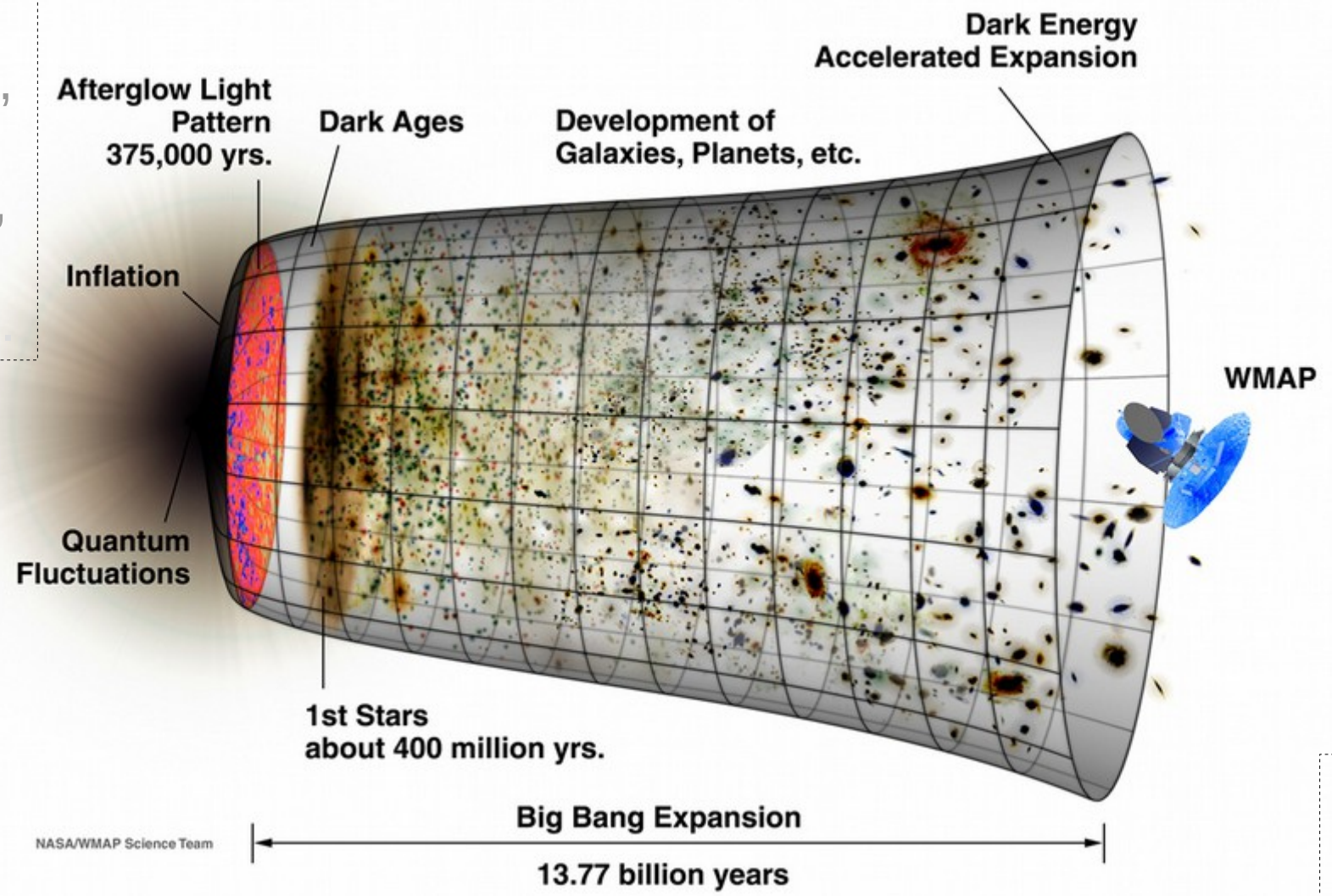
QUBIC, mmLab, Simons Array, LiteBIRD, CMB Stage-IV, CORE, Planck, ...

