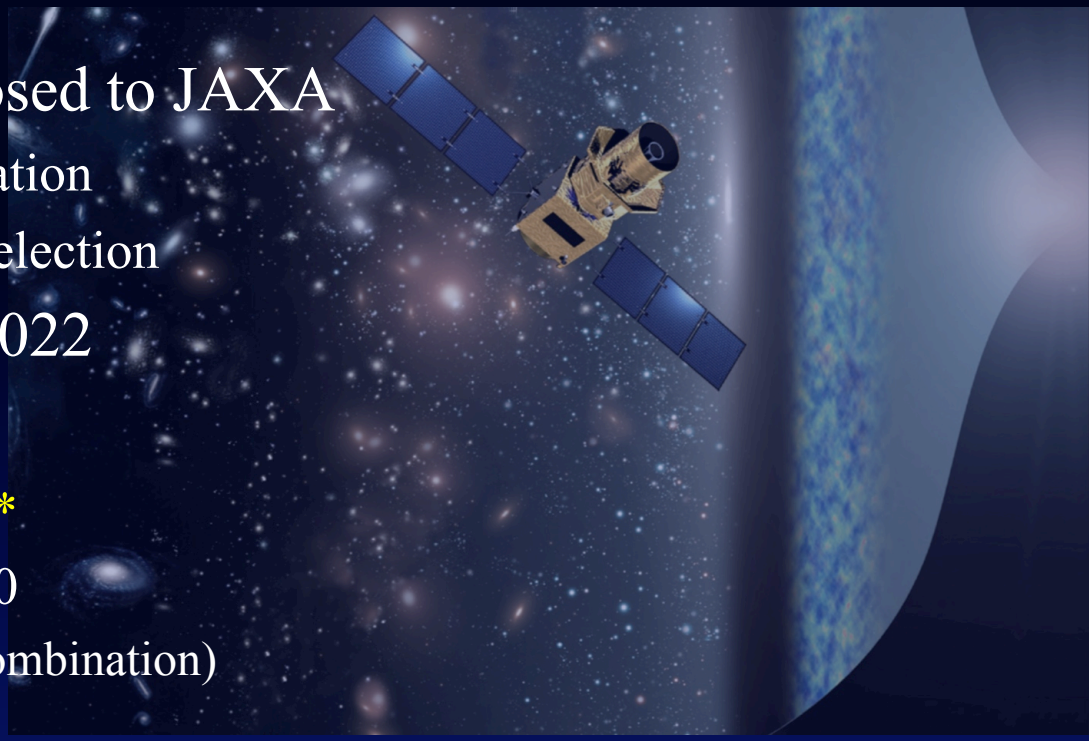
$$V^{1/4} = 1.06 \times 10^{16} \times \left(\frac{r}{0.01} \right)^{1/4} [\mathrm{GeV}]$$

V: Inflaton potential, r: tensor-to-scalar ratio

- Arguably the first observation of quantum fluctuation of space-time !

