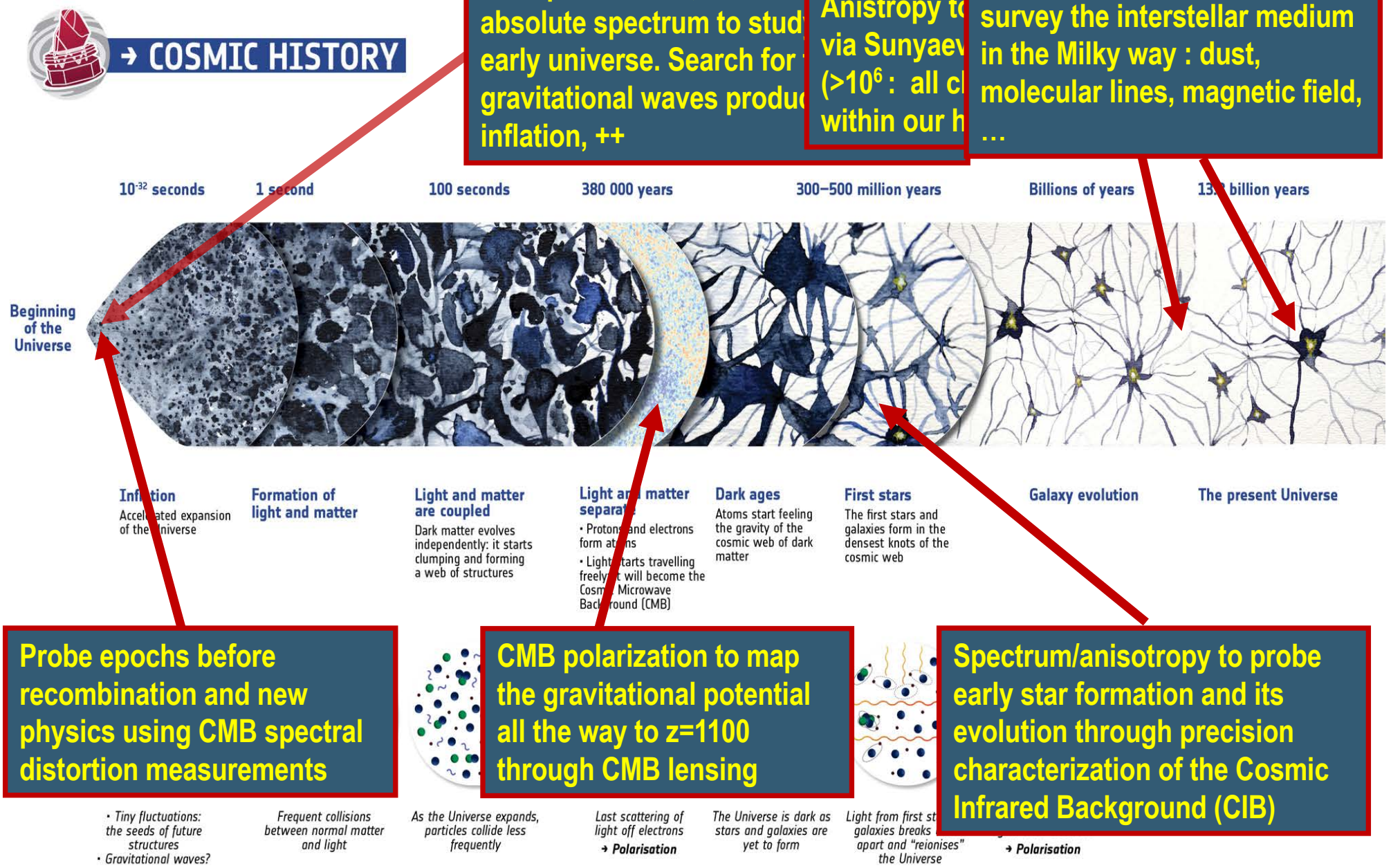
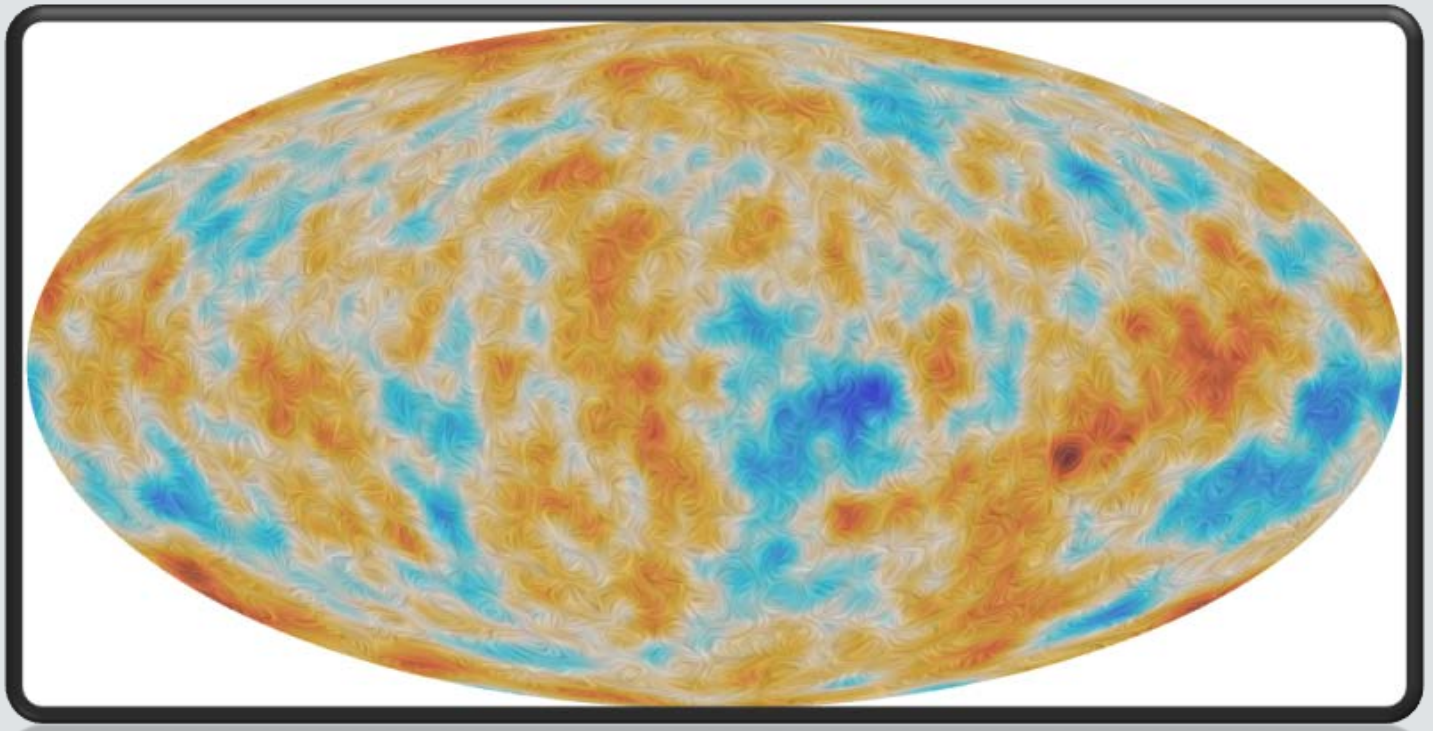
TOWARDS A EUROPEAN COORDINATION FOR CMB EXPERIMENTS

