Cosmology: Work Force

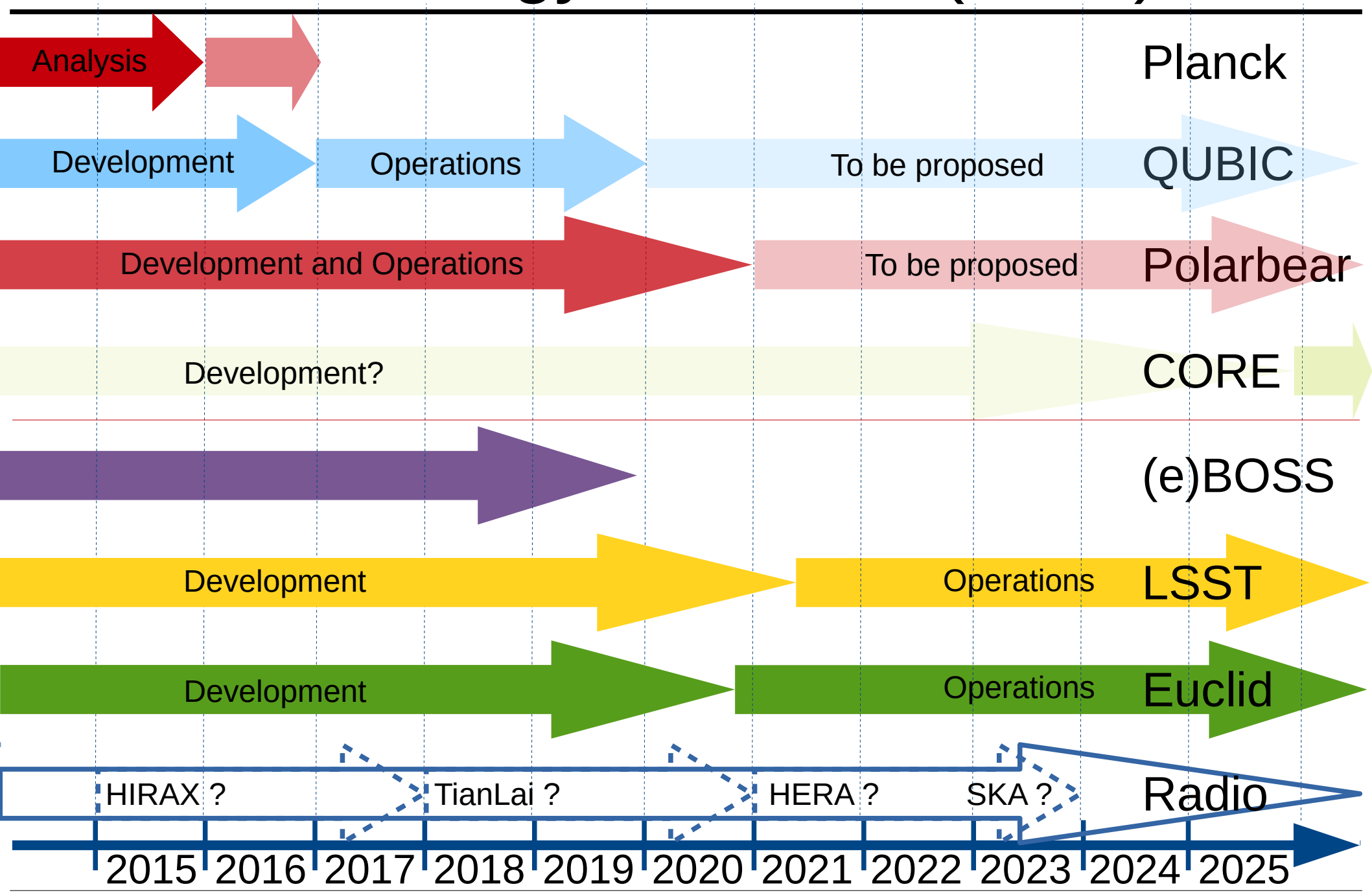
Today

- Permanent Members
  - 9 CNRS Researchers
  - 5 University
  - 2 CEA
  - 1 Observatory
  - 2 Emeritus
- 8 Graduate Students
- 4 Postdocs
- 4 Associates
- Plus V. Guiffo & other admin., affiliates, etc.

