

# LiteBIRD Overview

L. Montier

on behalf of LiteBIRD Collaboration

**LiteBIRD**  
a  
y

13 May 2024





# Looking back to the origins...

... of LiteBIRD

2008

2015

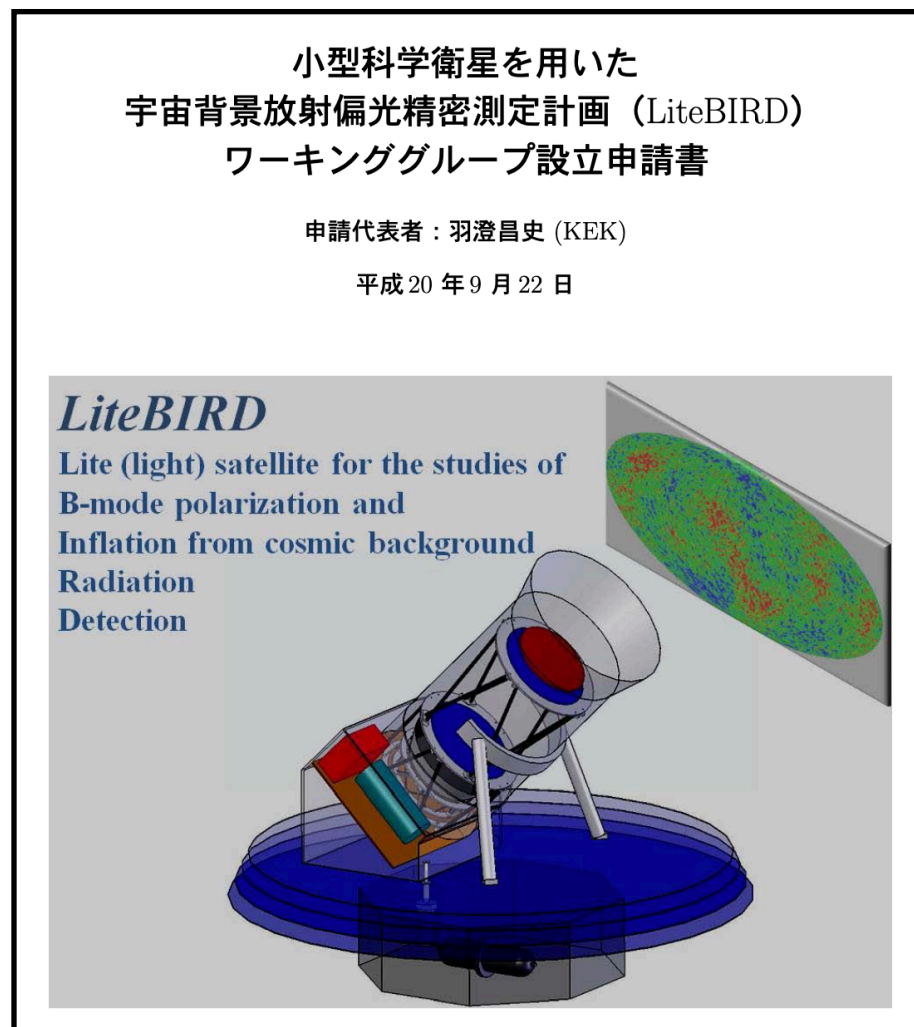
2015

First submission of LiteBIRD to JAXA

Selection by JAXA among the 10 candidates for Large Class Satellite Missions

JAXA Invitation to European Scientists

Few people involved in France



September 24, 2015.

Dear European Cosmic Microwave Background Colleagues,

Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency (ISAS, JAXA) considers its <strategic L-class missions> as the main pillar that sustains its space science activity. The strategic L-class missions

...

program, when materialized in a solid manner. I am looking forward to a nice Europe-Japan teaming-up for a reasonable size CMB mission that will fly timely.

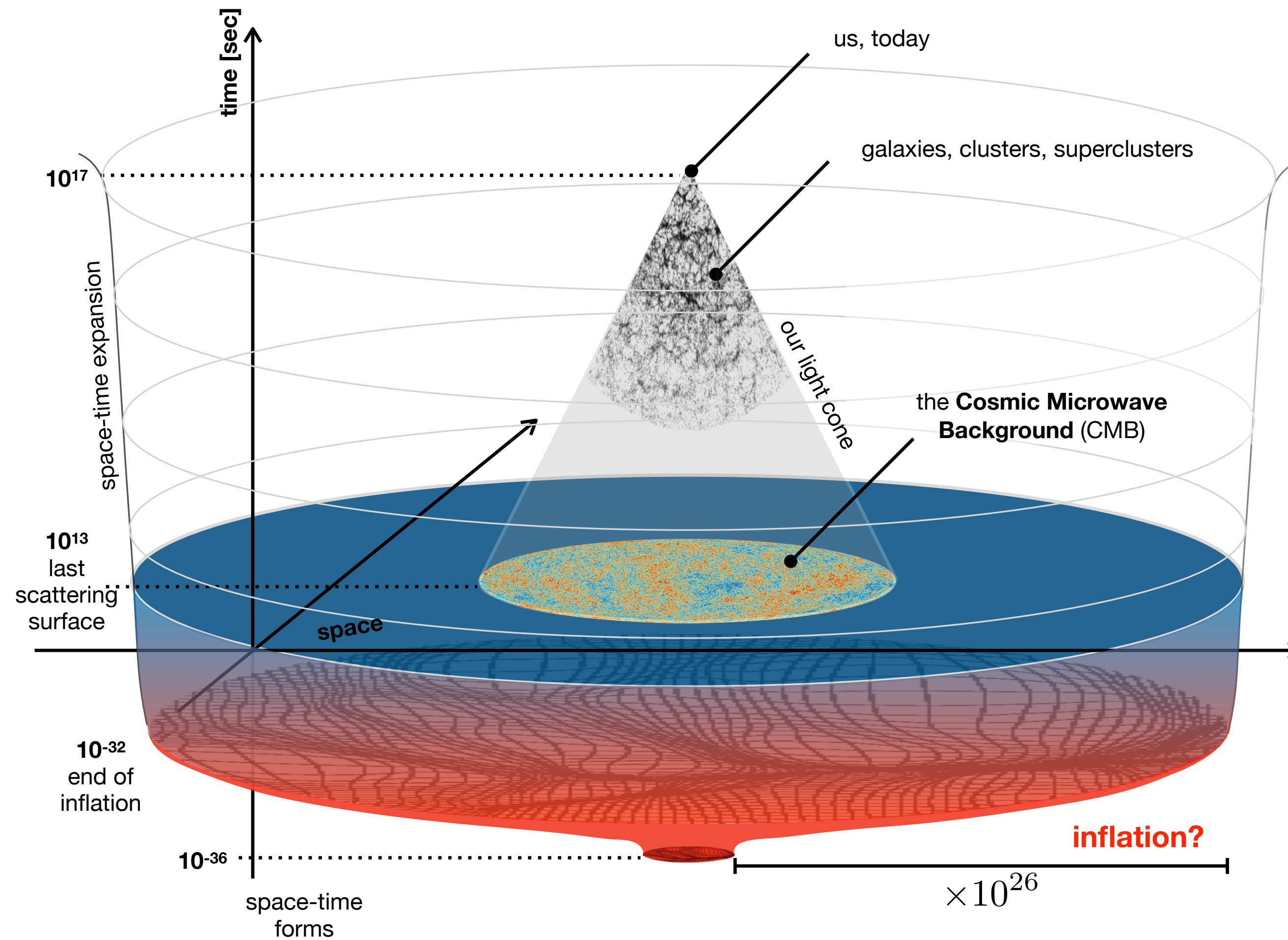
Sincerely,

Saku Tsuneta  
Director General  
Institute of Space and Astronautical Science  
Japan Aerospace Exploration Agency