Nicola Vittorio


→ COSMIC HISTORY
CMB polarization, Gaussia
absolute spectrum to stud
early universe. Search for
gravitational waves produc
inflation, ++
Anistropy t
via Sunyaev
(>10^6 : all c
within our h
Spectrum and polarization to survey the interstellar medium in the Milky way : dust, molecular lines, magnetic field, …
10^-32 seconds
1 second
100 seconds
380 000 years
300–500 million years
Billions of years
13 billion years
Beginning of the Universe
Inflation
Accelerated expansion of the Universe
Formation of light and matter
Light and matter are coupled
Dark matter evolves independently: it starts clumping and forming a web of structures
Light and matter separate
• Protons and electrons form atoms
• Light starts travelling freely: it will become the Cosmic Microwave Background (CMB)
Dark ages
Atoms start feeling the gravity of the cosmic web of dark matter
First stars
The first stars and galaxies form in the densest knots of the cosmic web
Galaxy evolution
The present Universe
Probe epochs before recombination and new physics using CMB spectral distortion measurements
CMB polarization to map the gravitational potential all the way to z=1100 through CMB lensing
Spectrum/anisotropy to probe early star formation and its evolution through precision characterization of the Cosmic Infrared Background (CIB)
• Tiny fluctuations: the seeds of future structures
• Gravitational waves?
Frequent collisions between normal matter and light
As the Universe expands, particles collide less frequently
Last scattering of light off electrons
→ Polarisation
The Universe is dark as stars and galaxies are yet to form
Light from first st
galaxies breaks
apart and "reionises"
the Universe
→ Polarisation
www.esa.int
European Space Agency

The ‘Planck era’



- The Planck Legacy release is imminent
- The ESA/Planck mission has created
  - *world-class CMB community in Europe,*
  - *unique, world-leading expertise in space-based CMB research.*

Planck

Ground & in-flight calibration plan

Kourou, French Guyana,
14 May 2009, h 10:12

LFI cooled to 20K Ref loads to 4K

HFI Polarisation Sensitive Bolometers

START SURVEY

EXTENSION 2 — 48 months
EXTENSION 1 — 29 months
NOMINAL MISSION — 15.5 months

1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016

COBRAS & SAMBA PROPOSALS

COBRAS/SAMBA SELECTION

REDBOOK

LFI & HFI CONSORTIA

INSTRUMENT & DPC DEVELOPMENT

BLUEBOOK

INSTRUMENT LEVEL TESTS

CSL TEST

LAUNCH

EARLY RESULTS

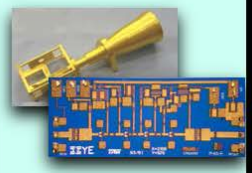
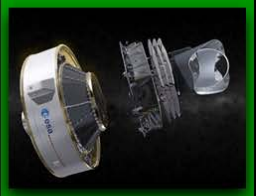
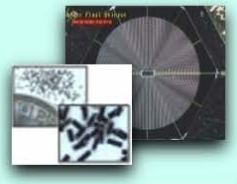
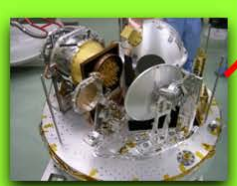
HFI EOL

2013 RELEASE

LFI EOL

2015 RELEASE

FINAL RELEASE

	Unit	Assembly	Instrument	Satellite	In-flight
LFI				CSL Campaign 	 CPV & FLS
HFI					
	Qualification Model Flight Model				

Data Processing Centers

Flight Data analysis

The ‘after-Planck era’

- Data from future CMB satellite missions
  - *in more than a decade from now.*
- European coordinated effort on
  - *ground-based infrastructure*
  - *sub-orbital technology*

  to fully exploit
  - *the expertise acquired with Planck*

The ‘Florence process’

- ‘Towards the European Coordination of the CMB programme’
  - *Villa Finaly: September 2015, 2016, 2017*
  - *Coordinating group*
    - Francois Bouchet & Ken Ganga
    - Eiichiro Komatsu & Joe Mohr
    - Marco Bersanelli & Nicola Vittorio
    - Enrique Martinez-Gonzalez & Jose-Alberto Rubiño-Martin
    - Michael Brown & Anthony Challinor
    - …: … & …

H2020/European Research Infrastructures

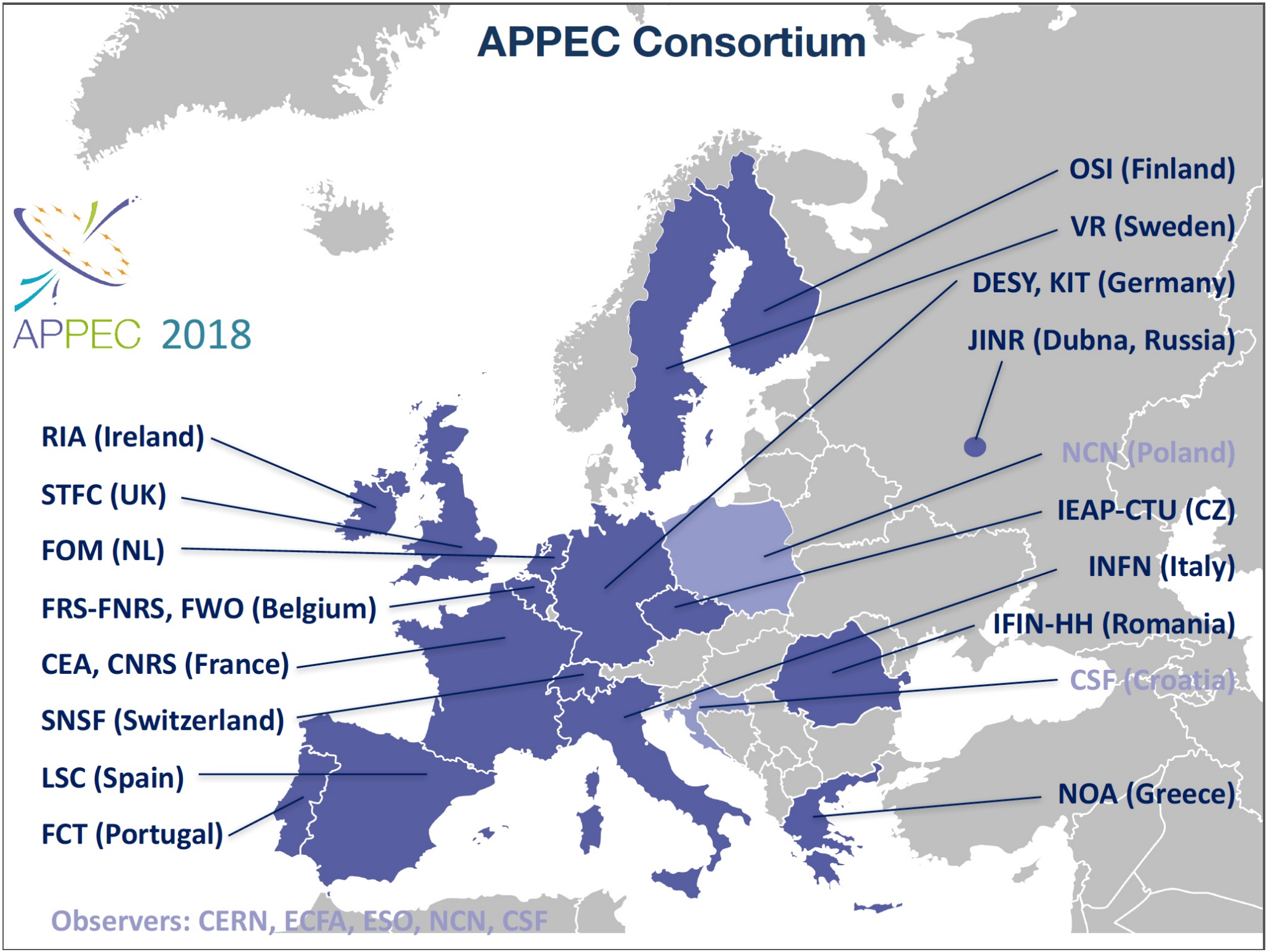
- Design Study for 4th Generation European Ground-Based CMB Research
  - *WP:*
    - Proposal and Study Management:
    - Requirements & Analysis:
    - Site Evaluation, Construction & Operation:
    - Telescope & Optics:
    - Focal Plane & Detectors: KIDs; TESs; HEMTs
    - Cryogenics: i
    - System Calibration and Characterization:
    - Governance:
  - *Nodes and people in charge:*
    - CNRS: Ken Ganga
    - Milan: Marco Bersanelli
    - Roma-I: Paolo de Bernardis
    - INFN: Giovanni Signorelli
    - IAC: Jose-Alberto Rubino-Martin
    - CSIC: Enrique Martinez-Gonzalez
    - UC: Eduardo Artal
    - Cardiff: Peter Hargrave
    - MPA: Eiichiro Komatsu
    - NUIM: Creidhe O'Sullivan
    - NOA: Manolis Plionis

