LiteBIRD

A Small Satellite for the Studies of B-mode Polarization and Inflation from Cosmic Background Radiation Detection

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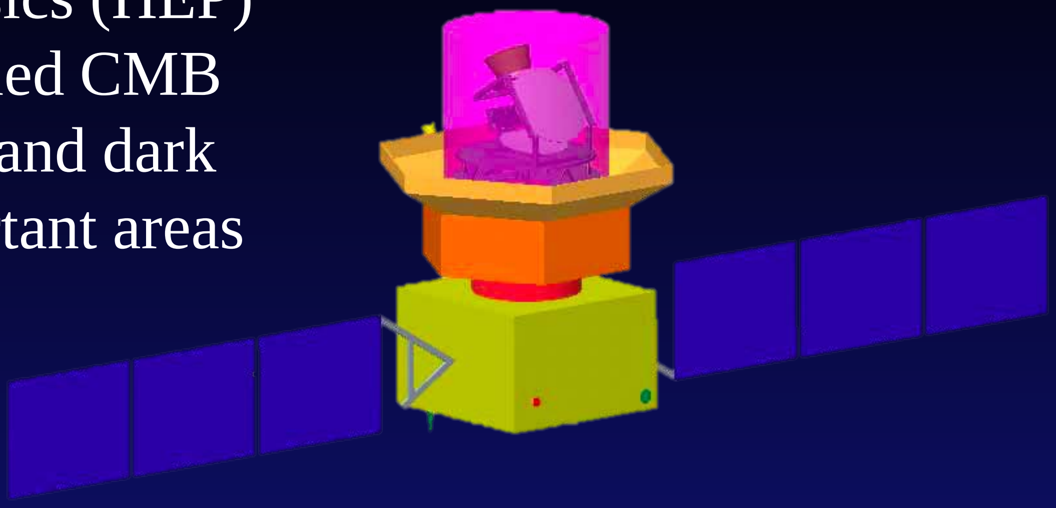
On behalf of the LiteBIRD working group

Overview

- Candidate for JAXA's future missions on "fundamental physics"
- Working group authorized by Steering Committee for Space Science (SCSS) of Japan
- One of eight most important future projects by astronomy/astrophysics division of Science Council of Japan New
- Japanese High Energy Physics (HEP) community has also identified CMB polarization measurements and dark energy survey as two important areas of their "cosmic frontier".



LiteBIRD working group

- 64 members (as of Mar. 1, 2013)
- International and interdisciplinary

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JAXA
H. Fuke
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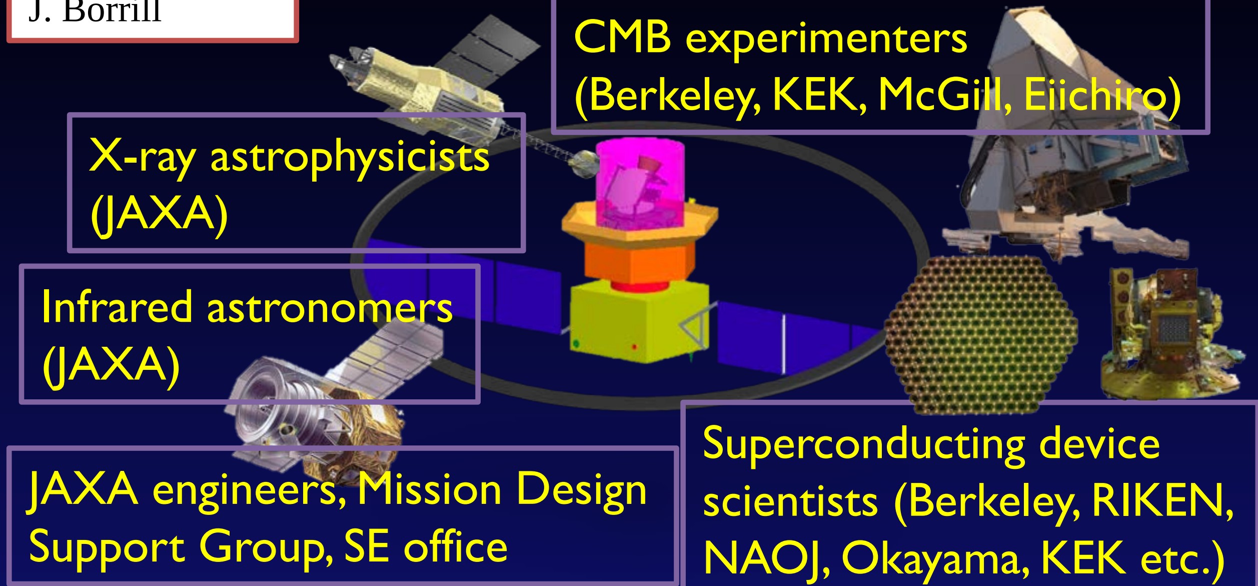


LiteBIRD mission

- Check representative inflationary models
  - ***requirement on the uncertainty on r***

    (stat. ⊕ **syst.** ⊕ **foreground** ⊕ **lensing**) **$\delta r < 0.001$**

No lose theorem of LiteBIRD

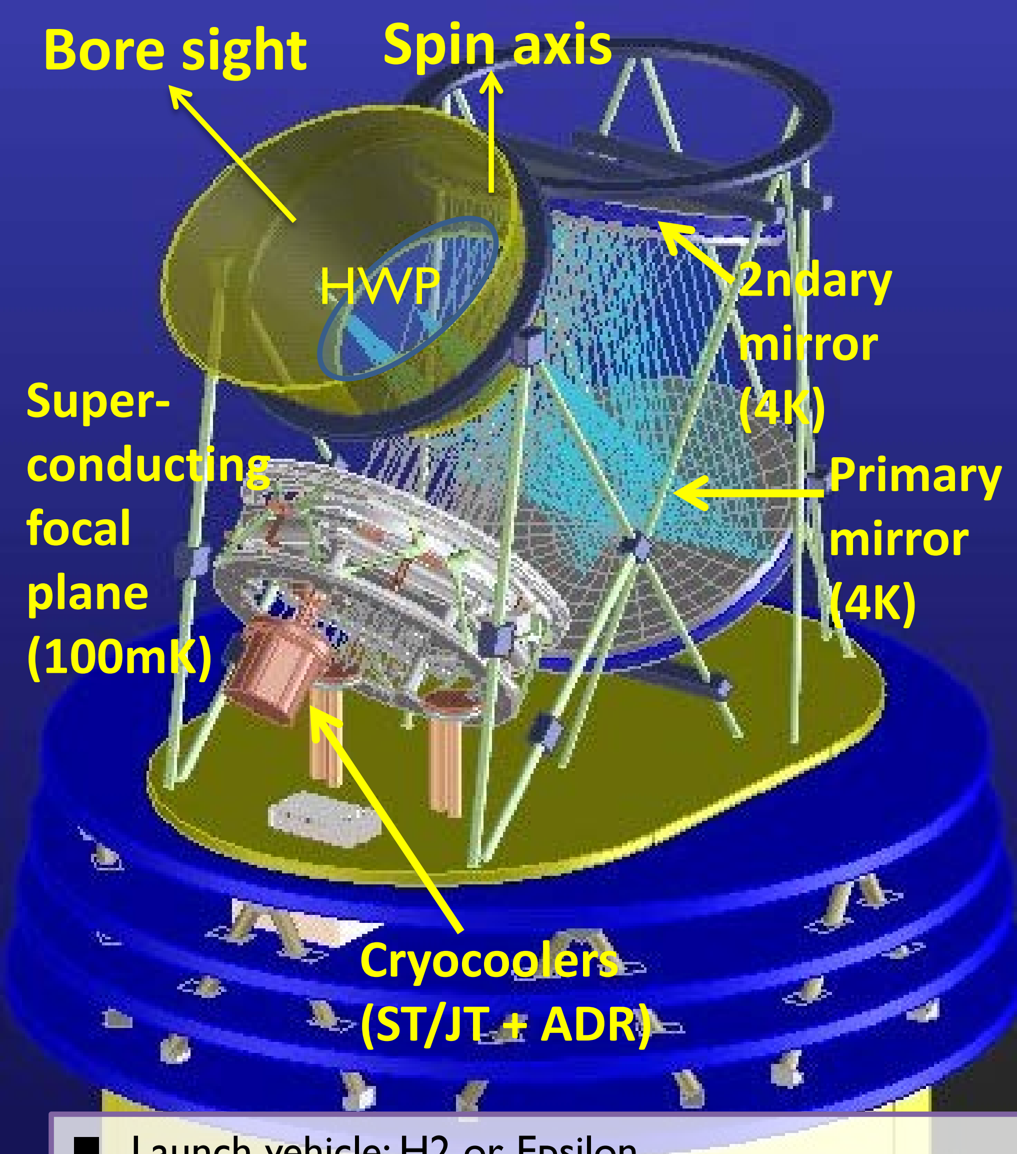
- Many inflationary models predict r>0.01 → >10sigma discovery
- Representative inflationary models (single-large-field slow-roll models) have a lower bound on r, r>0.002, from Lyth relation.

