Milano, 3 July 2019 – INFN CSN2

CMB experiments: LiteBIRD

& ongoing ground-based programs LSPE and QUBIC

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Milano, 3 July 2020 Marco Bersanelli – LiteBIRD other CMB Experiments













Ground-based experiments

Post-Planck challenges:

- CMB Spectral distortions
- Sunyaev-Zel'dovic effect



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Probing the very early universe

Exponential expansion in very early universe: $N \sim 10^{26}$ in $\delta t \sim 10^{-36}$ s

Possibility to explore GUT-scale physics

Potential of single field slow-roll:











Planck 2018: inflation parameters

Very powerful constraint on spectral index (and running) Planck's B-mode main constraint from TT at multipoles <100



 $\frac{r_{0.002}}{r_{0.002}} < 0.10 \qquad n_{\rm S} = 0.9659 \pm 0.0041 \quad \text{[Planck T+P+L]} \\ r_{0.002} < 0.065 \qquad n_{\rm S} = 0.9670 \pm 0.0037 \quad \text{[Planck T+P+L + BK14 + BAO]}$

These results disfavour all simple integer power-law inflation potentials

Major global effort for the future: Sub-orbital, Space







100

Multipole Moment. *l*

1000



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10

10-6



LiteBIRD payload and task share



June 2019: Mission selected as next JAXA L-class mission Strong international support: Europe (France, Italy), US, Canada

Collaboration: about 200 researchers (growing), with CMB, x-ray, HEP, background PI M.Hazumi (KEK), US PI A. Lee, EU PI L. Montier, Can PI M. Dobbs,



LiteBIRD instruments

- Low Frequency Telescope (LFT): reflective system
- Medium-High Frequency Telescope (MHFT): two refractive systems
- Polarization modulators (transmissive & rotating HWP)
- Detectors: Transition Edge Sensor (TES) arrays (4732 detectors)
- Cryogenic cooling to 0.1K







LiteBIRD scanning strategy



- L2 orbit ensures high stability environment
- Scanning strategy optimised for polarization measurements
 - Uniform full sky coverage
 - Every pixel visited frequently from different angle directions



Orbit: L2 Lissajous





LiteBIRD extra science



Cosmic variance limited measurement of E-mode polarization on large angular scales:

- ightarrow Reionization optical depth
- ightarrow Break degeneracy with neutrino mass







LiteBIRD extra science

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 $\sigma(\Sigma m_{\nu}) = 0.015 \text{ eV}$

 $> 3\sigma$ detection of minimum mass for normal hierarchy

 $> 5\sigma$ detection of minimum mass for inverted hierarchy

NB: staistical errors only





LiteBIRD: INFN contribution

Coordinator: G. Signorelli (Pisa)

- Warm Readout Electronics
 - Flight qualification of selected components
 - SQUID control units (LFT + MHFT)
 - electronic boards
 - mechanics
 - thermal interfaces
 - (digital assembly DAC/ADC boards)
- Detector study
 - Study of CR impact on detectors
 - on-beam test of detectors
- Data Analysis
 - simulation
 - map making
 - CMB parameters extraction

















LiteBIRD at Milano CMB group



MHFT calibration: From Bread-Board to Subsystem level - C. Franceschet et al.





- Breadboard: A simple refractive optics system to validate modeling vs measurements
- Use already available hardware
- No focal plane TES detectors ⇒ well-known horn
- Lenses are no AR-coated
- Room temperature measurements













LiteBIRD at Milano CMB group



Simulation team & Instrument Model (IMO) – M. Tomasi et al.

GitHub public site (litebird_sim)