LiteBIRD Overview

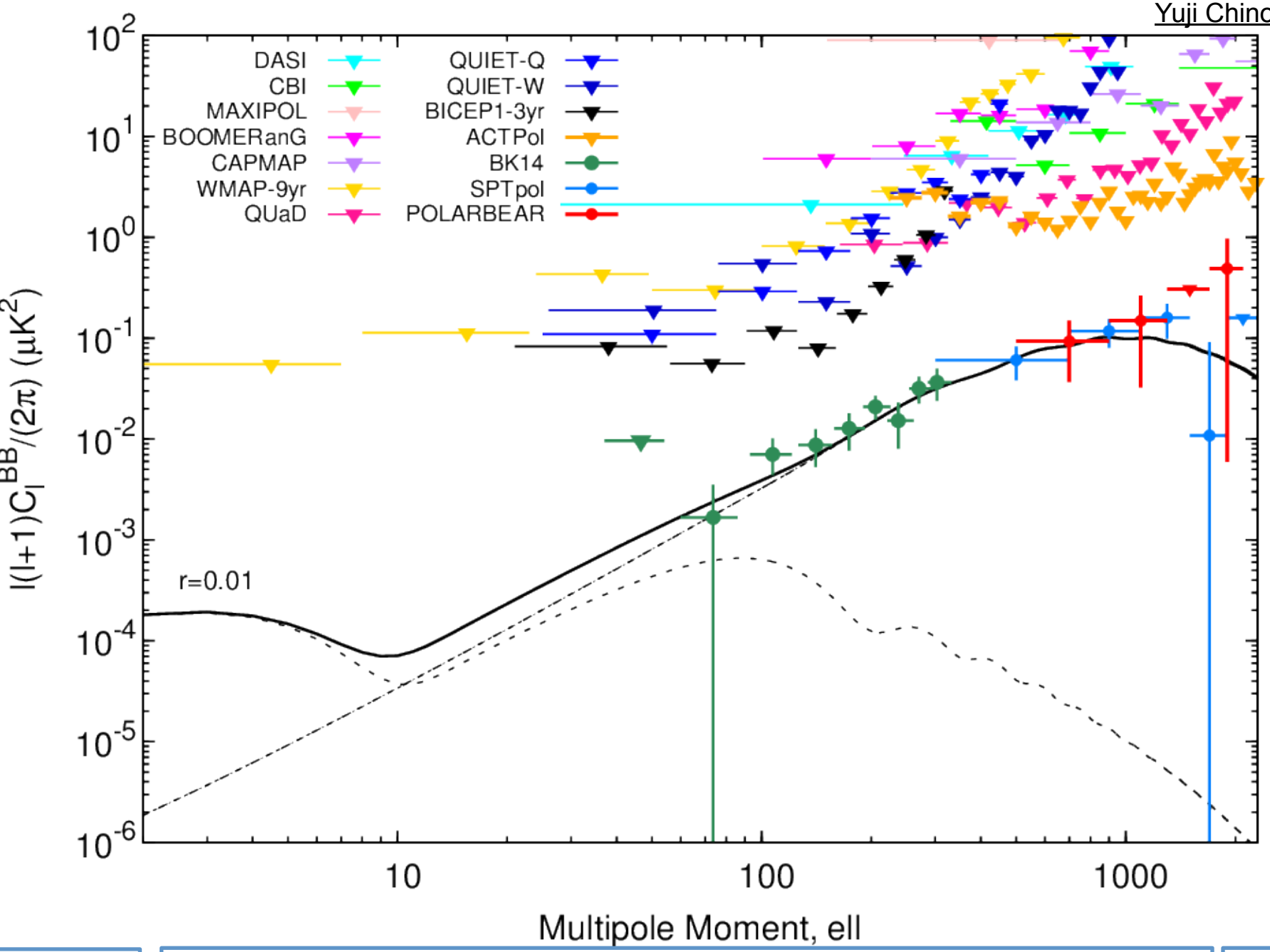
Lite (Light) Satellite for the Studies of B-mode Polarization and Inflation from Cosmic Background Radiation Detection



