Cosmic Orbital and Suborbital Microwave ObservationS

CMB-Stage IV ⊗ LiteBIRD

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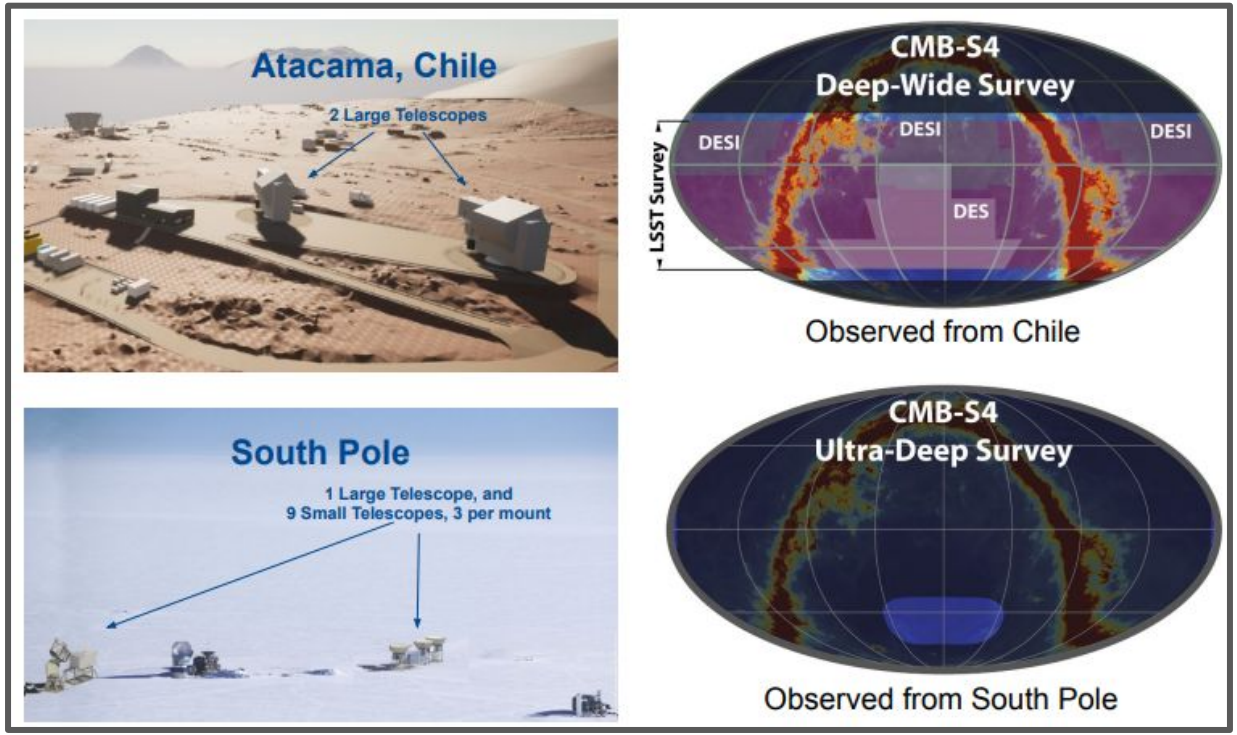
Outline

- CMB-Stage IV
- Memorandum of Understanding
- Goals
- Organization
- Early Analyses
- Interfaces & Schedule

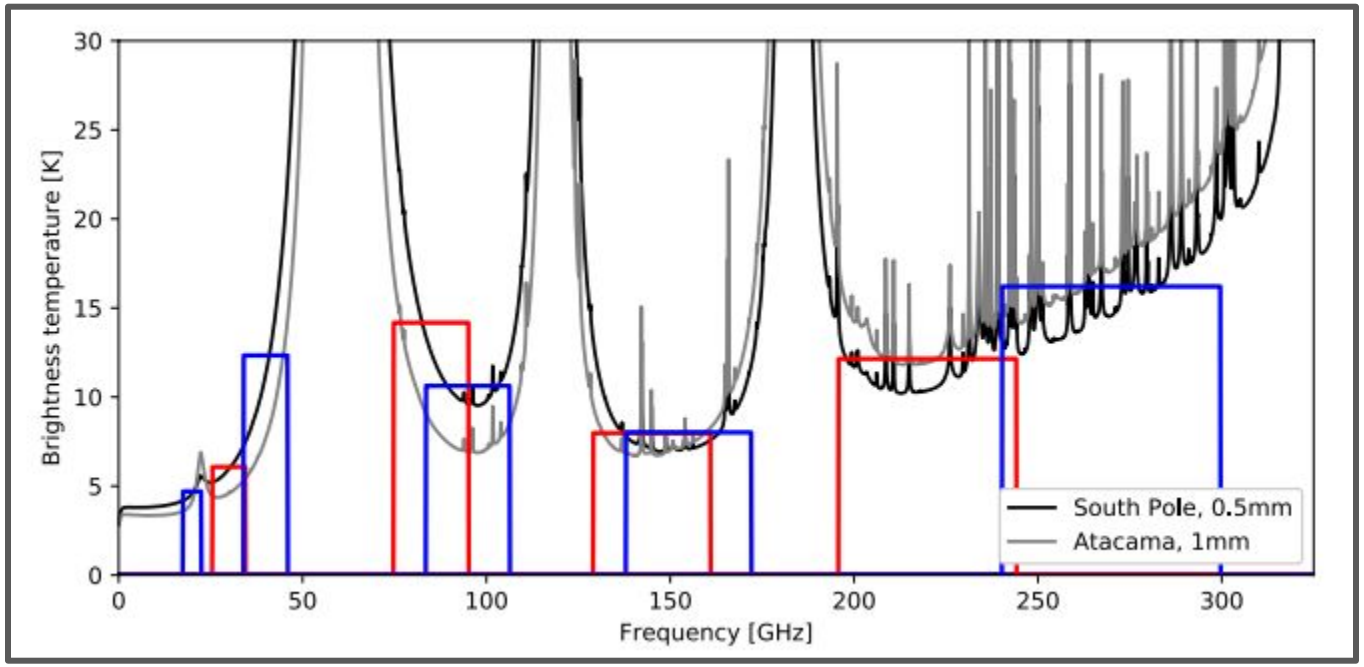
CMB-Stage IV



CMB-S4

Cosmic Orbital and Suborbital Microwave ObservationS

CMB-Stage IV



arxiv.org/abs/1907.04473

CMB-Stage IV: LAT Receivers

Property	ULF	LF		MF		HF	
Center frequency (GHz)	20	27	39	93	145	225	278
FWHM (arcmin)	10.0	7.4	5.1	2.2	1.4	1.0	0.9
Fractional bandwidth	0.25	0.22	0.46	0.38	0.28	0.27	0.16
NET ($\mu K\sqrt{s}$) per detector	438	383	250	302	356	737	1840
$N_{detectors}$ per tube	160	320	320	3460	3460	3744	3744
N_{wafers} per tube	4	4		4		4	