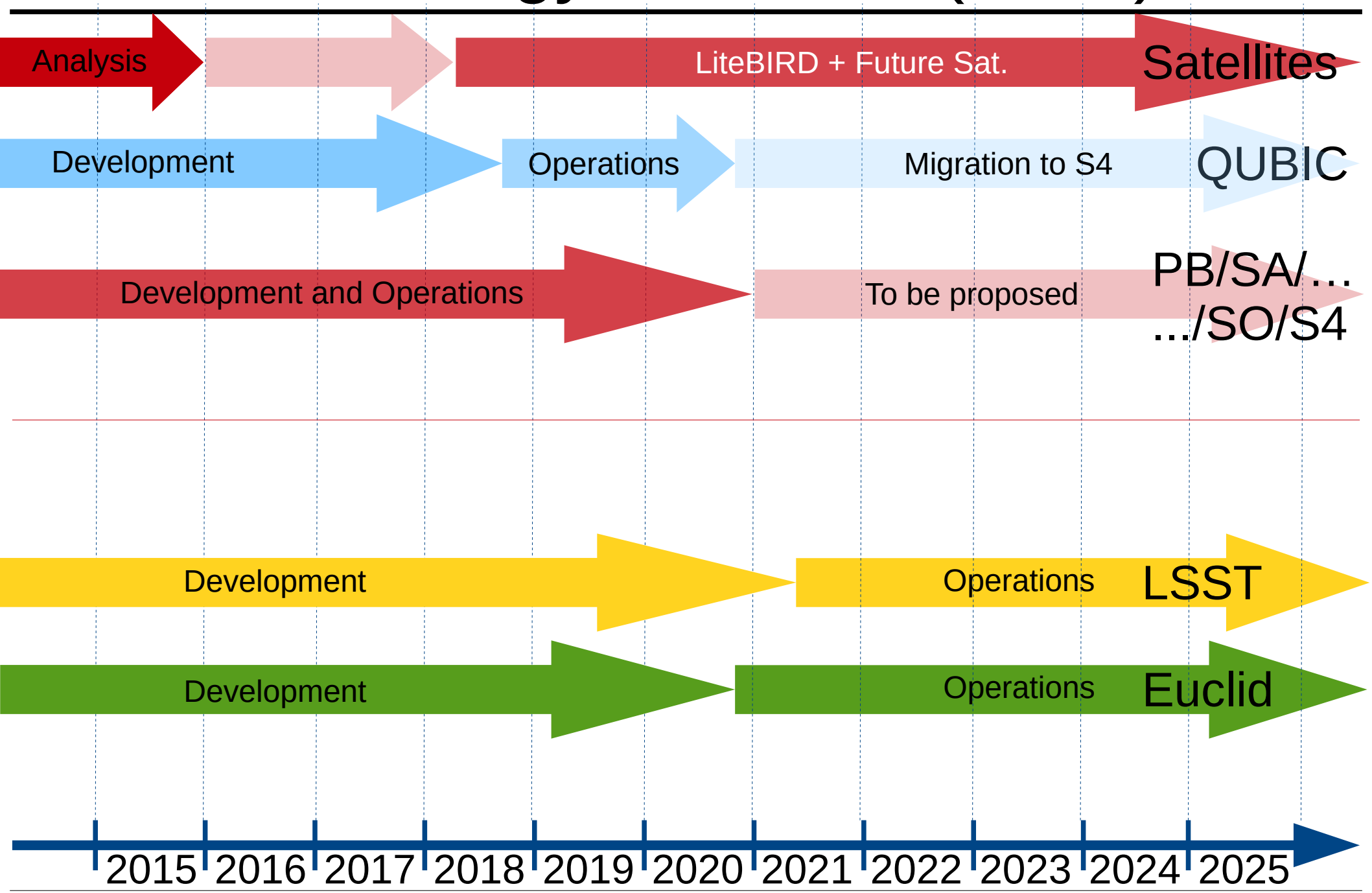
2017

- Permanent Members
  - 7 CNRS
  - 4 University
  - 2 CEA
  - 1 Observatory
  - 3 Emeritus
- 7 Graduate Students
- 3 Post-Docs (inc. PCCP)
- 4 Associates
- About 20 other admin. & « affiliates »