# Looking back to the origins...

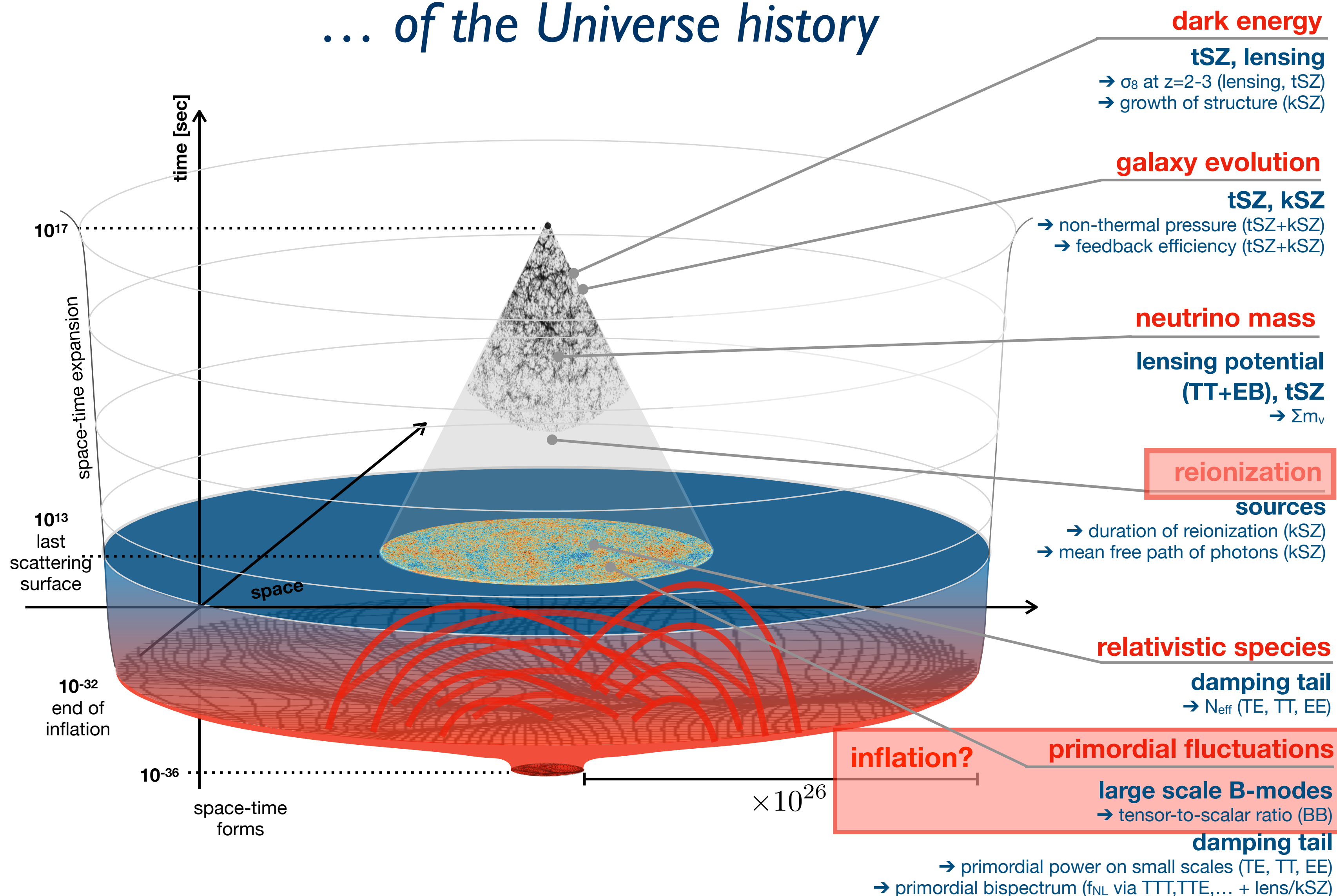


## ... of the Universe history



# Looking back to the origins...

## ... of the Universe history



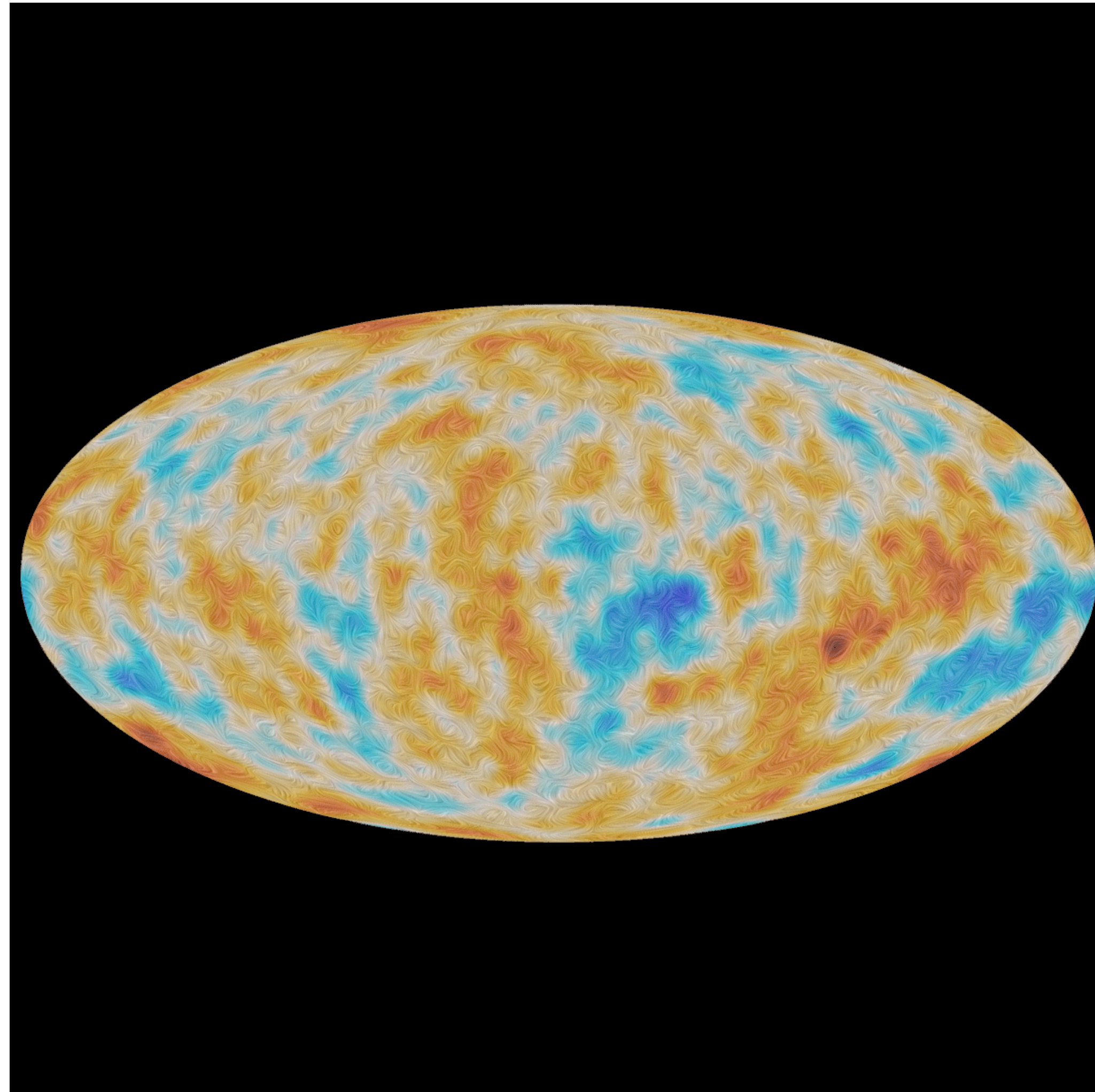
# Looking back to the origins...

... for imprints of gravitational waves on CMB polarisation signal

E-Modes



Curl-free



B-Modes

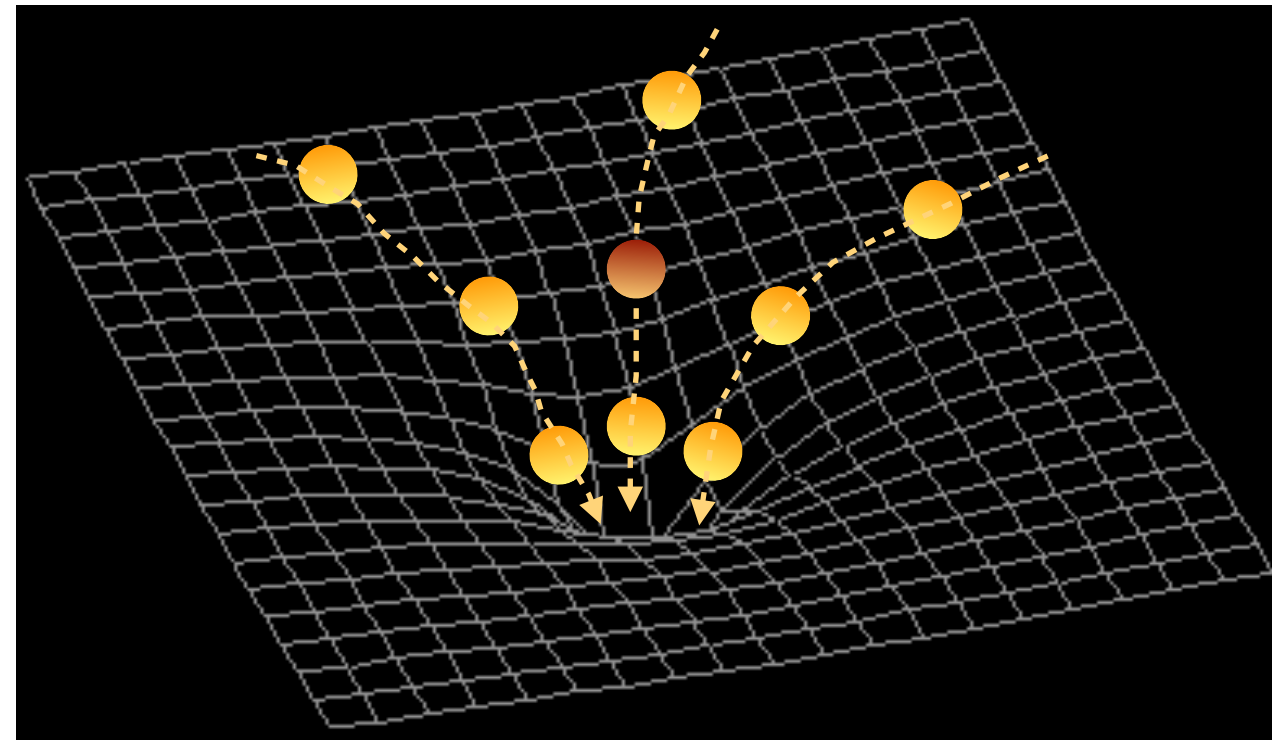


Div-free

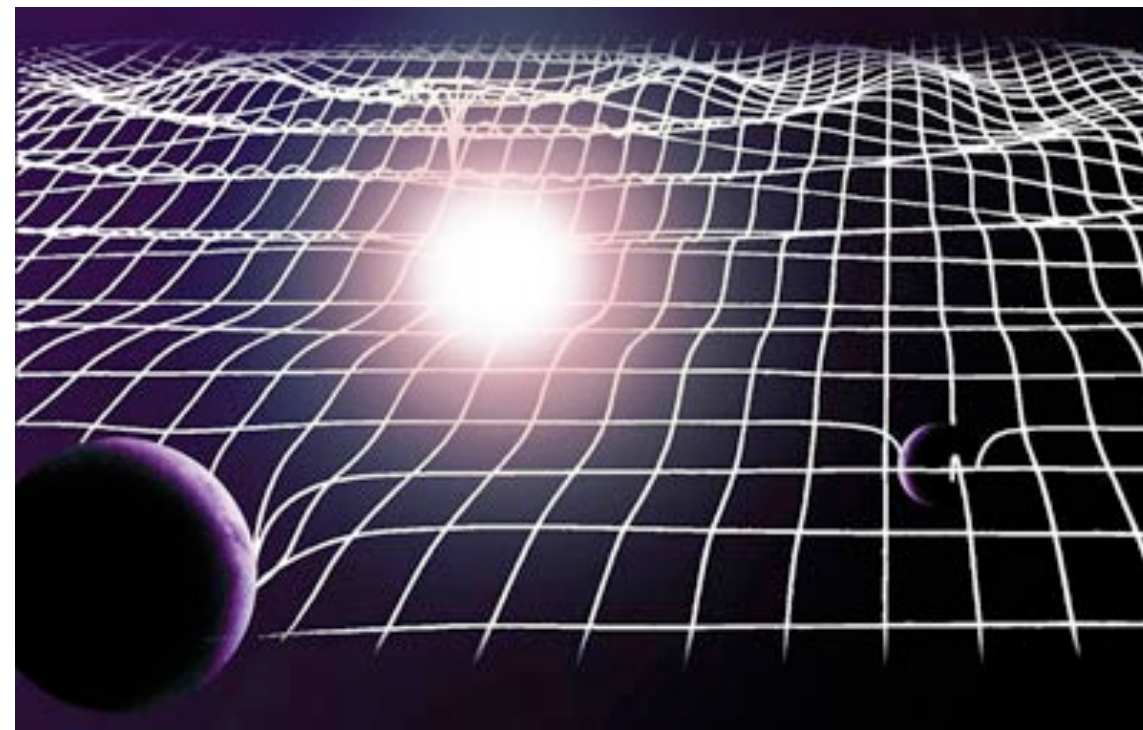
# Looking back to the origins...

... as tracers of the Inflation period

Density fluctuations



Gravitational waves

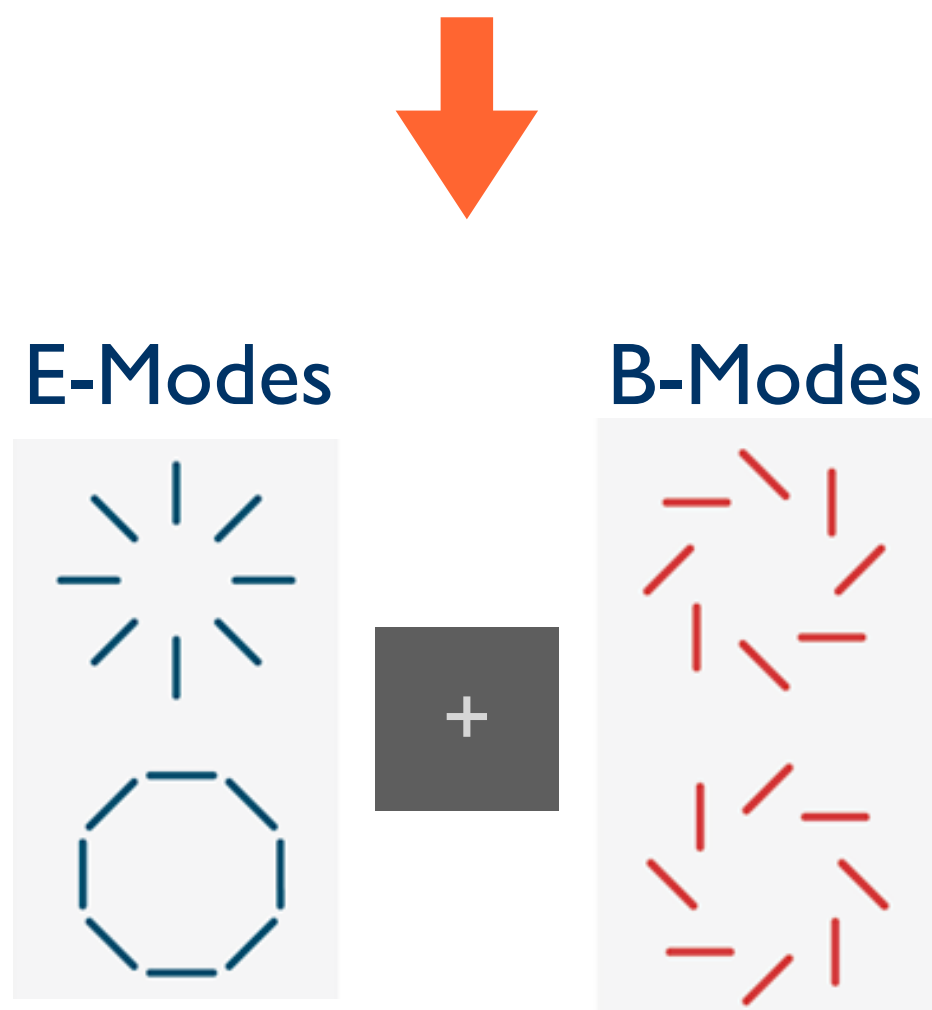
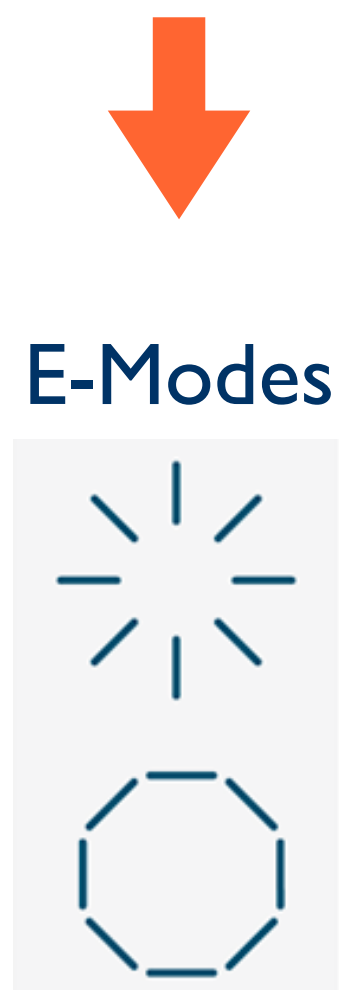


