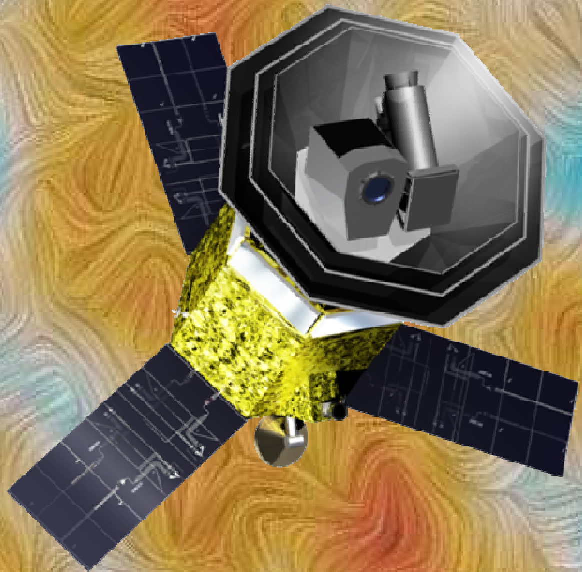
Milano, 3 July 2019 – INFN CSN2

CMB experiments:

LiteBIRD

& ongoing ground-based programs LSPE and QUBIC

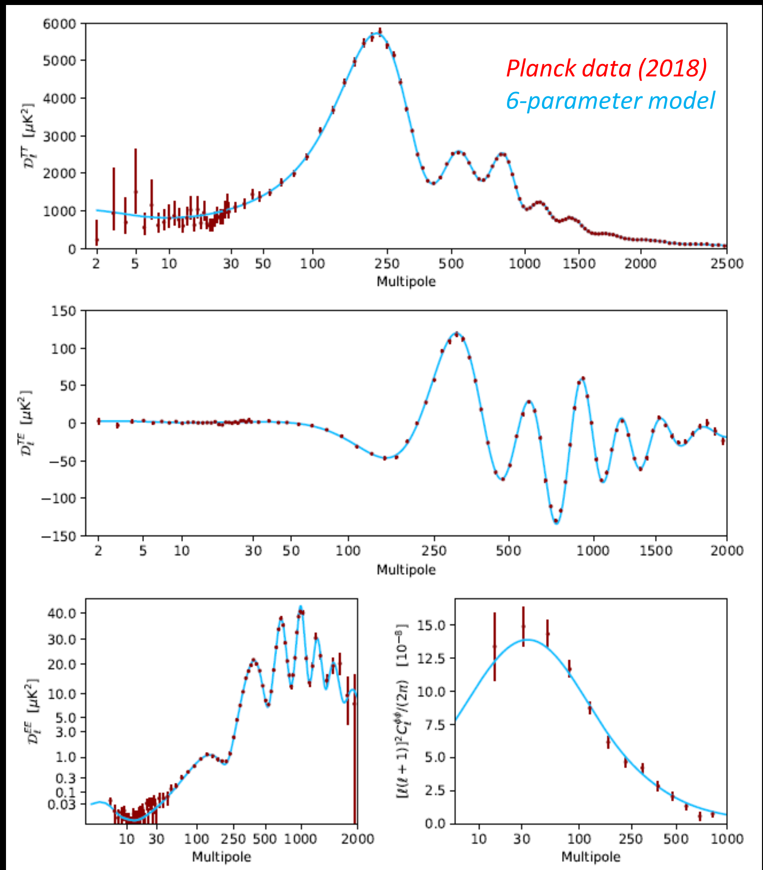


Marco Bersanelli

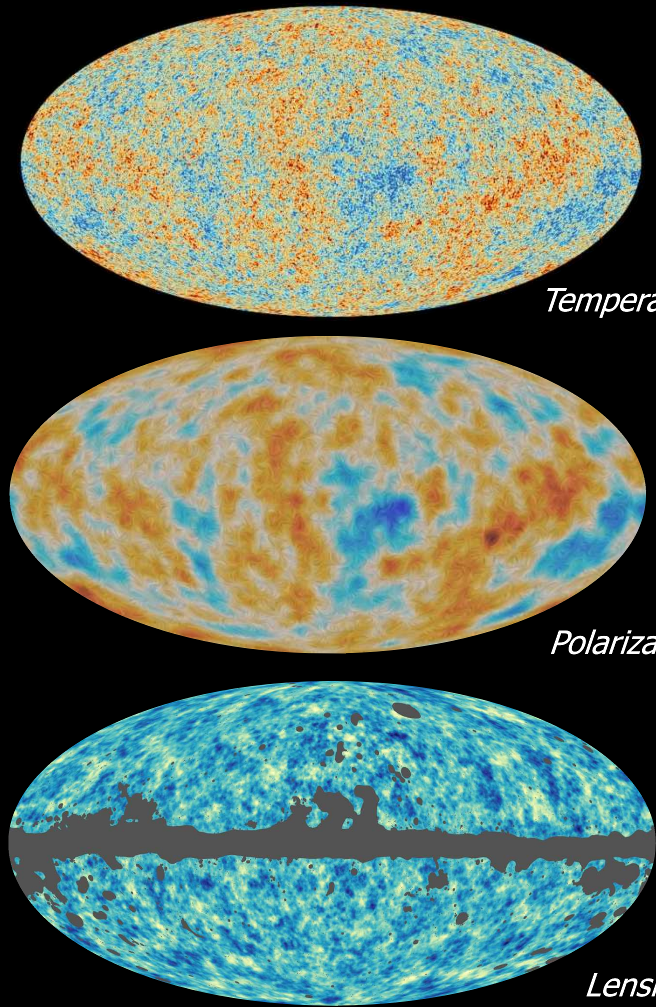
Università degli Studi di Milano

INFN Sezione Milano

PLANCK



Planck Collaboration 2018



Post-Planck challenges:

- B-modes in CMB polarization ← *Major global effort*
- CMB Spectral distortions
- Sunyaev-Zel'dovic effect