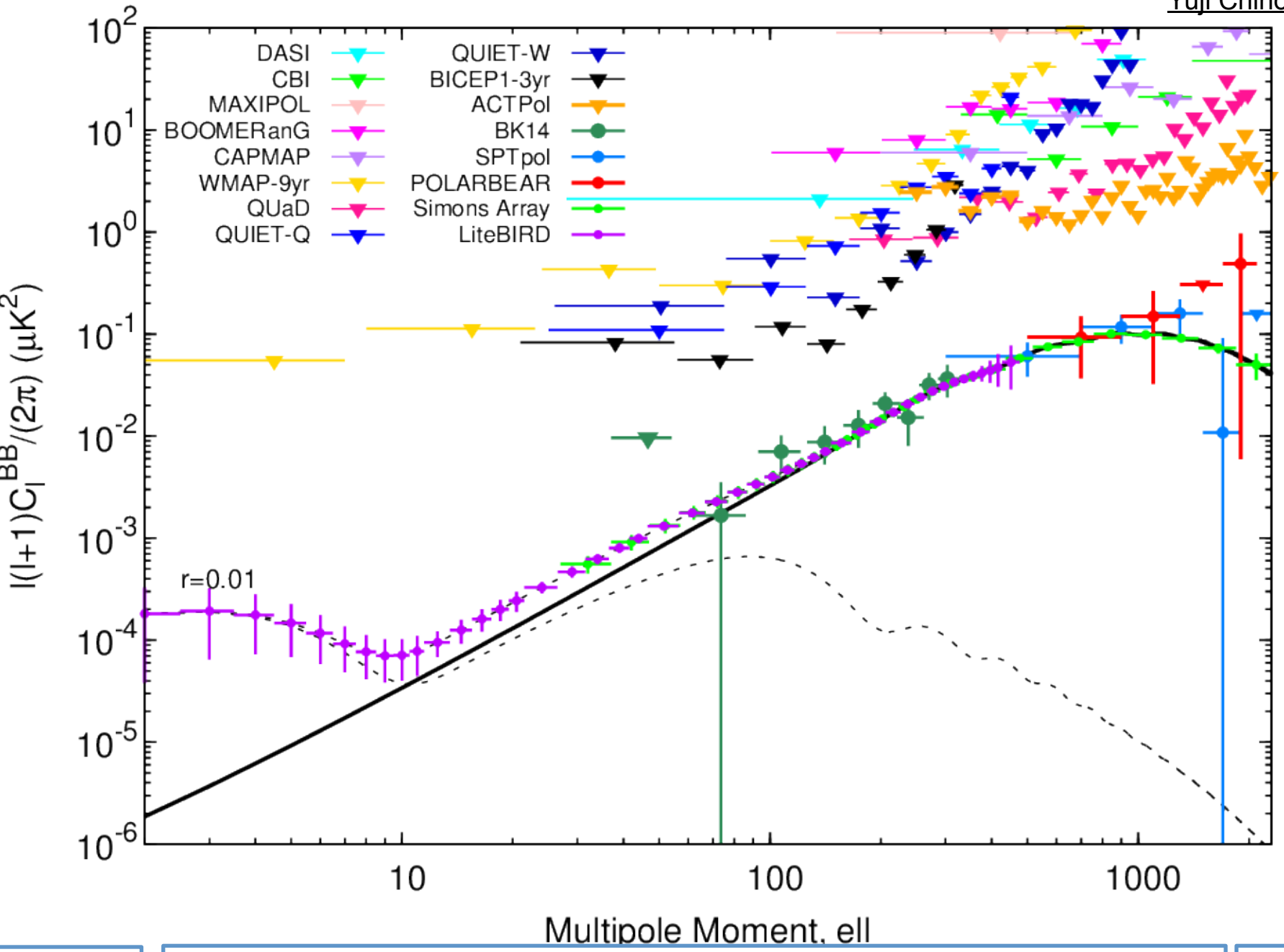
- CMB B-mode satellite proposed to JAXA
  - Also to NASA for US participation
  - Both proposals passed initial selection
- Proposed launch year: JFY 2022
- Mission Requirements
  - Total uncertainty on r < 0.001*
  - Multipole coverage: $2 \leq \ell \leq 200$
    - Each bump (reionization, recombination) with >5sigma if r > 0.01
- Orbit: L2
- Observing time: 3 years

*Our current studies yield $\sigma(r) = 2 \times 10^{-4}$ (for r=0) for 3 year observation