Inflation

Quantum fluctuations of Spacetime

Primordial Gravitational Waves

Vortex in CMB polarisation map (B-modes)



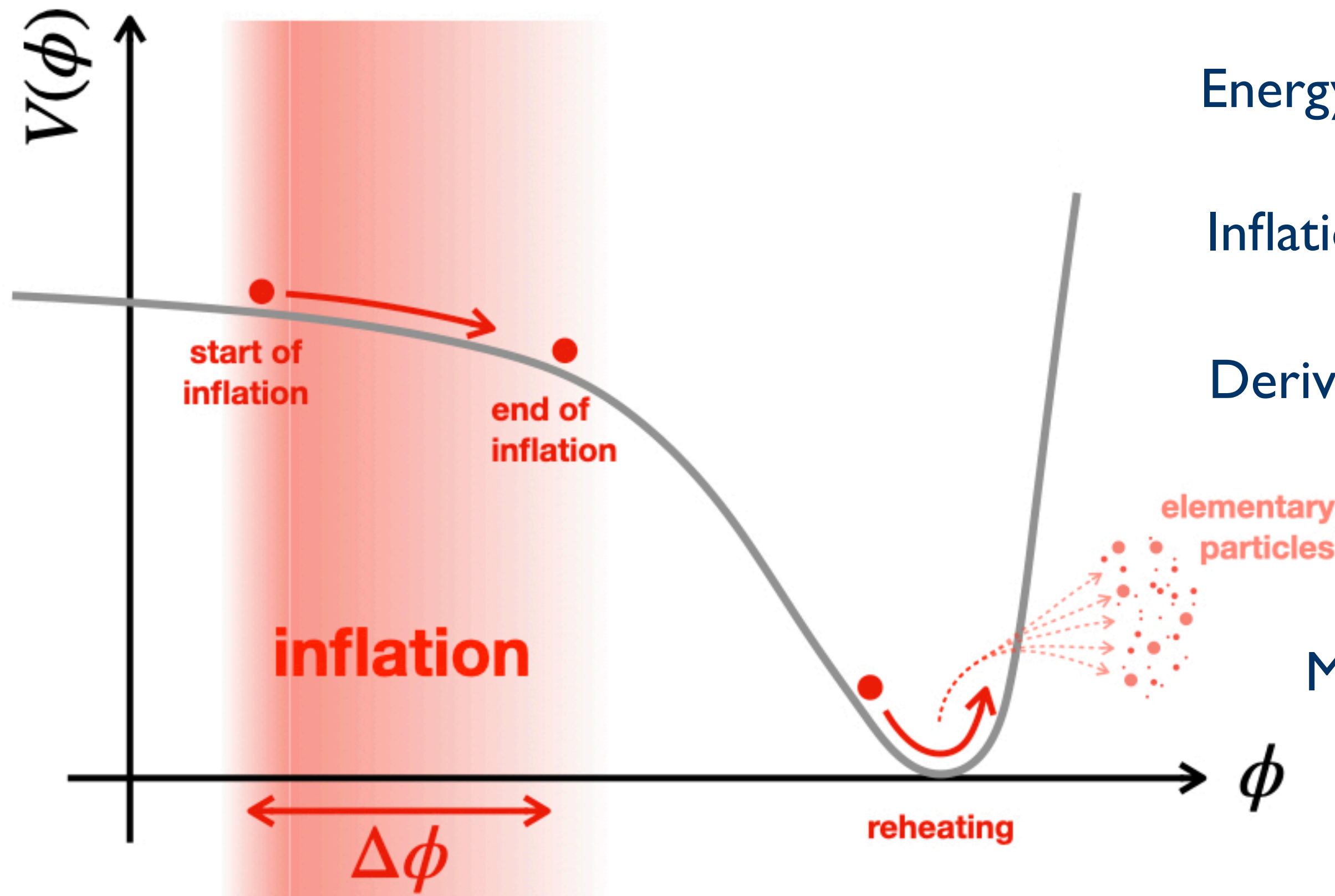
Opportunity to probe the Cosmic Inflation but also to shed light on GUT-scale physics

Observational test of quantum gravity

# Looking back to the origins...

... as tracers of the Inflation period

$r$  gives direct constraints on the shape of the Inflation potential:



Energy scale of inflation:  $V^{1/4}(\phi) \simeq 10^{16} \text{ GeV} \left( \frac{r}{0.01} \right)^{1/4}$

Inflation field excursion:  $\frac{\Delta\phi}{M_P} \simeq \mathcal{N}_* \left( \frac{r_*}{8} \right)^{1/2} \simeq \left( \frac{r}{0.001} \right)^{1/2}$

Derivatives of potential:  $r = 8M_{\text{Pl}}^2 \left( \frac{V_\phi}{V} \right)^2$

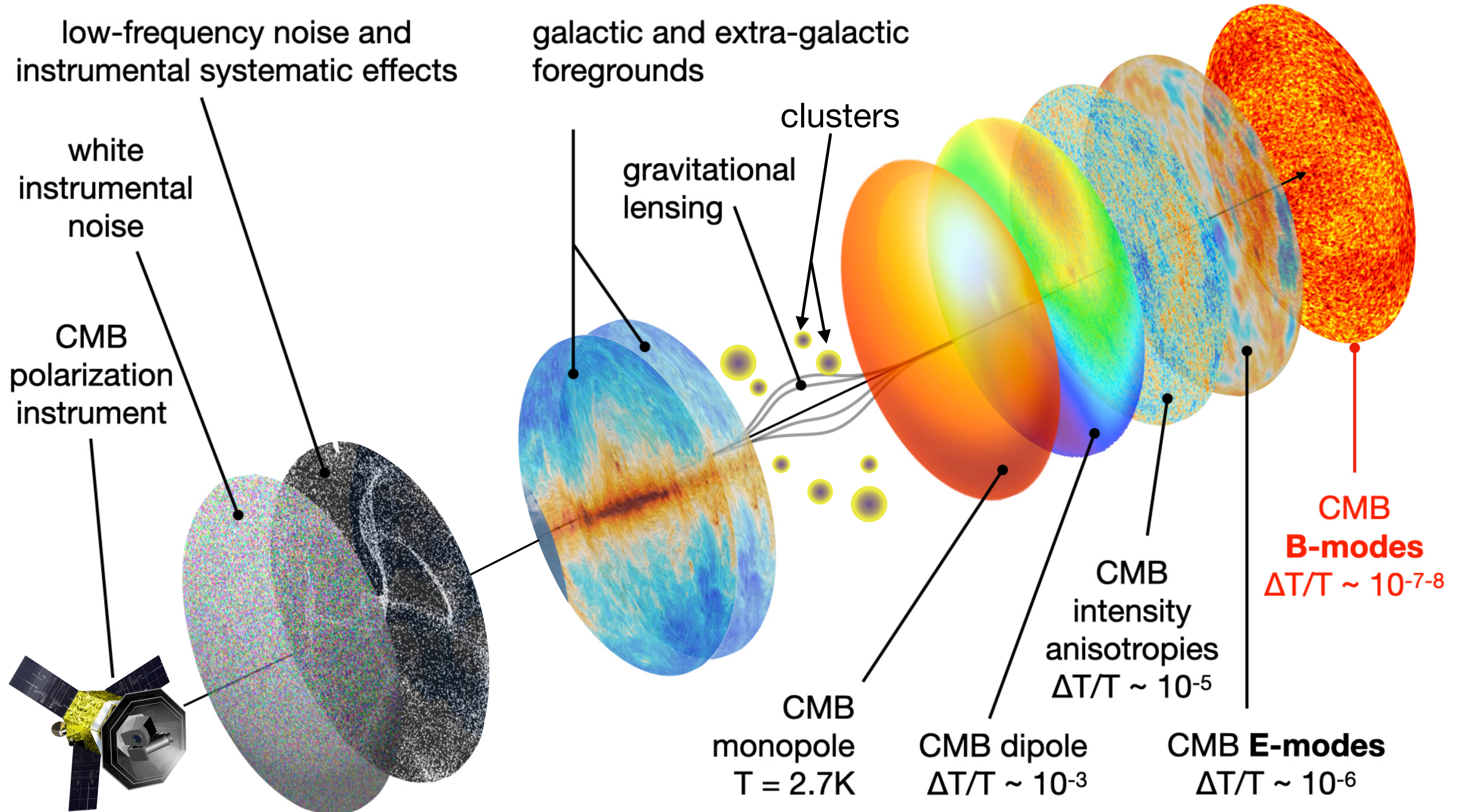
$$n_s - 1 \equiv \frac{d \ln \mathcal{P}_\zeta}{d \ln k} \simeq -3M_{\text{Pl}}^2 \left( \frac{V_\phi}{V} \right)^2 + 2M_{\text{Pl}}^2 \frac{V_{\phi\phi}}{V}$$

Many open questions:

- Where did field come from ?
- Why did the field start in slow-roll ?
- Why is the potential so flat ?
- How do we convert the field energy into particles ?

# Looking back to the origins...

## ... and the Challenge of detecting the CMB B-Modes



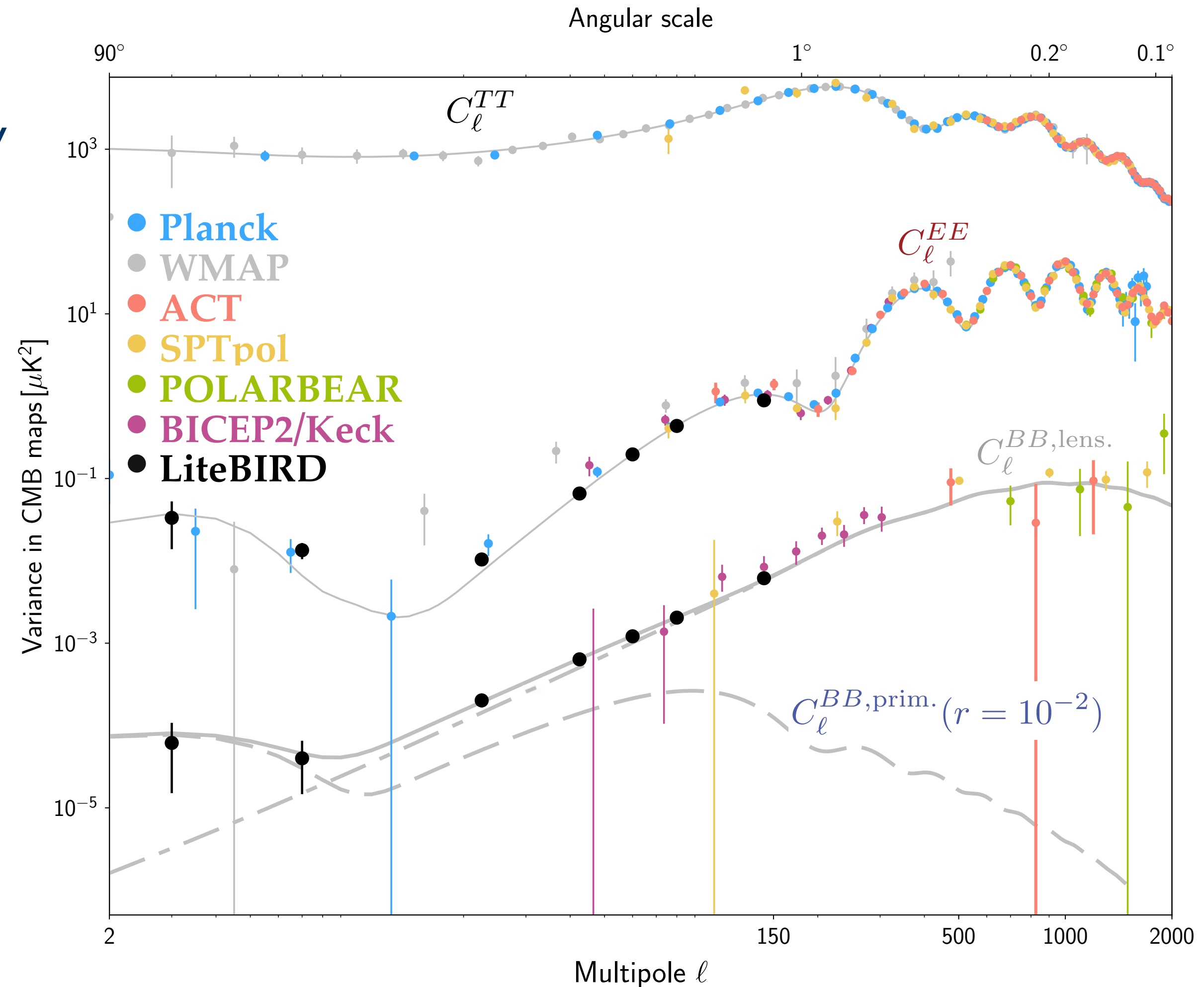
Credits: Josquin Errard





## Main Scientific Objectives

- Definitive search for the **B-mode signal** from **cosmic inflation** in the CMB polarization
  - Making a discovery or ruling out well-motivated inflationary models
  - Insight into the quantum nature of gravity
- Current best constraint:  $r < 0.032$  (95% C.L.)  
(Tristram et al. 2021, combining BK18 + Planck PR4 data)
- Science requirements (no external data):
  - For  $r = 0$ , **total uncertainty of  $\delta r < 0.001$**
  - For  $r = 0.01$ , 5- $\sigma$  detection of the reionization ( $2 < \ell < 10$ ) and recombination ( $11 < \ell < 200$ ) peaks independently
- LiteBIRD will improve current sensitivity on  $r$  by a factor  $\sim 50$
- Huge discovery impact (evidence for inflation, knowledge of its energy scale, ...)