Ground-based experiments

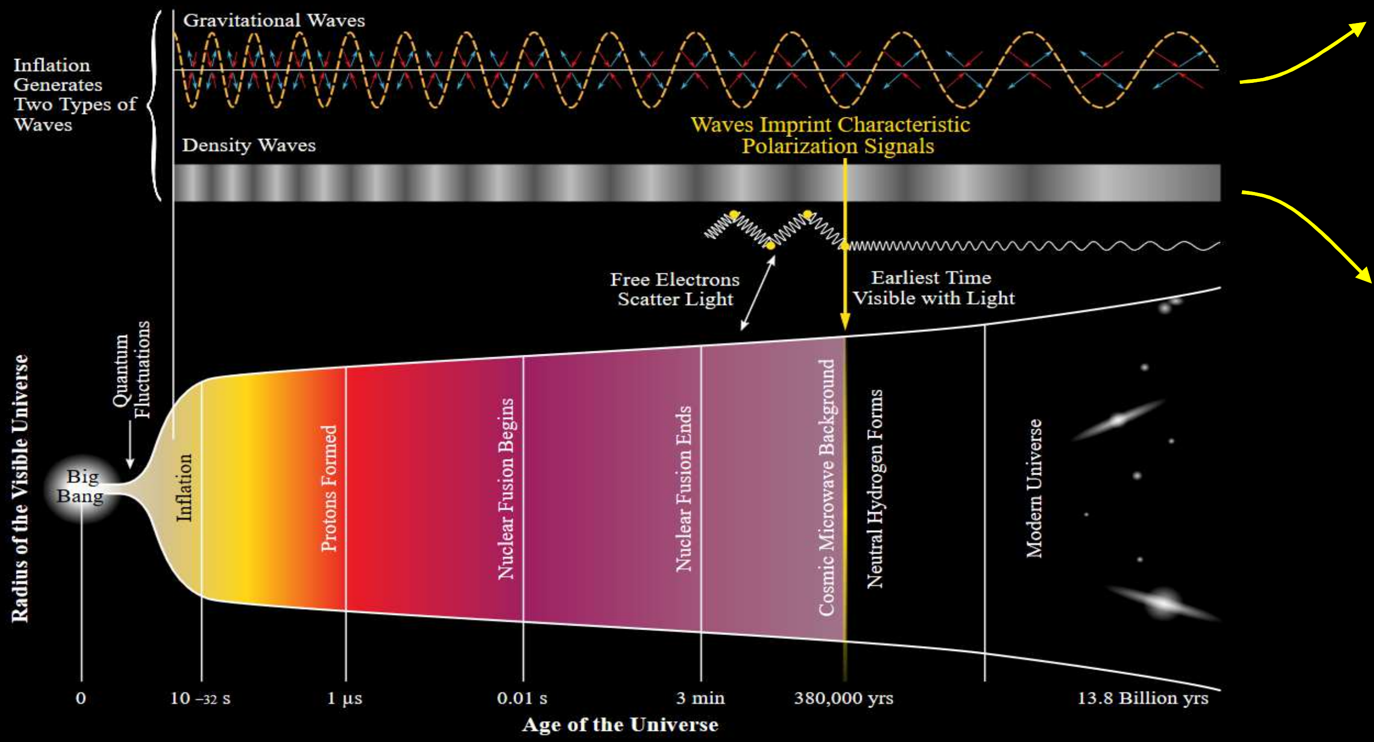
Probing the very early universe

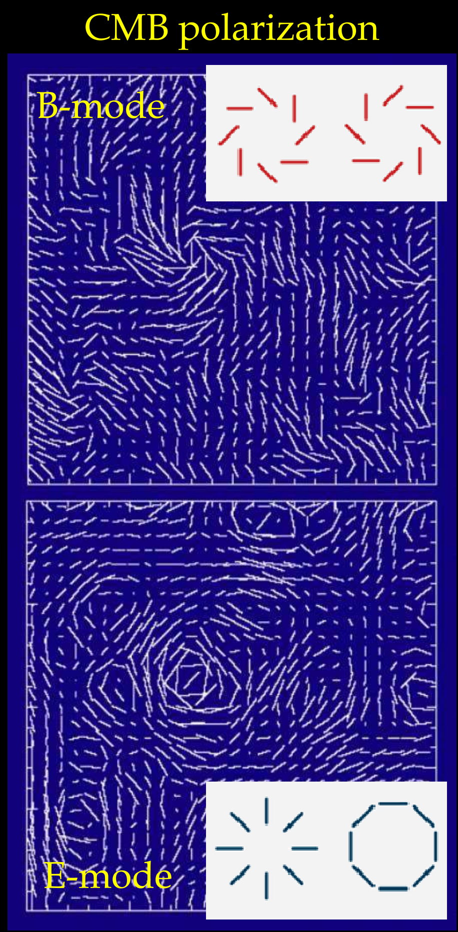
Exponential expansion in very early universe: N~10^{26} in $\delta t \sim 10^{-36}$ s

Possibility to explore GUT-scale physics

Potential of single field slow-roll:

$$V^{1/4} \approx 1.04 \times \left(\frac{r}{0.01}\right)^{1/4} \times 10^{16}\ \mathrm{GeV}$$

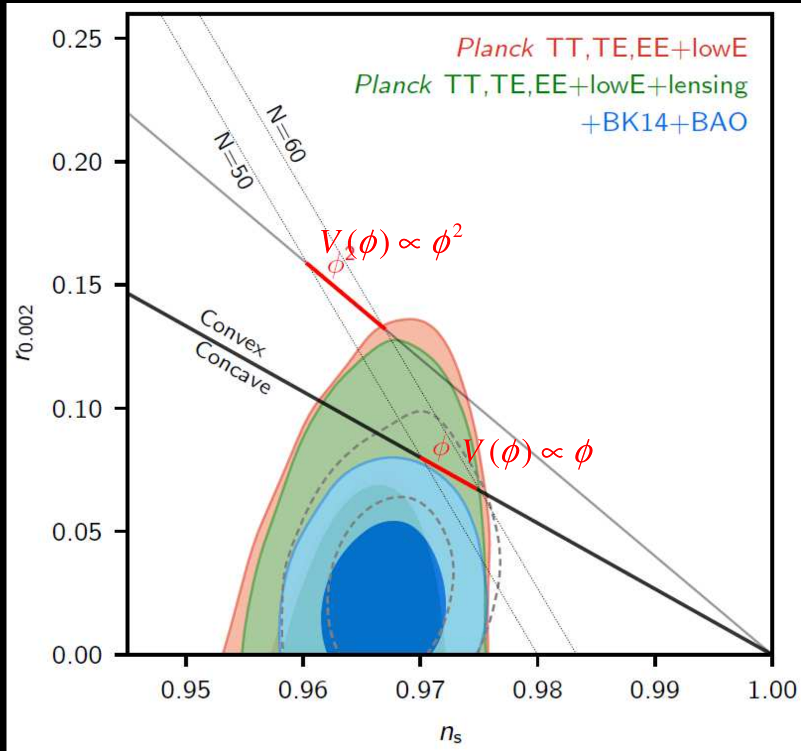




Planck 2018: inflation parameters

Very powerful constraint on spectral index (and running)

Planck's B-mode main constraint from TT at multipoles <100



$r_{0.002}$ = tensor to scalar ratio at pivot scale 0.002 Mpc

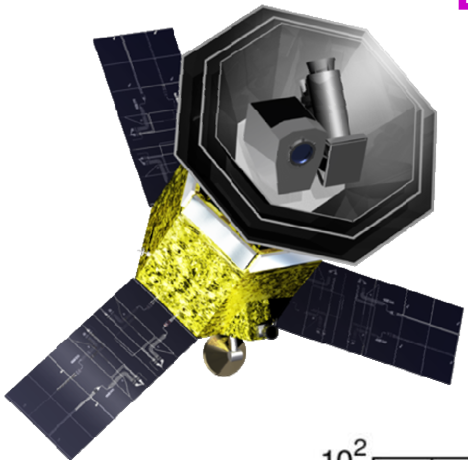
$r_{0.002} < 0.10 \quad n_S = 0.9659 \pm 0.0041$ [Planck T+P+L]

$r_{0.002} < 0.065 \quad n_S = 0.9670 \pm 0.0037$ [Planck T+P+L + BK14 + BAO]

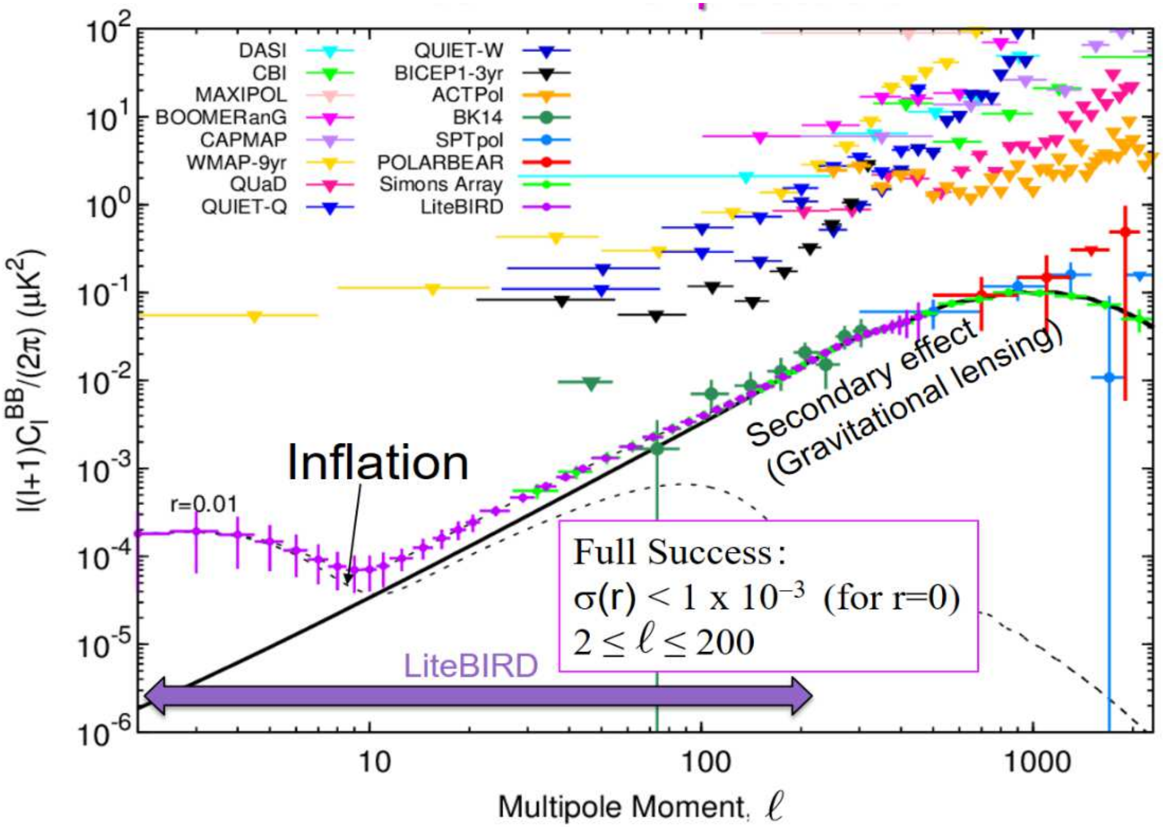
These results disfavour all simple integer power-law inflation potentials