Chile (Wide Field Survey – 2 LATs

N_{tubes} per LAT	0	2	12	5
Data rate (2 LATs)	10.8 TB/day			

South Pole (Delensing Survey – 1 LAT)

N_{tubes}	1	2	12	4
Data rate (1 LAT)	5.0 TB/day			

Total (3 LATs)

$N_{detectors}$	160	1920	1920	124560	124560	52416	52416
$N_{detectors}$ total	357952						
N_{wafers}	4	24		144		56	
N_{wafers} total	228						

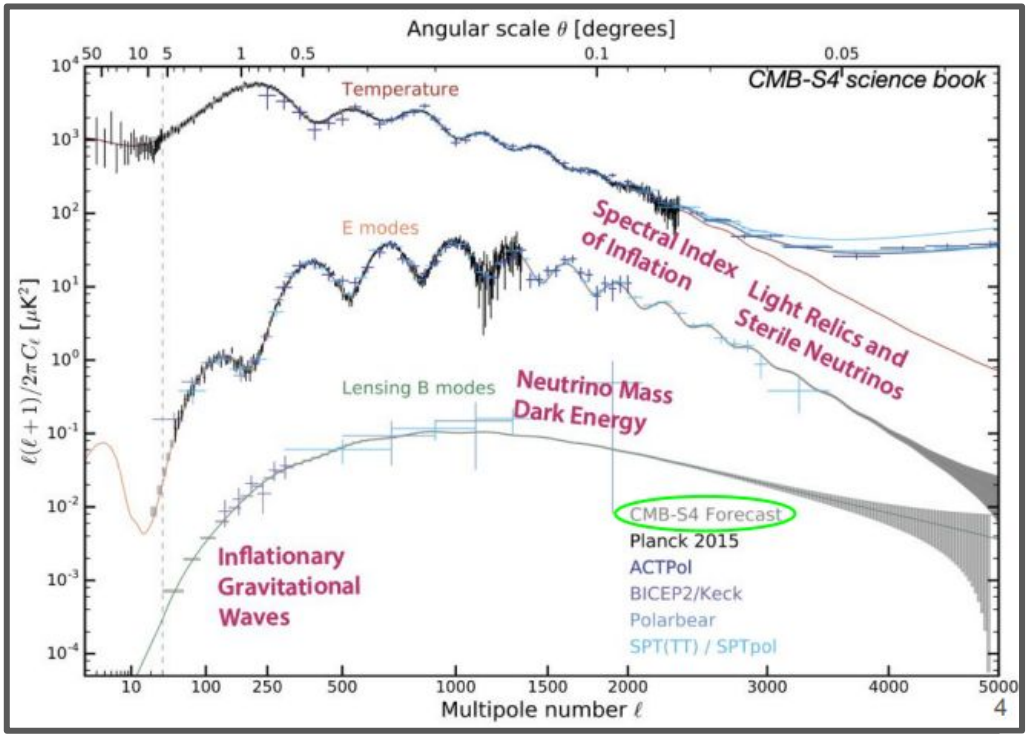
arxiv.org/abs/1907.04473

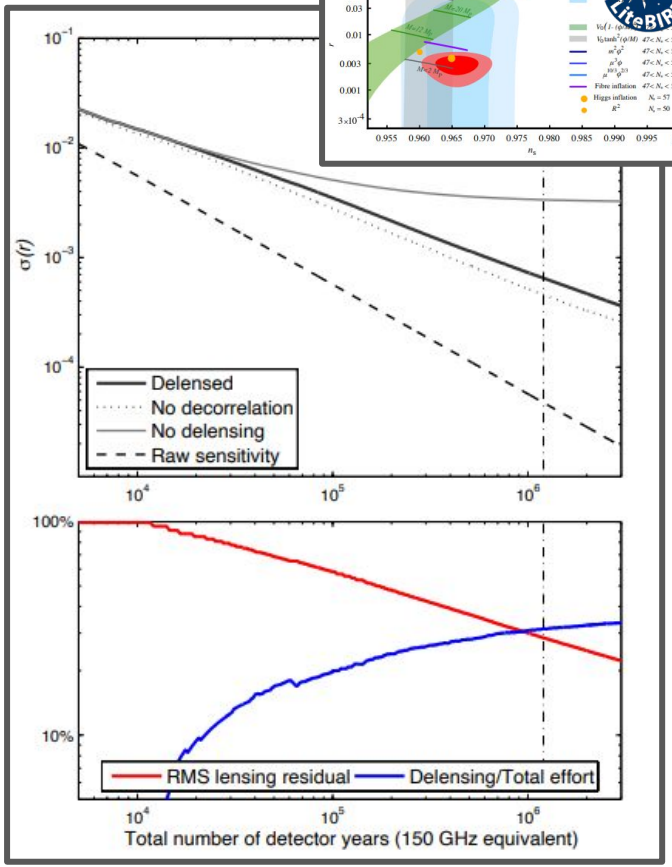
CMB-Stage IV: SAT Receivers

Property	LF		CF High		CF Low		HF	
Center frequency (GHz)	30	40	85	145	95	155	220	270
Primary lens diameter (cm)	55	55	55	55	55	55	44	44
FWHM (arcmin)	72.8	72.8	25.5	25.5	22.7	22.7	13	13
Fractional bandwidth	0.3	0.3	0.24	0.22	0.24	0.22	0.22	0.22
NET ($\mu K\sqrt{s}$) per detector	177	224	270	238	309	331	747	1281
N_{det} per optics tube	288	288	3524	3524	3524	3524	8438	8438
N_{tubes}	2		6		6		4	
N_{wafers}	24		72		72		36	
N_{wafers} total	204							
$N_{detectors}$	576	576	21144	21144	21144	21144	33752	33752
$N_{detectors}$ total	153232							
Data rate (18 optics tubes)	1.7 TB/day							