47 institutes and 150 people interested

- ASDC-ASI
- Athens Nat. Obs.
- Bonn
- Cantabria
- Cambridge
- Cardiff
- CNRS
- CSIC
- UGC-Granada
- IAC
- ICC-Barcelona
- INFN
- Imperial College
- Instituto Argentino de Radioastronomía
- Manchester
- Maynooth
- Milan
- Milano-Bicocca
- MPA
- Oviedo
- Oxford
- RCAAM
- Roma I
- USAL-Salamanca
- Sissa
- Stockholm University
- UCL
- UPV/EHU

E4/ESFRI design study proposal

- We did OK
  - *…but not 'enough OK'*
- Remarks:
  - *The European community was very responsive*
  - *The size of the effort and the financial support are much larger than what can be done in any single country*
  - *To continue to do cutting-edge CMB science, we need a European-wide effort.*
- Plan:
  - *Resubmit the proposal, with a better definition of the proposed infrastructure*


APPEC Consortium
APPEC 2018
OSI (Finland)
VR (Sweden)
DESY, KIT (Germany)
JINR (Dubna, Russia)
NCN (Poland)
IEAP-CTU (CZ)
INFN (Italy)
IFIN-HH (Romania)
CSF (Croatia)
NOA (Greece)
RIA (Ireland)
STFC (UK)
FOM (NL)
FRS-FNRS, FWO (Belgium)
CEA, CNRS (France)
SNSF (Switzerland)
LSC (Spain)
FCT (Portugal)
Observers: CERN, ECFA, ESO, NCN, CSF

APPEC Recommendation

- The European Astroparticle Physics Strategy by APPEC
  - *presented the 9th of January, 2018, in Bruxelles.*
- Among the APPEC Recommendations for the 2017-26 there is the recognition that
  - *"The future CMB program sets the stage for a range of opportunities to link key themes together and provides a potential stepping-stone towards further fundamental discoveries".*

Ground-based CMB polarization

- The CMB field is advancing rapidly!
- "Stage 3" experiments have ~10,000 detectors
- CMB-S4 Science Book (arXiv://1610.02743)