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

LiteBIRD central objective



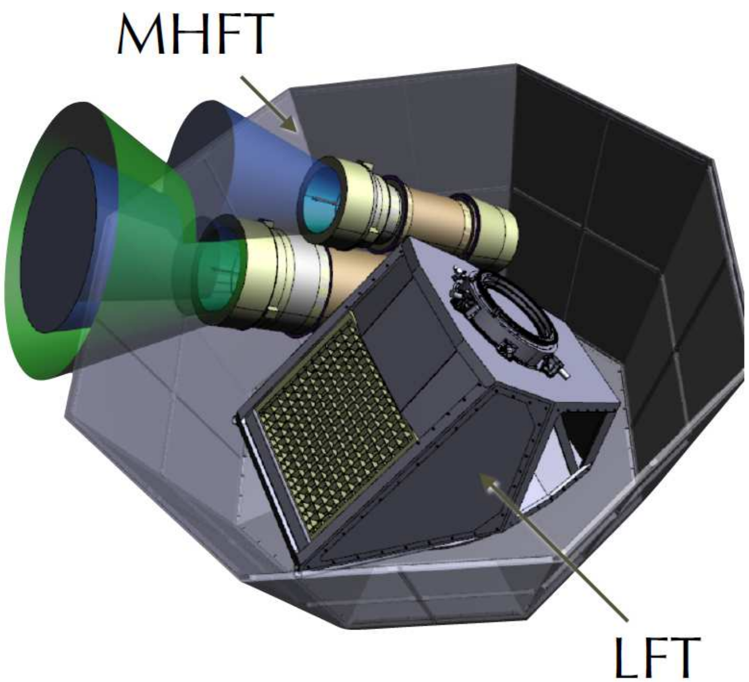
- **Objective: CMB B-modes, r ~ 10^{-3}**
- Sensitivity: < 3uK arcmin, Resolution: ~degree
- Lissajous orbit in L2, full-sky, 3 years
- Frequency range: 40-400 GHz
- Detectors: ~ 3500 TES, 100mK, HWP
- Launch foreseen in 2028

