# Requirement analysis for LiteBIRD's optical system

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## Abstract

Primordial gravitational wave background is generically predicted by cosmic inflation theories. Amplitude of the waves indicates energy scale of cosmic inflation. LiteBIRD, the 2nd ISAS strategic large mission, makes a full-sky map of the microwave background polarization to detect a signal of the gravitational waves. Since the signal of primordial gravitational wave origin (B-mode pol.) is expected to be much weaker than that of primordial density fluctuation origin which has been already observed, it is essentially important to identify and mitigate systematic errors.

In this year, we achieved performance verification of LiteBIRD's low frequency telescope (LFT) by simulations with real beam pattern given by measurement of a 1/4 scaled model of the telescope. To identify true optical characteristics at performance tests, we have to understand behavior of measurement errors. By performing full beam convolution simulations, we quantified how beam imperfection found in the measured beam pattern affects our science and learned how to improve the measurement system of the scaled model.

Ref. URL: http://litebird.jp/eng/

## Reasons and benefits of using JAXA Supercomputer System

Since LiteBIRD will achieve scan observation for full sky polarization mapping, beam convolution is repeated at a frequency of about 20Hz (and for a period of one year). Beam functions, which are measured by use of the 1/4 scaled model, spread over an area of several thousand square degrees with arcminute resolution. For every sampling, integrands are evaluated on O(10^6) grid points. The integrations with incessant coordinate transformations require a high performance computing resource.

This inter-university research is powerfully promoting the LiteBIRD project which is the 2nd ISAS strategic large mission. The outcomes of this research are counted as bases of LiteBIRD's optics design.



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## Achievements of the Year

We investigated an impact of beam imperfection found in the measured beam pattern of the 1/4 scaled model by performing a simulation suite of LiteBIRD observation which consists of scan, beam convolution, and map making.

(Fig.1) shows the differential beam map of two detectors in the 45(=180/4)GHz band whose sensitivity directions are mutually orthogonal. (Top-left window in the figure 1) shows the measurement system for the scaled model. While the measured beam patterns are roughly consistent with designed beam pattern of the telescope, it contains irregular structure such as cross-polarization due to feed pattern imperfection, mismatch of beam centers, and widely spreading scan noise. (Fig.2) shows angular power spectra of false polarization leaked from temperature inhomogeneity of the microwave background. In the main beam area, we found false polarization due to 1% differential ellipticity originating from cross-polarization. In the area of very near sidelobes, the centers of the two beam pattern exhibited mismatch of 40arcsec, which made false polarization of the flat spectrum in the figure. Also, it was indicated that large angular correlation in the polarization map was contaminated by measurement errors in the far sidelobes including scan noise. Owing to these evaluations, we obtained a concrete principle for updating the measurement system based on quantitative requirements.