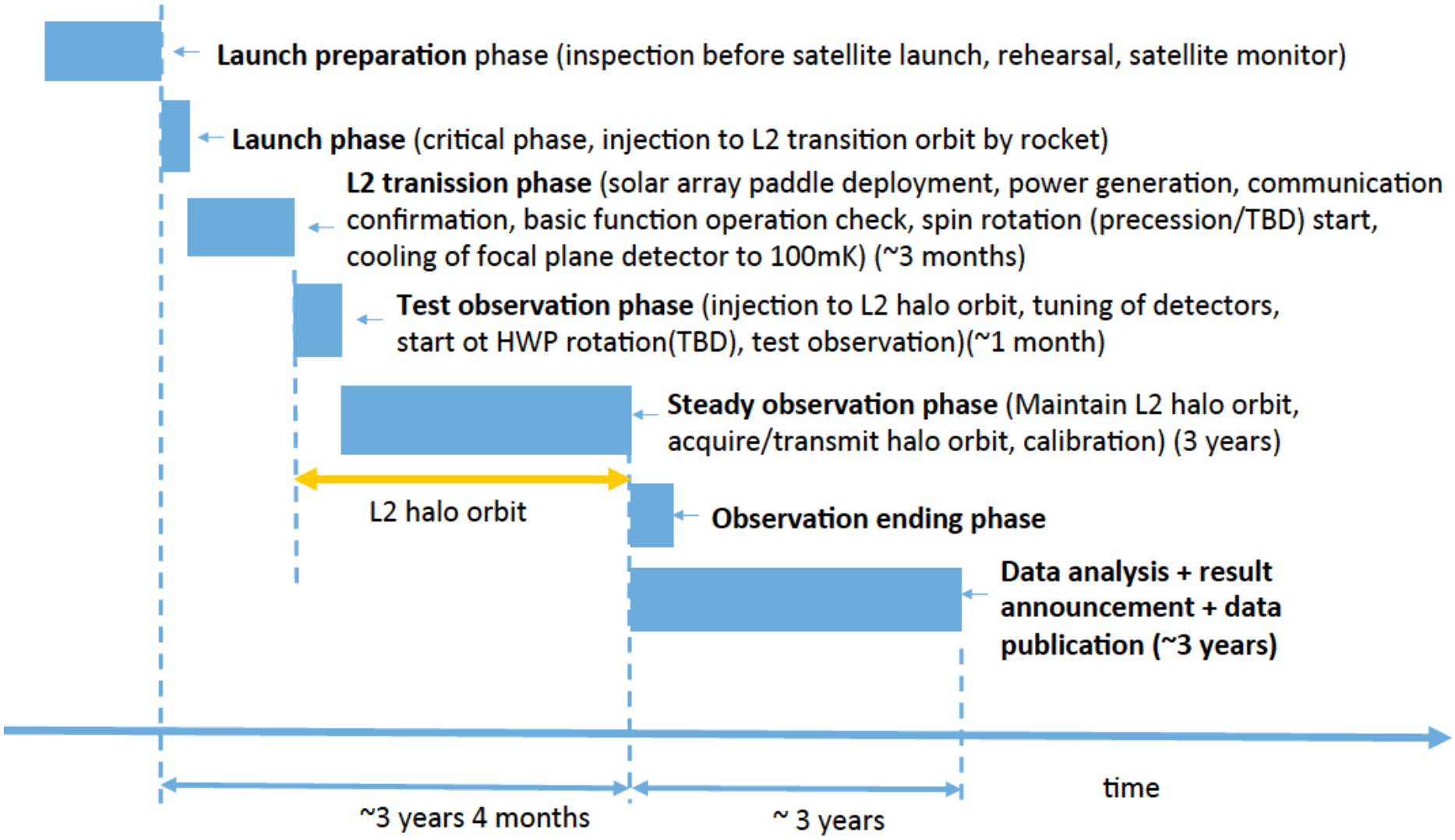
Yuji Chinone



Yuji Chinone



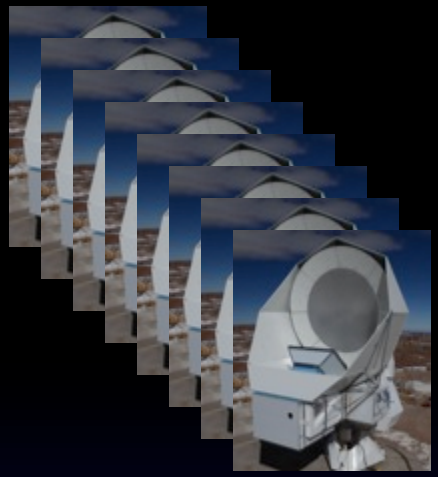
Provisional operation concept



Basic Strategy

Powerful Duo

X



Focused mission
$\sigma(r)<0.001$
$2 \leq \ell \leq 200$
w/ many byproducts

Telescope arrays on ground
$30 \leq \ell \leq 3000$~10000
e.g. CMB-S4

Improving $\sigma(r)$ by delensing with other observations is defined as “extra success” in LiteBIRD Mission Definition.

Why in space ? – Clear advantages

- Frequency bands are much less limited in space
  → better foreground rejection capability
  - Lines due to O_2 and H_2O need to be avoided on ground
  - Balloons also suffer from O_2 lines around 60 GHz
  - High frequencies (e.g. 353GHz that Planck relies on for foreground removal) are hard to access on ground
- No atmospheric noise
- Can observe the full sky and lowest multipoles
  - Both bumps (reionization, recombination) can be detected
  - Lensing B-mode small even for $r < 0.01$

Why targeting σ(r) < 0.001 ?