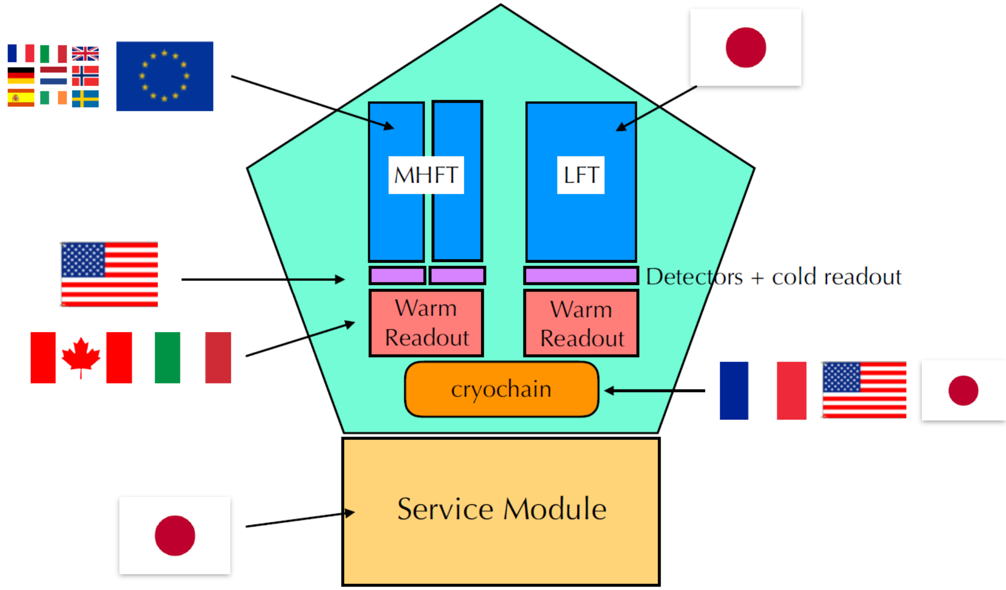


LiteBIRD payload and task share

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,





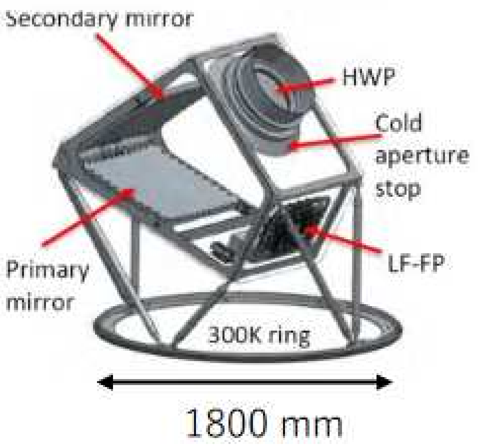
Integration and testing 

Data analysis 

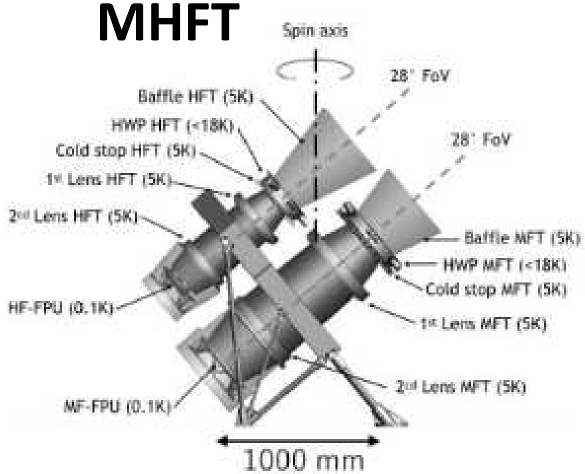
LiteBIRD instruments

- 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

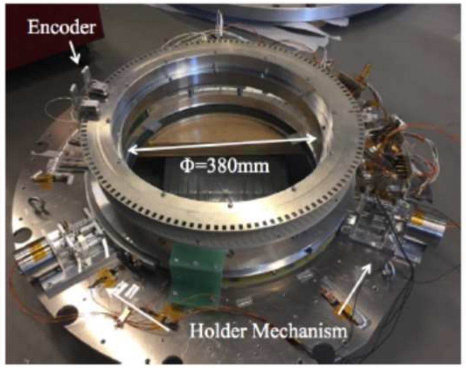
LFT

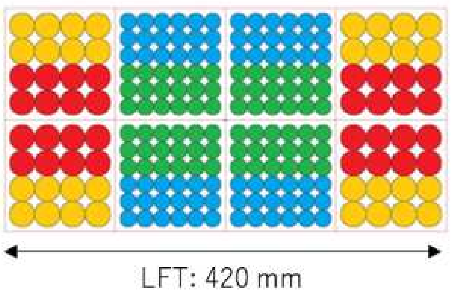


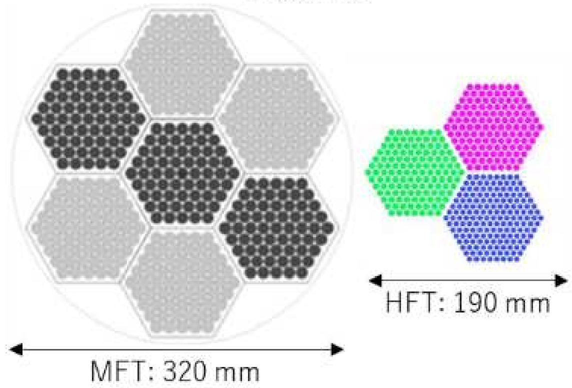
MHFT

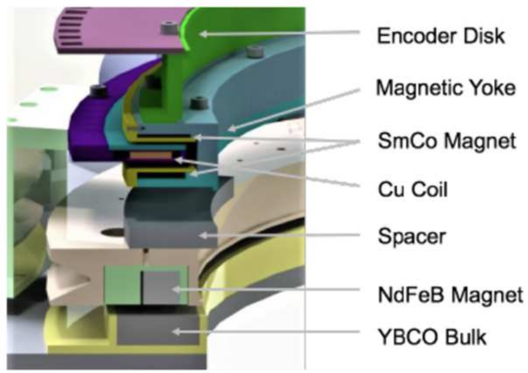


Pol modulator (HWP)





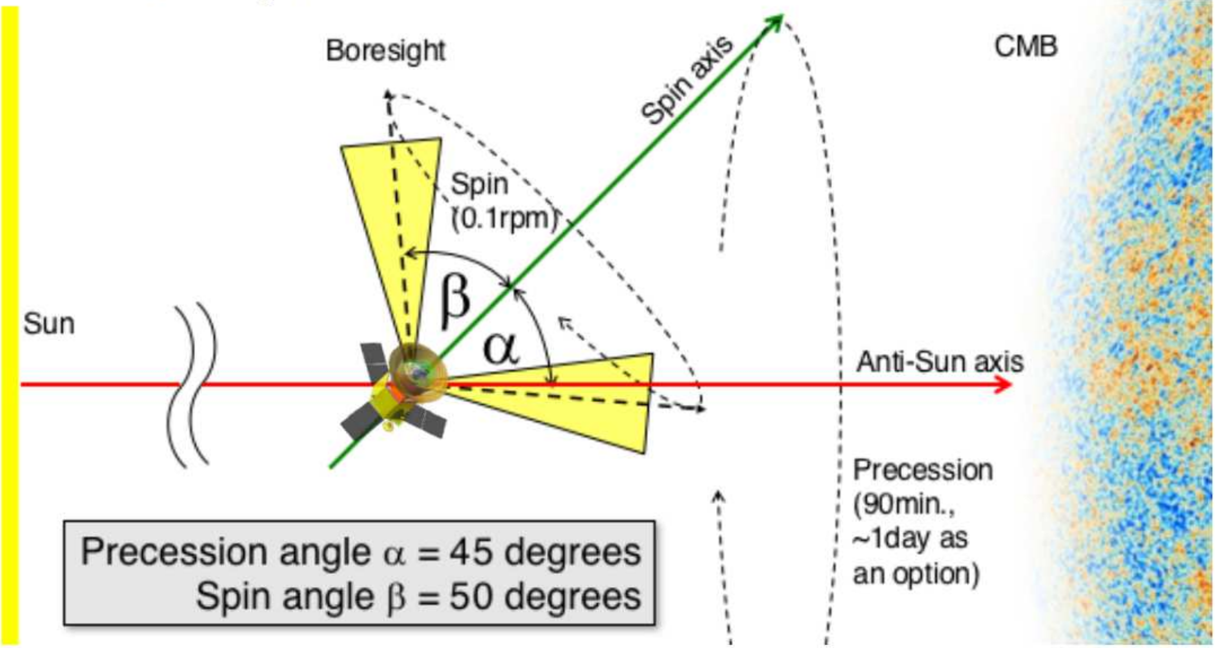


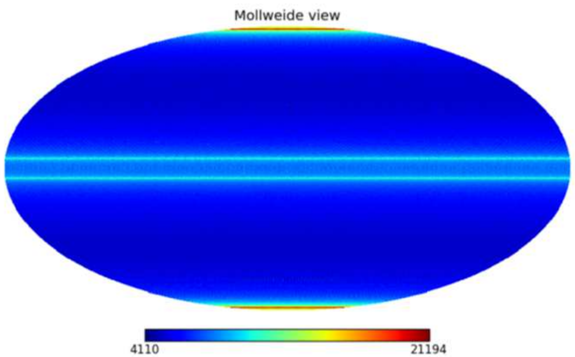


LiteBIRD scanning strategy

- 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





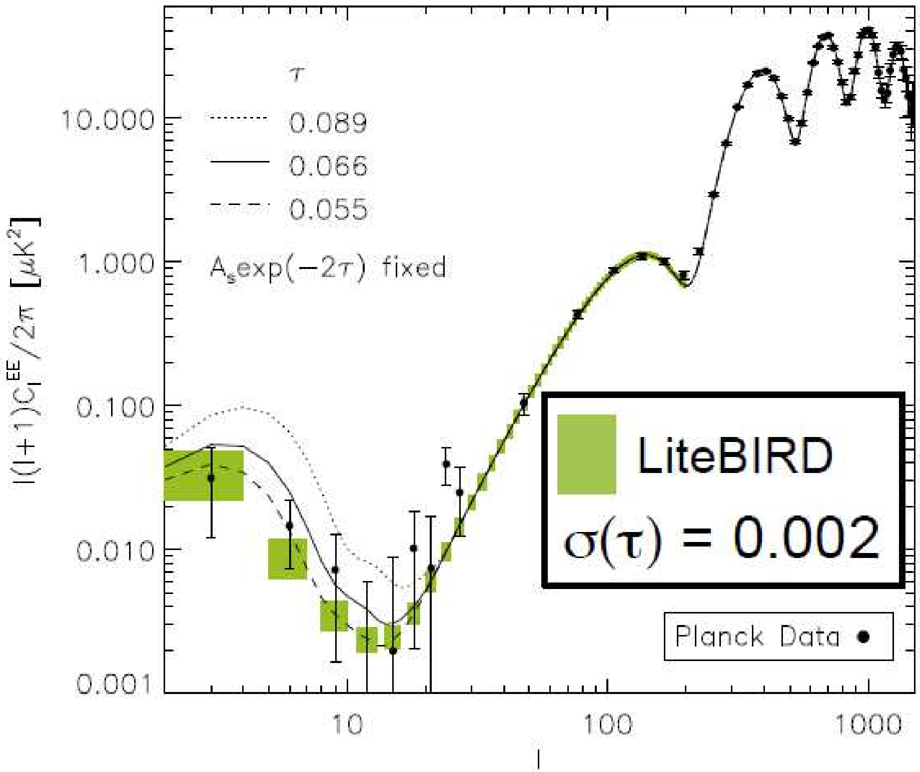
Hit map of LiteBIRD after 1 year observation