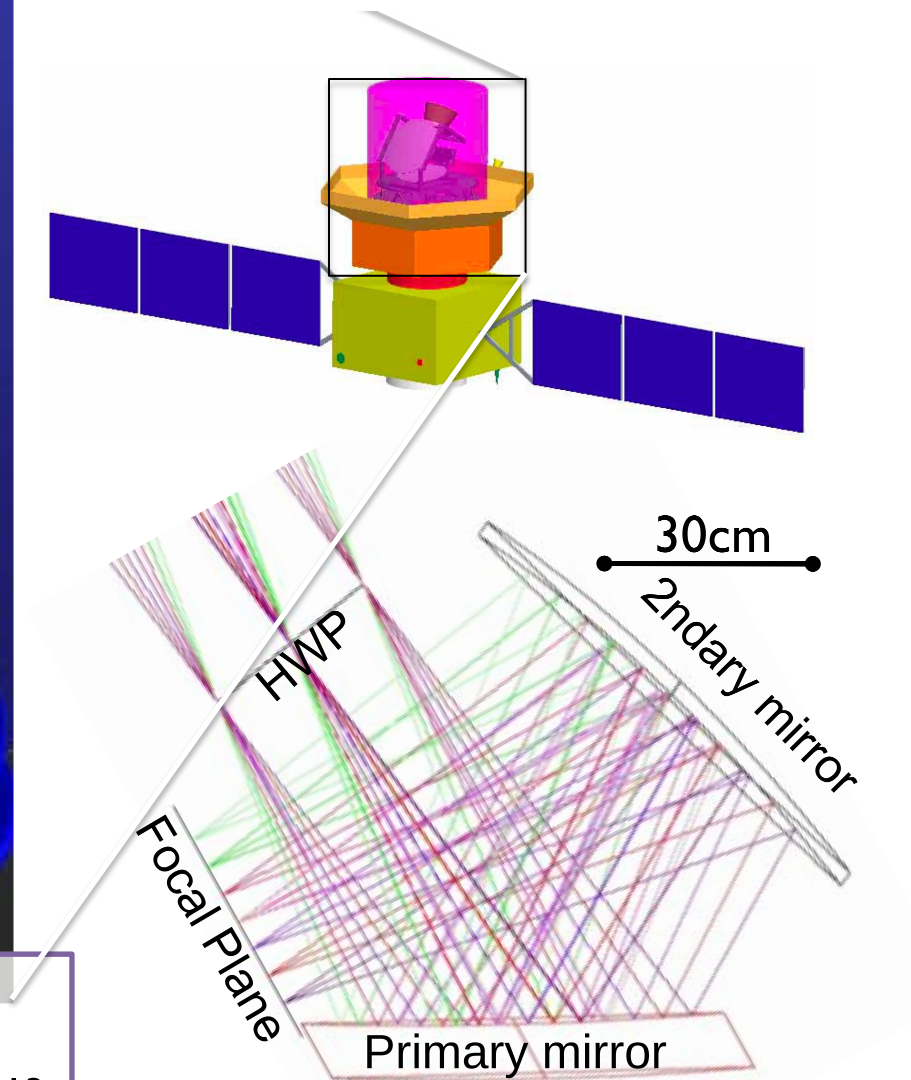
$$r = \frac{1}{N^2}\left(\frac{\Delta\phi}{m_{\rm pl}}\right)^2 \approx 2\cdot 10^{-3}\left(\frac{\Delta\phi}{m_{\rm pl}}\right)^2$$

  - no gravitational wave detection at LiteBIRD → exclude representative inflationary models (i.e. r<0.002 @ 95% C.L.)
- Early indication from non-space-based projects → power spectra at LiteBIRD !

Simiar to LHC Higgs case (Occam's razor)

System overview





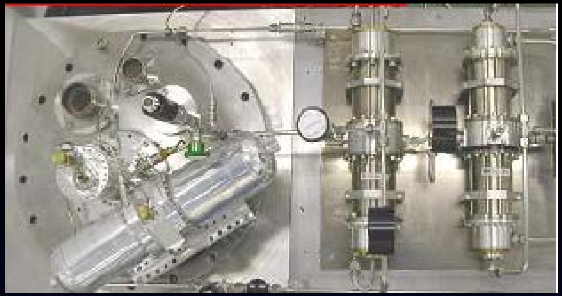
Crossed Dragone Configuration

- Launch vehicle: H2 or Epsilon
- w/ EPIC-type scan strategy
- To be ready for Mission Definition Review in JFY2013
- Target launch year: 2020 (LEO or L2)

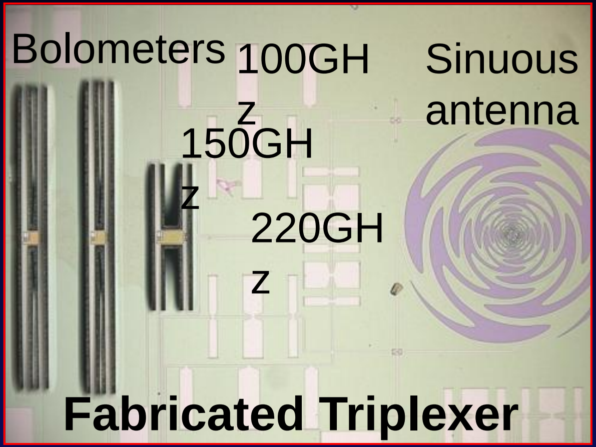
Three key technologies to make LiteBIRD light

- Small mirrors (~60cm)
- Warm launch with mechanical coolers
  - Technology alliance with SPICA for pre-cooling (ST/JT)
  - Alliance with DIOS (X-ray mission) for ADR
- Multi-chroic focal plane
  - ~2000 TES (T_{bath}=100mK, $\delta\nu/\nu$ ~ 0.3), or equivalent MKIDs
  - Technology demonstration with ground-based projects (POLARBEAR, POLARBEAR-2, GroundBIRD)