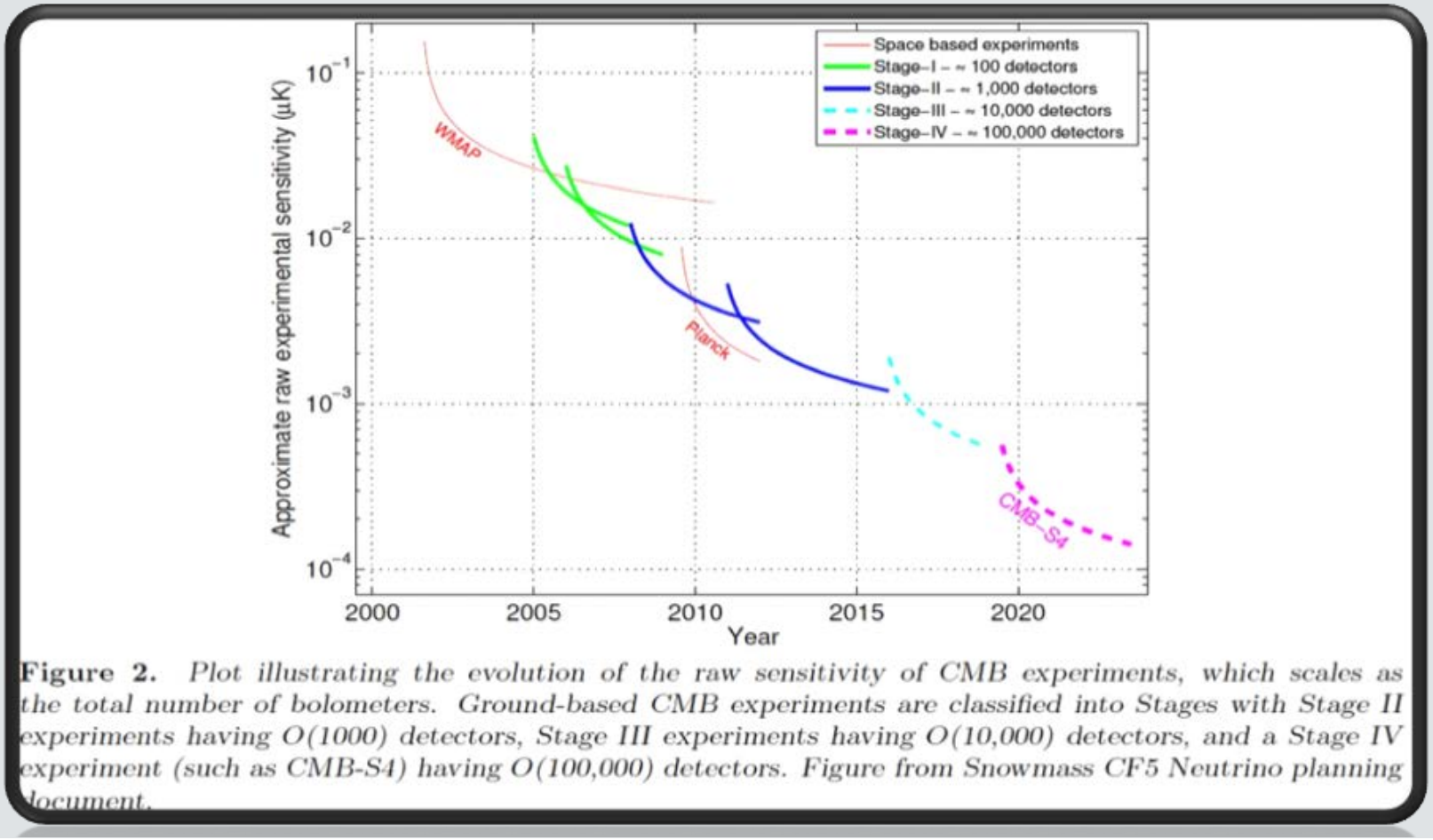


Figure 2. *Plot illustrating the evolution of the raw sensitivity of CMB experiments, which scales as the total number of bolometers. Ground-based CMB experiments are classified into Stages with Stage II experiments having O(1000) detectors, Stage III experiments having O(10,000) detectors, and a Stage IV experiment (such as CMB-S4) having O(100,000) detectors. Figure from Snowmass CF5 Neutrino planning document.*

Ground-based CMB polarization

- CMB Stage 4 experiments should be able to set unprecedented limits on the neutrino sector, the dark sector, and Inflation
- CMB-S4 Science Book (arXiv://1610.02743)

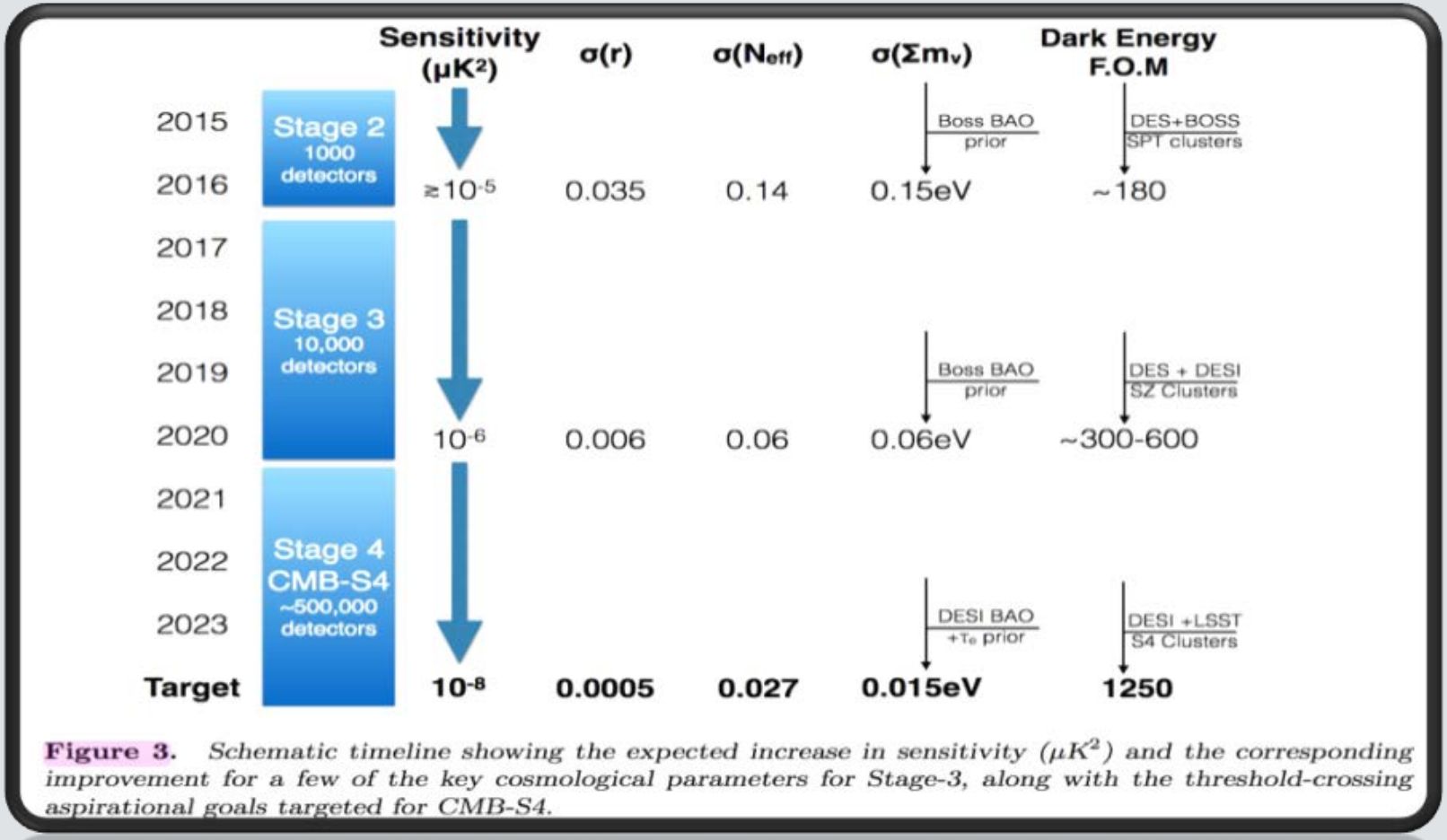
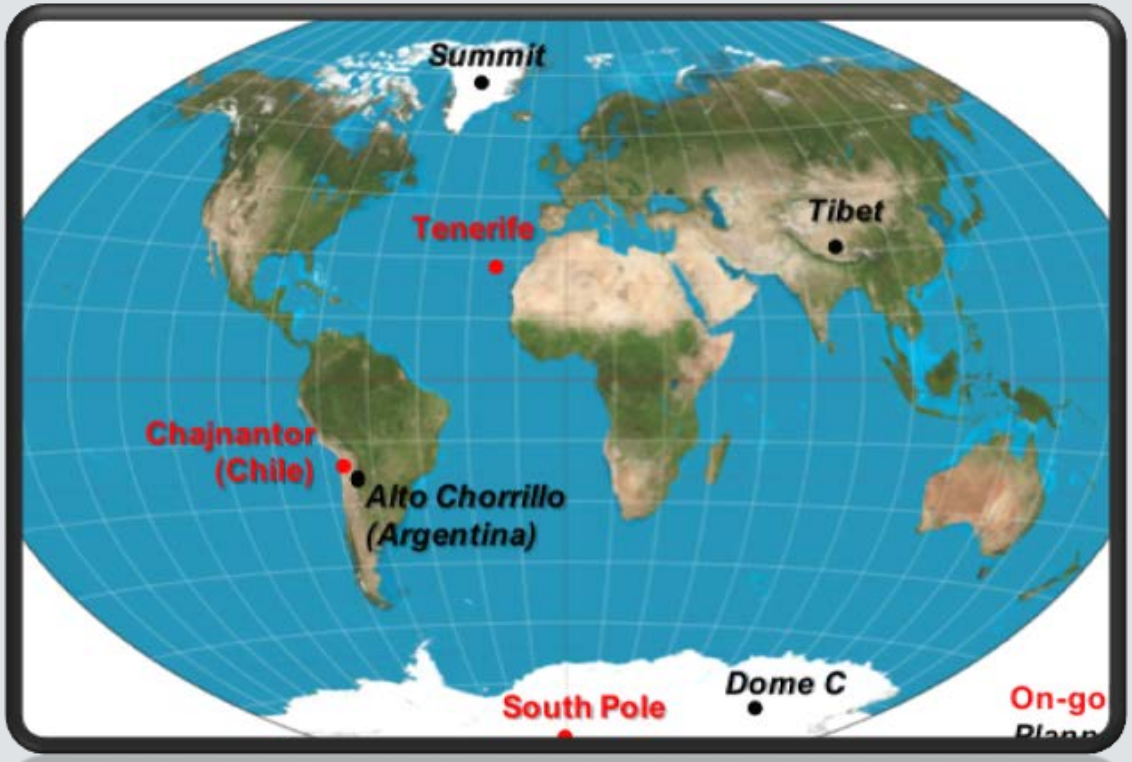