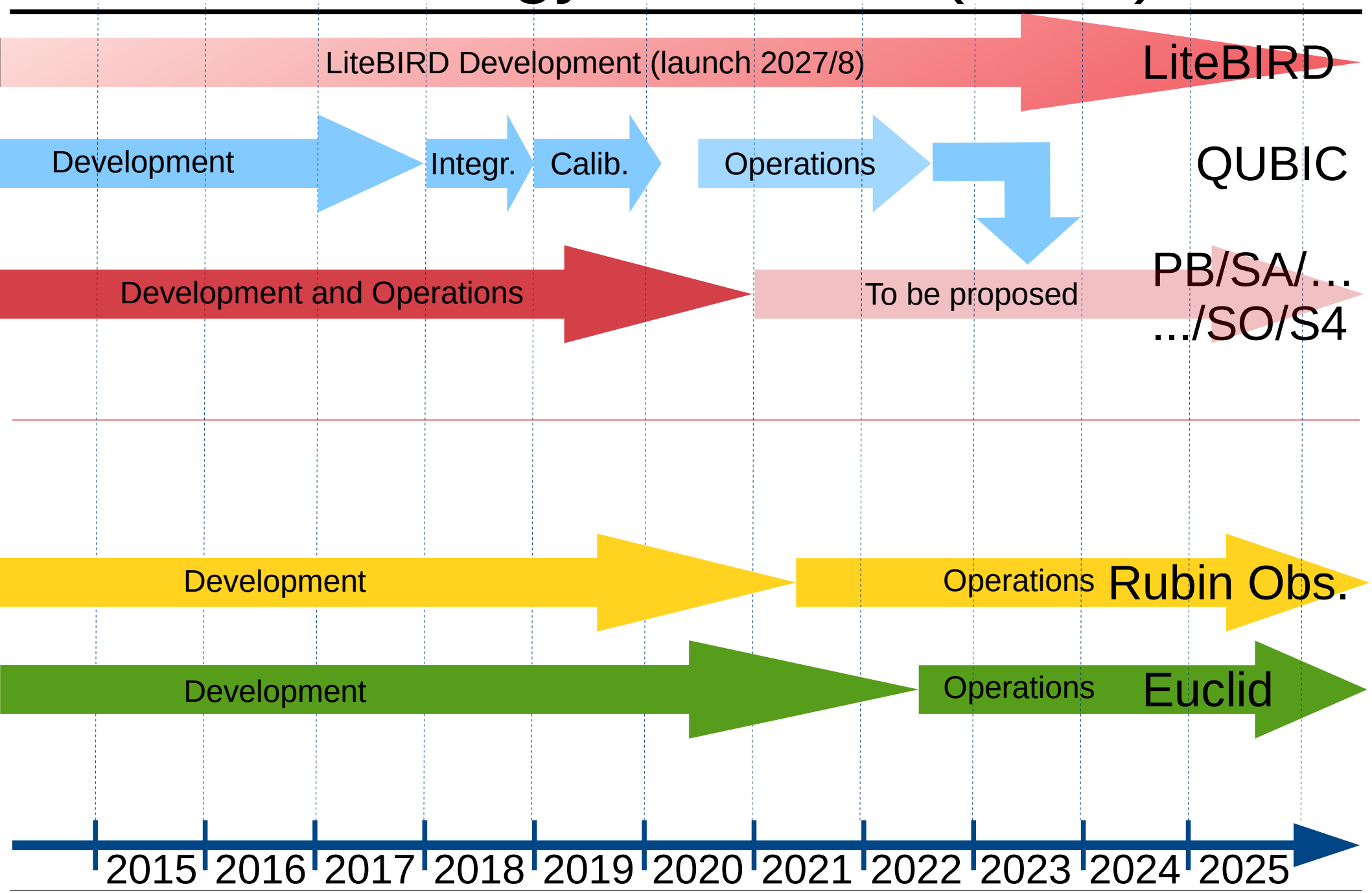
Cosmology: Timeline (2015)



Cosmology: Timeline (2017)