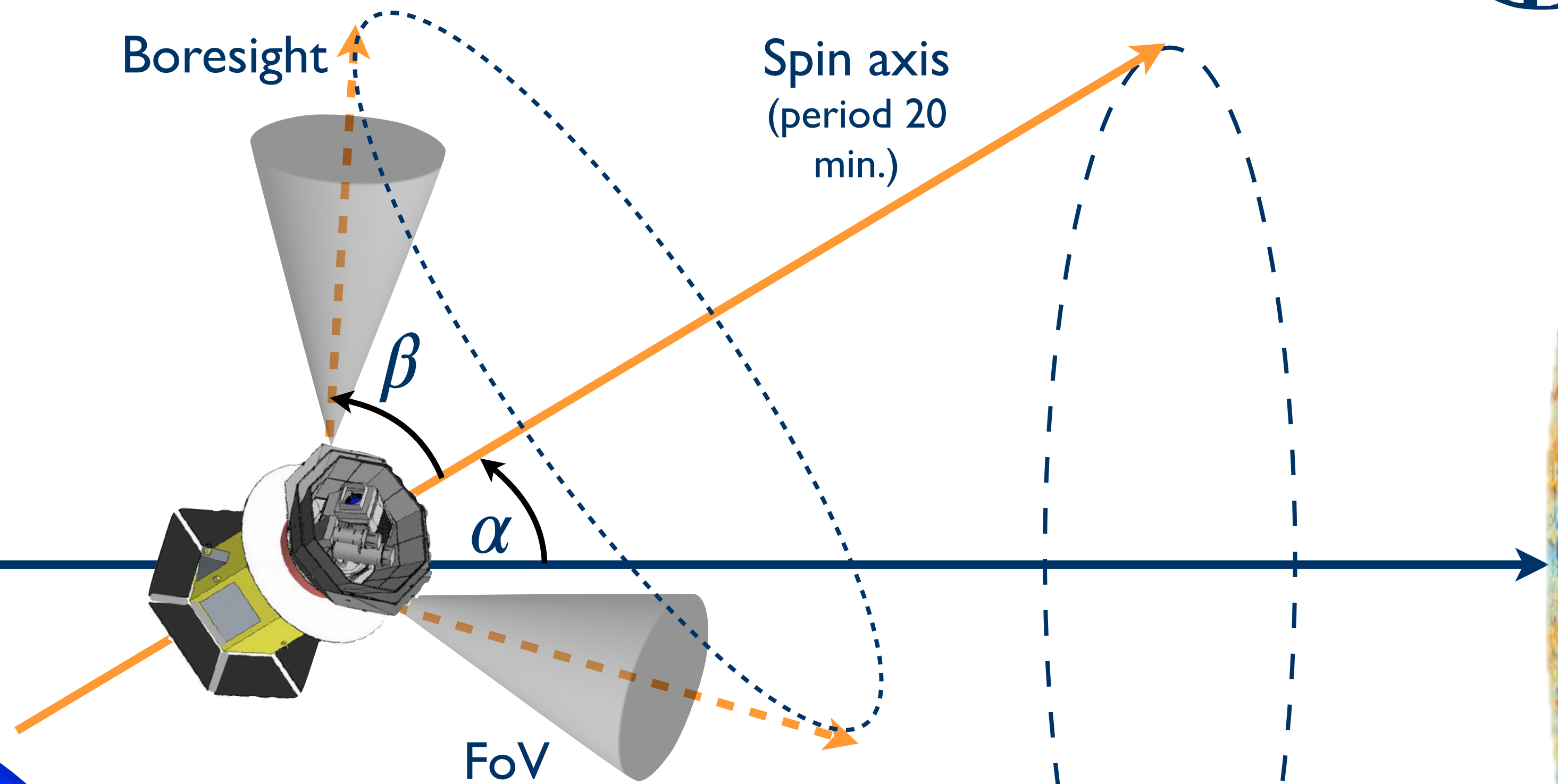
# LiteBIRD Mission



## Scanning Strategy

- 3-year survey, Sun-Earth L2 Lissajous orbit
- Precession angle:  $\alpha = 45^\circ$
- Spin angle:  $\beta = 50^\circ$

Sun



B  
M  
C

**$N_{hit}$  map for a  
3-year survey  
(Galactic projection)**

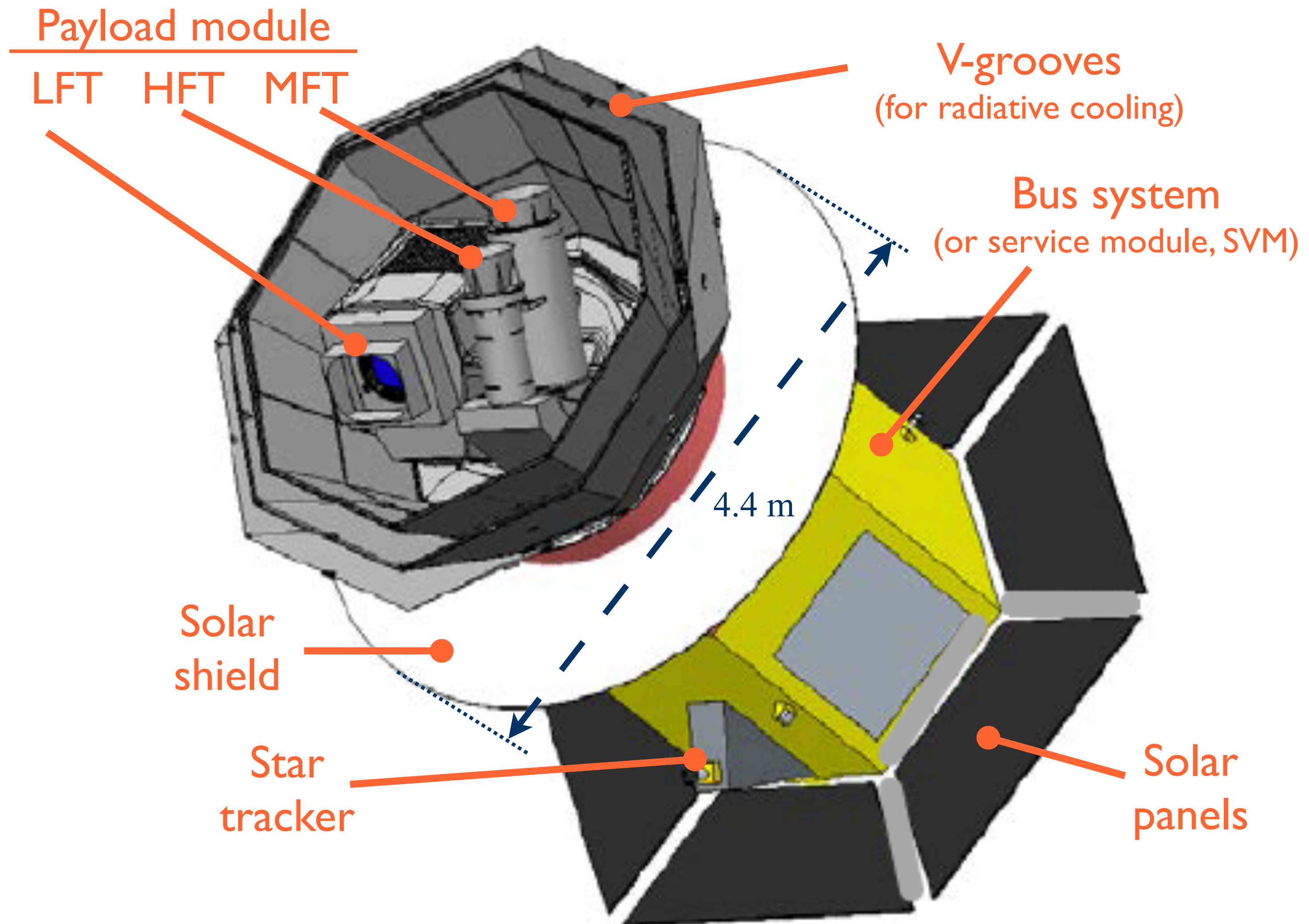


Precession (anti-Sun) axis  
(precession period,  $\sim 3.2$  h)

## Spacecraft Overview

- **3 telescopes** are used to provide the **40-402 GHz** frequency coverage
  1. **LFT** (low frequency telescope)
  2. **MFT** (middle frequency telescope)
  3. **HFT** (high frequency telescope)
- Multi-chroic transition-edge sensor (TES) **bolometer arrays** cooled to **100 mK**
- Polarization modulation unit (PMU) in each telescope with **rotating half-wave plate** (HWP), for  $1/f$  noise and systematics reduction
- Optics cooled to **5 K**

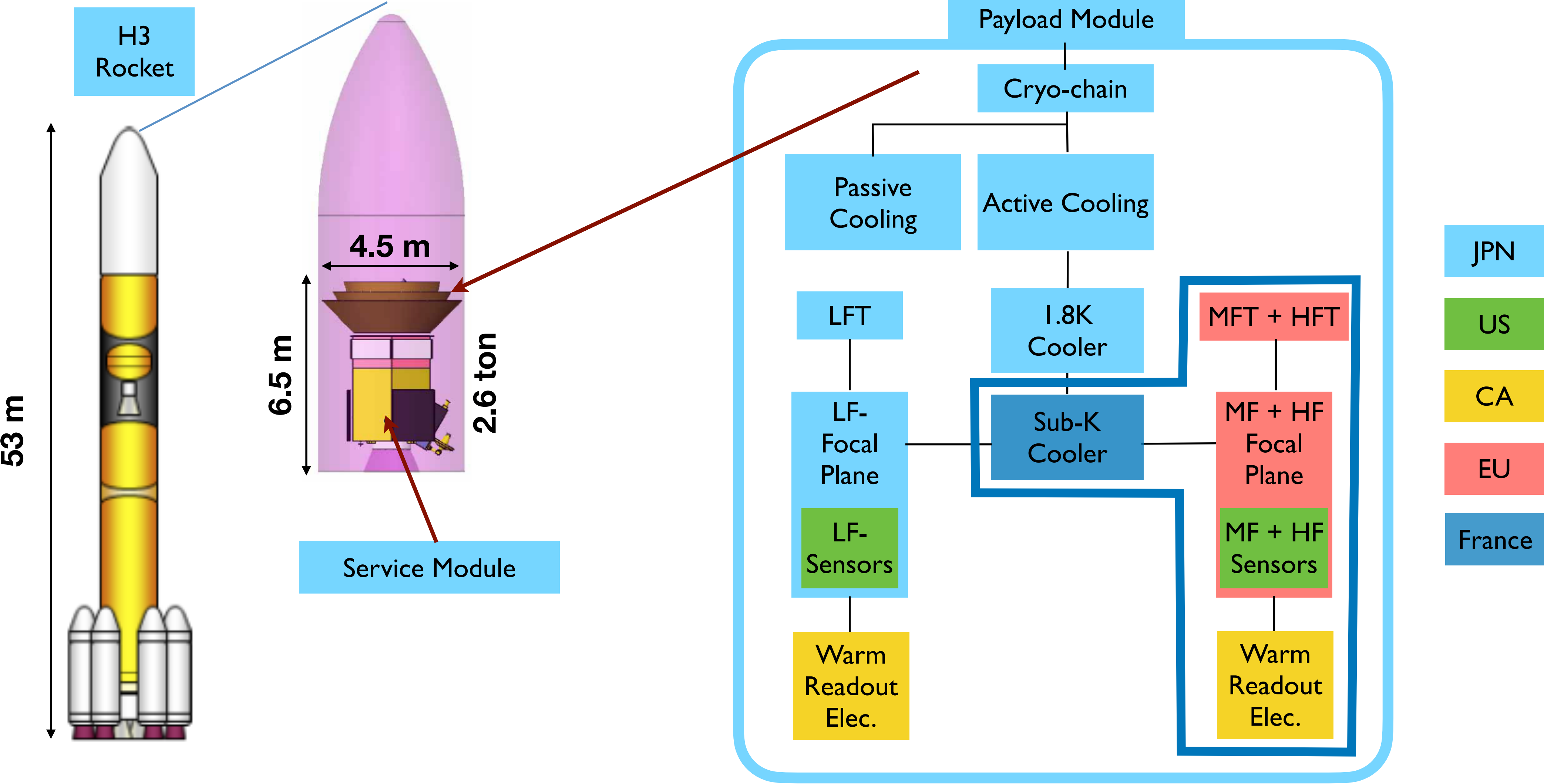
- Mass: 2.6 t
- Power: 3.0 kW
- Data: 17.9 Gb/day