arxiv.org/abs/1907.04473

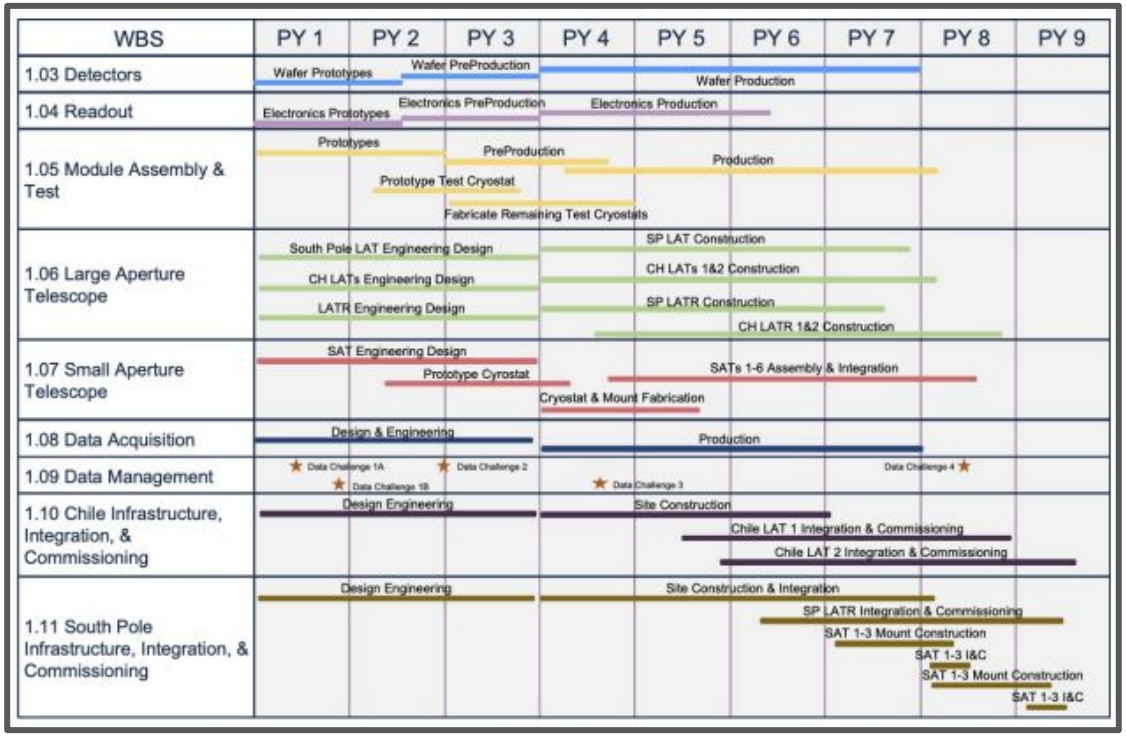
CMB-Stage IV





arxiv.org/abs/2208.12619

CMB-Stage IV



arxiv.org/abs/2203.08024

CMB-S4 ⊗ LiteBIRD Memorandum of Understanding

- Process Started in early 2022
- Parallel Committees Drafting for Both Collaborations:
  - Action in the Interim Publication Board for LiteBIRD, led by Banday (with Gerbino)
  - Action in the External Collaboration Committee for CMB-S4, led by Knox
- For LiteBIRD, Approval by the IPB and IGB by late 2022
- For CMB-S4, Approval by the ECC & GB (including Baccigalupi, Gerbino), by late 2022
- Teams on both Collaborations set in early 2023 by Banday, Bleem
- Work is Starting

Science Case
&
Paper Project

Memorandum of Understanding between the LiteBIRD and CMB-S4 Collaborations

The LiteBIRD and CMB-S4 Collaborations agree to work together on the joint project defined in this Memorandum of Understanding. The MoU is subscribed by: the LiteBIRD PI on behalf of the LiteBIRD collaboration; and the CMB-S4 Spokespeople on behalf of the CMB-S4 collaboration. For any point where further agreement is required than specified in this MoU, these parties will act on behalf of their collaborations, respectively.

1. The principal goal of the project is to quantify the synergy between the LiteBIRD and CMB-S4 projects based on forecasts using LiteBIRD and CMB-S4 simulations.
2. Two lines of analysis will be pursued: i) an assessment of the impact of LiteBIRD high-frequency and low-frequency maps on CMB-S4 r forecasts and ii) an assessment of the impact of CMB-S4 de-lensing information on LiteBIRD r forecasts. Other analyses, if they require an exchange of proprietary data, are only possible via amendment of this MoU.
3. The aim is to publish the findings of the project in a single joint paper on a timescale of less than two years. Both Collaborations are jointly responsible for the writing and reviewing of the joint paper, which must be formally approved by both Collaborations before submission for publication.
4. The joint paper will be a Key paper as defined by both collaborations. The author list will be "The CMB-S4 and LiteBIRD Collaborations:" followed by an alphabetical list of the authors. Eligibility of authors from each Collaboration will follow each Collaboration's rules. The paper will go through the appropriate internal review process of each Collaboration. The paper will be submitted to a journal to be decided jointly later and to the arXiv at the time of submission. The paper will follow a style agreed by both teams that is appropriate to the selected journal.
5. Both Collaborations reserve the right to withdraw from the joint project if they are unable to commit the resources necessary for successful completion; in this case, the joint project will stop and an agreement will be made specifying to what extent each of the two Collaborations may use the data provided within this project and publish any of the project's preliminary results. A decision to withdraw by CMB-S4 would be communicated to LiteBIRD through the CMB-S4 Spokespeople. A decision to withdraw by LiteBIRD would be communicated to CMB-S4 by the LiteBIRD Interim Governance Board (IGB)[1].
6. All the data and information exchanged or generated within the joint project are strictly confidential until published. Any release of data and/or information prior to its publication in any kind of public outlet has to be requested and approved in advance by both Collaborations. The request will be made by the working group to the CMB-S4 Executive Team and the LiteBIRD IGB, which are also the bodies that will communicate the decisions regarding approval.
7. Public announcement of results will be coordinated to recognize both teams, and will coincide with the submission of the paper for publication. The timing of publication,

[1] In the event that the LiteBIRD governance structure is revised such that the IGB is replaced by a different board or committee, then this document will be amended appropriately by mutual agreement of the subscribers to the document.

CMB-Stage IV

Data Products & Team

organization of any press conferences, and contents of any press releases will take into account the needs of LiteBIRD and CMB-S4 funding agencies and institutions. The results of the paper will be jointly announced and information is not to be used or released prior to publication without formal approval of the two Collaborations.

8. A public release of data products associated with the paper will occur at the time of the acceptance of the paper for publication. A list of products will be proposed by the Working Group and reviewed by both collaborations for approval.
9. A Working Group consisting of members of both Collaborations will be engaged in the analysis, with access to the exchange data products and software. Each Collaboration will formally propose members who will work on the joint project. The membership of the Working Group shall be clearly identified and maintained on a web site accessible by members of both Collaborations. Members will need to be registered and agree to the proprietary policy, as expressed in item 10 below, to gain access.
10. Data and software will be freely shared within the Working Group, as needed for the project. For this purpose, a secure site will be set up by the Working Group on a server that is accessible only by registered Working Group members. The intention of restricting access to only Working Group members, rather than allowing access to all members of either Collaboration, is to ensure that all work with these data is within the scope of this MoU. The site will include a list of all the data items that have been made available. After publication of the joint paper, the contents of the archive are open to all members of both Collaborations.
11. Two Working Group Coordinators, one from each Collaboration, will be responsible to coordinate the day-to-day work and to ensure that data and information flow adequately within the Working Group.They will organize telecons and face-to-face meetings of the Working Group as needed. In the interest of efficiency and at the discretion of the Coordinators, telecons may be held by a subset of the Working Group, but brief notes will always be posted to the website/wiki that is open to any member of either Collaboration.
12. The Working Group will develop a single Project Proposal sufficient to meet the requirements of each Collaboration's project approval procedure. Amendments to this proposal resulting from these procedures will be implemented by the Working Group, and the revised Project Proposal will be resubmitted to both Collaborations for approval.
13. A preliminary list of data products to be shared will be included in the Project Proposal. Further items may be added to the list on the basis of need, as proposed by the Working Group and with approval by the S4 Governing Board and LiteBIRD IGB. Data products and analysis methods are shared only for the purpose of this joint analysis and must not be used for any other purpose. They must not be distributed or made accessible to Collaboration members outside of the Working Group.
14. For the development of the joint paper, version-controlled repository software will be utilized. Each Collaboration will name those members of the Working Group who will be responsible for the actual writing of the paper; only these authors will have write access to the repository.
15. Amendments to this MoU are subject to the approval of both Collaborations. Such approval is to be indicated by the subscribers.