Prototype crossed Mizuguchi-Dragone mirror



2ST/JT BBM



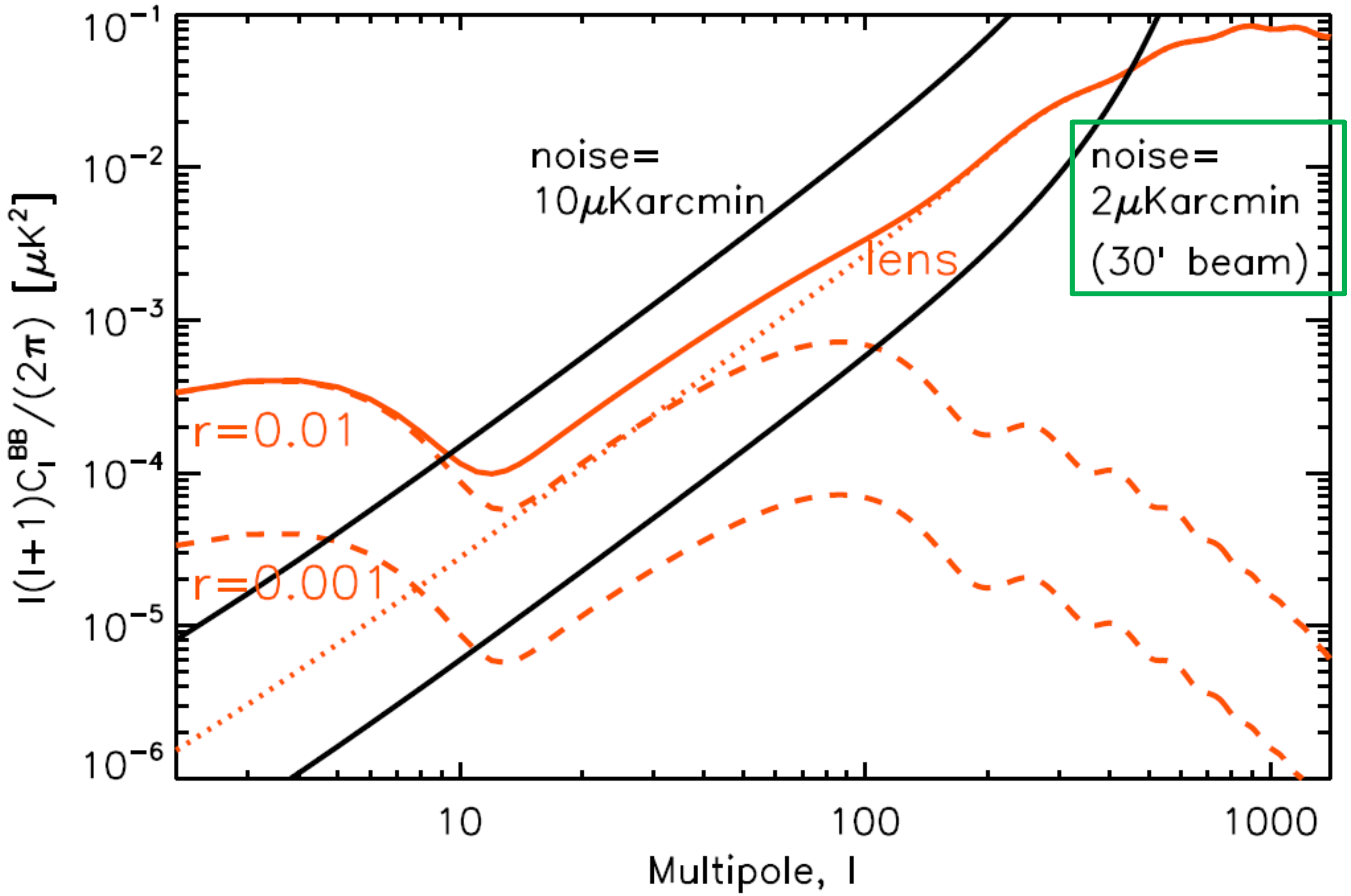
UC Berkeley TES option

Systems Engineering for LiteBIRD

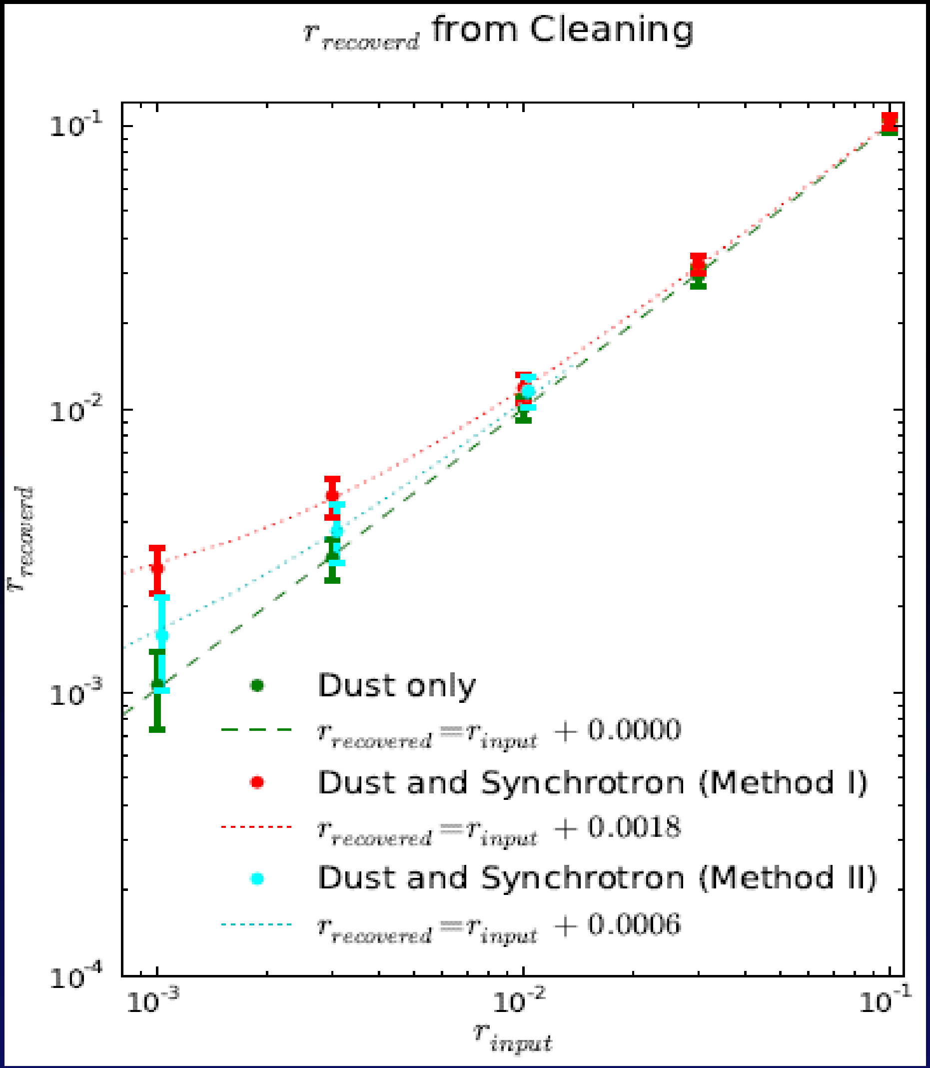
Focal plane requirement

Noise level: goal = 2μK･arcmin
(requirement: < 3μK･arcmin)

To be well below "lensing floor"



Foreground removal and observing bands



- Foreground removal
  → ≥4 bands in 50-270GHz

N. Katayama and E. Komatsu,
ApJ 737, 78 (2011)
(arXiv:1101.5210)

pixel-based polarized
foreground removal
(model-independent)
very small bias
r~0.0006
with 60,100,240GHz (3 bands)

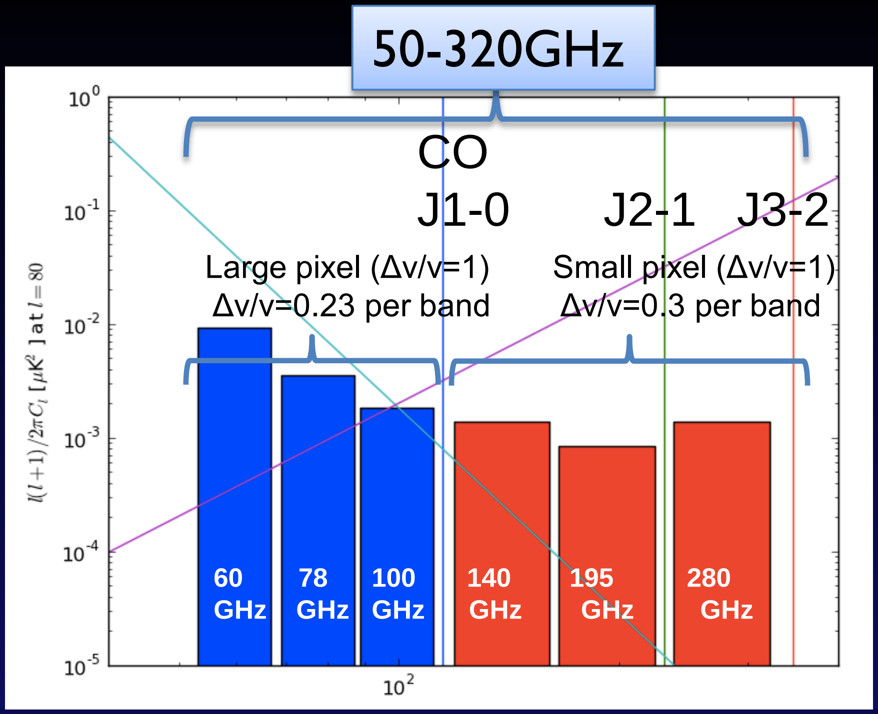
LiteBIRD band selection for multi-chroic pixels

We chose the band locations with the following reasons.