Figure 3. *Schematic timeline showing the expected increase in sensitivity (μK^2) and the corresponding improvement for a few of the key cosmological parameters for Stage-3, along with the threshold-crossing aspirational goals targeted for CMB-S4.*

Ground-based CMB polarization

- Clear tendency to concentrate in few, high-quality sites
  - *Excellent atmosphere*
  - *Sharing of infrastructure*
- S4: South Pole and Atacama, Chile;
  - *Small and large telescopes for*
    - B-mode, de-lensing, high-l cosmic structure science;
  - *500,000 detectors*
    - 300k on 3 large telescopes;
    - 200k on 14 small telescopes)



A European 'Whitepaper'

Table of contents – TBC

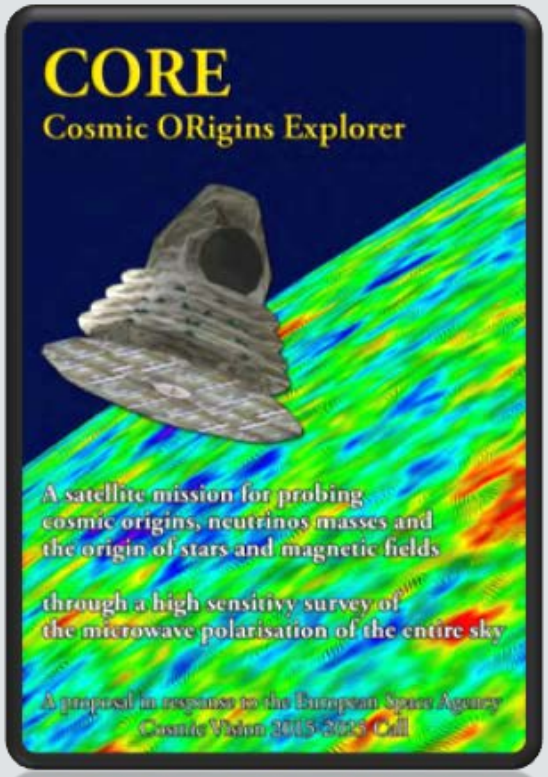
- Introduction
- The Scientific Questions:
  - Neutrino Sector, Dark Sector, Inflation, ...
- The Requirements to answer these questions
- What do we need to do?
- The Community
- The State of the Art Today
- The Scientific Landscape for the Coming Years
- Mid- and long-Term Roadmap

Important questions to be asked

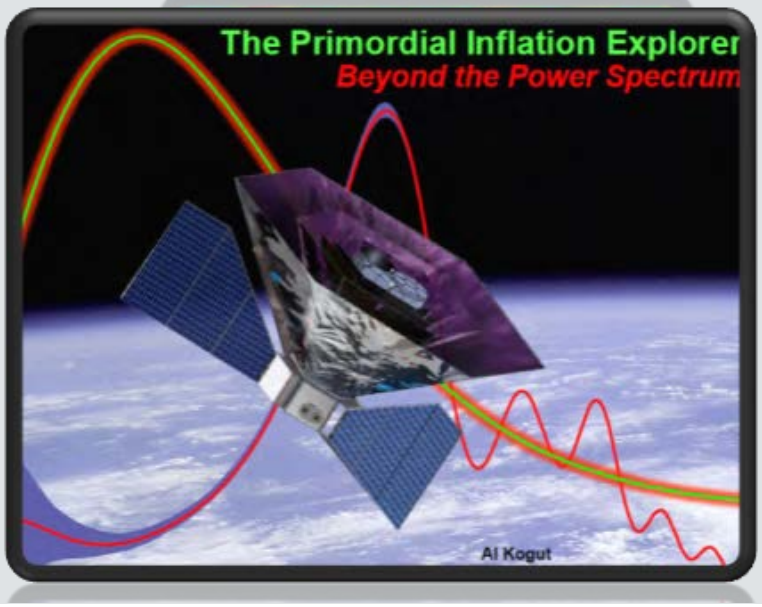
- ***What contribution should Europe be making to***
  - ground-based CMB experiments and/or to existing S3/S4 plans?
  - invest on the synergy building up at the Tenerife site between Spain and Italy, with UK participation and, possibly Japan involvement?
  - balloon-borne CMB experiments?
  - CMB space missions?
  - spectral distortion measures and if so, what is the process?

CMB Space mission

- The ESA/Core mission proposal
  - *'incompatible with the boundary conditions for the M5 Call"*