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Annex: Publication Policy Differences

This summary of publication policy differences was used to guide the creation of this MoU and is included here for reference.

	CMB-S4	LiteBIRD
Project proposal process	Project: 1. A collaboration member proposes a project to a Working Group (WG), including the project lead, initial team (including external collaborators), description, estimated completion date, and final products. 2. The External Collaboration Committee (ECC) determines if an MOU is required and, if so, represents CMB-S4 in establishing one. 3. The WG reviews the proposal, resolves any conflicts, and submits it to the Science Council (SC) with a recommendation for the project type. 4. The WG announces the project to the Collaboration for discussion, conflict resolution, and team sign-up. 5. The SC reviews the proposal and requests revision as necessary. 6. On approval, the Publication Board (PB) records the project and its category.	Project Study: 1. A collaboration member proposes a project study to the Publication Board (PB) including a definition of the goals and expected development of the study. 2. The PB registers the project, checks consistency with other studies, comments on the scope, and moderates any conflicts. 3. The associated project study team is open to all members of the collaboration, and can include MOU partners. It should be led by one or two full or external* collaborators. Project Paper: 1. A collaboration member proposes a project paper to the PB including title, abstract, relationship to other papers, paper team (including coordinator(s) and style controller), proposed category, initial author list, proposed journal, schedule 2. The PB registers the paper, checks consistency with publication policies and other papers, moderates any conflicts, approves the project, considers the journal choice, sets up an internal review team, appoints a rapporteur, checks the style controller, and sets up a dedicated paper repository. 3. The PB and Membership Board (MB) will help the Interim Governing Board (IGB)

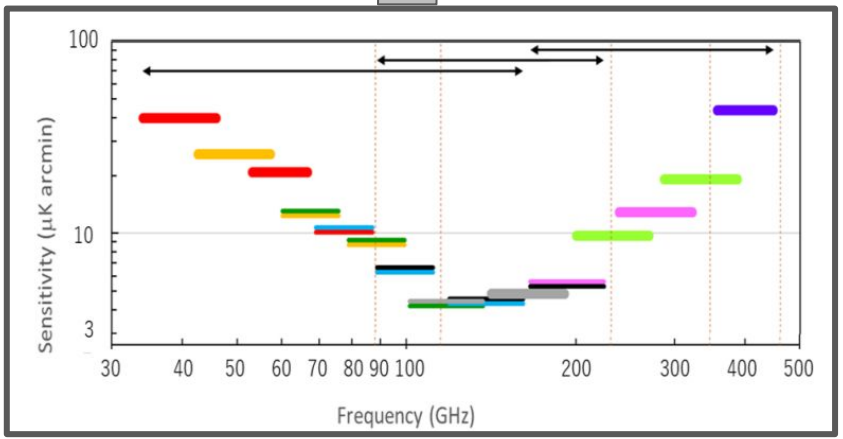
		coordinate any MOU. * "external collaborator" is a LiteBIRD internal membership category, not a member of another collaboration.
	LiteBIRD has distinct project study and project paper proposals, whereas CMB-S4 has these in common. For our purposes it is important that both collaborations identify this as a key project, which means that we must submit both study and paper proposals to LiteBIRD. • Develop a single common proposal sufficient to meet both collaborations' rules and requirements for both a study and a paper, including a joint initial team with a lead from each collaboration. • Revise jointly in response to each collaboration's feedback to maintain consistency.	
Project execution process	1. The project team undertakes the proposed scope of work. 2. Any substantial change in scope requires a revision of the project proposal and recirculation to the collaboration. 3. Any reclassification of the project category requires unanimous agreement of the project team and a supermajority of the PB, or a supermajority of the Governing Board (GB) 4. The PB will solicit progress reports from the WG twice yearly. If no progress is made in one year the project will be deemed inactive.	1. The project study team undertakes the proposed scope of work.
	LiteBIRD has no process for changes in scope • Any changes in scope shall only occur with the formal agreement of both collaborations.	
Key paper authorship	• The author list will be "The CMB-S4 Collaboration: [alphabetical list]" • All active and legacy members of the collaboration will be added as authors, with opt-out available on request. • Non-members who have performed critical work may be added by petition by a senior member	• The author list will be "LiteBIRD Collaboration: [alphabetical list]" • All eligible full and external collaborators will be invited to opt-in. • The corresponding author will be a generic LiteBIRD email address.

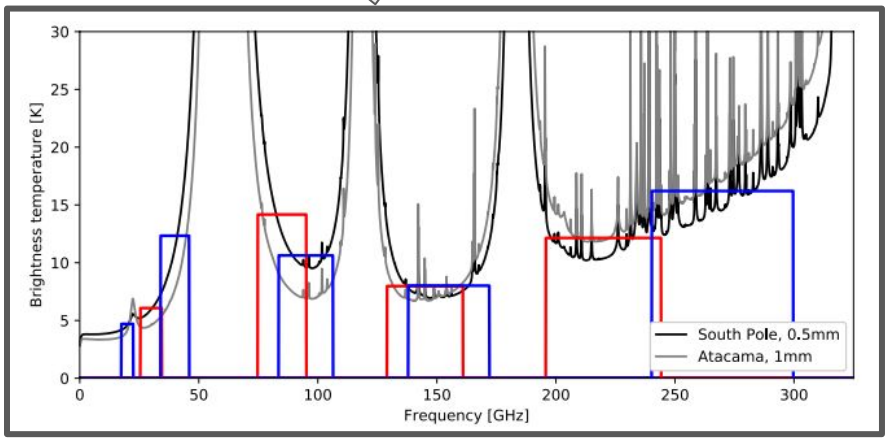
CMB-Stage IV

	Assuming both collaborations approve this as a key project • The author list will be "The CMB-S4 and LiteBIRD Collaborations: [single alphabetical list]" • Authorship rights will follow each collaboration's own rules • The corresponding author will be a generic address that itself redirects to generic CMB-S4 and LiteBIRD email addresses	
Publication review process	• The project team drafts the publication, entitled "CMB-S4: [paper description]", in coordination with the relevant WGs and in a repository visible to the entire collaboration. • The PB appoints a primary and secondary reviewer (PB non-members) and rapporteur (PB member), at least one of whom is a senior member, and announces this to the collaboration. • When the project team is ready, the PB announces a formal three-week comment period (though comments are welcome at any time). All comments and responses are made available to the collaboration. • After the formal review period the reviewers provide a written report to the project team and PB. • When the WG coordinators and rapporteur are satisfied that all comments have been addressed, they present the paper to the PB for final approval. • The PB announces the planned submission date and notice for final reading to the collaboration.	• The project paper team drafts the publication. • The project team presents the draft to the PB and notifies the collaboration. • The PB reviews the draft and suggests improvements, collects comments from the collaboration, and approves the paper as "content complete" after iteration. • The project team submits the final draft to the PB • The PB initiates the opt-in process, validates the author list, category, and journal, performs a final style edit, approves the paper for submission, and submits a recommendation to the IGB. • On receiving the referees' report, the project team addresses the points raised. • The rapporteur presents the revised paper to the PB. • The PB approves resubmission
	CMB-S4 has no formal process for responding to a referees' report. • Proposed paper title (eg. "CMB-S4 and LiteBIRD Collaborations: Assessing Complementarity Through Joint Simulations") • The collaboration-wide internal review processes will be conducted jointly, with the rapporteurs producing a common report to go to each PB • All submission decisions require the approval of both collaborations.	
Other publication	• All CMB-S4 publications must include a standard	• From Tony: "There is a LiteBIRD set of acknowledgements, with