1. Katayama-Komatsu (2010) suggested the range of frequency from 50-270 GHz based on the template subtraction.
2. We want to exclude the CO lines.
3. From the practical consideration such as AR coating on a lenslet array, it is reasonable to limit the bandwidth to Δν/ν~1.

Above three constraints naturally put us to the band locations.

- Some room for low frequencies.
- Interesting option of distributed band centers (more studies needed).



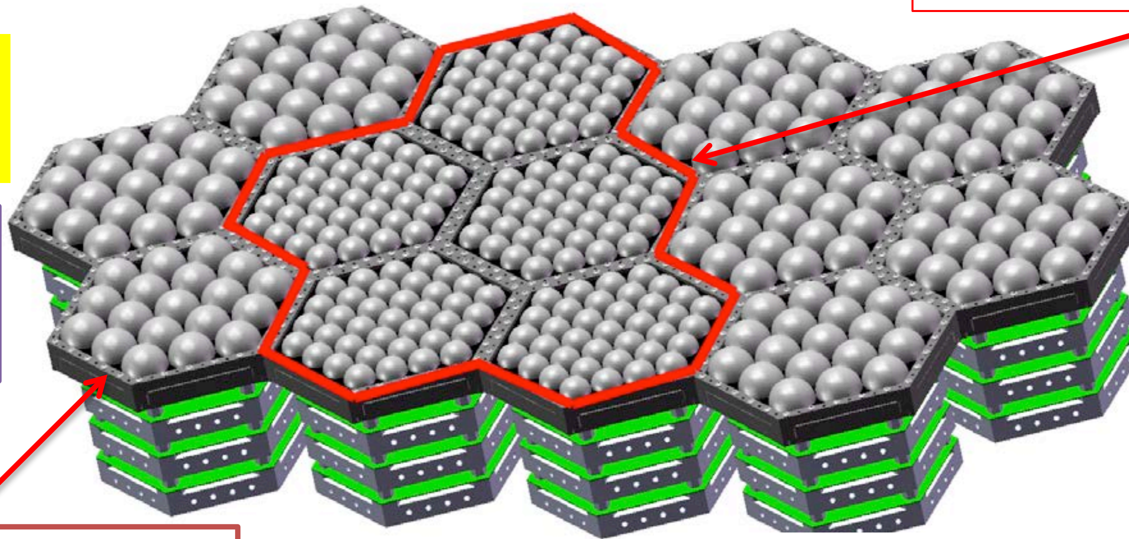
LiteBIRD focal plane design

UC Berkeley TES option

2022 TES bolometers

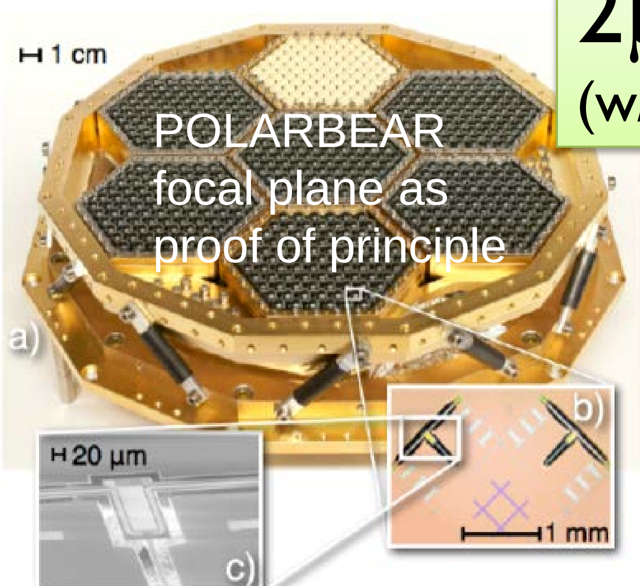
T_{bath} = 100mK

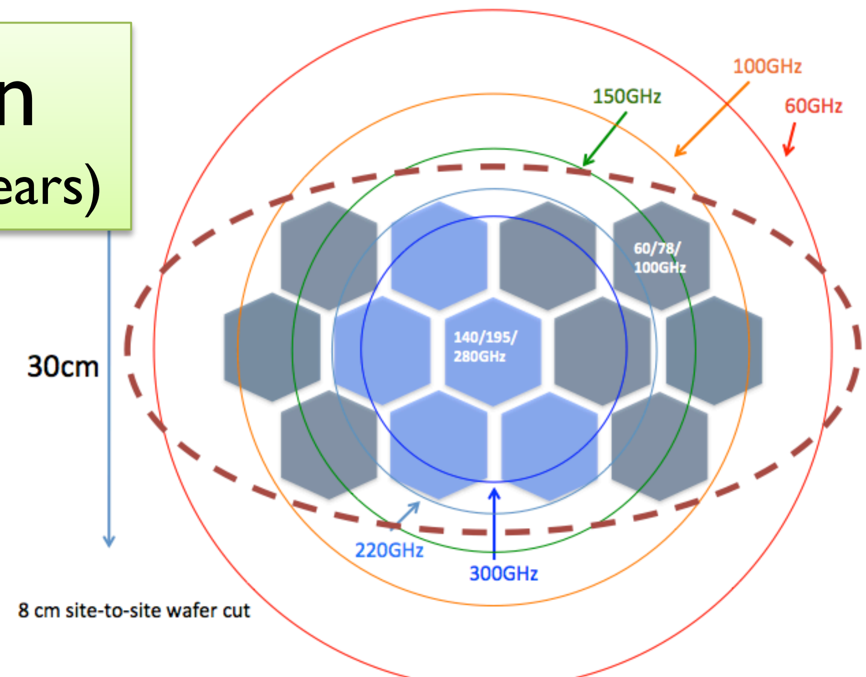
tri-chroic（140/195/280GHz）



tri-chroic（60/78/100GHz）

2μKarcmin
(w/ 2 effective years)