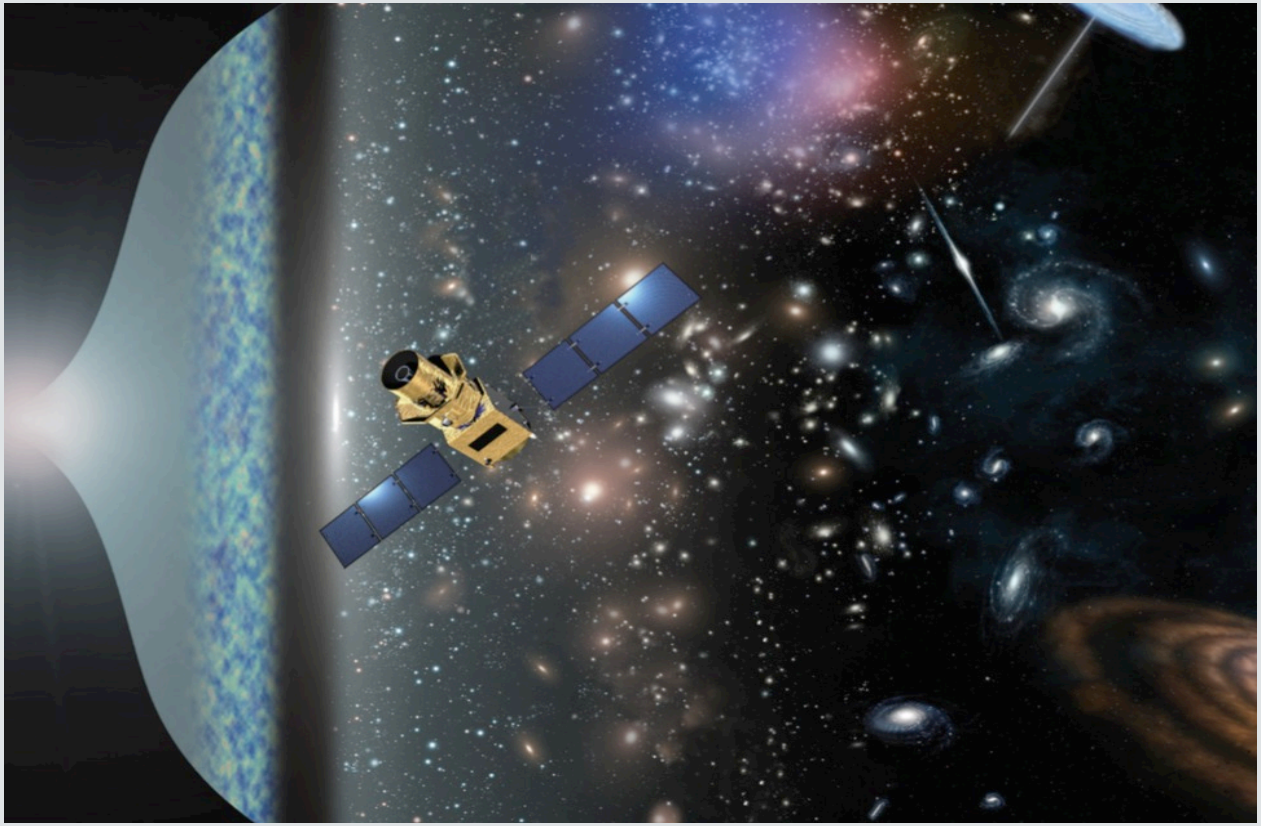


- The NASA/PIXIE proposal
  - *not selected...*
  - *no other space mission to measure CMB spectral distortions*



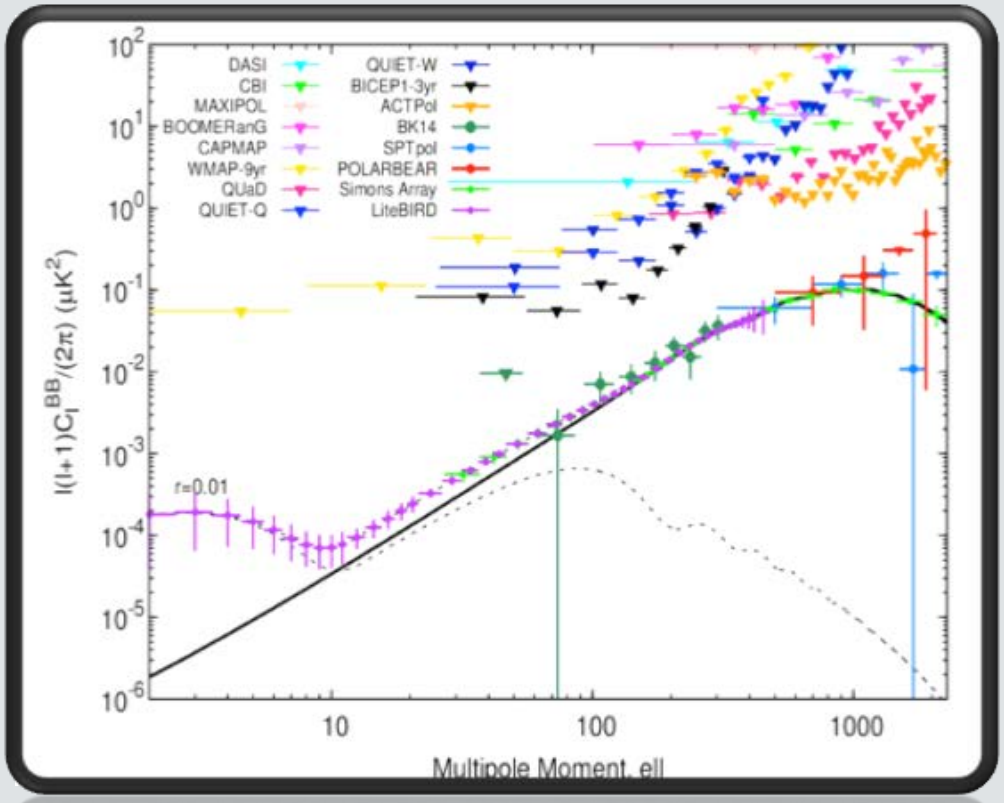
JAXA/LiteBIRD satellite

- Lite (Light) Satellite for the Studies of B-mode Polarization and Inflation from Cosmic Background Radiation Detection
  - *Japanese PI: Masashi Hazumi, US PI: Adrian Lee*



LiteBIRD: a focused mission

- Detect r with σ(r=0)<0.001
- σ(r) includes
  - *statistical uncertainties*
  - *instrumental systematic uncertainties*
  - *uncertainties due to residual foregrounds and bias*
  - *uncertainties due to lensing B-mode*
  - *cosmic variance (for r > 0)*
  - *observer bias*
- The above sensitivity without delensing.



LiteBIRD status and deadlines

- CMB polarization all-sky survey
  - *proposed to ISAS in response to a call for a strategic large mission in 2015.*
- One of the two missions selected for Phase-Al study
  - *The other is Solar-Power-Sail Trojan mission*
- ISAS/JAXA Phase-Al
  - *started in September 2016*
- Selected by MEXT as one of 7 projects listed in
  - *"Roadmap 2017 on promotion of large research projects"*
- Final selection
  - *end of 2018 – beginning of 2019*

JAXA's proposed a European role

- Europe should take charge of delivering the High Frequency Telescope (HFT). This include
  - *Design Model*
  - *Engineering Model*
  - *Flight Model*
  - *Testing and calibration*
  - *Possible backup design for warm readout*
  - *Sub-K cooling system*
- The US team should deliver the detector focal plane to Europe
- Europe should deliver to Japan the HFT, integrated and tested

European Contribution

US

Focal Plane

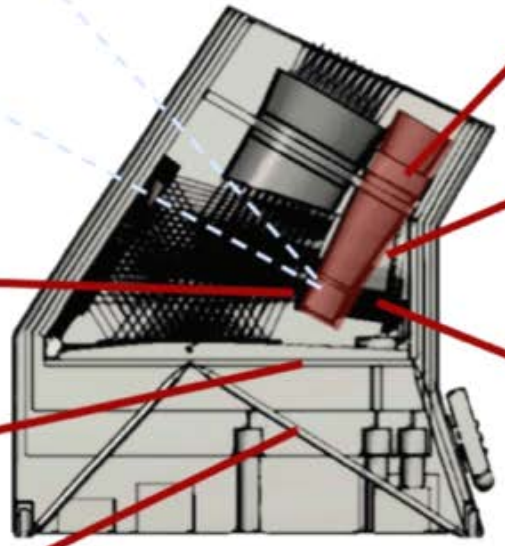
Cold Electronics

Sub-K cooler (LFT+HFT)

Warm Electronics

DPU

Computing Resources



Rotating Half Wave Plate

Optics

Mechanical Structure

AIV

Ground Station

Calibration

International collaboration for LiteBIRD (by MH)

Provisional task sharing

- Japan: LFT, HWP, precoolers, spacecraft, launch, operation
- US: Focal-plane units for LFT and HFT, cold readout
- Canada: warm readout (DfMUX)
- Europe: HFT, Sub-K cooler
- All: Data analysis and scientific exploitation

Teams and supports from space agencies

- US team (led by A. Lee) is supported by NASA for technology development.
- Canadian Space Agency (CSA) supported warm readout technology development by McGill group. CSA issued (July 17, 2017) a Request for Proposals (RFP) to conduct a (Canadian) contribution study for the LiteBIRD mission.
- European LiteBIRD consortium is being organized. Some of members are already registered as LiteBIRD external collaborators.