# LiteBIRD Mission



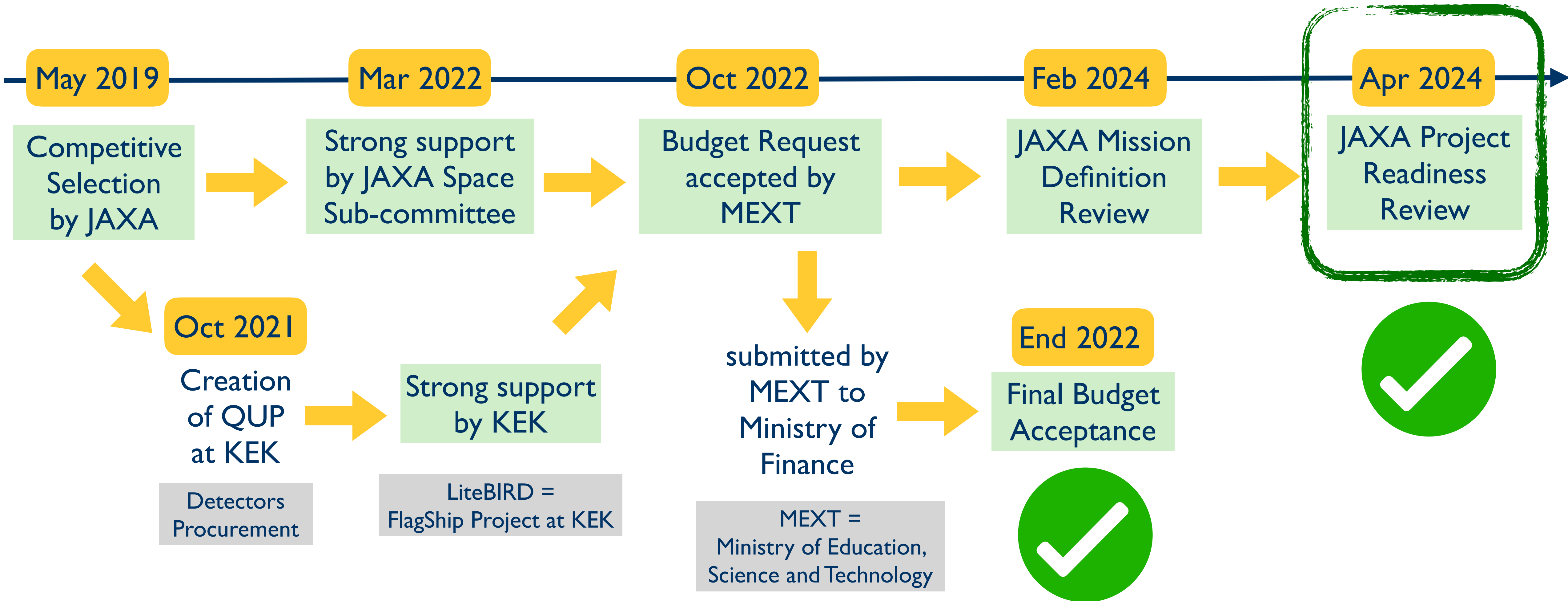
## International Task Sharing



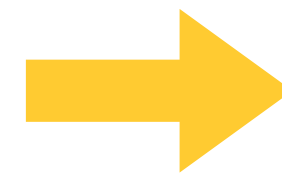


# Programmatic in Japan

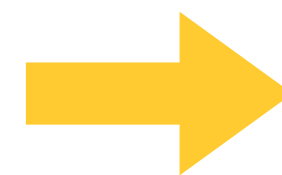
## Toward the JAXA LiteBIRD Project Phase



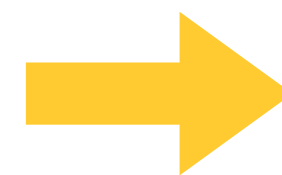
## Entering the JAXA LiteBIRD Project Phase



- **Launch Date has been revised :** 2032 FY  
(due to industry constraints)



- JAXA will enter into **Pre-Project Phase** by mid 2024, with a 'JAXA Phase-A' lasting 3 years (equivalent to Phase-BI at ESA)



- **New organisation** will have to be put in place making clear distinct responsibilities between

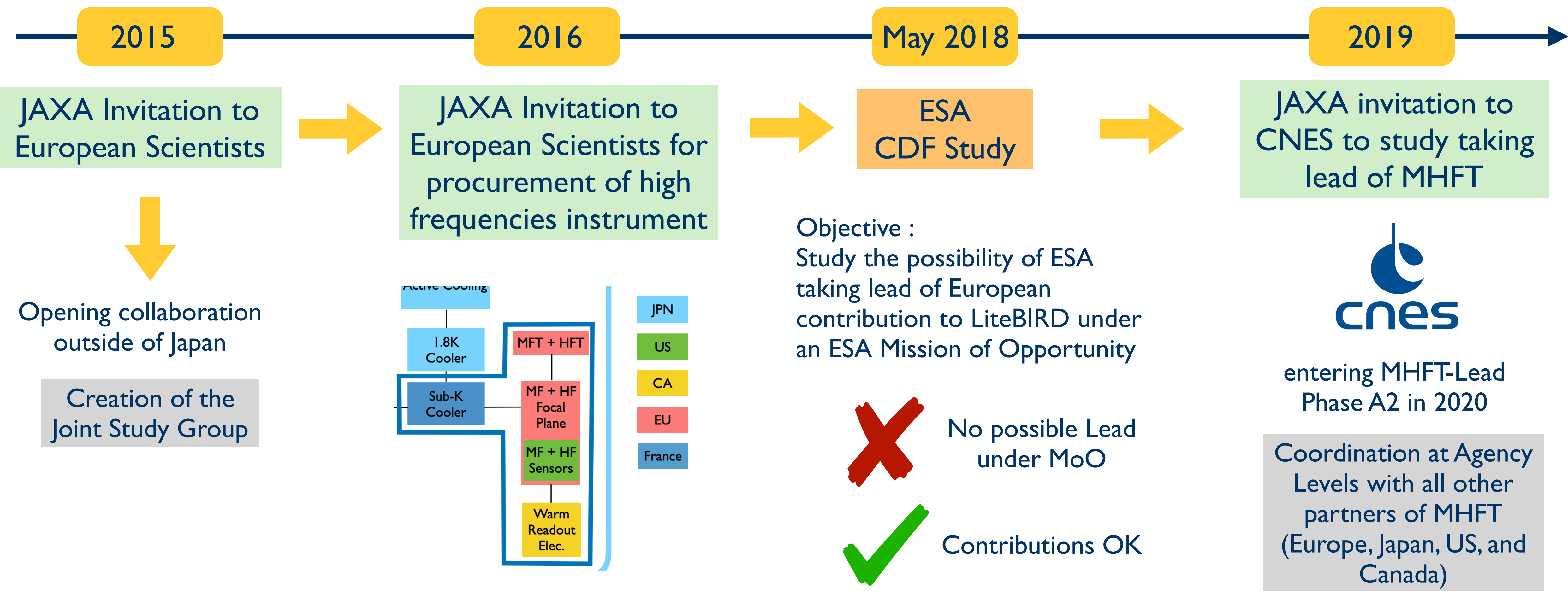
Project  
(dealing with instruments)

&

Collaboration  
(dealing with science analysis)

# Programmatic in Europe

## Building the European Collaboration



# Programmatic in Europe

## Consolidating the European Commitment



Committed in Phase-A2 leading the MHFT since 2020

France ✓

APC (Paris)  
CEA-DAp (Saclay)  
CEA-SBT (Grenoble)  
ENS-LERMA (Paris)  
IAP (Paris)  
IAS (Orsay)  
Institut Néel (Grenoble)  
IPAG (Grenoble)  
IRAP (Toulouse)  
IJCLab (Orsay)  
LAM (Marseille)  
LESIA (Paris)  
LPSC (Grenoble)

Italy ✓

Università di Roma "Tor Vergata"  
Università di Milano  
Sapienza Università di Roma  
INAF/IASF, Bologna  
INAF/OATS, Trieste  
Università di Milano-Bicocca  
Università di Genova  
INFN-Sezione di Pisa  
Università di Ferrara  
Università di Padova  
SISSA – Trieste

UK ✓

Cardiff University  
University of Cambridge  
Imperial College London  
University of Manchester  
University College London  
University of Oxford  
University of Portsmouth  
University of Sussex

Germany ✓

Max Planck Society (MPA, MPE, MPIfR)  
Ludwig-Maximilians-Universität München  
Universität Bonn  
RWTH Aachen Universität

### Phase-A commitment:

- France:
  - Phase A I 2018
  - Phase A2 (MHFT leadership) 2020
- Italy: 2018
- Spain: 2021
- Germany: 2022
- Belgium: 2022
- UK 2023
- Poland 2023

Spain ✓

IFCA, IDR/UPM, DICOM/UC  
ICCUB, IAC  
Universidad de Oviedo  
Universidad de Salamanca  
Universidad de Granada  
CEFCA

Holland

SRON  
RuG

Norway

University of Oslo

Sweden

Stockholm University

Ireland

Maynooth

Belgium ✓

CSL  
University Louvain

Polland ✓

Copernicus Center

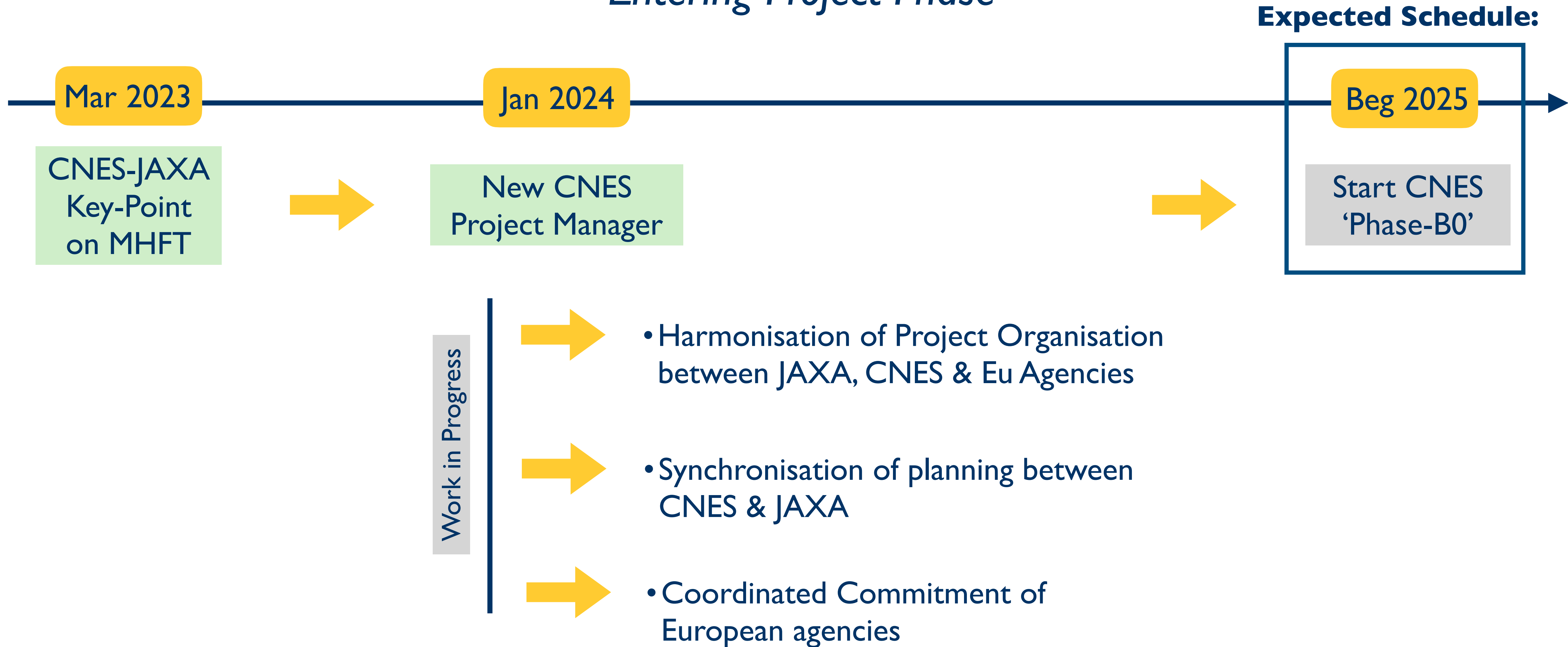
All European Partners  
working with CNES toward  
Phase-B commitment