LiteBIRD focal plane design

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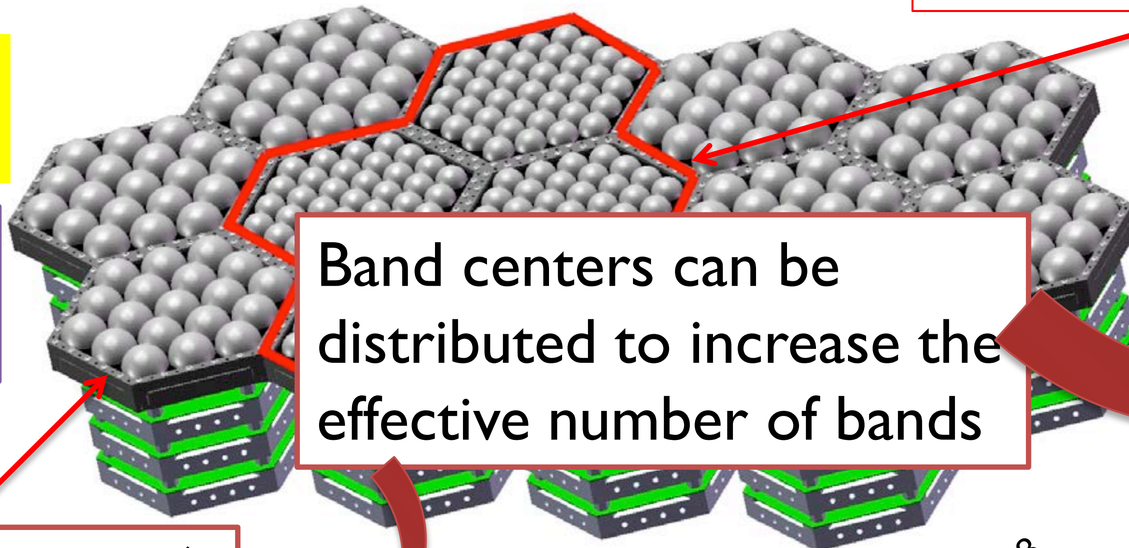
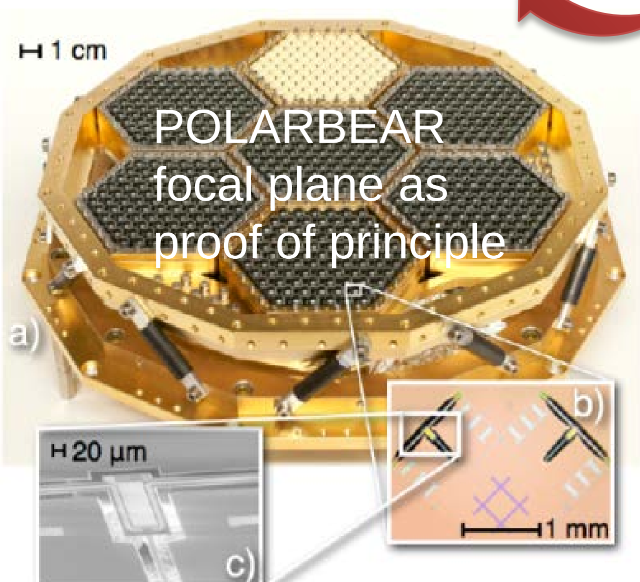
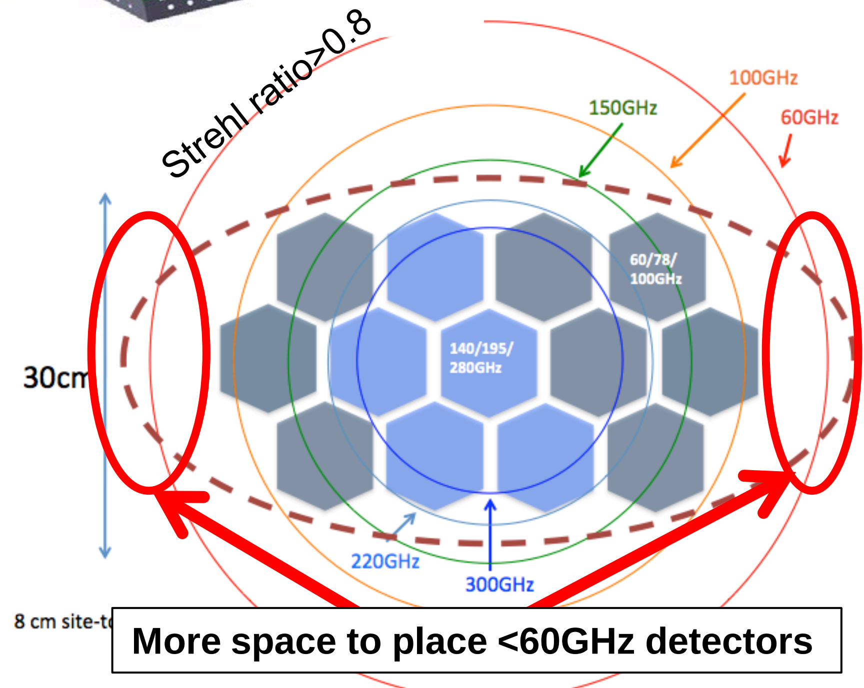


Band centers can be distributed to increase the effective number of bands

tri-chroic (60/78/100GHz)