Joint Study Group has been formed between LiteBIRD Phase A team and external collaborators. Studies on foreground, systematics, calibration and HFT ongoing.

JSG structure and participants

HFT

- P.Ade
- P. de Bernardis
- A. Challinor
- P. Hagrave
- S. Masi
- M. de Petris
- C. Tucker
- B. Maffei
- G. Pisano

Calibration and Testing

- P.Ade
- P. de Bernardis
- A. Challinor
- P. Hagrave
- S. Masi
- M. de Petris
- C. Tucker
- M. Bersanelli
- L. Montier
- G. Savini

Foregrounds

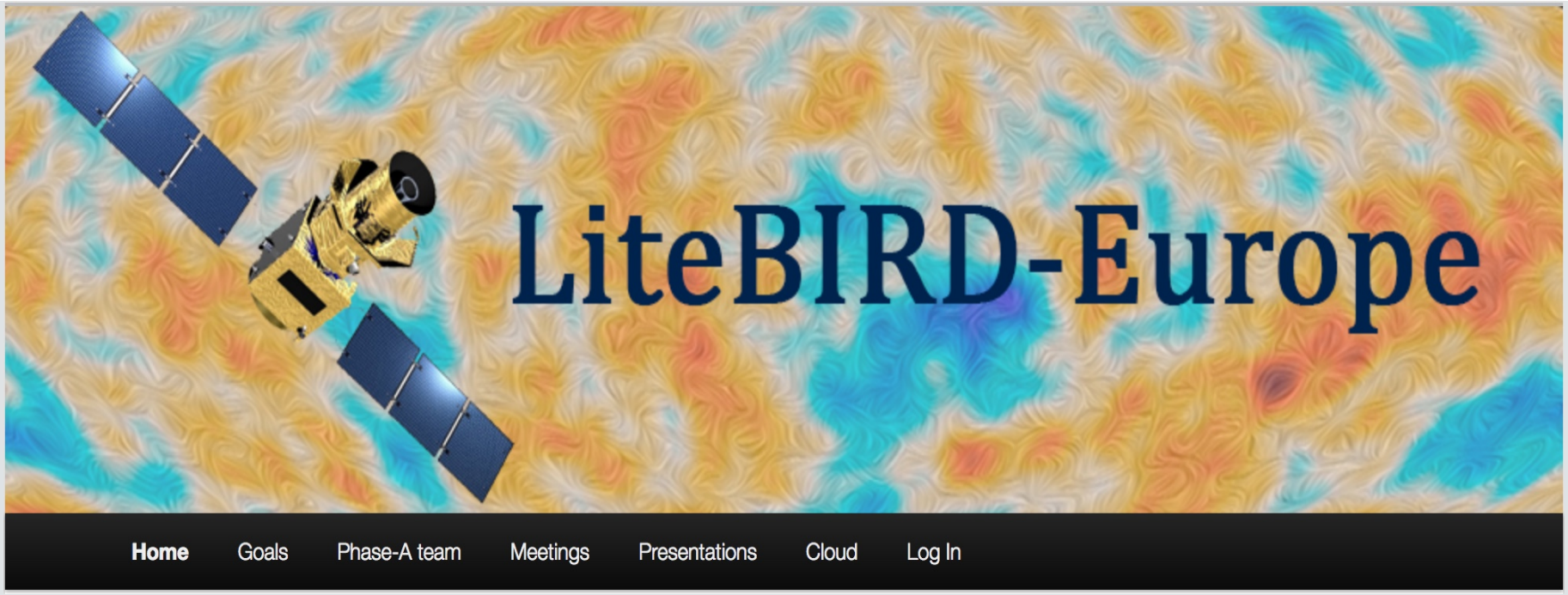
- D.Alonso
- J.Aumont
- C. Baccigalupi
- F. Boulanger
- C. Dickinson
- H. K., Erikson
- U. Fuskeland
- J. Grain
- N. Krachmalnicoff
- A. Mangilli
- D.Poletti
- M. Remazeilles B.Thome M.Tristram
- F. Vansyngel
- I.Wehus

Systematics

- M. Brown
- M. Bucher
- K. Ganga
- A.Gruppuso
- D. Molinari
- P. Natoli
- G. Patanchon
- F. Piacentini D.Thomas

Towards a European Coordination

- Cardiff: general discussion on the European participation
- Paris: general discussion on the European organization