~240 scientists, including experts on instrument and data analysis



# Programmatic in Europe

## Entering Project Phase



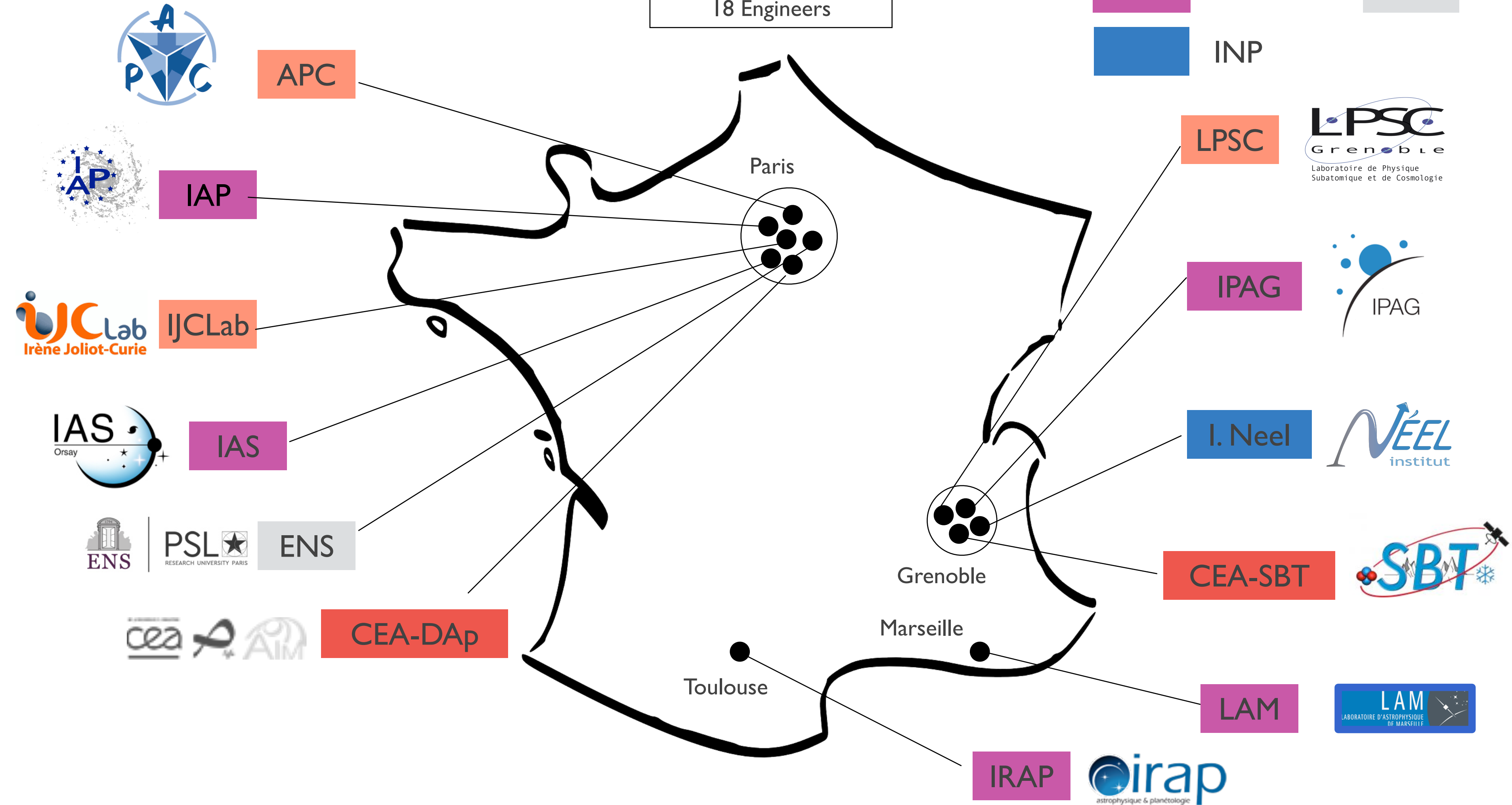
# The French LiteBIRD Collaboration



## LiteBIRD France

37 Scientists  
18 Engineers

- IN2P3
- INSU
- INP
- CEA
- ENS



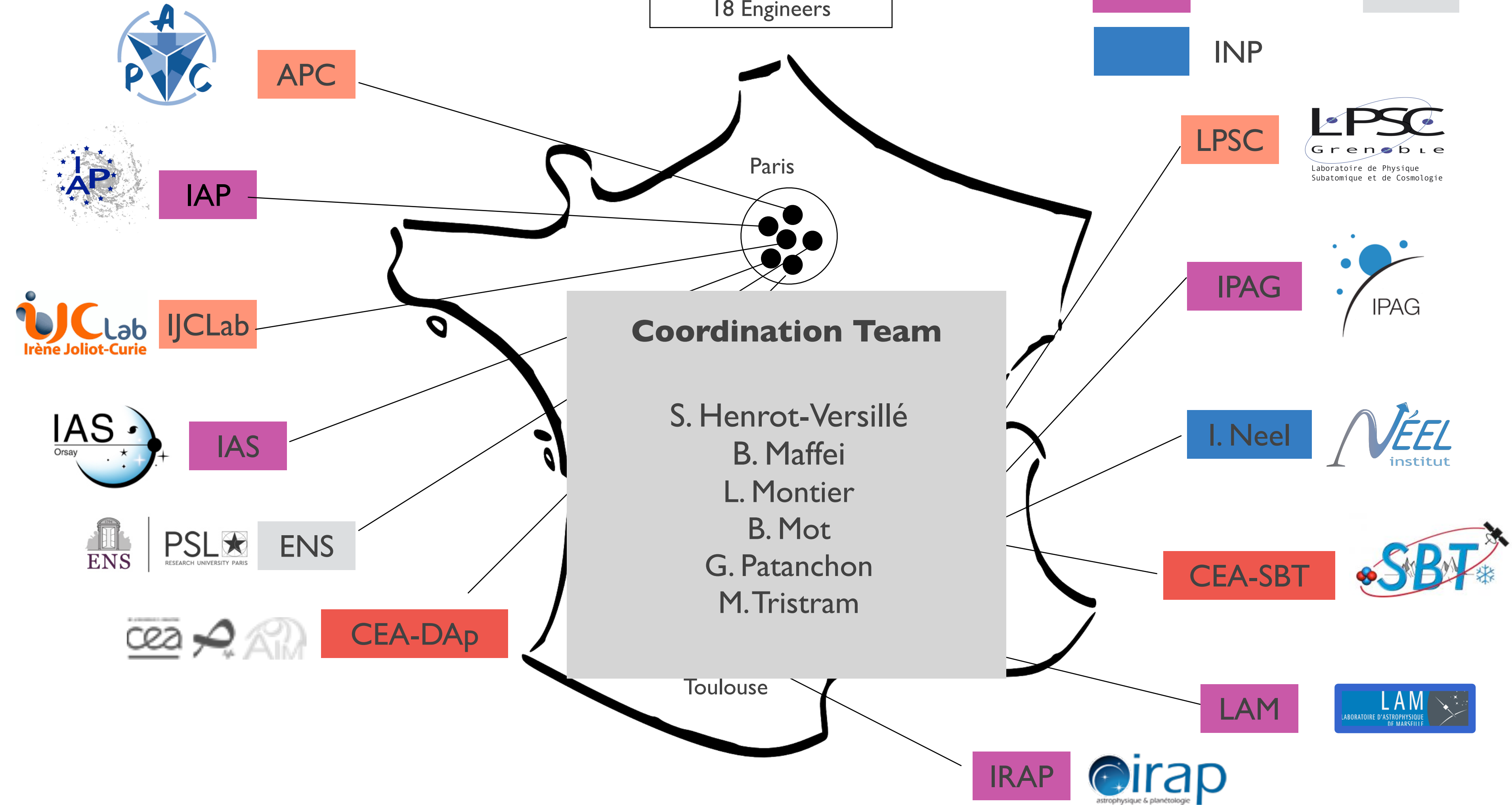
# The French LiteBIRD Collaboration



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- ENS





# The French LiteBIRD Collaboration



- HWP Mechanism
- Cold Aperture Stop
- FPGA Warm Readout Electronics



- Front Baffles
- Lenses / Filters
- HWP



- Sensor Modules
- Delivered by QUP Japanese
- Collaboration with US teams



- Magnetic Shielding

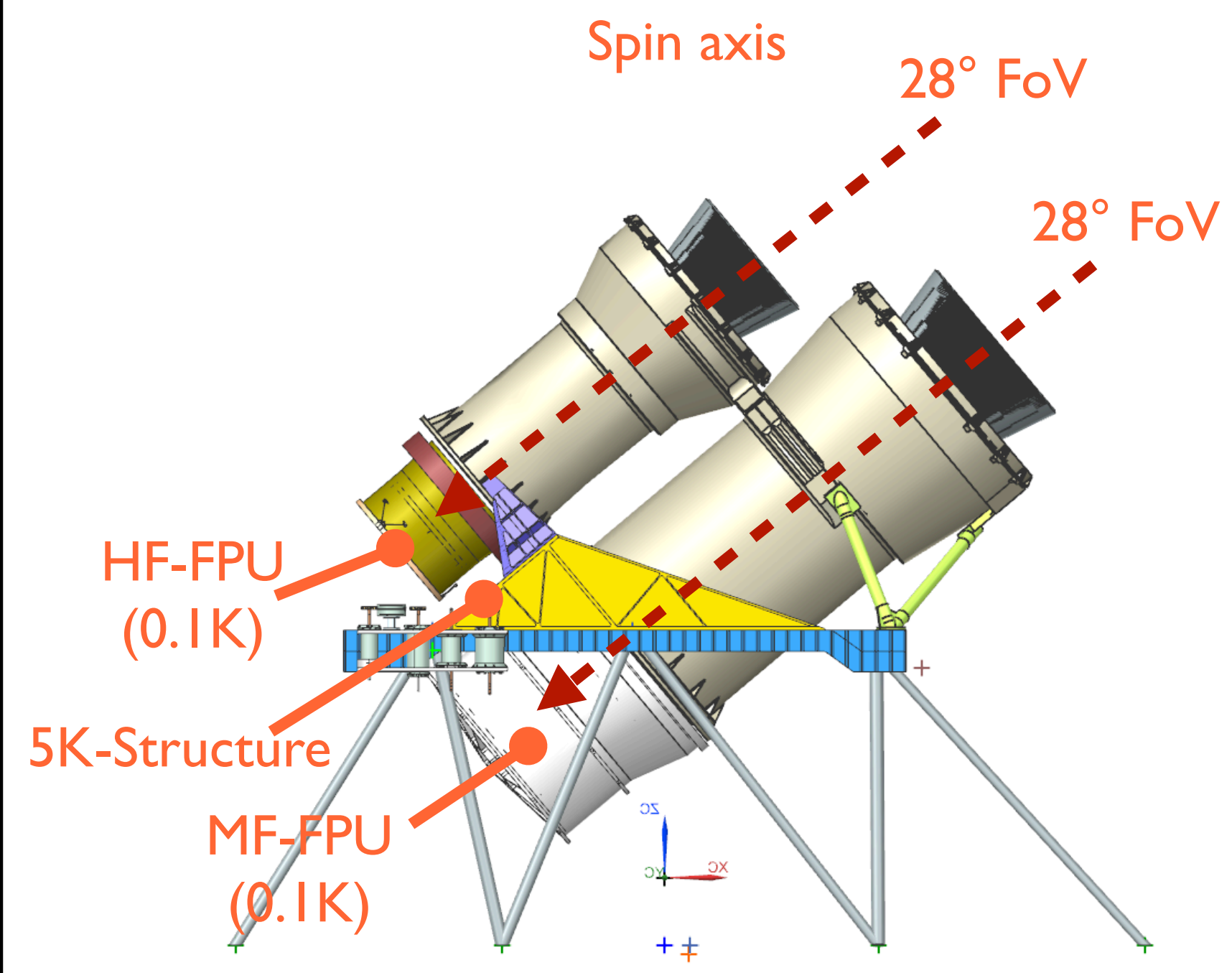


- Thermometers readout electronics



- Warm Readout Electronics

## Hardware contributions



leading the MHFT

Objectives: Demonstration of technical feasibility by end of 2024

(see Session on Instrument)