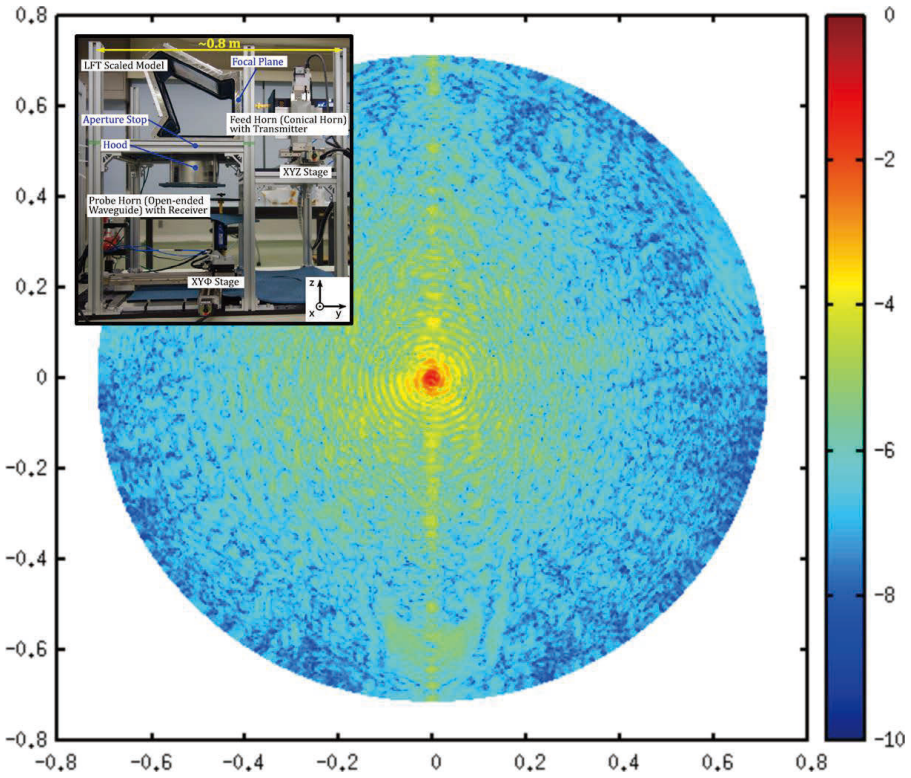


Fig. 1: Differential beam pattern of LiteBIRD LFT 1/4 scaled model (top-left window) at 45 (=180/4) GHz band : H.Takakura et al., IEEE TST vol. 9, issue 6 (2019)



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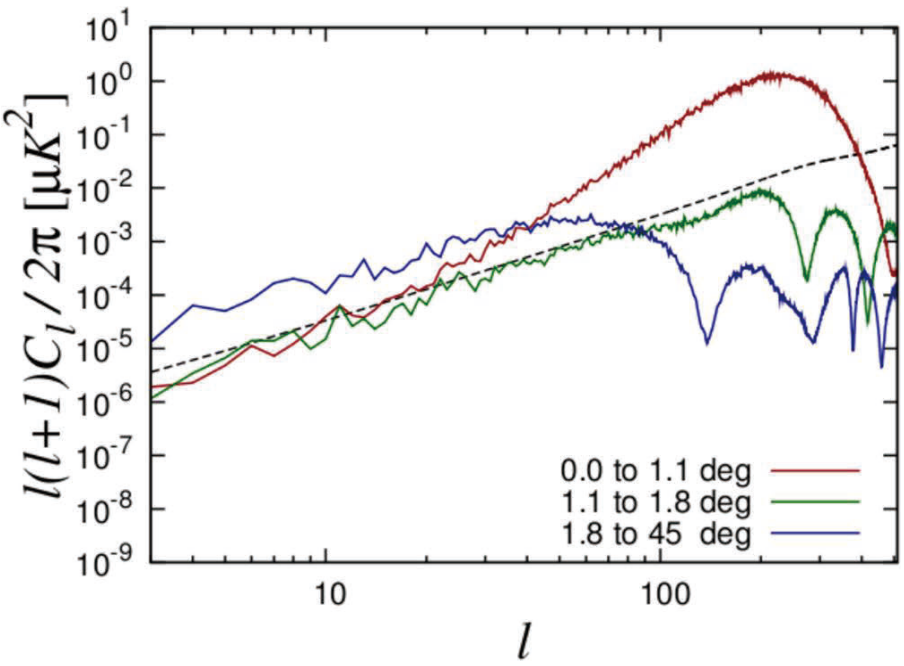


Fig. 2: Angular power spectra of false polarization due to beam mismatch

## Publications

- Non peer-reviewed papers

LiteBIRD: an all-sky cosmic microwave background probe of inflation: Bulletin of the American Astronomical Society 51, 7, 286 (2019)

- Oral Presentations

Ryo Nagata, "On the systematic effects of LiteBIRD observation XIII", Astronomical Society of Japan 2019 autumn annual meeting

- Web

http://litebird.jp/eng/



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## Usage of JSS2

### Computational Information

| | |
|---|---|
| Process Parallelization Methods | MPI |
| Thread Parallelization Methods | OpenMP |
| Number of Processes | 32 |
| Elapsed Time per Case | 2.5 Hour(s) |

### Resources Used

Fraction of Usage in Total Resources[*1](%): 0.23

Details

| Computational Resources | | |
|---|---|---|
| System Name | Amount of Core Time (core x hours) | Fraction of Usage[*2](%) |
| SORA-MA | 2,114,525.58 | 0.26 |
| SORA-PP | 22.21 | 0.00 |
| SORA-LM | 0.00 | 0.00 |
| SORA-TPP | 0.00 | 0.00 |

| File System Resources | | |
|---|---|---|
| File System Name | Storage Assigned (GiB) | Fraction of Usage*2(%) |
| /home | 9.54 | 0.01 |
| /data | 1,907.35 | 0.03 |
| /ltmp | 1,953.13 | 0.17 |

| Archiver Resources | | |
|---|---|---|
| Archiver Name | Storage Used (TiB) | Fraction of Usage*2(%) |
| J-SPACE | 0.25 | 0.01 |

[*1]: Fraction of Usage in Total Resources: Weighted average of three resource types (Computing, File System, and Archiver).

[*2]: Fraction of Usage：Percentage of usage relative to each resource used in one year.



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