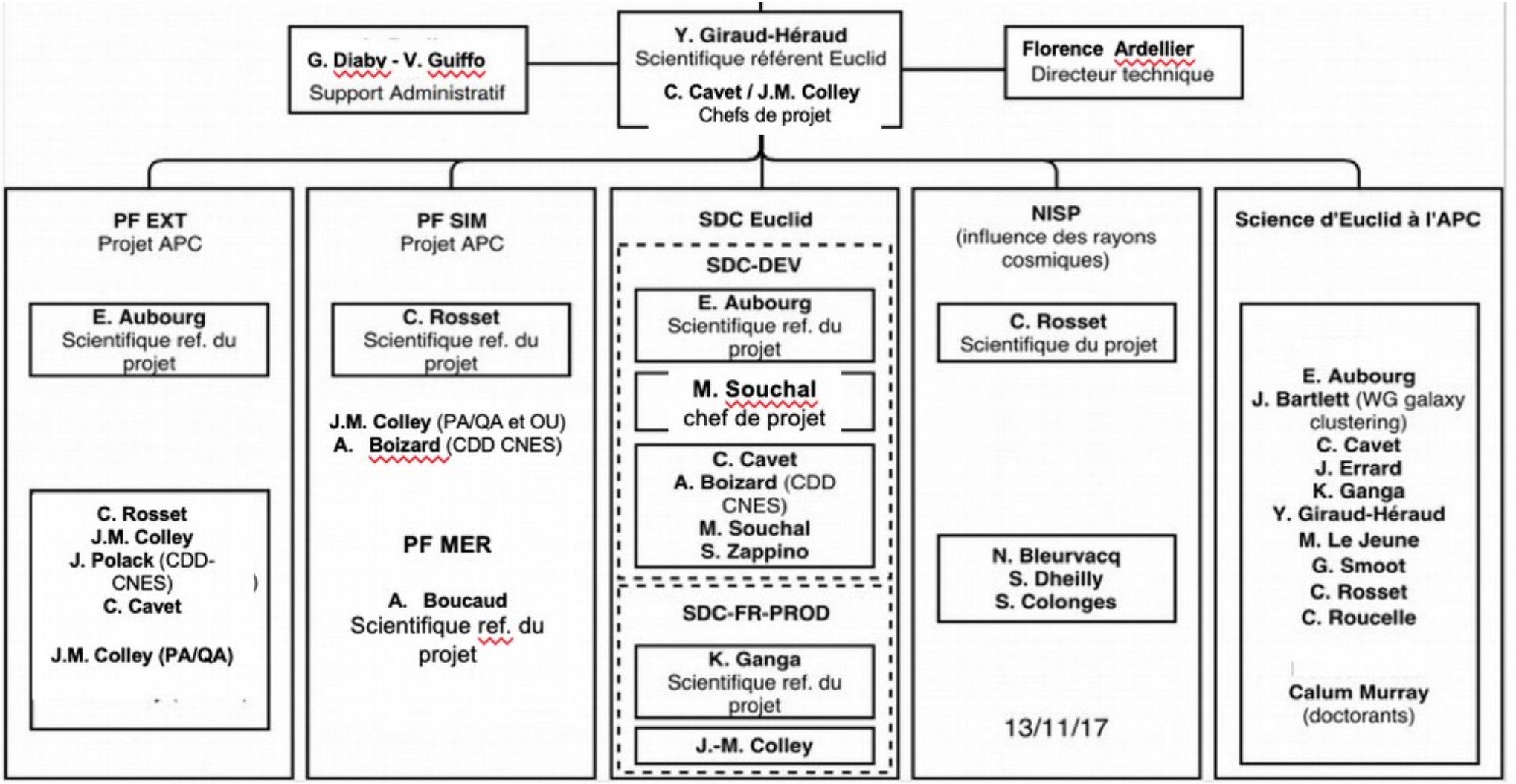
Cosmology: Timeline (2020)



Euclid

- ESA's M2 cosmology mission: the near-term successor to Planck
- Launch *scheduled* for 2022, with 7 years of operations
- APC SGS contributions
  - Euclid external data processing (EXT): LSST
  - validation of the external data simulations (SIM)
  - characterization of the galaxy morphology (MER)
  - CODEEN: Euclid Software development platform
- APC instrumental contribution
  - pre-Launch NISP Radiation Testing (finished)
- APC scientific involvment
  - Correlation of cosmological probes (CMB, LSS, …)
  - Galaxy Cluster Science (co-lead of the SWG)
- Euclid-France SDC Reference Scientist (link to CCIN2P3)