- Many models predict r>0.01 → >10σ discovery.
- What if we do not see the signal ?
  - Focus on the simplest models based on Occam's razor principle.
  - Single field models that satisfy slow-roll conditions give

$$r \simeq 0.002 \left(\frac{60}{N}\right)^2 \left(\frac{\Delta\phi}{m_{pl}}\right)^2$$

Lyth relation

N: e-folding, m_{pl}: reduced Planck mass

  - Establishing a bound r < 0.002 (95%C.L.) will rule out large field models that satisfy the Lyth relation. Setting this limit is a very significant contribution to cosmology and fundamental physics.
    - More model-dependent studies come to the same conclusion

If evidence is found before launch

- r is fairly large → Comprehensive studies by LiteBIRD !
- Much more precise measurement of r from LiteBIRD will play a vital role in identifying the correct inflationary model.
- LiteBIRD will measure the B-mode power spectrum w/ high significance for each bump if r>0.01.
  - Deeper level of fundamental physics

$\sigma(r) < 0.001$ for $2 \leq \ell \leq 200$ is what we need to achieve in any case to set the future course of cosmology

No-Lose Theorem of LiteBIRD

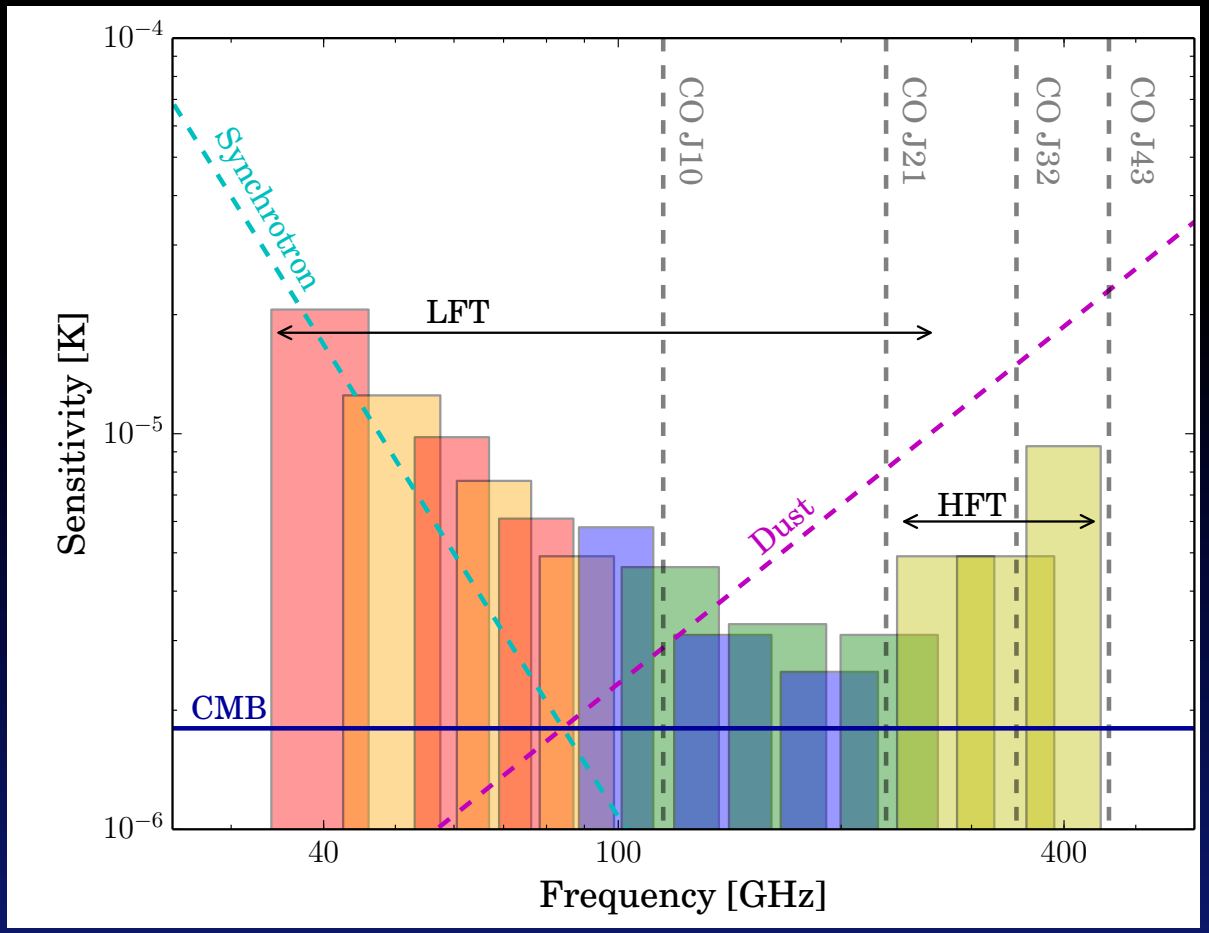
Scientific "Shopping List"