notes	acknowledgment, agreed to and updated by the GB, and made available by the PB. • The collaboration will pay page charges for key projects.	some rules for inclusion/exclusion of subsets. This is not detailed in the publication policy, but will be included in the revised document under development."
	• Split page charges?	
Data/ software/ computing access rights	• Senior, postdoc and student members have full data access rights, and computing resource access rights subject to any other collaboration and/or project policy. • Software access is unspecified, but all members have access to the CMB-S4 github repository.	
	• Each collaboration will independently generate simulations based on common agreed inputs and to a common agreed standard. • The resulting maps and any necessary ancillary data (to be determined and agreed) will be made available to both collaborations exclusively for the purposes of the studies detailed in this MOU, including possible extensions.	

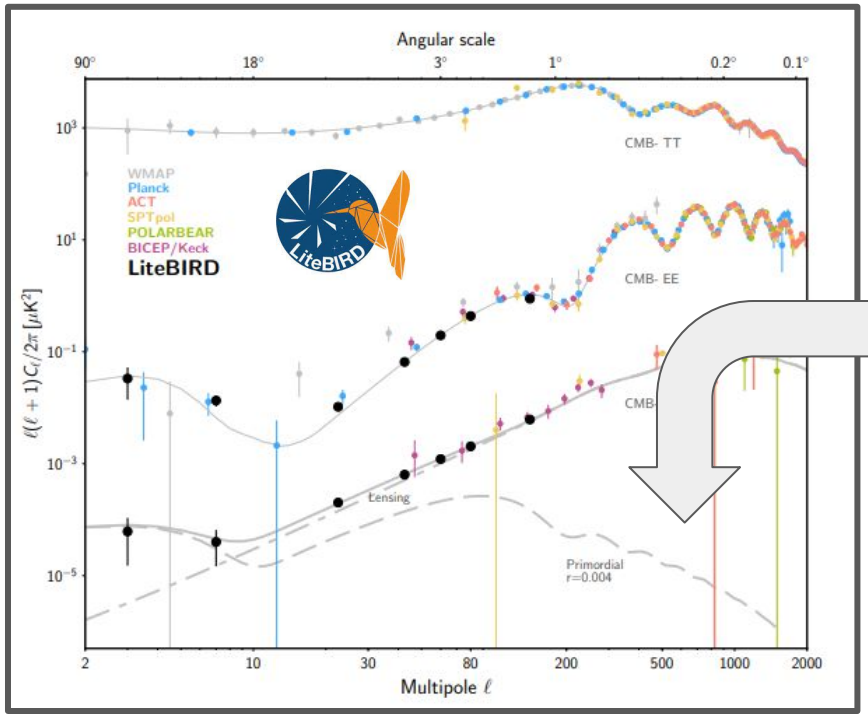
Goals: Improved Foreground Cleaning on CMB-S4