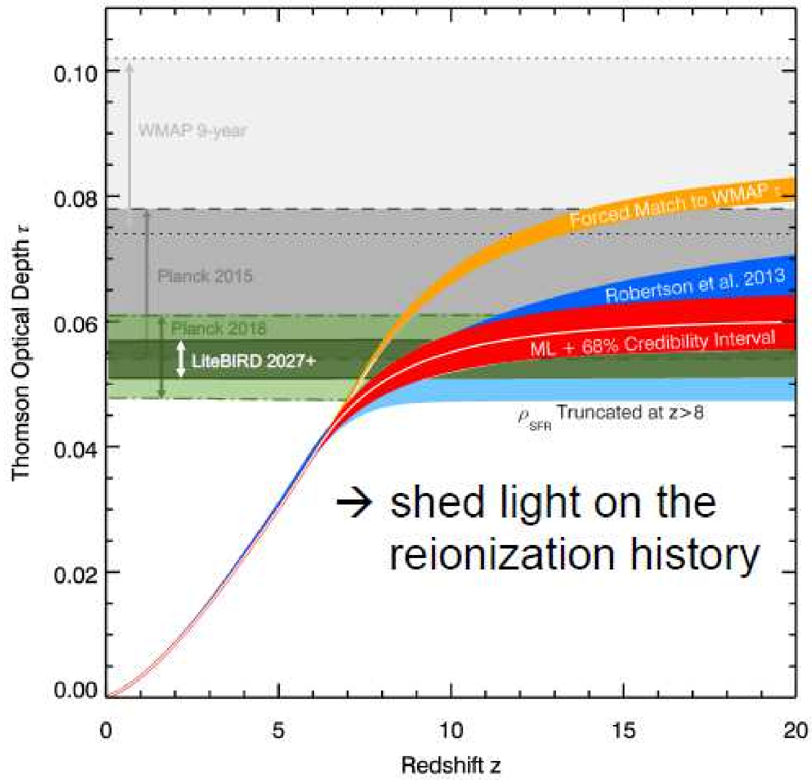
LiteBIRD extra science

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

→ *Reionization optical depth*

→ *Break degeneracy with neutrino mass*





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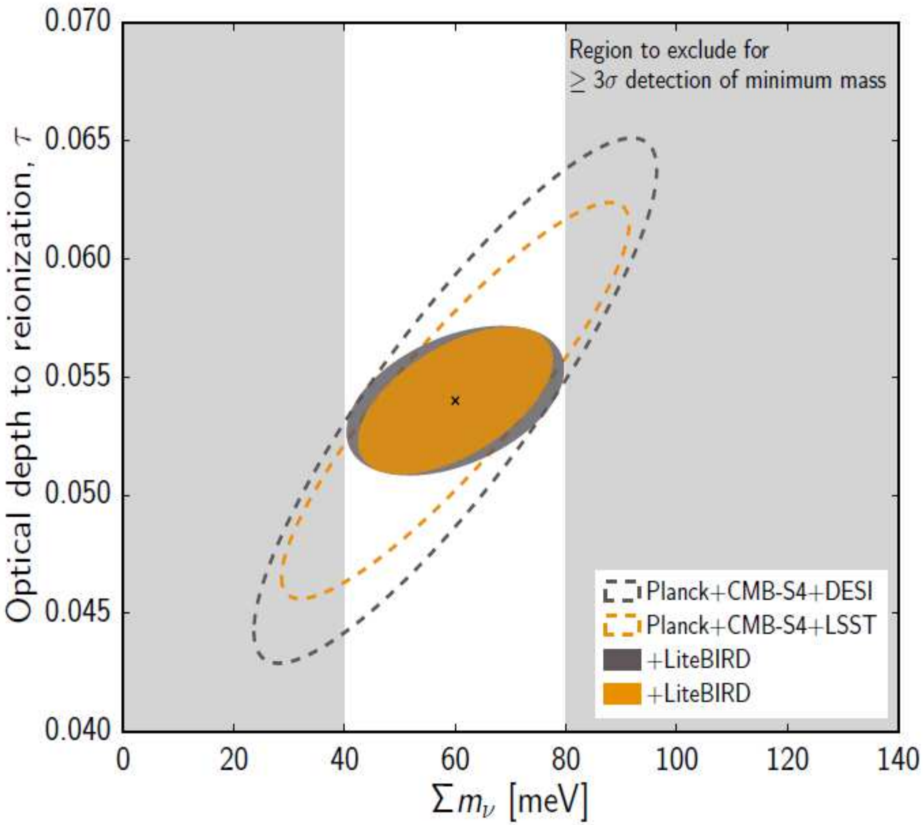


$$\sigma(\Sigma m_\nu) = 0.015 \text{ eV}$$

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

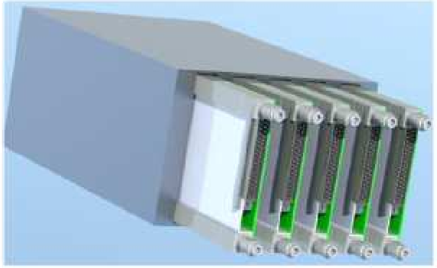
$> 5\sigma$ detection of minimum mass for inverted hierarchy

NB: staistical errors only

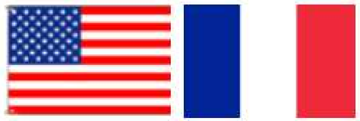
LiteBIRD: INFN contribution

Coordinator: G. Signorelli (Pisa)

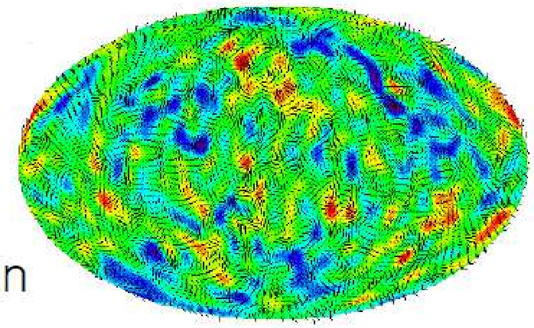
- Warm Readout Electronics
  - Flight qualification of selected components
  - SQUID control units (LFT + MHFT)
    - electronic boards
    - mechanics
    - thermal interfaces
  - (digital assembly DAC/ADC boards)

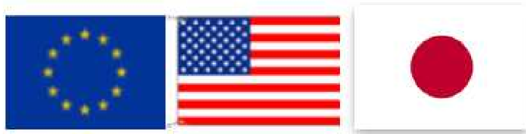


- Detector study
  - Study of CR impact on detectors
  - on-beam test of detectors



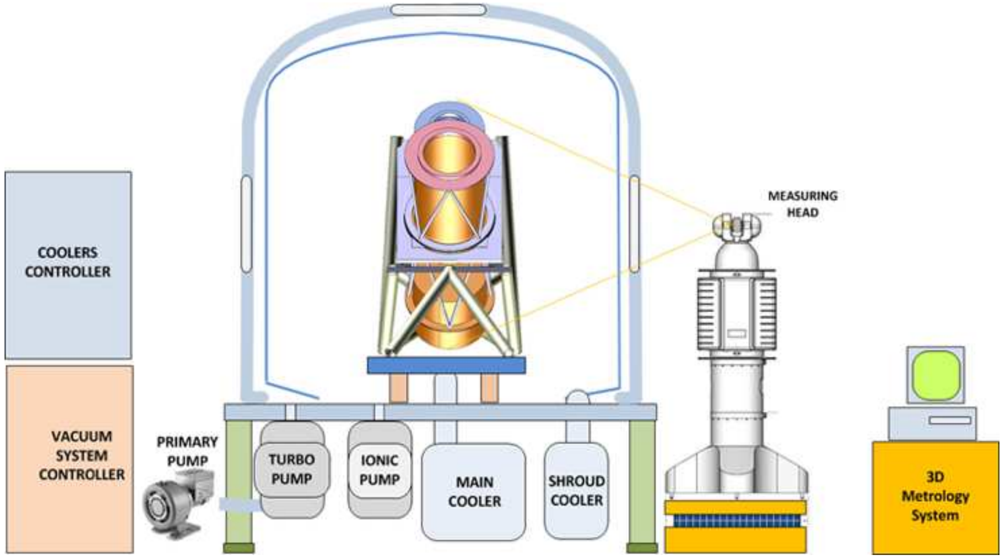
- Data Analysis
  - simulation
  - map making
  - CMB parameters extraction