- LiteBIRD will provide precise and accurate whole-sky maps of B-mode and E-mode.
  - C_l^{BB} → Inflation and Quantum Gravity (r, n_t)
    → Lensing B-mode down to very low ℓ
  - C_l^{EE} → Reionization history, τ
  - Power spectrum deviation from ΛCDM
    → e.g. Parity Violation in Gravity, Quantum Loop Gravity, Primordial Magnetic Field
  - Bi-spectrum (BBB etc.)
    → Tensor non-Gaussianity
  - Non-standard patterns (e.g. bubbles) in the maps
    → e.g. Multiverse
  - Foreground Science
  - Galactic Magnetic Field (in particular at large galactic attitude)

LiteBIRD is a focused mission with many by-products.

3. LiteBIRD Global Baseline for Phase A Studies

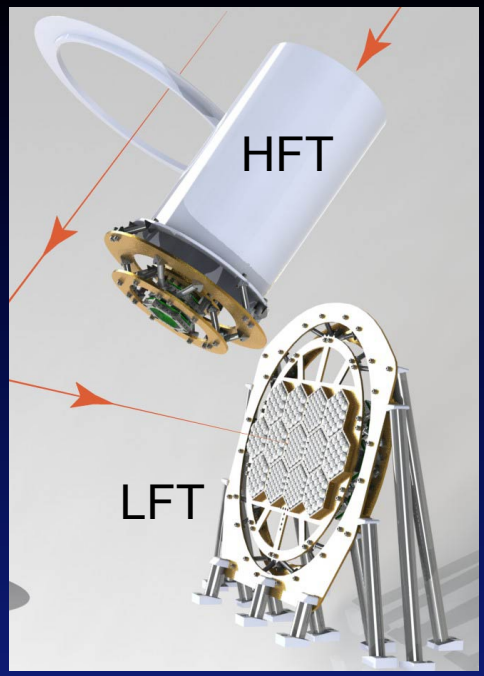
15 frequency bands



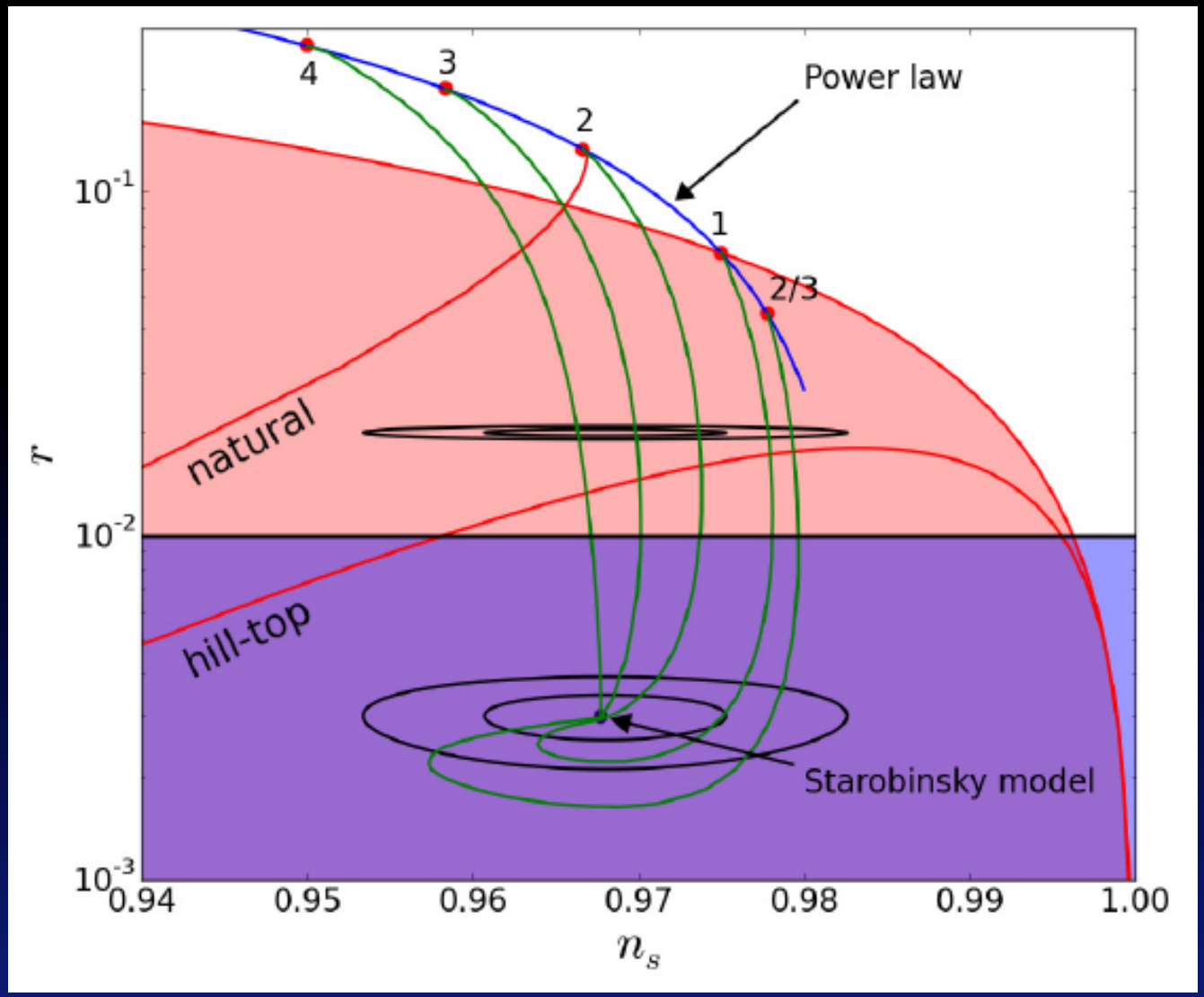
Polarization sensitivity

2.4 μKarcmin

(3 year operation, including margin)



LiteBIRD constraints on r vs. n_s plane (15 bands)



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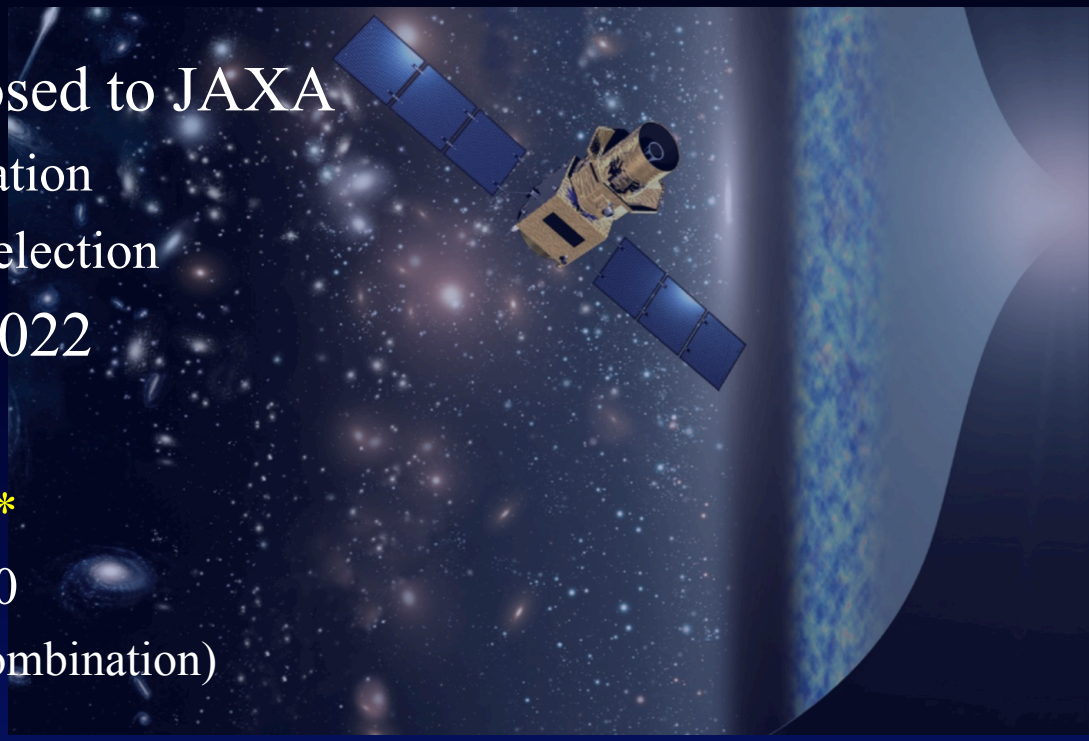

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