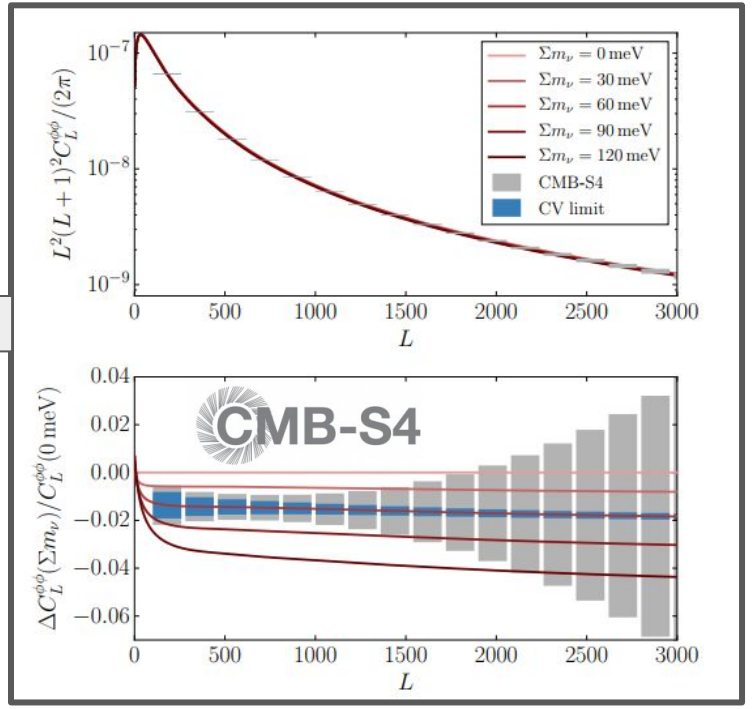




arxiv.org/abs/2202.02773

Goals: Improved de-Lensing on LiteBIRD

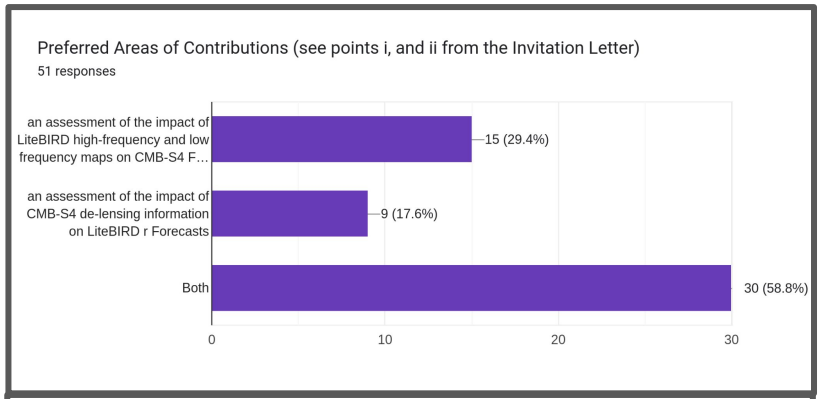


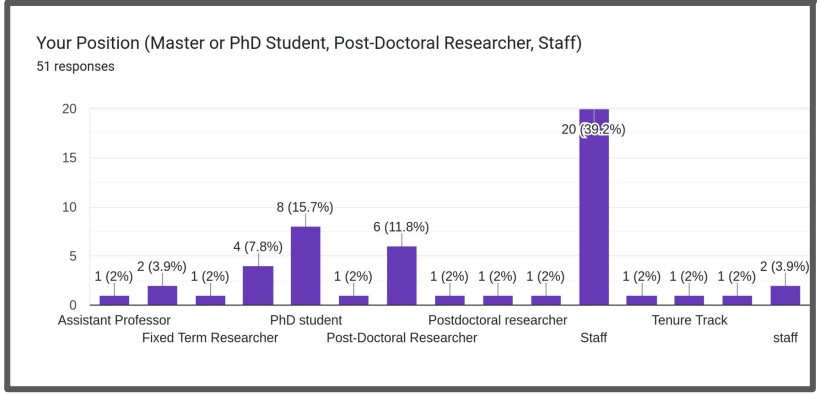


arxiv.org/abs/2202.02773, arxiv.org/abs/1610.02743

Cosmic Orbital and Suborbital Microwave ObservationS

Organization: Team





Convenor for LiteBIRD: Toshiya Namikawa

giuseppe puglisi	universita' di catania
Raphael, Flauger	UC San Diego, San Diegc
Carlo Baccigalupi	SISSA, Trieste, Italy
Anto Idicherian Lonappa	University of Rome, Tor
Samantha Lynn Stever	Okayama University, Japa
Anthony J. Banday	CNRS-IRAP (Toulouse)
Jonathan Aumont	IRAP
Toshiya Namikawa	Kavli IPMU
Arianna Rizzieri	Laboratoire APC, Paris
Lukas, Tobias, Hergt	University of British Colun
Josquin Errard	APC, Paris
Radek Stompor	CNRS, Centre Pierre Bin
Elena de la Hoz	Centre Pierre Binétruy (Cl
Patricia Diego-Palazuelos	Instituto de Física de Can
Blake Daniel Sherwin	University of Cambridge
Kazunori Kohri	KEK
Jens Chluba	JBCA
Michele	Maris
Marco Bortolami	University of Ferrara, Ita
Hideki Tanimura	Kavli IPMU
Giovanni SIGNORELLI	INFN Sezione di Pisa
Nicolo' Elia Raffuzzi	University of Ferrara
Nicoletta Krachmalnicol	SISSA
Serena Giardiello	Cardiff University
Alessandro Carones	University of Rome Tor
Alessia Ritacco	INAF - Cagliari
Giulia Piccirilli	Università di Roma Tor
Giacomo Galloni	University of Rome Tor
Benjamin Dan Wandelt	IAP, Paris, France
Marcos López-Caniego	Universidad Europea de M
Stéphane Ilic	IJCLab, Orsay, France
Avinash Anand	University of Rome "Tor V
Eric Hivon	Institut d'astrophysique de
Hirokazu Ishino	Okayama University
Clement Leloup	Kavli IPMU, Tokyo, Japan
Silvia Micheli	Sapienza University of F
Giulia Conenna	Università degli studi di
Daniela Paoletti	INAF-OAS Bologna
Martina Gerbino	INFN Ferrara
Margherita Lembo	University of Ferrara, Fe
Mario Ballardini	Department of Physics a
Massimiliano Lattanzi	INFN Ferrara
Luca Pagano	University of Ferrara
Thejs Brinckmann	University of Ferrara, Ita
Fabio Finelli	INAF OAS Bologna
Marina Migliaccio	University of Rome Tor
Patricio Vielva	Instituto de Física de Can
Mathieu Remazeilles	Instituto de Física de Can

Organization: Communication

Thursday, April 20, 2023

Attending (please add by yourself): Toshiya Namikawa, Anto Lonappan, Fabio Finelli, Marco Bortolami, Margherita Lembo, Patricia Diego, Carlo Baccigalupi, Daniela Paoletti, Nicolò Raffuzzi, Silvia Micheli, …

Apologies: Jens Chluba, Martina Gerbino

Notes:

- Status of the S4-side
  - https://drive.google.com/drive/folders/1EeFQmOucujWe_jV0JHkVeG03MS_P9NOJ
- Our scope/goals
  - Simulation
    - Post-PTEP simulation is needed to be updated to match the S4 realizations
    - AI: Giuseppe: Ask the S4 side for simulation coordination
  - Available pipeline/codes/likelihood
    - AI: Carlo: Pointing component separation codes to Toshiya
  - Whether LiteBIRD component-separated E-modes help to improve phi and delensing
    - For creating the lensing B-mode template, large-scale LiteBIRD E-modes would be useful. The lensing phi map would not be useful since the phi is reconstructed from only small-scale CMB anisotropies
- Practicalities
  - Telecons
    - Several possibilities.
  - Wiki page
    - AI: Toshiya: create a Wiki page
  - Proposal for Project Study
    - AI: Toshiya: start the document for the proposal
  - CPU hours: how to share among LiteBIRD and S4
    - AI: Toshiya: Ask Julian/Kimmy
- AOB
  - Present a 5min talk at a global telecon
  - Next call: try to organize an initial LiteBIRD x S4 telecon

April 26th: Andrea & Toshiya Items for Discussion in the First General Call:

- **Foregrounds**
- **Communication Schedule**
- **Platforms for Data Exchange**
- **Paper Proposal for Both Collaborations**
- **…**

May 25th: First General Call

Early Analyses

PTEP

Prog. Theor. Exp. Phys. **2015**, 00000 (19 pages)
DOI: 10.1093/ptep/0000000000

LiteBIRD Science: Improving Sensitivity to Inflationary Gravitational Waves with Multitracer Delensing