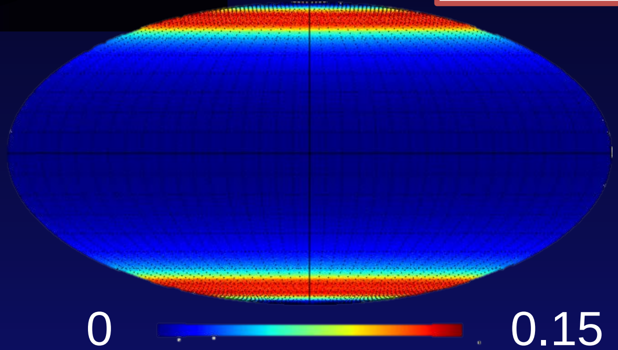
More space to place <60GHz detectors

Scan Strategy

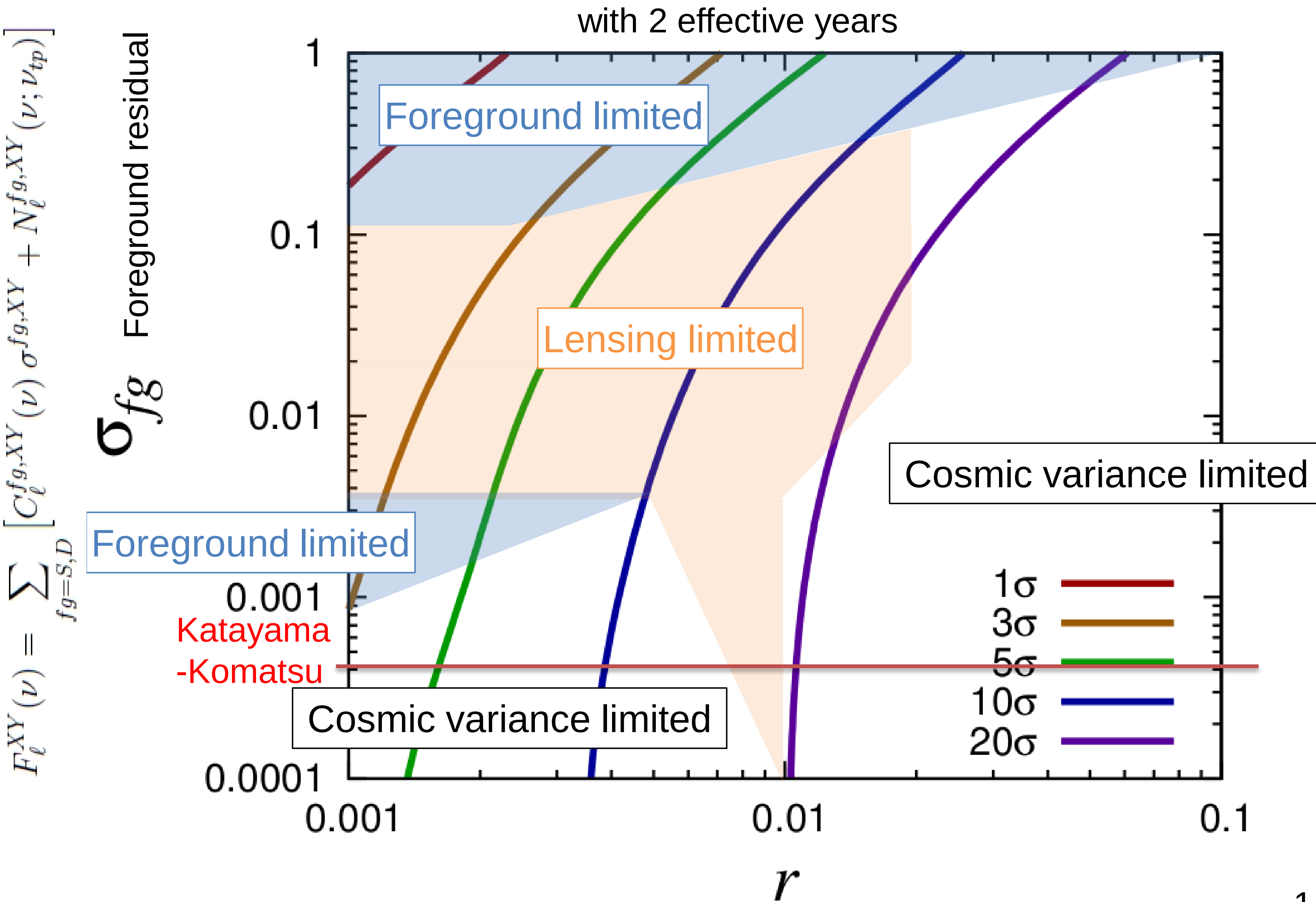
EPIC-type scan adapted to LEO

Uniformity and cross link as good as the case for L2

cross link



Expected sensitivity on r



Systematic Error Mitigation

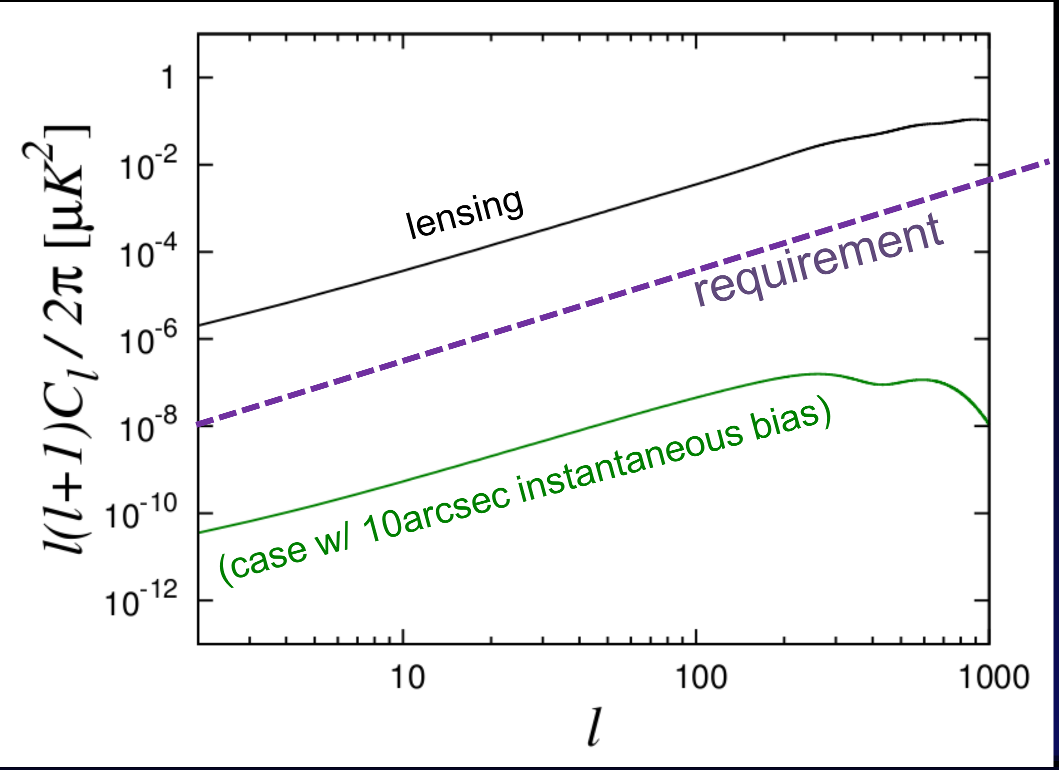
- Detailed studies with JAXA engineers are in progress
- One of the areas we should learn a lot from Planck !
- Lots of sources due to “differential XX” can be mitigated by continuously-rotating HWP. Full demonstration at ground-based projects is a key to our success.

Ex) pointing knowledge

Pointing error (instantaneous)
= random ⊕ bias

bias is mitigated by
good cross linking
→ requirement on bias
(instantaneous) is <2arcmin.

(requirement on random error
is less stringent)