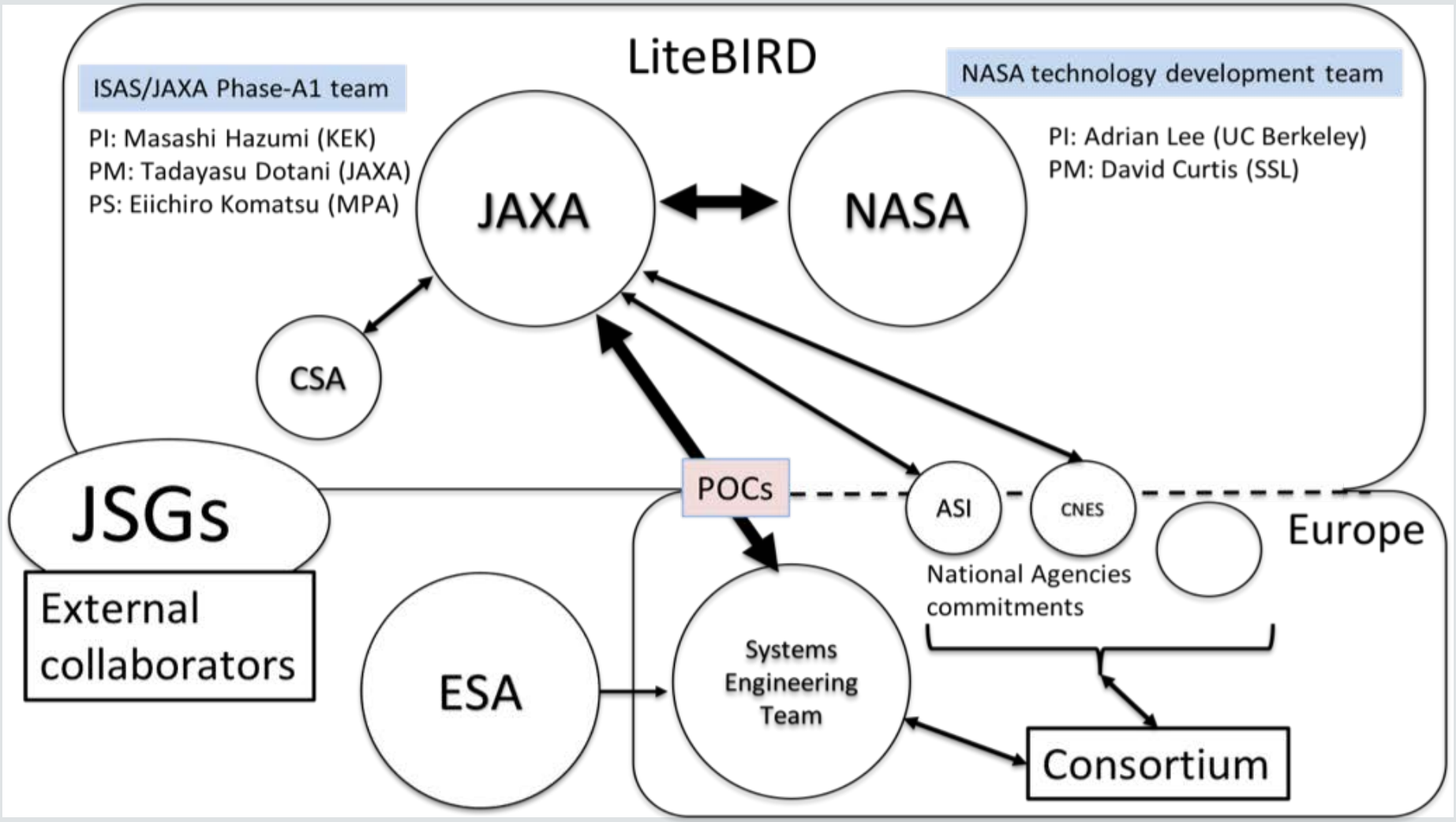


- http://www.litebird-europe.eu/
- No single country has the resources to provide the HFT single- handedly
- European cooperation is essential
- ESA and national agencies
  - *interested in having a visible and identifiable role*
- Important to organize a consortium
  - *strongly advised by ESA*
  - *to have a credible management structure to deliver the HFT*
  - *to be inserted in a Project Management Module*

The LiteBIRD-Europe Phase-A team

- Phase-A activities coordinated by
  - *a Steering Committee, represented on outside by a Spokesperson, and a Deputy Spokesperson.*
- Spokesperson:
  - *Ludovic Montier*
- Spokesperson Deputy:
  - *Erminia Calabrese*
- Systems Engineer:
  - *Baptiste Mot*
- Steering Committee
  - *Erminia Calabrese, Paolo De Bernardis, Jian-Rong Gao, Eiichiro Komatsu, Enrique Martinez-Gonzalez, Ludovic Montier, Giampaolo Pisano, Radek Stompor, Nicola Vittorio, Ingunn Kathrine Wehus*
- SC Chair:
  - *Nicola Vittorio*

PROJECT MANAGEMENT MODEL Phase A (By MH)



European Institutions involved in the activities

France

- APC (Paris)
- CEA-DAp (Saclay)
- CEA-SBT (Grenoble)
- ENS-LERMA (Paris)
- IAP (Paris)
- IAS (Orsay)
- Institut Néel (Grenoble)
- IPAG (Grenoble)
- IRAP (Toulouse)
- LAL (Orsay)
- 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

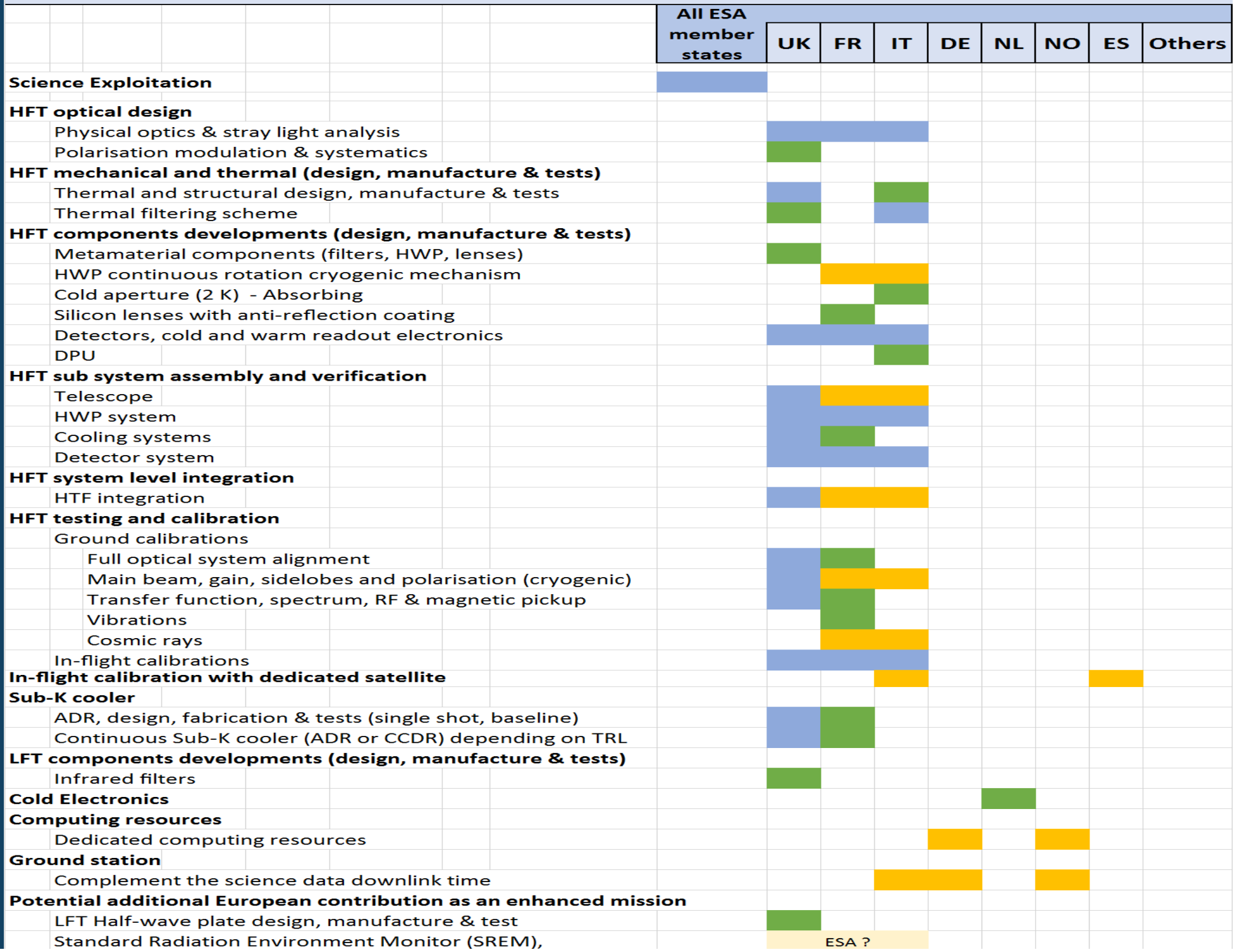
- Max Planck Society (MPA, MPE, MPIfR)
- Ludwig-Maximilians-Universität München
- Universität Bonn
- RWTH Aachen Universität

Spain

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

- The Netherlands: SRON RuG
- Norway: University of Oslo

Desiderata Litebird Team



Towards a European Coordination

- Torino - Feb 8-9th 2018
  - *INFO and program @ www.LiteBIRD-Europe.eu*

to finalize the Governance Structure and coordinate Phase A1 activities