Euclid@APC Organization



Work with LSST

Simu-lations

Project Support

Cosmic Ray Tests

"Science"

Cosmology: LSST Team at APC

- Core LSST Team:
  - Bastien Arcelin PhD year 2, AstroDeep
  - Eric Aubourg (EA) DR CEA CCS/AstroDeep
  - Jim Bartlett (JB) — PR P7 — Amas
  - Alexandre Boucaud (AB) — IR — CCS/AstroDeep
  - Ken Ganga — DR — AstroDeep
  - Cécile Roucelle — MDC P7 — AstroDeep
  - Maude Le Jeune — IR — AstroDeep
  - Françoise Virieux (FV) — IR — CCS/AstroDeep
- AstroDeep : 2 interns, 2 postdocs for 2 years, 1 new PhD
- + Synergies to be developed with Euclid, with CMB, with AHE
- All APC members have data rights.

Cosmology: LSST Update 2020

- Construction
  - Filter exchange system has been delivered to SLAC and is being integrated on the camera (the focal plane is completed).
  - CCS development but will ramp down (EA AB FV)
  - FCS tests during integration (AB FV EA)
- Science preparation
  - EA now chair of DESC collaboration council
  - AstroDeep ANR 2019-2023 (APC + CEA/DAp + LORIA, PI EA)
    - Bayesian neural networks for weak shear analysis
  - Cluster analysis preparation (JB)

QUBIC: the QU Bolometric Interferometer for Cosmology

Scientific Objectives & Collaboration:

- **Primordial B-modes search** σ(r)=0.01 (2 years)
- **Improved constraints on dust properties** (Spectro-Imaging Δν/ν~0.05 => Dust "local" SED)
- **France-Argentina-Italy +UK,Ireland:** 130 people
- **At APC: Instrument design and Management**:
  - Spokesperson, Instrument Scientist, Project
  - Manager, Calibration Scientist
  - 6 researchers (3.3 FTE), 8 ITA (4 FTE), 2 PhD
- **Site: 5000m a.s.l. near Salta, Argentina**

Design:

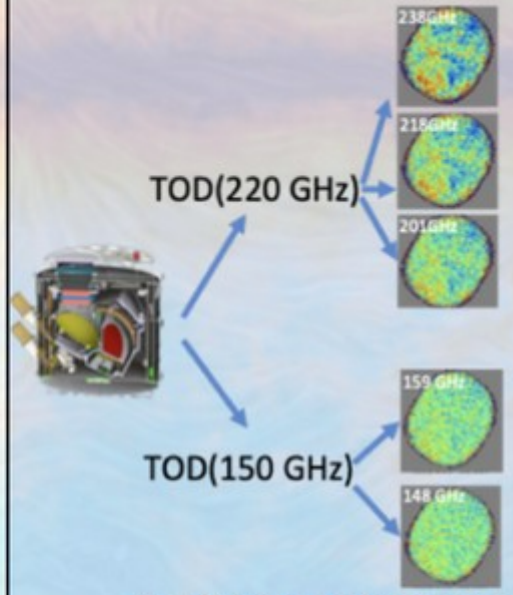
- 400 elements (first) Bolometric Interferometer
- 22 arcmin FWHM synthesized beam
- 150 and 220 GHz wide bands
- 1024 TES / band @ 300 mK with NEP=4×10^{-17} W.Hz$^{-½}$
- 128:1 SQUIDs + SiGe ASIC Multiplexing

Recent activities:

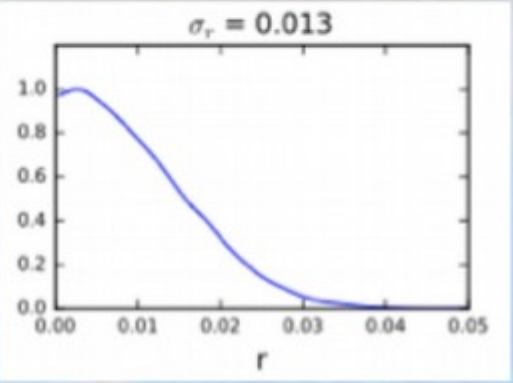
- 2018: Technological demonstrator Integration at APC (64 horns, 256 TES), first cooldowns
- 2019: Calibration at APC
- 2020: Successful CNRS Review (Jan.),
  => Bolometric Interferometry validated
  => TD compliant with requirements