LiteBIRD Roadmap

POLARBEAR

TES

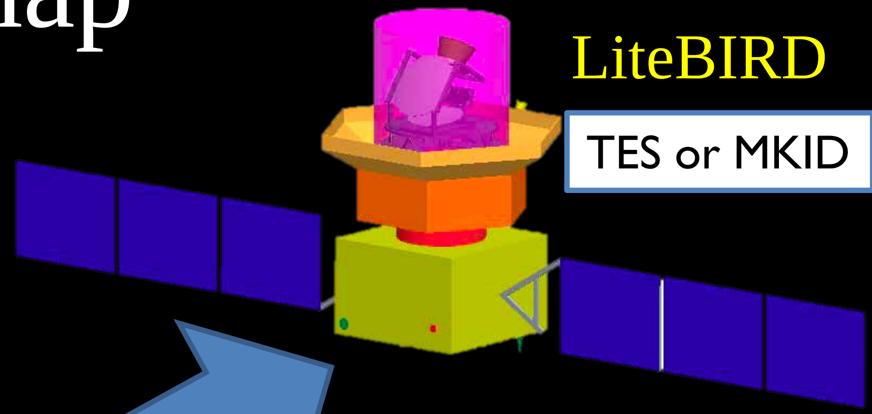
POLARBEAR-2

TES

Previous talk

GroundBIRD

MKID



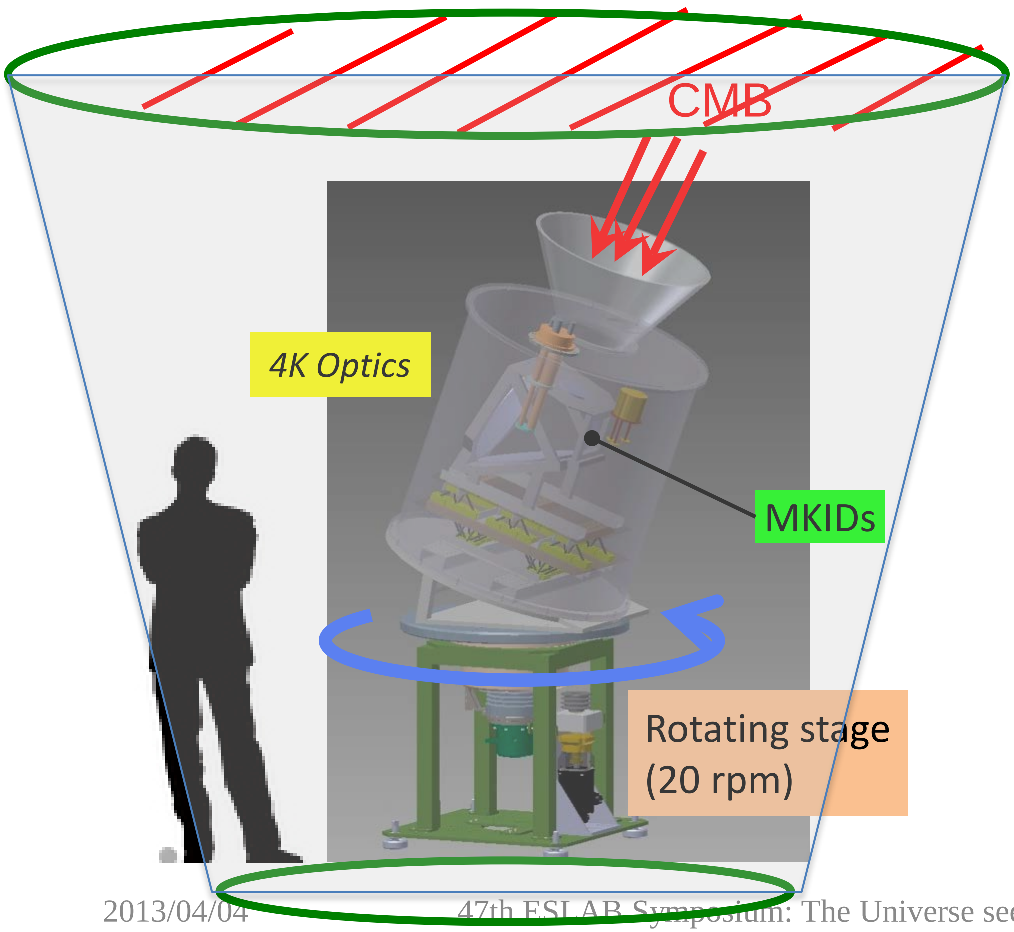
LiteBIRD

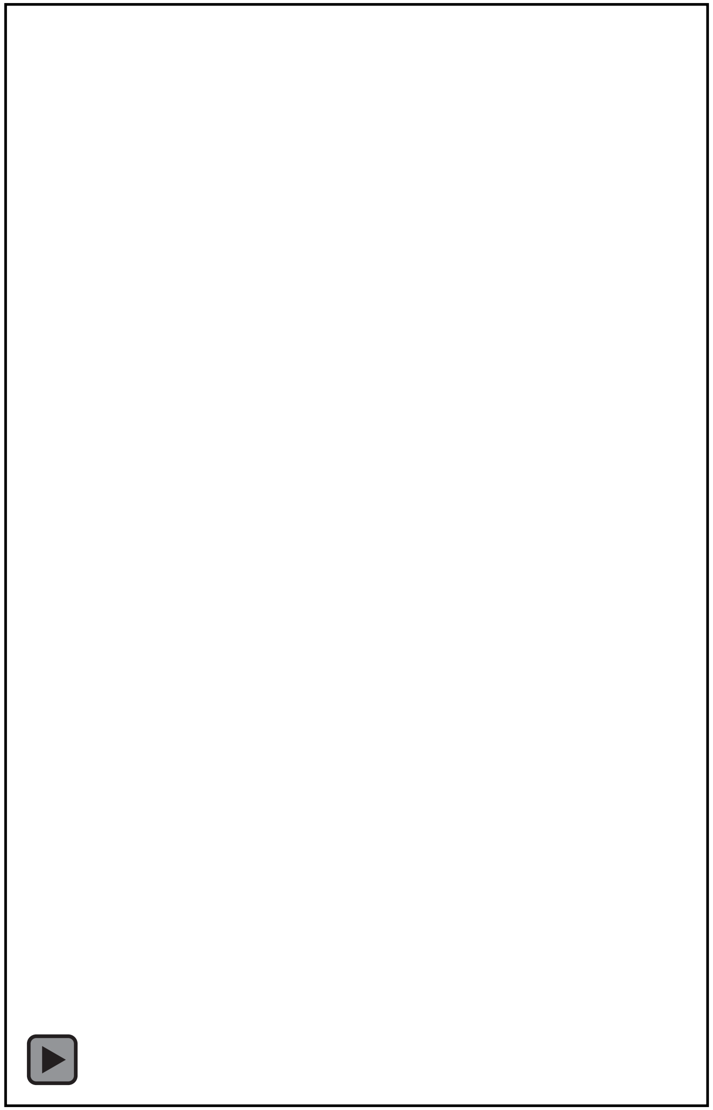
TES or MKID

- Ground-based projects as important steps
  - Verification of key technologies
  - Good scientific results
- International projects

GroundBIRD "satellite on the ground"

- Spinning telescope for 1/f noise suppression
- Access to l < 10 (fsky=30%)
- Sparse wire grid for absolute angle cal.
- Test-bench for LiteBIRD technologies
- Initial tests in Japan in 2014, then to Atacama





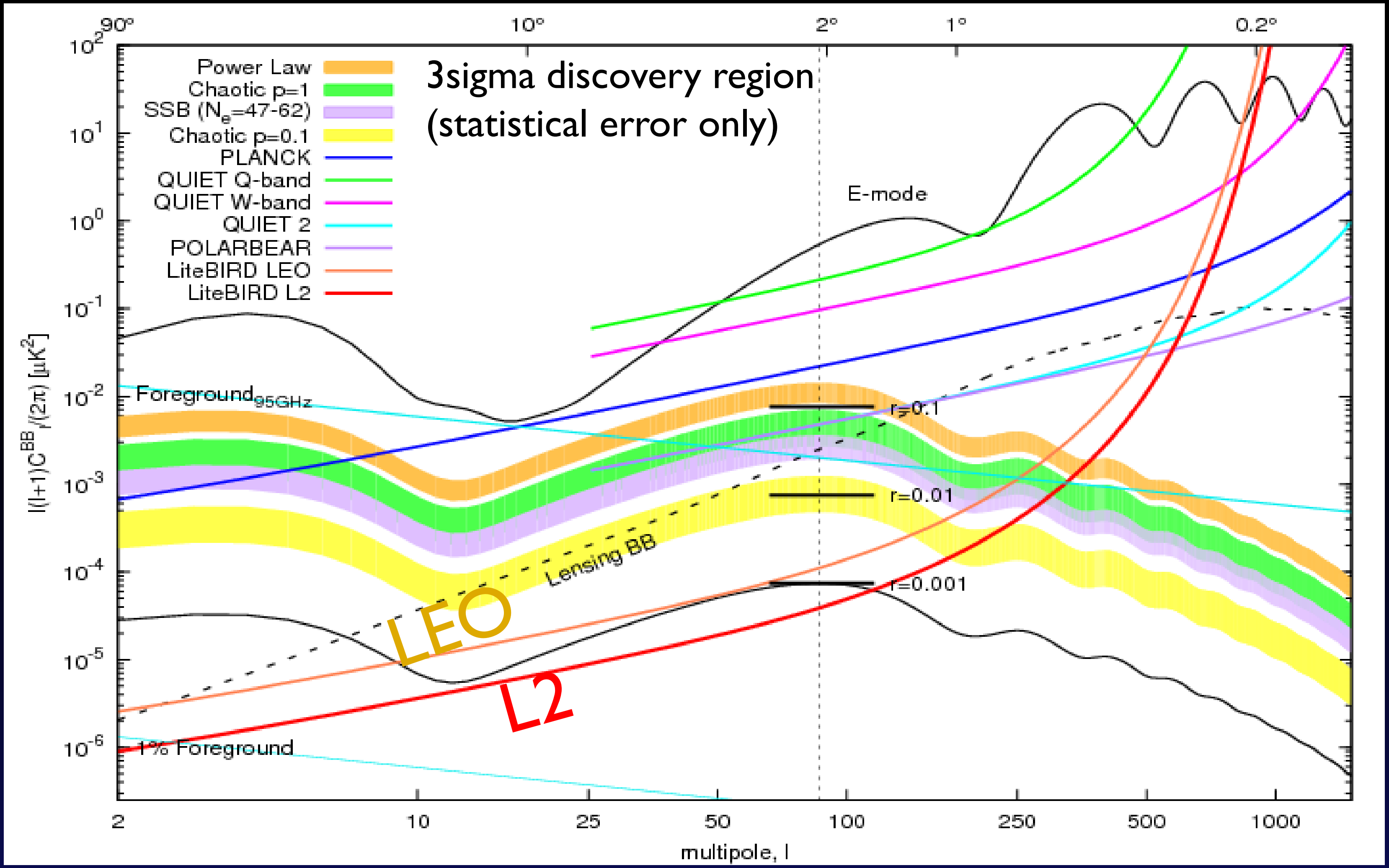
test of rotating stage @ KEK

Summary

- CMB polarization will be the frontier in the post-Planck era
  - Best probe to discover primordial gravitational waves
  - Unique tests of inflation and quantum gravity
- The full success of LiteBIRD is to achieve $\delta r<0.001$.
- LiteBIRD (with focusing on r measurements)
  + ground-based super-telescopes will be one of the most cost-effective ways for broad scientific objectives
- No show-stopper in design studies so far. Technology verification in ground-based projects in next ~3 years will be crucial. The LiteBIRD roadmap includes such ground-based projects.