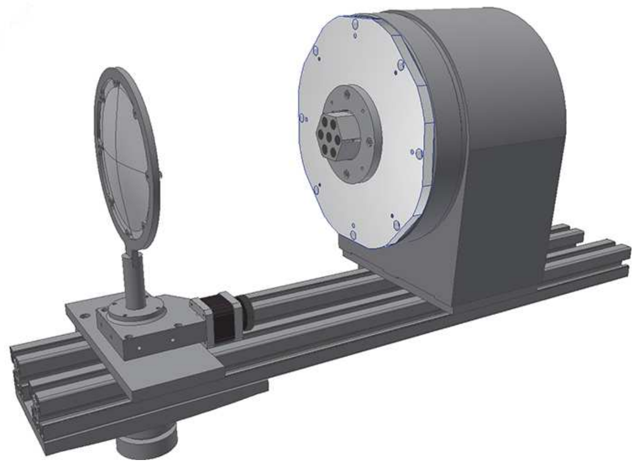




LiteBIRD at Milano CMB group

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



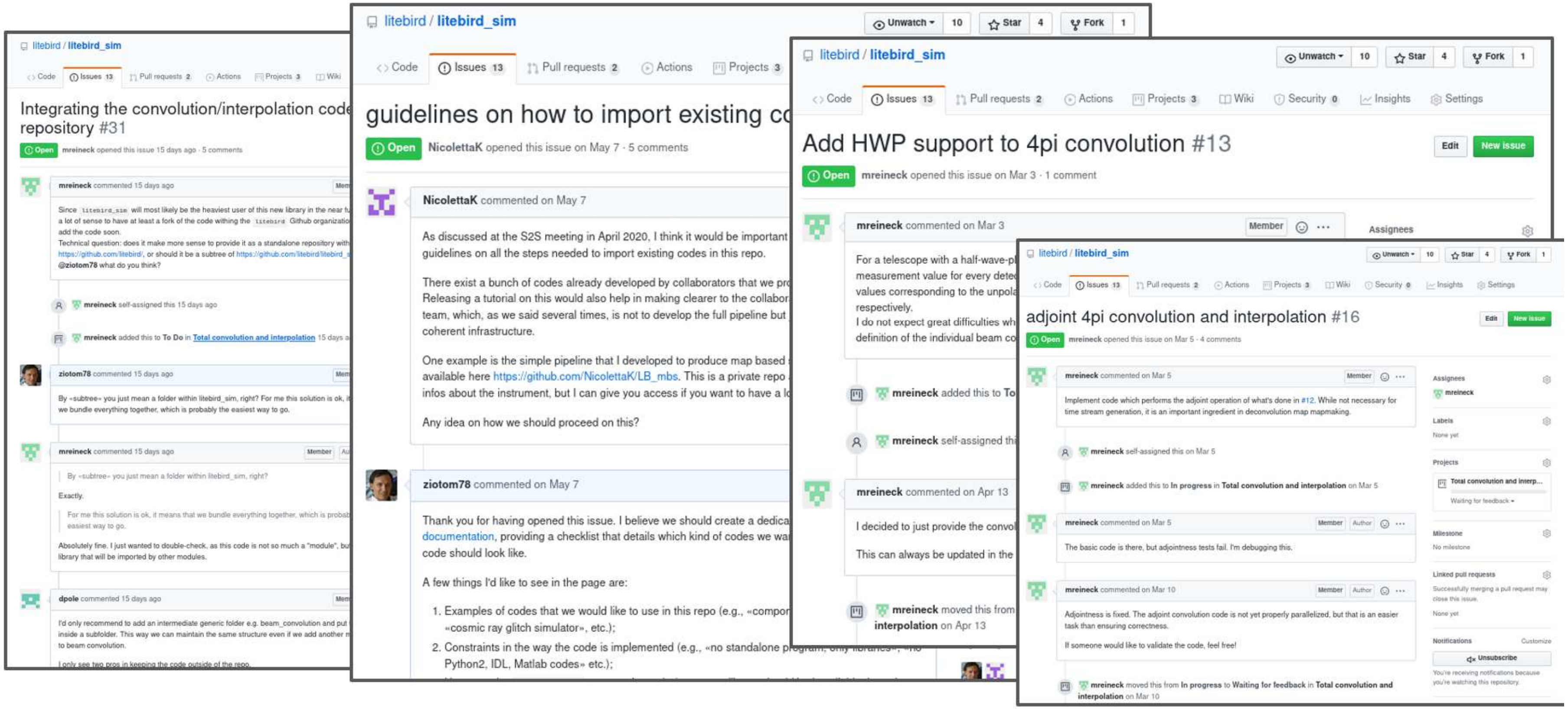


- Breadboard: A simple refractive optics system to validate modeling vs measurements
- Use already available hardware
- No focal plane TES detectors ⇨ well-known horn
- Lenses are no AR-coated
- Room temperature measurements

LiteBIRD at Milano CMB group

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

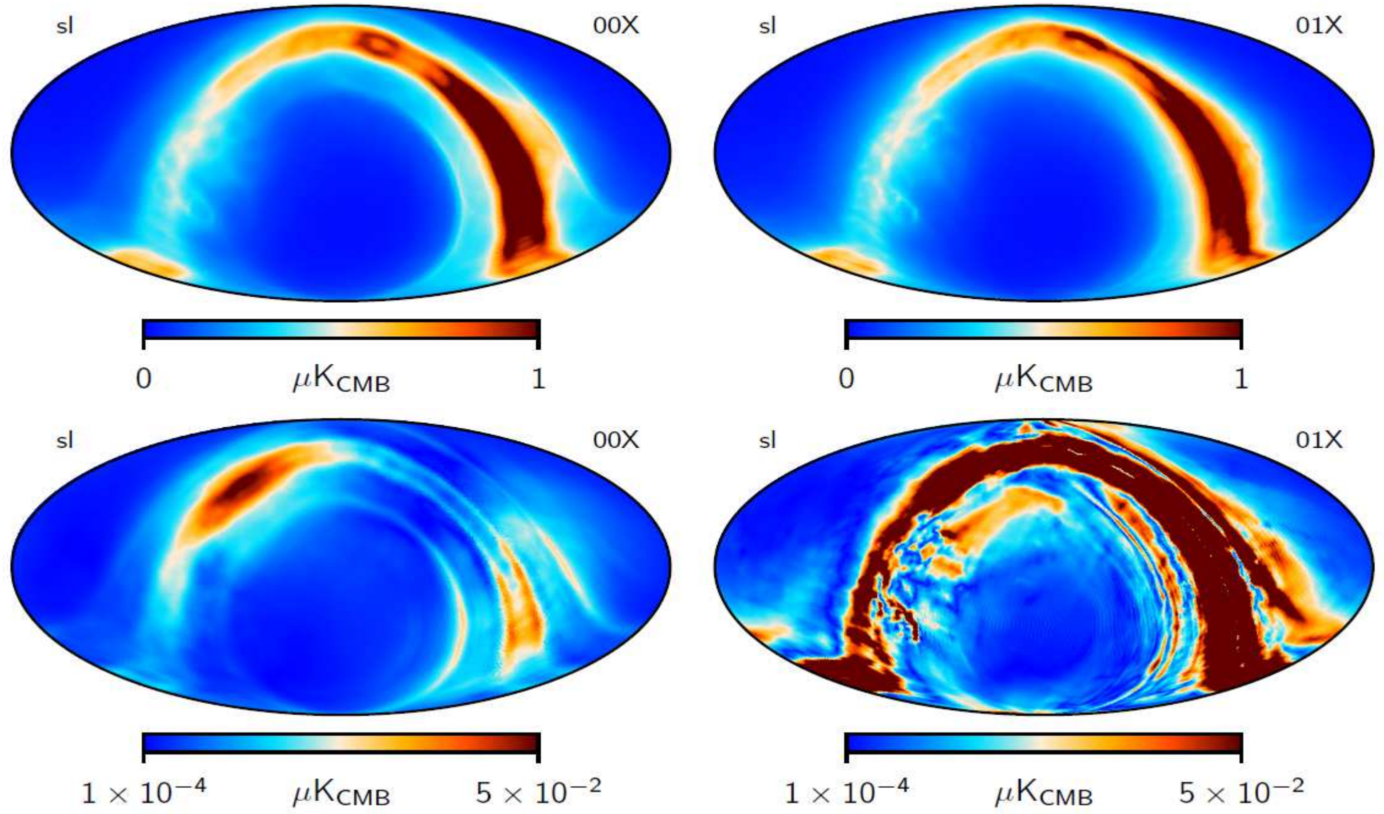
GitHub public site (litebird_sim)