WP1	Instrument Design & Management	irap, UC Lab, IAS, PFC, cea, SBT
WP2	Mechanical Structure	irap, UC Lab
WP3	Focal Plane Structure	IAS
WP4	Electronics & on-board software	irap
WP5	Prototype	irap, UC Lab, IAS
WP6	Calibration	UC Lab, IAS, LPSC, NEEL, PFC, LAM, IPAG, irap
WP7	Data-Analysis / Sims	
WP8	Sub-K Cooler (LFT, MFT, HFT)	cea, SBT



## Data-Analysis contributions

### Data Management

(see Overview's talk)

### Systematics Effects

(see Guillaume Patanchon's talk)

### IMo

### Performance Tool

(see Louise Mousset's talk)

### Simulation Tools

(see Eric Hivon's talk)

### Component Separation

### Map-Making & Likelihood

(see Arianna Rizzieri's talk)

### Science Analyses

- LiteBIRD: Tests of Cosmic Inflation  
(see Clement Leloup's talk)
- LiteBIRD: Isotropy and Statistics  
(see Anthony Banday's talk)
- LiteBIRD: Optical Depth, Reionization of the Universe, and Neutrino Masses  
(see Stéphane Illic's talk)
- LiteBIRD: Cosmic Birefringence  
(see Josquin Errard's talk)
- LiteBIRD: Mapping the Hot Gas in the Universe  
(see Marian Douspis's talk)
- LiteBIRD: E-modes  
(see Arianna Rizzieri's talk)
- LiteBIRD: Galactic Science  
(see Jonathan Aumont's talk)

# Organisation: Science Collaboration



## LiteBIRD Collaboration

PI: Masashi Hazumi (JPN)  
 PI-US: Adrian Lee (LBNL)  
 PI-CA: Matt Dobbs (Mc Gill)  
**PI-EU: Ludovic Montier (IRAP)**



**Interim Governance Board**

40 members  
**(7 French)**

### Joint Study Groups

systematics	<b>G. Patanchon (APC)</b> H. Ishino (IPMU) J. Borrill (LBNL)
foregrounds	N. Katayama (Japan) R. Flauger (US) C. Baccigalupi (Europe)
calibration	T. Matsumura (Japan) K. Arnold (US) <b>S. Henrot-Versille (IJClab)</b>
Payload Module	Y. Sekimoto (Japan) K. Thompson (US) <b>B. Mot (IRAP)</b>

### Data Management Group

Instrument Model Team	<b>S. Henrot-Versillé</b>
Simulation Team	M. Tomasi
Production Team	G. Puglisi
Map-making, Power-Spectrum, Likelihood algorithms	Y. Chinone

Paolo Natoli (Italy)  
**M. Tristram (IJClab)**

### Publication Board

**A. Banday (IRAP)**  
 T. Matsumura (Japan)

Liaison:  
**J. Aumont (IRAP)**

### Speaker Selection

B. Barreiro (Spain)

### Membership Board

M. Hazumi (Japan)  
 A. Lee (US)  
 E. Calabrese (UK)

Deep involvement of the French community in the LB collaboration and in the management levels



# Organisation: Science Collaboration

## The Science Study Groups

Since Jul 2021

LiteBIRD PTEP Paper accepted in Nov 2022

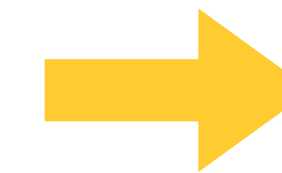
A new set of Science Study Groups dedicated to science forecast with LiteBIRD.  
Short term goal (1-2 years)

### 9 Scientific Forecasts Groups

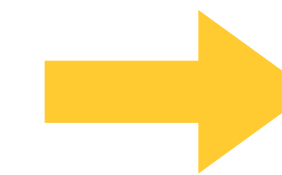
- LiteBIRD: Isotropy and Statistics A. Banday
- LiteBIRD: Tests of Cosmic Inflation
- LiteBIRD: Optical Depth, Reionization of the Universe, and Neutrino Masses M. Tristram
- LiteBIRD: Cosmic Birefringence J. Errard
- LiteBIRD: Mapping the Hot Gas in the Universe
- LiteBIRD: Primordial Magnetic Fields
- LiteBIRD: Gravitational Lensing of the CMB
- LiteBIRD: Cross-correlation Science
- LiteBIRD: E-modes

### Galactic Science Project Study (GSPS) J. Aumont

- 3D Galaxy
- Dust Properties / AME
- Foreground Separation techniques for Galactic Science



• 48 published papers  
 • 3 post-PTEP to be published  
 • 7 post-PTEP in prep.  
 • 36 other papers in prep.



MoU between CMB-S4 and LiteBIRD

Science Forecast Activity is increasing  
We have to put more resources on this

Opportunity to include new members on dedicated forecast activities

# Organisation : Project



Since Jul 2021

**Role:** Responsibility of the design, the development and the delivery of the MHFT instruments + sub-K chain

under CNES lead

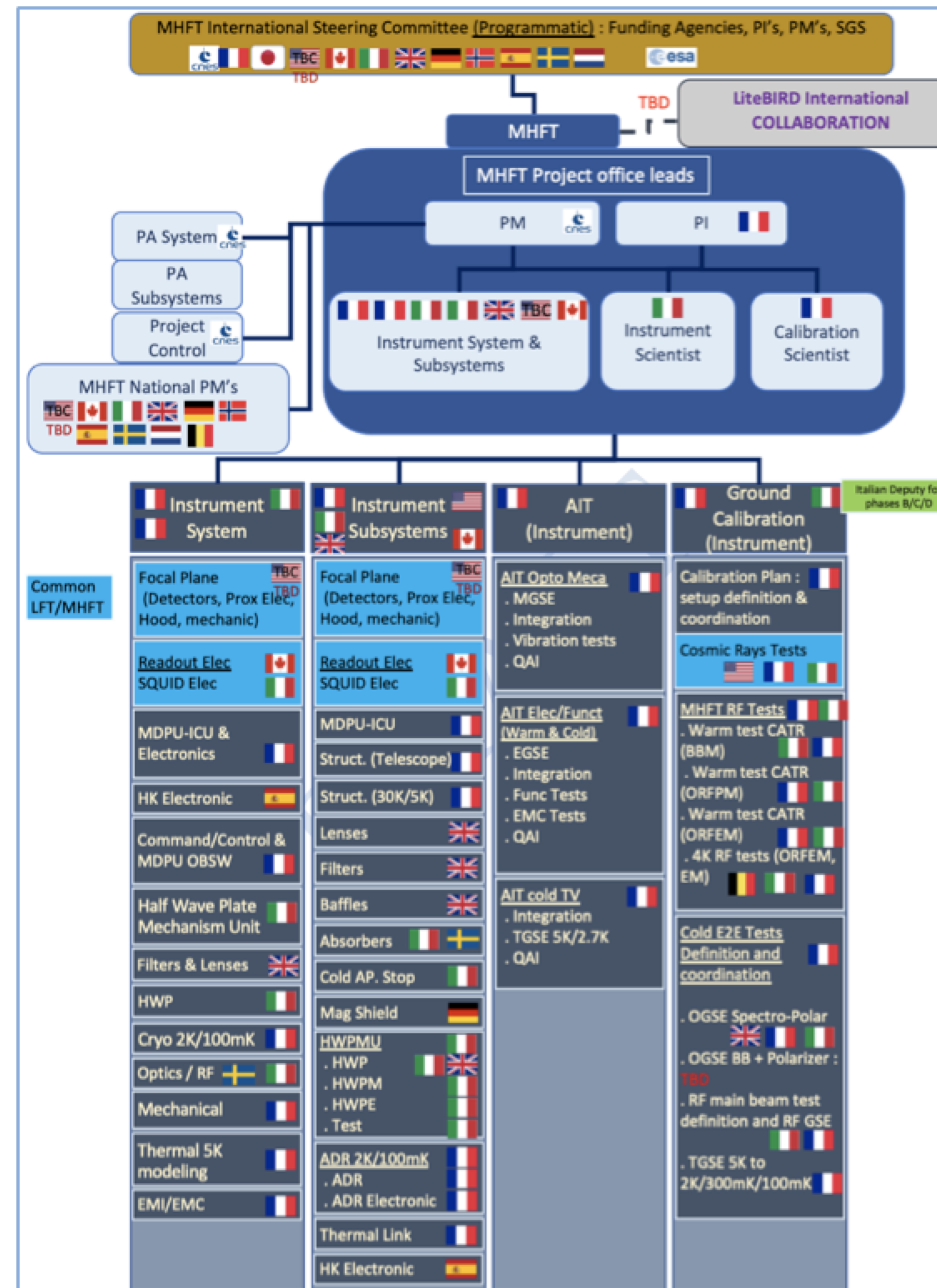


## Composition:

Chaired by the CNES-PM  
co-Chaired by MHFT-PI

Mostly composed of people from the **international** collaboration.

## MHFT-Project Office



- L. Montier MHFT PI
- S. Henrot-Versillé Calibration Scientist
- B. Mot System Lead
- B. Maffei System Advisory Scientist

- System
  - D. Rambaud
  - W. Marty
  - T. Prouvé
  - G. Roudil
  - J-P Thermeau
- Sub-Systems
  - J-C Le Clech
  - J-M Duval
- Calib
  - A. Catalano