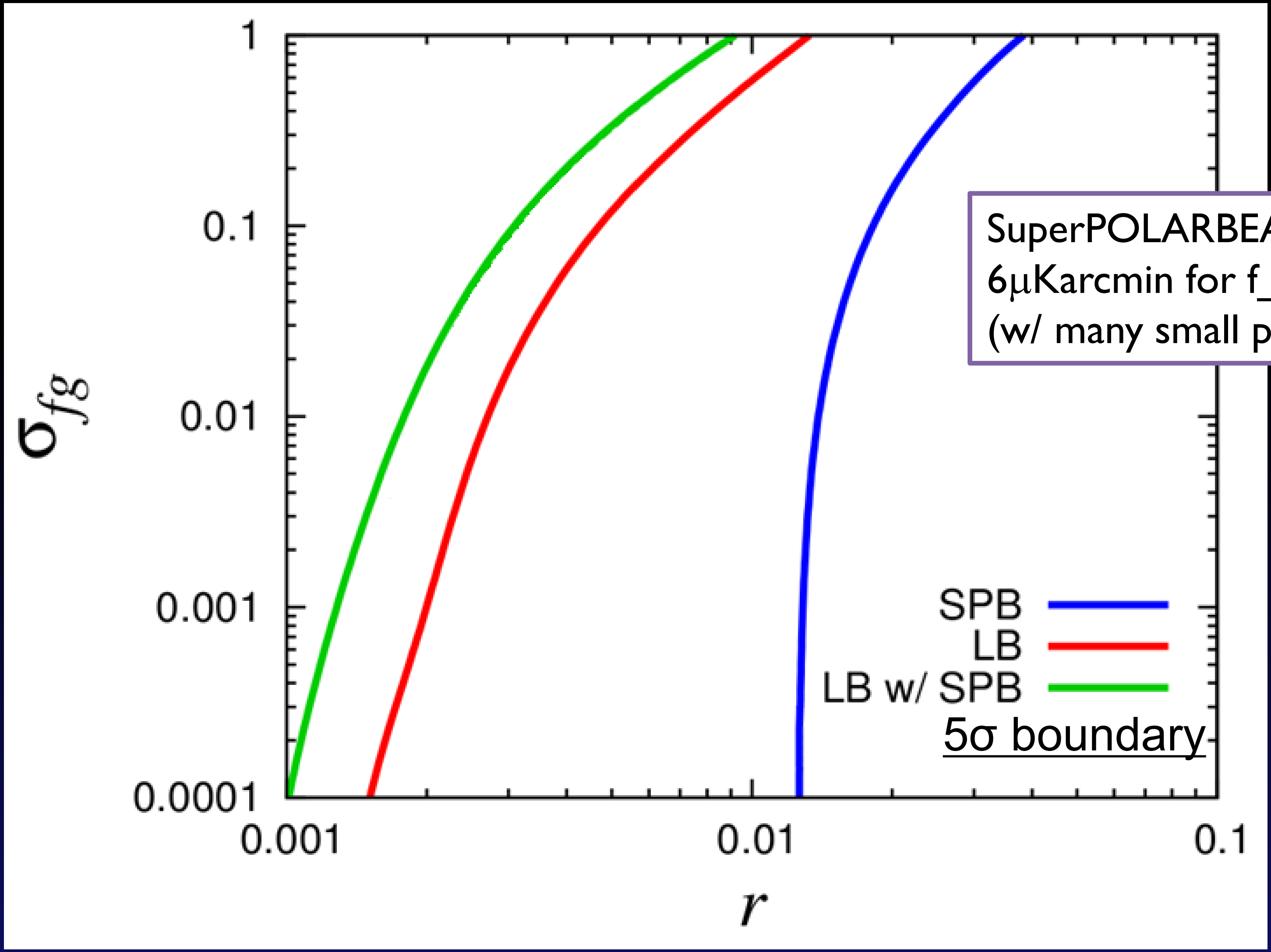
Backup Slides

L2 vs. LEO



Both cases satisfy the requirement on statistical error

Delensing with SuperPOLARBEAR



SuperPOLARBEAR assumes 6μKarcmin for f_sky = 0.75 (w/ many small patches)

The design goal for LiteBIRD is to achieve 2 μKarcmin and the requirement is 3 μKarcmin. Throughout this memo we assume the observational time of 2 years with full efficiency and 70 % of sky coverage. With these assumptions, the corresponding combined NET over all the bolometers on the focal plane, so called "NET array", is $NET_{arr} = 0.9\ \mu K\sqrt{s}$ and $1.4\ \mu K\sqrt{s}$ for the goal and requirement, respectively.

Bath temperature [mK]	Aperture & mirror temperatures 4 [K]	6 [K]	10 [K]	30 [K]
100	0.89 (1.49)	1.09 (1.78)	1.46 (2.30)	2.74 (4.15)
300	0.94 (1.58)	1.15 (1.90)	1.54 (2.44)	2.88 (4.39)
560	1.00 (1.69)	1.22 (2.03)	1.64 (2.62)	3.06 (4.69)

Band GHz	Bandwidth %	NET [$\mu K\sqrt{s}$]	Pixel # per wafer	Wafer #	Bolometer #	NETarr [$\mu K\sqrt{s}$]	Sensitivity [μKarcmin]
60	0.23	96	19	8	304	5.4	14.1
78	0.23	61	19	8	304	3.5	8.9
100	0.23	44	19	8	304	2.5	6.4
140	0.3	38	37	5	370	1.9	4.8
195	0.3	32	37	5	370	1.54	4.0
280	0.3	39	37	5	370	1.9	4.9
Total			168	13	2022	0.9 ($1.5^{\dagger}$)	2.3 ($3.8^{\dagger}$)

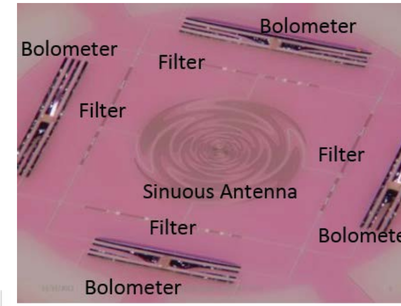
Table 2: The summary of the sensitivities. †The weighted sensitivity only using the 100 and 140 GHz bands.

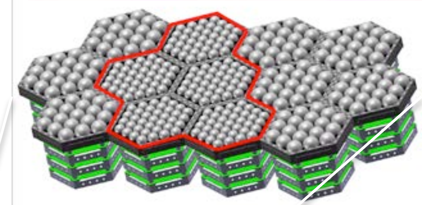
We limit the total number of detectors as ~2000. The MUX factor of 64 (2W/SQUID) will keep the readout power below 70W.

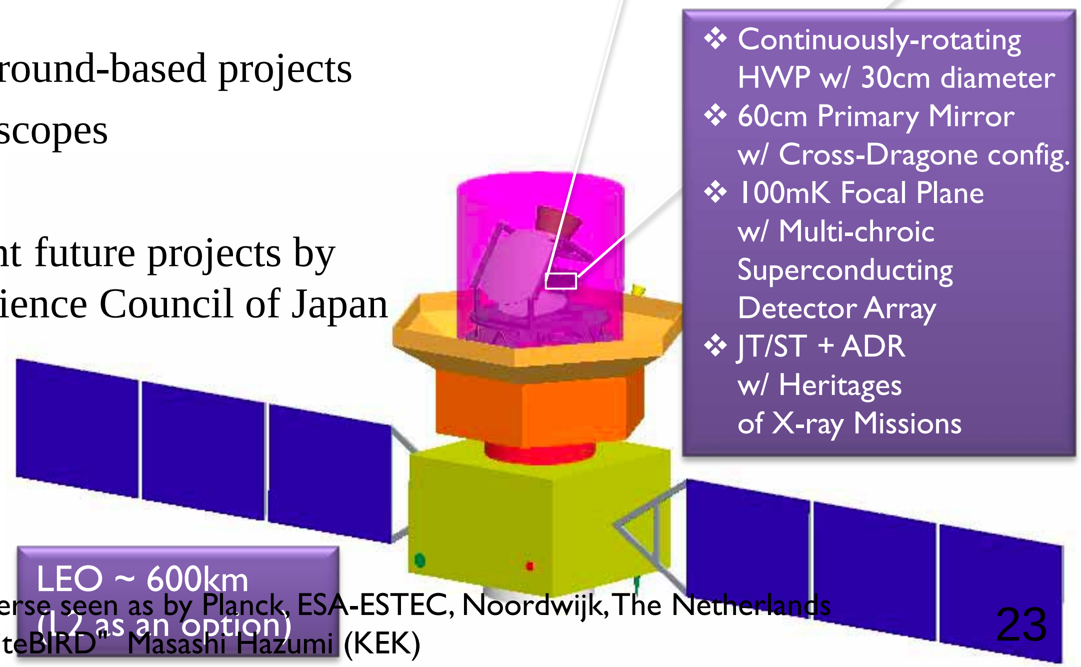
LiteBIRD

Lite (Light) Satellite for the Studies of **B**-mode Polarization and **I**nflation from Cosmic Background **R**adiation **D**etection

- JAXA-based working group (more than 60 members from JAXA, KEK, Kavli IPMU, NAOJ, Berkeley/LBNL, McGill, Riken, MPA and Japanese universities)
- Scientific objectives
  - Precision B-mode measurements for stringent tests of cosmic inflation
  - Tests of quantum gravity theories
  - ***Full success: $\delta r < 0.001$ (stat. $\oplus$ syst. $\oplus$ foreground $\oplus$ lensing)***
- Observations
  - Full-sky CMB polarization survey at a degree scale (30arcmin @ 150 GHz)
  - 6 bands b/w 50 and 320 GHz
- Strategy
  - Part of technology verification from ground-based projects
  - Synergy with ground-based super-telescopes
- Project status/plan
  - Selected as one of eight most important future projects by astronomy/astrophysics division of Science Council of Japan
  - Recognized as one of key future JAXA missions
  - International and interdisciplinary
  - Synergy with X-ray mission R&D
  - Target launch year: ~2020







Advantages of LiteBIRD

- Not a pathfinder; small but no compromise in r sensitivity
- More launch options than a big satellite
- Less expensive
  - With LiteBIRD plus ground-based super-telescopes (e.g. O(100K) bolometers w/ arcminute angular resolution) as one package, science reach nearly as good as a large CMB polarization mission with ~1/5 total cost
- Better in terms of cooling (mirrors and baffles)
- The whole spacecraft can be tested in a large cryogenic test chamber
  - Better calibration data → less systematic uncertainties
  - Better pre-flight investigations → less chance of failure

Block diagram