LiteBIRD in Milan CMB group

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

In-flight calibration and beam simulations

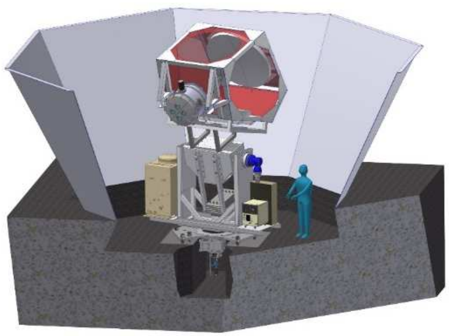


LiteBIRD/MFT Side-lobes maps in total intensity I (upper row) and in polarization intensity P (lower row) for the detector 00X at the centre of the focal plane (left) and an off-axis detector 01X (right). (See RA4/Annex 1 for details).The simulation is for 1 year observation.

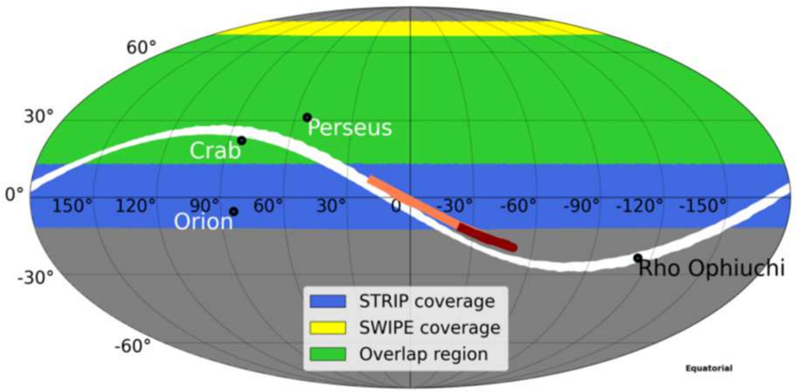
LSPE

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

STRIP
Ground-Based, Tenerife

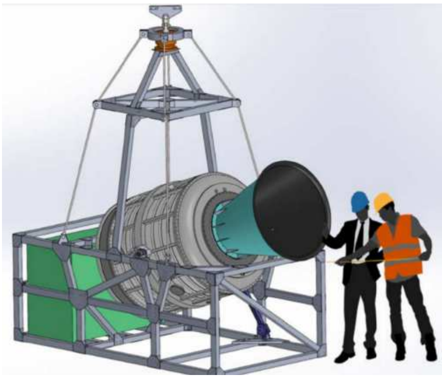


STRIP Telescope with ground screens and mounting structure



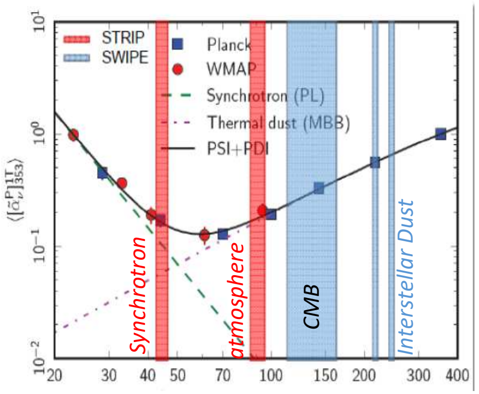
Map in Equatorial coordinates of the STRIP-SWIPE sky coverage

SWIPE
Balloon, Winter Arctic Flight



SWIPE accommodated in the balloon gondola

Foreground control

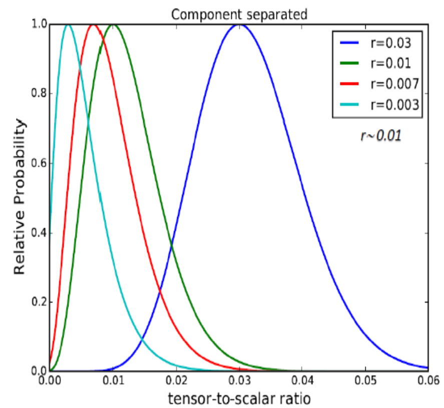


Performance

Instrument	STRIP		SWIPE		
Site	Tenerife		balloon		
Freq (GHz)	43	95	145	210	240
Bandwidth	17%	8%	30%	20%	10%
Angular resolution FWHM (arcmin)	20	10	85		
Detectors technology	HEMT		TES multimoded		
Number of detectors N_{det}	49	6	162	82	82
Detector NET ($\mu K_{CMB}\sqrt{s}$)	515	1139	12.6	15.6	31.4
Observation time	2 years		8 - 15 days		
Duty cycle	50%[1]		90%		
Sky coverage f_{sky}	37%		38%		
Map sensitivity $\sigma_{Q,U}$ ($\mu K_{CMB}\cdot$ arcmin)	102	777	10	17	34
Noise power spectrum $(N_\ell^{E,B})^{1/2}$ ($\mu K_{CMB}\cdot$ arcmin)	171	1330	16	28	55

[1]We 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).

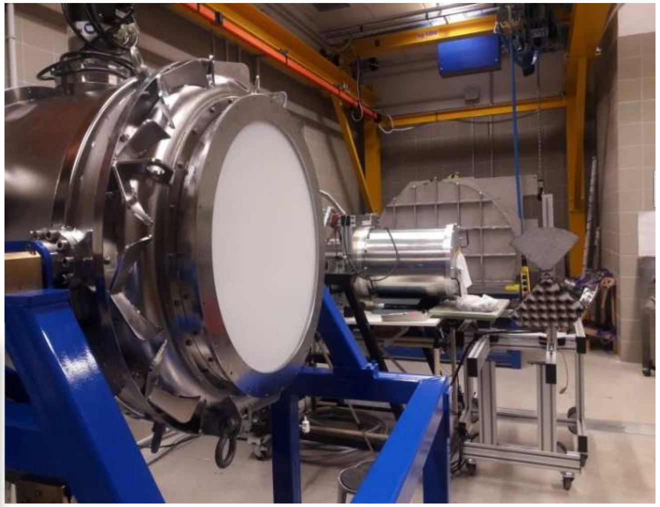
Tensor-to-scalar ratio

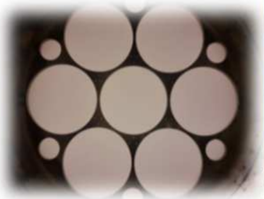


LSPE/STRIP
THE FOCAL PLANE INSTRUMENT

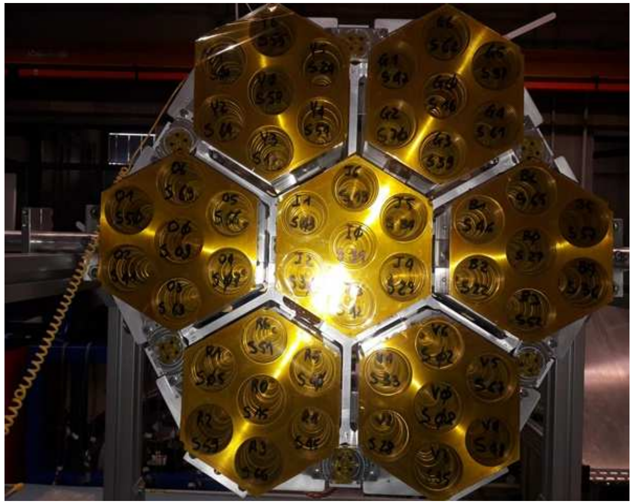
- Unit & subsystem (polarimeters, feedhorns, OMTs, electronics, cryostat) completed
- Instrument is now fully integrated with cryostat and electronics