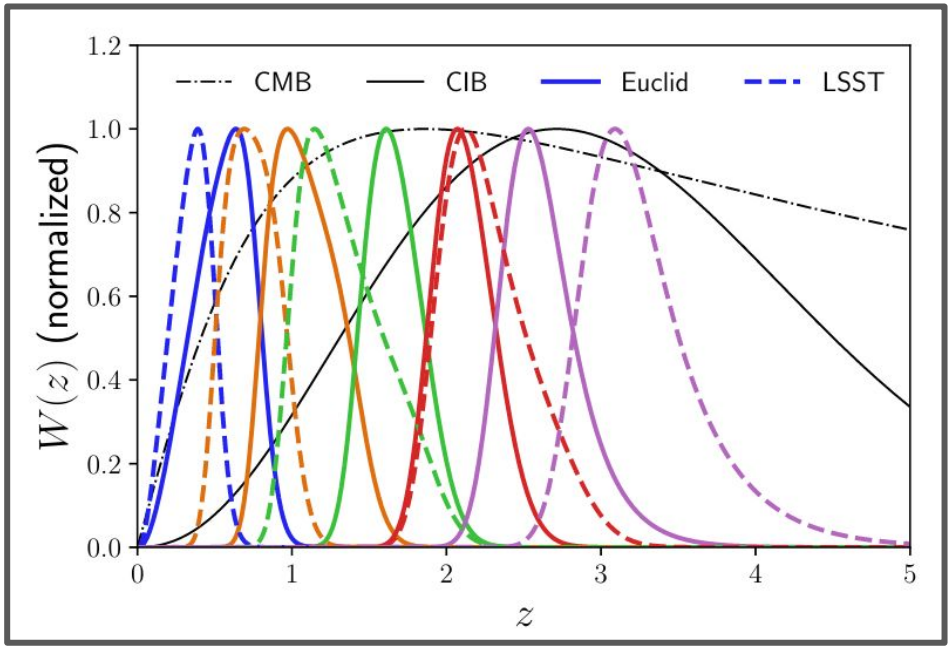
LiteBIRD Collaboration

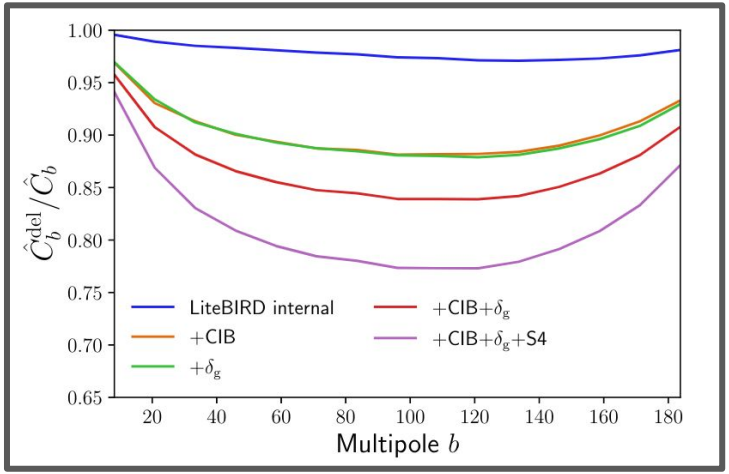
We estimate the efficiency of mitigating the lensing B-modes, the so-called delensing, for the LiteBIRD experiment with multiple external data sets of lensing-mass tracers. The current best bound on the tensor-to-scalar ratio, r, is limited by lensing rather than Galactic foregrounds, and delensing is now a critical step to improve sensitivity to r. In this paper, we extend the analysis of the LiteBIRD PTEP paper to the case, including several other mass tracers such as galaxies from Euclid and LSST-like surveys, cosmic infrared backgrounds, and CMB-S4-like lensing map. Although the residual Galactic foregrounds are the dominant source of the LiteBIRD B-modes, we find that the multi-tracer delensing will further improve the constraint on r by $\sim 20\%$.

Project Paper in Internal Review, Toshyia Namikawa, Anto Lonappan
Gravitational Lensing: LiteBIRD B-Mode de-Lensing

Early Analyses

	$\sigma(r=0)\times 10^3$
No-delensing	1.43
LiteBIRD internal	1.39
+ CIB	1.28
+ δ_g	1.30
+ CIB + δ_g	1.24
+ CIB + δ_g + S4	1.19





Project Paper in Internal Review, Toshyia Namikawa, Anto Lonappan
Gravitational Lensing: LiteBIRD B-Mode de-Lensing

Early Analyses

PTEP

Prog. Theor. Exp. Phys. **2015**, 00000 (19 pages)
DOI: 10.1093/ptep/0000000000

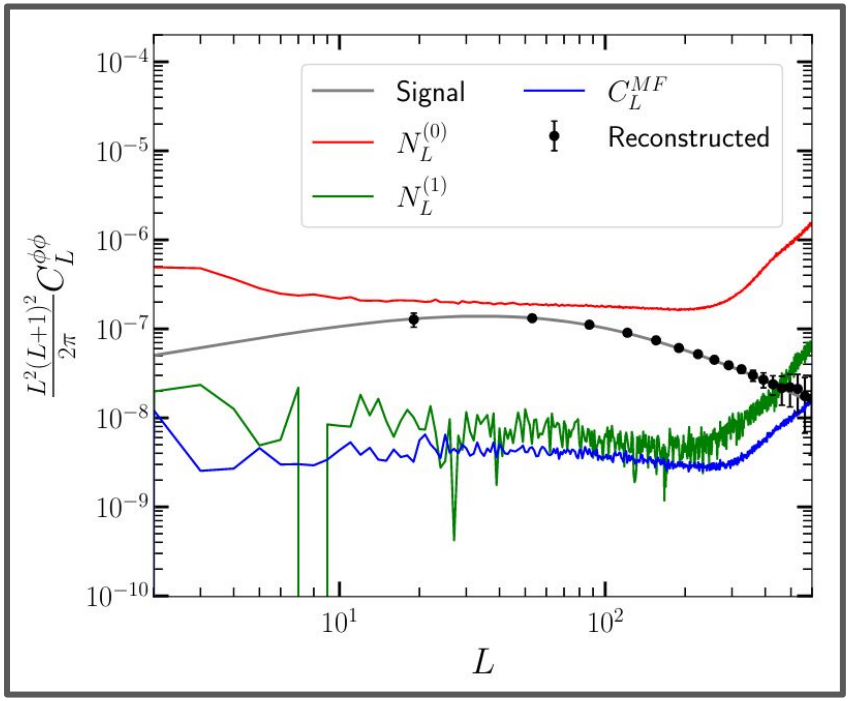
LiteBIRD Science: A full-sky measurement of gravitational lensing of CMB