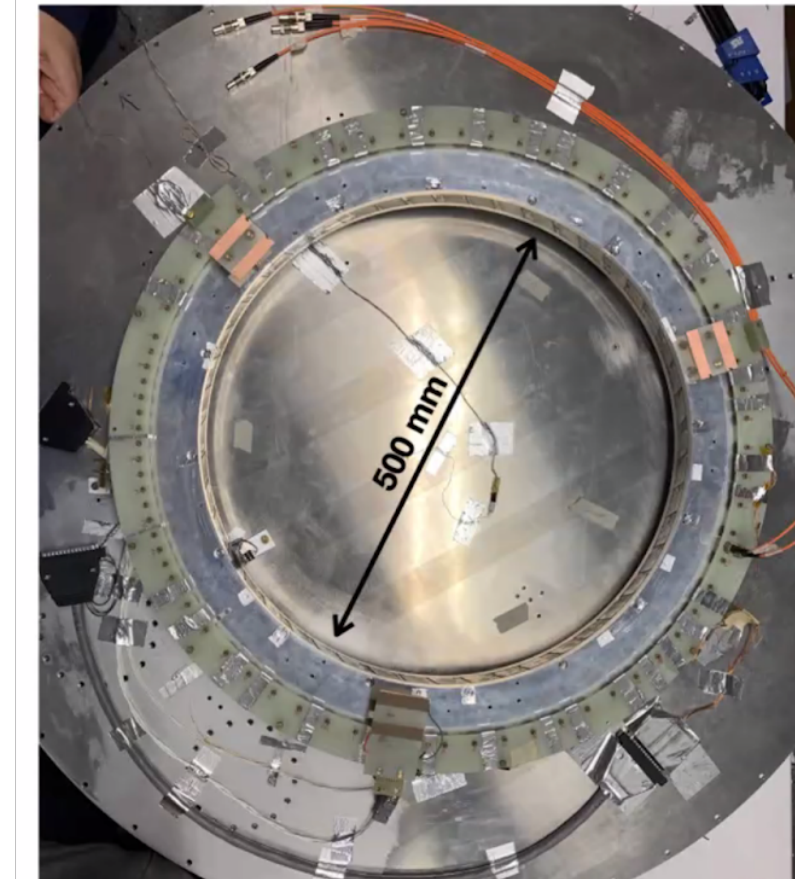


# Organisation : Project

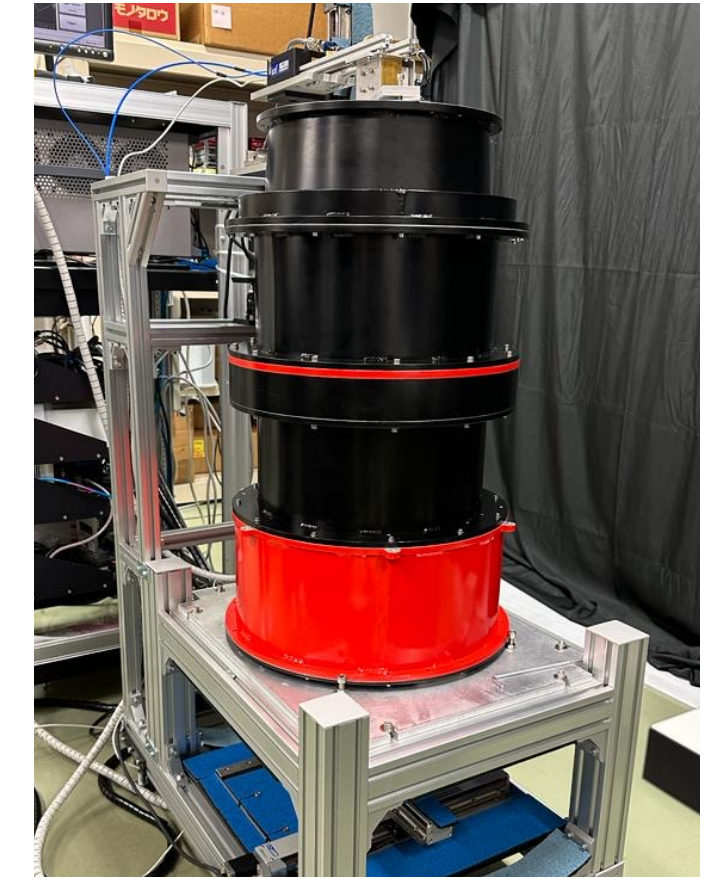
## The MHFT-Project Office Activity

### Tasks:

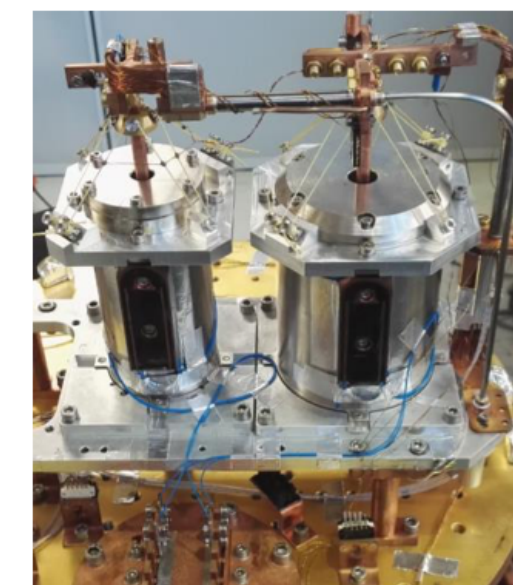
- Consolidation of Requirements Flow-Down from Science to Instrument levels
  - ➔ Dedicated Task Force on Requirements & Performances
  - ➔ Close connection with JSG / DMG groups
- Check Compliance of design with specifications
  - ➔ Close connection with European sub-system teams
- Check technical feasibility of the design at System / Sub-System / Calibrations levels
  - ➔ Prototyping: HFT, DPU, WRE, HWP Mechanism, Sub-K, Beam Measurements
- Check consistency with planning and procurement plan
  - ➔ Discussions with JAXA / QUP / US



HWP mechanism

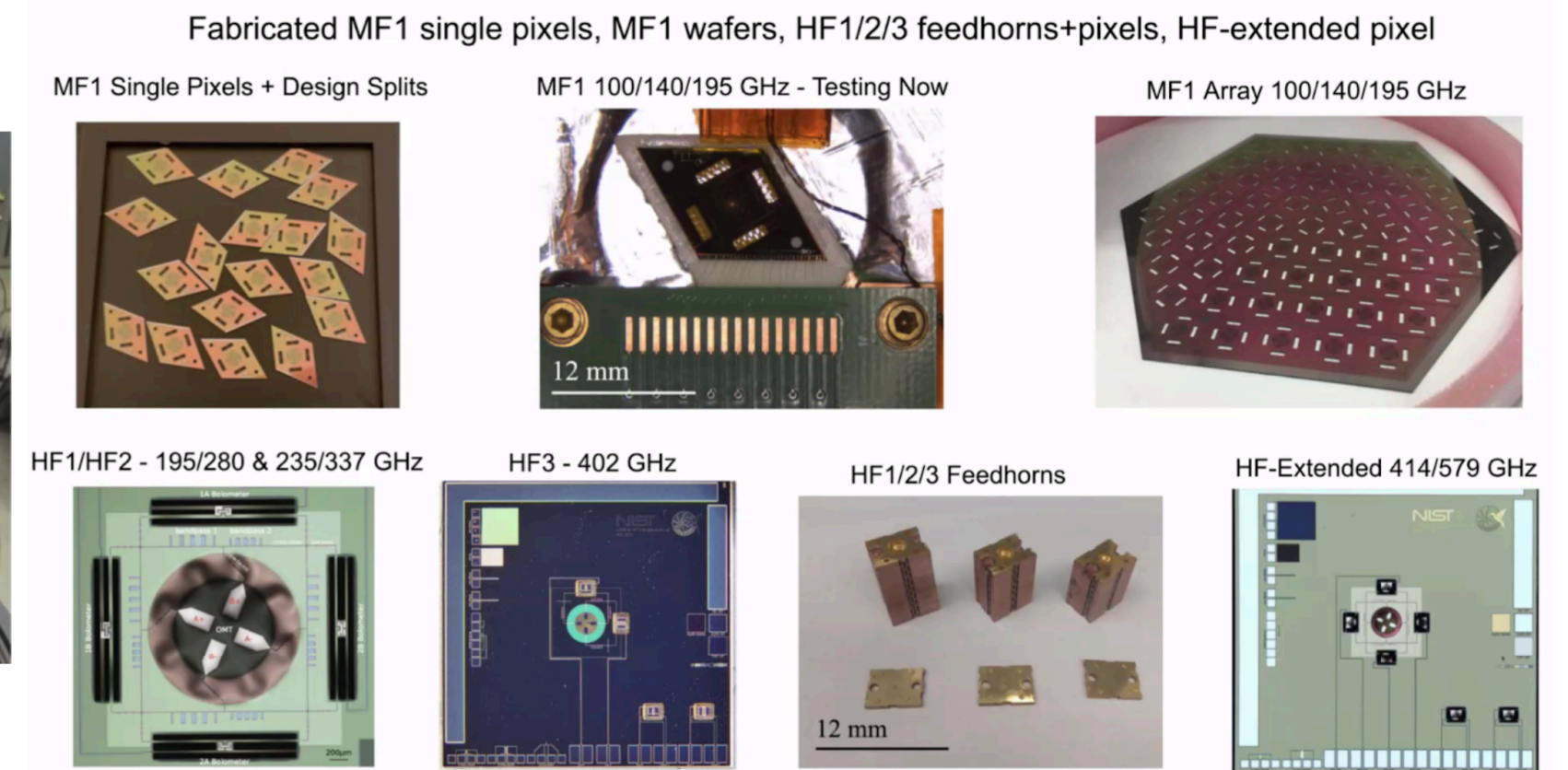


HFT prototype



4 hours cycles  
2.7 K interface

Sub-K

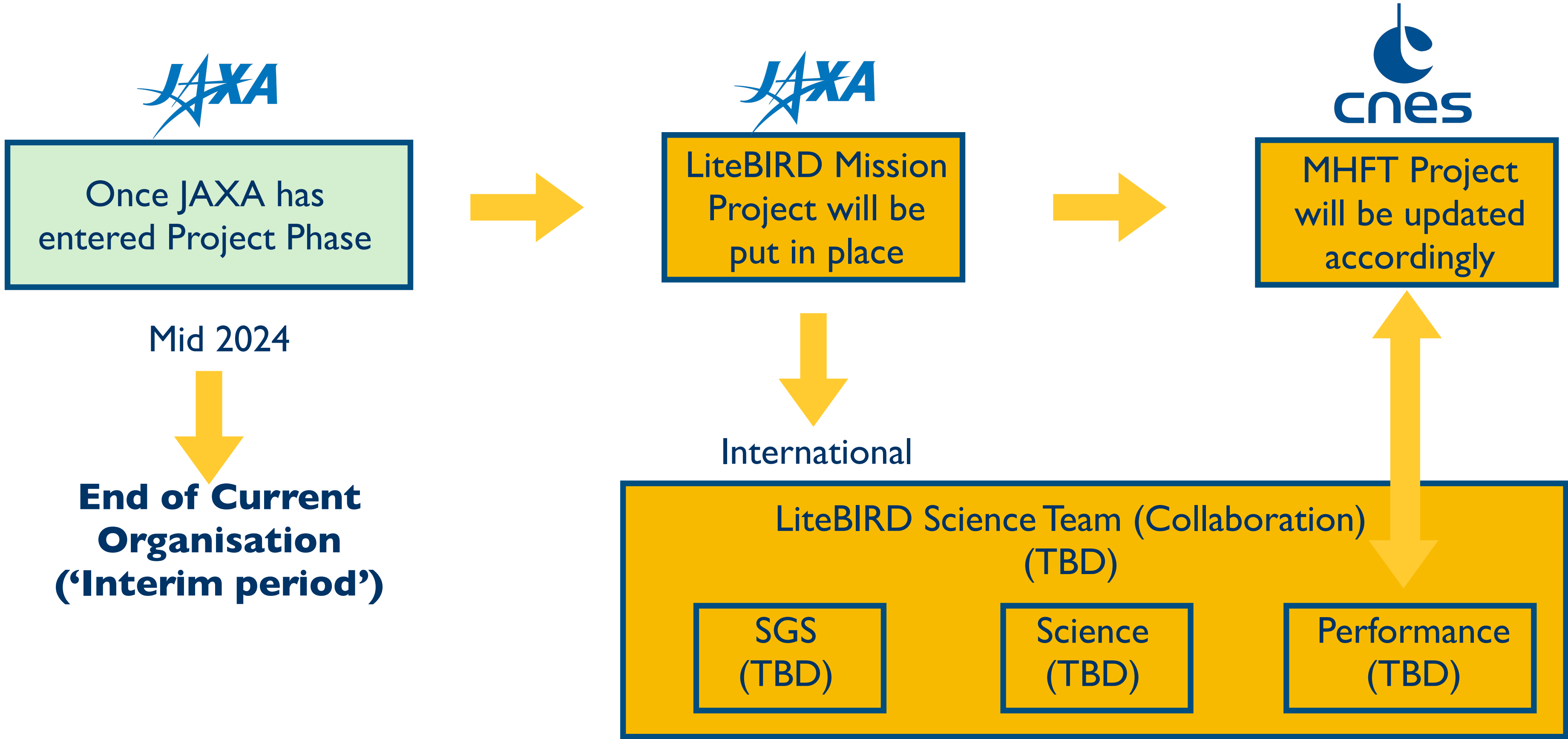


TES detectors array

# Organisation



*To be updated soon*



# Take-away Message



## Lots of activities in the last years

- ➔ JAXA committed to Pre-Project Phase (Equivalent to BI Phase @ ESA)
  - 3 years of Pre-Project Phase, before entering Project Phase
  - Launch date has been updated : 2032 FY
- ➔ CNES commitment into Phase-B0 to be decided by 2025
  - Synchronisation with JAXA
  - Agreement at agency level on Project Organisation
- ➔ Preparation of Science Exploitation has been reinforced: Science Study groups / papers / SGS / Simulations

## Major Milestones

- Beg-2025: Selection for Phase B CNES
- 2029: EM Delivery
- 2031: FM Delivery
- 2033: Launch