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	Al the code scon. ichnical question: does it make more sense to provide it as a standalone repository with tapy/github.com/litebird, or should it be a subtree of https://github.com/litebird_litebird_s		As discussed at the S2S meeting in April 2020, I think it would be important guidelines on all the steps needed to import existing codes in this repo.		For a telescope with a half-wave-p	🛛 liteb	member () ···· Assignees	10 g Star 4 y Fork
	@ziotom78 what do you think?		There exist a bunch of codes already developed by collaborators that we pro		measurement value for every detection values corresponding to the unpola	<5 Cor	de Olssues 13. In Pull requests 2: Actions Projects 3: Wilki O Security 0	🖂 İnsighta 🛛 🛞 Settings
	R Treineck self-assigned this 15 days ago FT Treineck added this to To Do in <u>Total convolution and interpolation</u> 15 days a	a n i i i i i i i i i i i i i i i i i i	Are team, which as we said several times, is not to develop the full pipeline but coherent infrastructure. One example is the simple pipeline that I developed to produce map based : available here https://github.com/NicolettaK/LB_mbs. This is a private repo- infos about the instrument, but I can give you access if you want to have a lo Any idea on how we should proceed on this?		respectively. I do not expect great difficulties wh definition of the individual beam co	adjo 000	cint 4pi convolution and interpolation #16	
<u>,</u>	ziotom78 commented 15 days ago Mem				R Rereineck added this to To R Rereineck self-assigned this	no 😨	meineck commented on Mar 5 Member 🔘 …	Assignees
	By -subtree- you just mean a folder within litebird_sim, right? For me this solution is ok, if we bundle everything together, which is probably the easiest way to go.			a a			Implement code which performs the adjoint operation of what's done in #12. While not necessary for time stream generation, it is an important ingredient in deconvolution map mapmaking.	Treineck
-	mreineck commented 15 days ago Member Au						R The metineck self-assigned this on Mar 5	None yet
1003	By -subtree- you just mean a folder within itebird_sim, right? Exactly:		ziotom78 commented on May 7		mreineck commented on Apr 13		Total convolution and interpolation on Mar 5	Projects
	For me this solution is ok, it means that we bundle everything logether, which is probab easiest way to go.		Thank you for having opened this issue. I believe we should create a dedica documentation, providing a checklist that details which kind of codes we wa code should look like.		I decided to just provide the convol		mreineck commented on Mar 5 Member Author 🔘 …	Milestone 1 No milestone
	Absolutely fine. I just wanted to double-check, as this code is not so much a "module", but library that will be imported by other modules.				This can always be updated in the		The basic code is there, but adjointness tests fail. I'm debugging this.	
			A few things I'd like to see in the page are:				mreineck commented on Mar 10 Member Author 😡 …	Linked pull requests Successfully merging a pull request m
25	apole commercia is days ago Men fd only recommend to add an intermediate generic folder e.g. beam convolution and put	put i	 Examples of codes that we would like to use in this repo (e.g., «compor «cosmic ray glitch simulator», etc.); Constraints in the way the code is implemented (e.g., «no standalone per 	(meineck moved this from interpolation on Apr 13		Adjointness is fixed. The adjoint convolution code is not yet properly parallelized, but that is an easier task than ensuring convolutions. If someone would like to validate the code, feel free!	None yet
	inside a subfolder. This way we can maintain the same structure even if we add another n to beam convolution.			ogram, om				Notifications Custom
	I only see two pros in keeping the code outside of the reco.		Python2, IDL, Matlab codes» etc.);				10 The second second the from In progress to Waiting for feedback in Total convolution and	A unsubscribe You're receiving notifications because you're watching this repository.





LiteBIRD in Milan CMB group



Planck LFI "Level S" adapted to the LiteBIRD mission – D. Maino et al.

In-flight calibration and beam simulations



LiteBIRD/MFT Side-lobes maps in total intensity I (upper row) and in polarization intensity P (lower row) for the detector 00X at the centre of the focal plane (left) and an off-axis detector 01X (right). (See RA4/Annex 1 for details). The simulation is for 1 year observation.





Si LSPE

Combining balloon and ground-based measurement to probe the very early universe

STRIP Ground-Based, Tenerife



STRIP Telescope with ground screens and mounting structure



Map in Equatorial coordinates of the STRIP-SWIPE sky coverage SWIPE Balloon, Winter Arctic Flight



SWIPE accommodated in the balloon gondola



Performance

Site Tenerife balloon Freq (GHz) 43 95 145 210 24
Freq (GHz)
Bandwidth 17% 8% 30% 20% 10
Angular resolution FWHM (arcmin) 20 10 85
Detectors technology HEMT TES multimoded
Number of detectors N _{det}
Detector NET ($\mu K_{CMB} \sqrt{s}$)
Observation time 2 years 8 - 15 days
Duty cycle
Sky coverage <i>f</i> _{sky}
Map sensitivity $\sigma_{Q,U}$ ($\mu K_{CMB} \cdot \operatorname{arcmin}$) 102 777 10 17 34
Noise power spectrum $(\mathcal{N}_{\ell}^{E,B})^{1/2}$ ($\mu K_{CMB} \cdot \operatorname{arcmin}$) 171 1330 16 28 5:

¹We estimate as 50% the time dedicated to sky observations, including calibration sources. We split the remaining 50% as follows: (i) 15% of lost time due to bad weather, (ii) 15% of unusable data when the Sun will have an angular distance from the nearest feed less than 10° [7], 20% of time dedicated to relative calibration (see Sect 4.1.2).

Tensor-to-scalar ratio





LSPE/STRIP THE FOCAL PLANE INSTRUMENT

- Unit & subsystem (polarimeters, feedhorns, OMTs, electronics, cryostat) completed
- Instrument is now fully integrated with cryostat and electronics



- Instrument-level test campaign started @INAF-OAS Bologna.
- Warm testing of instrument/electronics I/F ongoing remotely (due to lock-down)

LSPE/STRIP THE TELESCOPE AND MOUNT

- Telescope and mount H/W transported from Oxford University to Milano LASA Lab
- Structural analysis ongoing (INFN/MI external contract), first WP completed (Apr 2020)
- Design of remaining I/F (cable routing, electronics boxes) ongoing
- Preparing drone-based system for beam calibration at Tenerife



SITE PREPARATION

- Site: Teide Observatory (2400m), Instituto de Astrofisica de Canarias (IAC)
- Agreement between INFN, UniMI and IAC signed (April 2020, addendum to UniMI-IAC document)
- Requirements & preliminary design of telescope cover ready for Industrial call





Technical Demonstratod Campaign (8x8 element array) Test Campaign: Late Spring 2019

-0.2

0.3

0.12 E 0.04

-0.04

-0.1

-0.2 -0.12 -0.04 0.04 0.12 0.2

x [m]

-0.2 -0.12 -0.04 0.04 0.12 0.2

x [m]



10

Bigot-Sazy et al, A&A, 2013

r =

r = 10⁻³

10-6 1

100



-0.017 0.017

-0.017 0.017

0.05

0.01

-0.017

-0.052 -0.052

0.052

0.052

-24 -32 gp