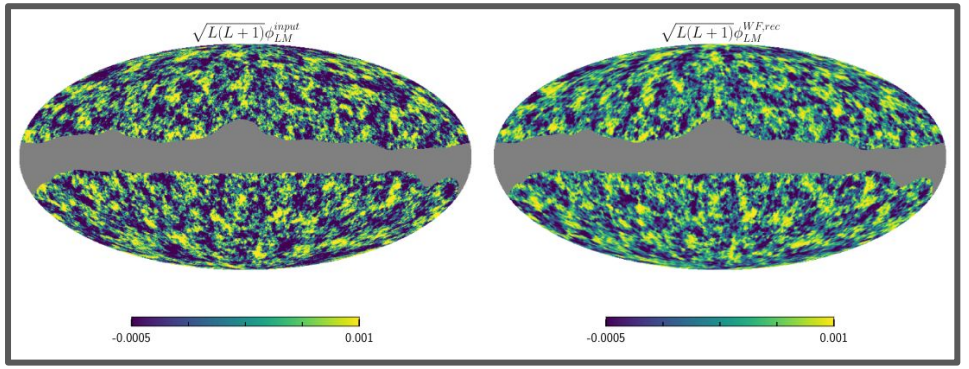
LiteBIRD Collaboration

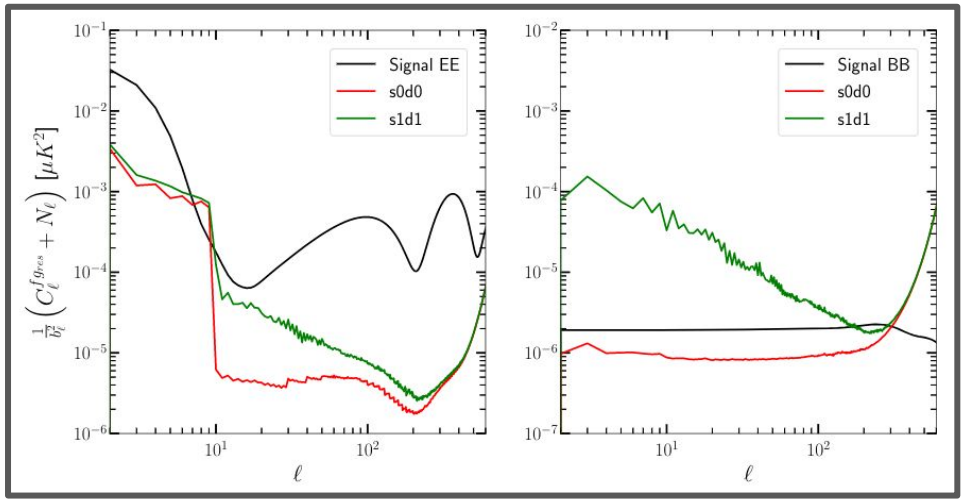
We explore the capability of measuring lensing signals in full-sky by the LiteBIRD polarization maps. Although the LiteBIRD is not sensitive to small-scale CMB anisotropies, the excellent sensitivity to polarization in full-sky enables us to reconstruct a nearly full-sky lensing map with polarization data alone. In this paper, we investigate a lensing measurement in the presence of the Galactic foregrounds, finding that several possible biases from Galactic foregrounds would be negligible after a component separation by the harmonic-space internal linear combination. The signal-to-noise ratio after the component separation is approximately 40, comparable to the latest measurement of the Planck data but with polarization alone. The LiteBIRD lensing map will complement the Planck lensing map and provide several opportunities for cross-correlation science, especially in the Northern hemisphere.

Project Paper in Internal Review, Anto Lonappan, Toshiya Namikawa
Gravitational Lensing: LiteBIRD Lensing Reconstruction

Early Analyses







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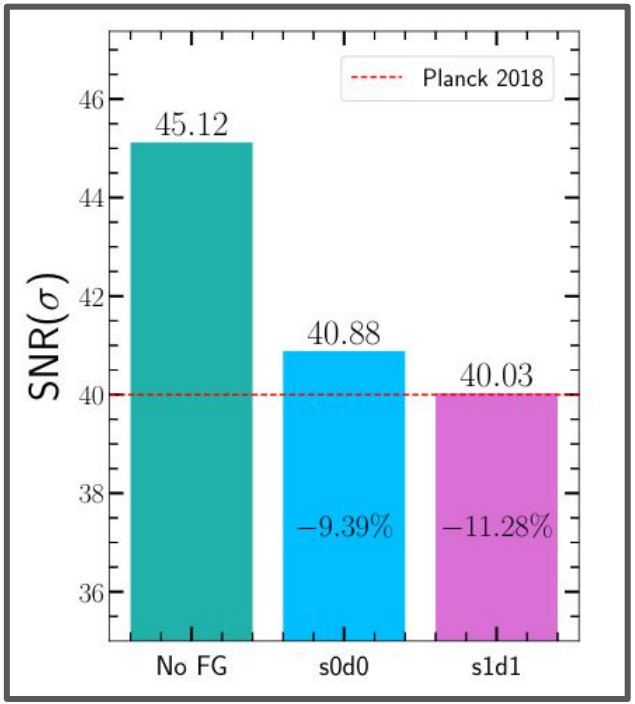
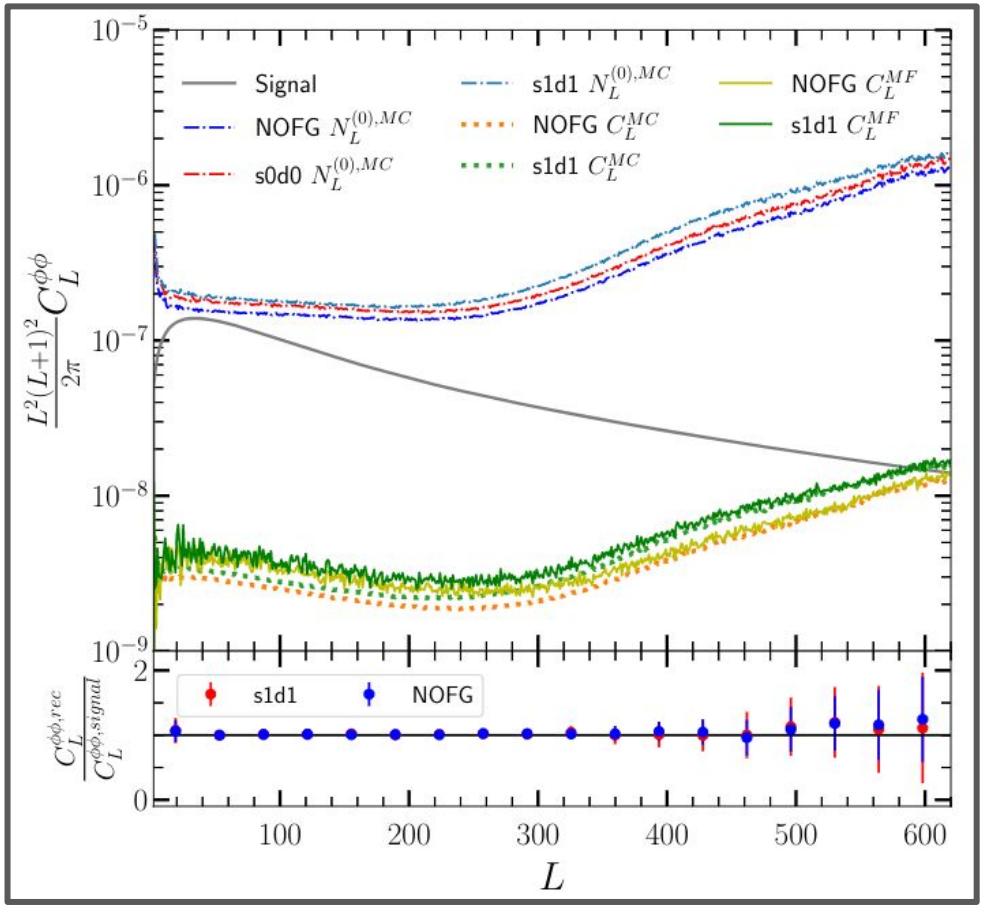
Early Analyses





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Interfaces & Schedule

- **Monitoring & Support:**
  - **Foregrounds JSG,**
  - **LowEllBB,**
  - **Map-Making, Estimators & Likelihood,**
  - **…**
- **This MoU: Path Finder, Single Project Paper, Map-Based, 1 Year Timescale:**
  - **Improved Component Separation for S4,**
  - **Improved De-Lensing for LiteBIRD,**
  - **Details being Set in these Weeks, Limited Treatment of Instrumental Systematics**
- **More Ambitious Analyses: Systematics, Timelines, Details Depending on the Path Finder Results**