Specificities of Bolometric Interferometry:

- **Spectro-Imaging** [Hamilton et al., in prep]
  - B.I. Synthesized beam depends upon frequency
  - Wide-band T.O.D. can be projected optimally onto sub-frequency maps (up to 5 bands)
  - Increased constraints on foregrounds (especially for non trivial dust models)



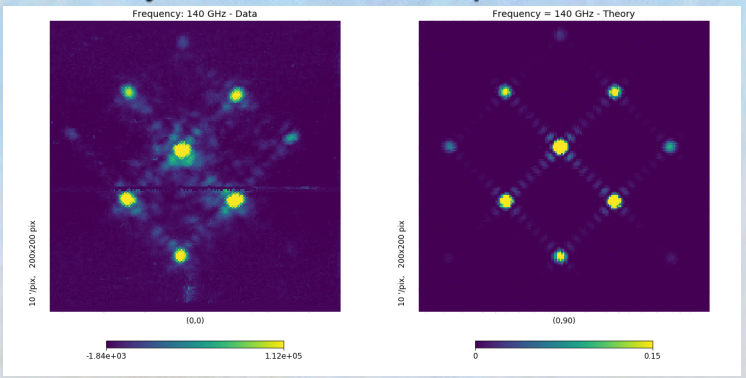
End-To-End simulations:
Dust+Tensor modes fitting
σ(r)=0.01 (2 years)



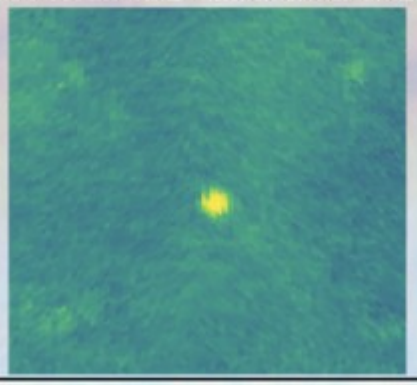
- **Self-Calibration observing individual baselines**
  - Increased ability to control instrument systematics [Bigot-Sazy et al., 2013]

QUBIC Calibration Results:

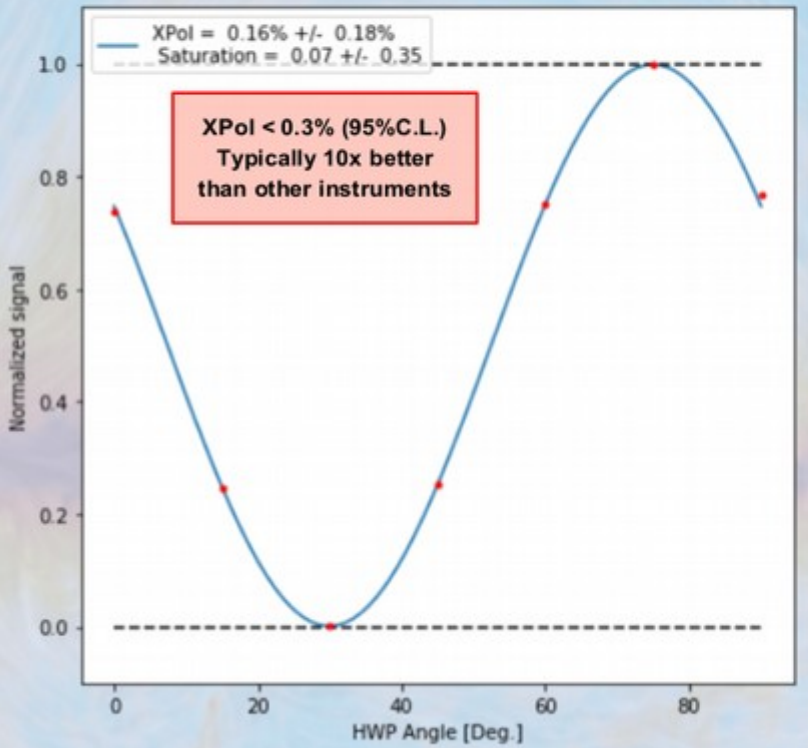
- Synthesized beam shape confirmation



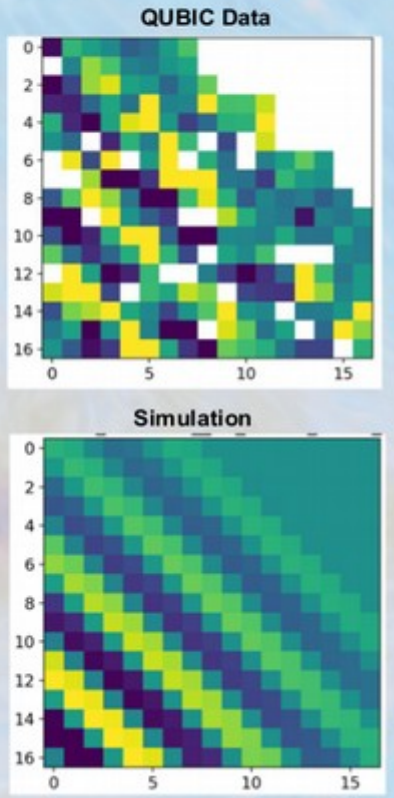
- End-To-End mapmaking (Cal.Src reconstruction)
  Expected FWHM 1.02° Measured: 1.0209+/- 0.0015



- Cross-Polarization measurement (HWP)



- Individual fringes

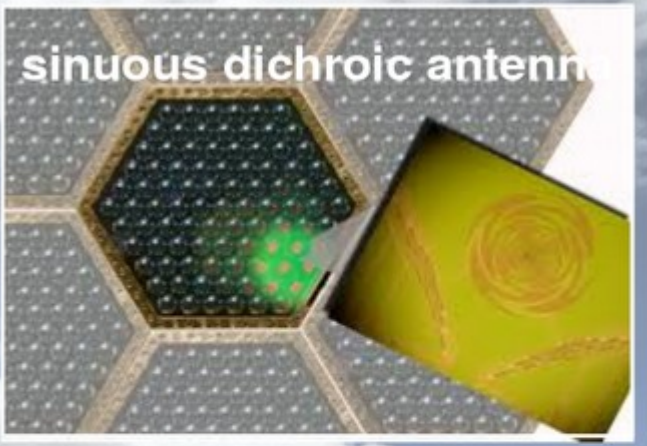


QUBIC Deployment plan:

- 2020: TD shipped to Argentina → **On Sky Demonstration of Bolometric Interferometry**
- 2021: Upgrade to First Instrument → **Stage III: σ(r) = 0.01 + unique Dust SED constraints**
- 2022…: Upgrades and Other modules → **Evolution to Stage IV: σ(r) = 0.001**
  - Multimodes (sensitivity x5)
  - B.I. on 12m LLAMA antenna (Lensing Physics)

  + Neutrinos, Dark Energy, SZ
  [With Spectro-Imaging]

Simons Array (2020-202?)
(= POLARBEAR phase II)



+ continuously rotating HWP

Basic facts

- evolution of POLARBEAR and "a stepping stone" towards Simons Observatory (PI: A.T. Lee UCB/LBNL);
- 3 x 3m Gregorian telescopes ➤ 3.5'@150GHz,
- multifrequency: 95, 150, 220, 270GHz
- ~25,000 multichroic, polarization-sensitive, TES detectors (a testbed for SO, S4, and LiteBIRD);
- Operations: 2020-2022
- Science goals: $\sigma(r) = O(10^{-2})$, $\sigma(\Sigma m_\nu) = O(40meV)$

POLARBEAR telescope

95+150GHz

220+270GHz

95+150GHz

APC involvement

2 researchers + 3 PhD students (8 total since 2009) + 1 postdoc

- remote observations/support for deployment;
- pipeline development and validation;
  - component separation (J. Errard);
  - map-making (H. El Bouhargani);
  - systematic effects modeling (C. Vergès);
  - scientific exploitation (B.Jost)

Simons Observatory (since 2017)

PARQUE ASTRONÓMICO ATACAMA, CHILE
SIMONS OBSERVATORY
ELEVATION: 5190m
22°57'S, 67°47'W
www.simonsobservatory.org