Cryostat and vacuum window

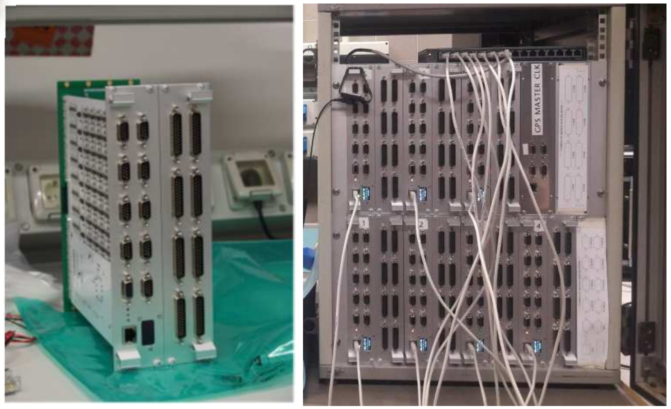




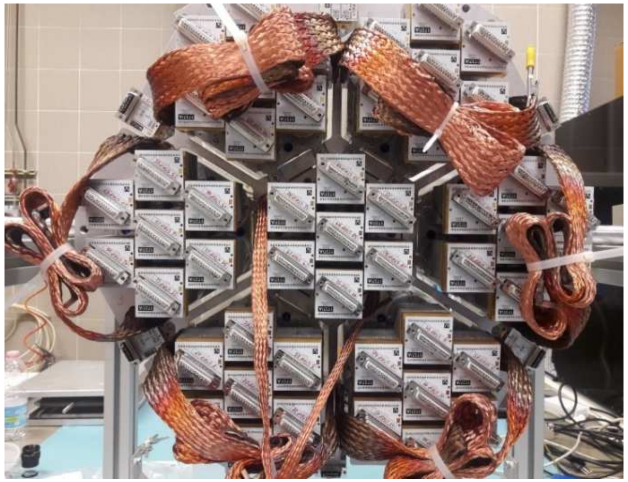
IR filters



STRIP Focal Plane (Q & W bands)



Electronics (BIAS board and DAQ)



STRIP polarimeter array

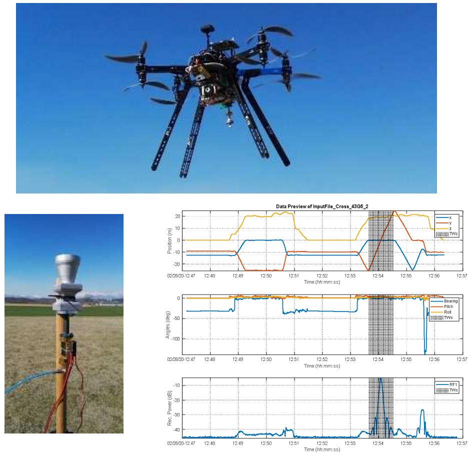
- Instrument-level test campaign started @INAF-OAS Bologna.
- Warm testing of instrument/electronics I/F ongoing remotely (due to lock-down)

LSPE/STRIP

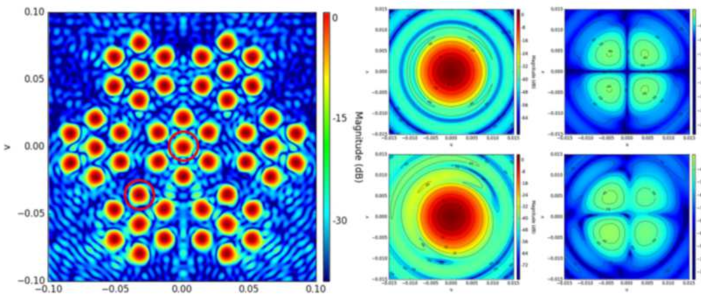
THE TELESCOPE AND MOUNT

- 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

STRIP telescope mirrors (LASA, MI)



Drone-based beam calibration (CNR/TO)



STRIP beams (co- and cross-pol)

SITE PREPARATION

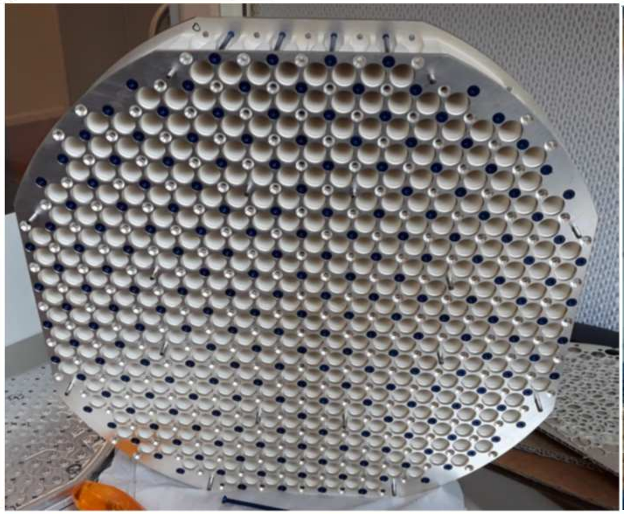
- Site: Teide Observatory (2400m), Instituto de Astrofisica de Canarias (IAC)
- Agreement between INFN, UniMI and IAC signed (April 2020, addendum to UniMI-IAC document)
- Requirements & preliminary design of telescope cover ready for Industrial call

QUBIC

INFN

Bolometric interferometry

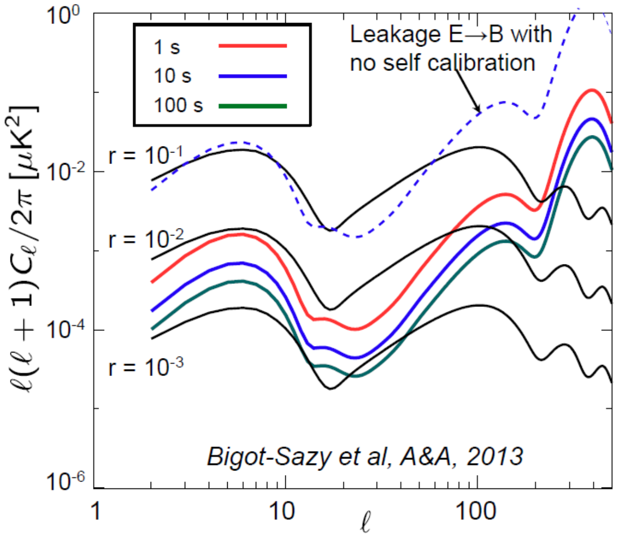
Cryogenic section of the detection chain

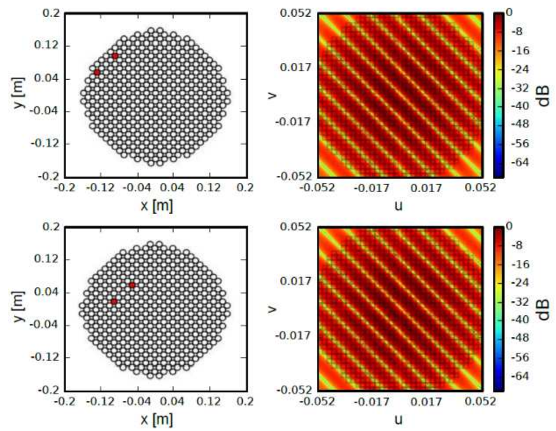


400 element back-to-back corrugated feed-horn array

The QUBIC integrated 1K box

Integration of the 1K box in cryostat shell





Technical Demonstratod Campaign (8x8 element array)

Test Campaign: Late Spring 2019