Basic facts

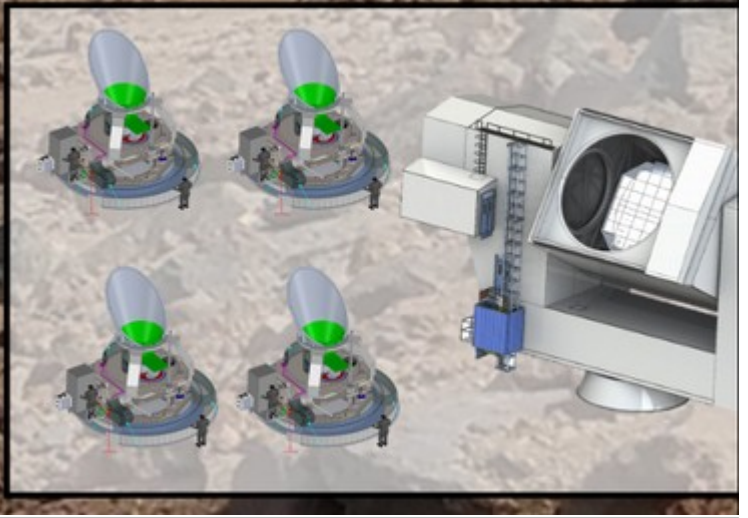
- multiple telescopes with range of apertures (1- 6m) and ~60k multi-chroic detectors.
- operating from the Atacama Desert;
- first light in late 2020;
- science targets: $\sigma(r) \sim 3\times10^{-3}$, $\sigma(\Sigma m_\nu) \sim 40$meV
- precursor for CMB-S4 (an ultimate CMB ground exp).

Collaboration

- based on POLARBEAR and ACT teams + newcomers;
- 8 countries, 42 official member institutions (8 from Europe, 1 from France), ~180 researchers;
- APC has an 'essential' member status since 2017 (absolved from yearly buy-in fees).

APC involvement

- 4 researchers, 3 PhD students;
- scientific exploitation and data analysis:
  - (co)-leadership of the B-mode pipeline development;
  - important contribution to the Pipeline Working Group;
  - systematic studies and modeling;
- active participation in the project governance:
  - Theory and Analysis, Membership, Publication Committees.



An ultimate, ground based CMB polarization experiment which will feature:
- **3 Large Aperture Telescopes (LATs) and**
- **14 Small Aperture Telescopes (SATs)**

They will be located at two sites: on the South Pole and the Atacama Desert.

Will feature 300k detectors on LATs and 200k detectors on SATs.

US-led and since 2019 officially a DOE project.

The first light expected ~2027 (8years of operations).

Science targets: $\sigma(r) \sim 5\times10^{-4}$ **(if** $r = 0$**),** $\sigma(\Sigma m_\nu) \sim 15$**meV (with DESI),** $\sigma(N_{eff}) \sim 0.03$

Synergy with Simons Observatory (technology/data analysis) and LiteBIRD (science).

It is an open collaboration actively searching for foreign partners/contributions.

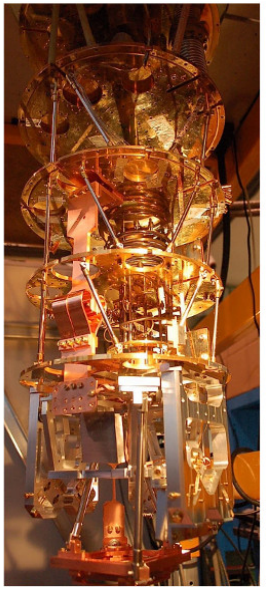
@APC

4 researchers involved currently in the project;

Active role in and (co-)leadership on efforts aiming at defining IN2P3, French, and European contributions to CMB-S4 beyond data analysis.

APC mm lab

- The team:
  - Permanents: Fabrice Voisin (10%), Damien Prêle (10%), Jean-Pierre Thermeau (40%), Steve Torchinsky (50%), Michel Piat (50%)
  - Postdoc: Jie Hu
  - PhD student: in October
  - Support of technical services
- Funding: ANR, CNRS, ESA, CNES
- Coming years:
  - QUBIC on site
  - NGCryo project: accepted IN2P3 project to develop sub-K mini-fridge
  - Polarized mm KIDs
  - SPIAKID: near-IR KIDs
  - Contributions to S4 development



Dilution
20mK

$^{4}He/^{3}He$ system
280mK

mm cryo deepstick
4K