Cosmology



Euclid, LSST, BOSS

Work Force

Today

- 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 »

2015

- Permanent Members
  - 7 CNRS Researchers
  - 3 university
  - 1 CEA
  - 1 Emeritus
- 5 Graduate Students
- 4 Postdocs
- 5 Associates

Project Evolution

- (e)BOSS work has finished at APC
- Planck has (almost) finished
- DESI work has moved to LPNHE
- SKA work is not being undertaken
- LSST & Euclid work is well-defined & long-term
- LiteBIRD proposals are being submitted
- Simons Array work continues
- QUBIC has begun integration
- Simons Observatory & CMB Stage 4 is being explored

HCERES Question #1

Please say more about the mechanisms for cross-group discussions, both within Cosmology and with the other groups (particularly Astroparticle, Gravitation). We are particularly interested in how students interact across groups.

- Within Cosmology, we have weekly meetings and discussions.
- With Theory & Gravitation we have shared students (cotutelles, stages) and try to organize joint discussions/projects (e.g., are the LIGO BHs primordial?).
- With Neutrinos we are trying to organize “basic” discussion sessions (e.g., how can we help each other?)
- With colleagues e have the COSMO-VIA, which has streamed APC & remote lectures (http://viavca.in2p3.fr/site.html)

HCERES Question #2

The Planck efforts were very successful, but these are now ending. Please give some indication about how some of the researchers are joining other projects – what is going well in this transition, and what needs additional attention?

- Bartlett → CORE, Euclid, LSST, S4
- Bucher → CORE, LiteBIRD
- Delabrouille → CORE
- Ganga → Euclid, S4
- Giraud-Héraud → Euclid
- Patanchon → CORE, LiteBIRD
- Piat → CORE, QUBIC
- Rosset → Euclid
- Stompor → LiteBIRD, Simons A/O

HCERES Question #3

"The goal is to be ready to exploit all possible synergies between LSST, Euclid, DESI/FORMOST, the Simons Observatory, and CMB Stage-IV." This is good, but we are interested in some specifics: what are the top-priority analyses, and why, or at least what are the first efforts and where might they lead next?

- First Detection of Cosmic Microwave Background Lensing and Lyman-α Forest Bispectrum, Doux, Schaan, Aubourg, Ganga, Lee, Spergel, Tréguer, Phys. Rev. D 94, 103506 (2016)
- First Steps the detection of SZ cluster mass via CMB lensing by Planck: *Planck 2015 results. XXIV. Cosmology from Sunyaev-Zeldovich cluster counts*
- Scientific Synergy Between LSST and Euclid, arXiv:1710.08489
- The POLARBEAR Collaboration, 'Evidence for Gravitational Lensing of the Cosmic Microwave Background Polarization from Cross-Correlation with the Cosmic Infrared Background', Physical Review Letters, 112, 131302, (2014) (Editor's choice) including J. Errard, M. Le Jeune, J. Peloton, D. Poletti, R. Stompor

HCERES Question #3 (continued)

"The goal is to be ready to exploit all possible synergies between LSST, Euclid, ~~DESI/FORMOST,~~ the Simons Observatory, and CMB Stage-IV." This is good, but we are interested in some specifics: what are the top-priority analyses, and why, or at least what are the first efforts and where might they lead next?

- Tomographic reconstruction of the matter field by cross-correlation of CMB lensing maps with LSS tracers with known redshift. Constraints on dark energy, dark matter, neutrino mass and modified gravity.
- Comparison of Euclid lensing and CMB lensing to control systematics in both.
- Studies of the circum-galactic medium and the relation between baryons and dark matter through observations of the SZ effect and CMB halo lensing. This requires observations at CMB frequencies of large samples of galaxies, groups and clusters selected in the optical/NIR.
- Multi-wavelength cluster cosmology: samples selected in optical/NIR compared with samples selected via SZ greatly improve control of systematics. Mass measurements with Euclid shear measurements and CMB lensing at redshifts beyond the reach Euclid.

HCERES Question #4

What are the current plans for APC personnel to spend time working abroad (*e.g.*, SLAC and Chile, in the case of LSST). Are there issues with travel support?

For LSST the priority is to ensure the integration and commissioning tasks for which we need lots of travel to SLAC and Chile. This is true for others labs – not just APC. The IN2P3 LSST budget covers a number of labs, and the LSST Board makes decisions across labs.

For QUBIC we have made an ANR request for the period 2019-22 for ~200k€ (about 20 trips/year)

For SA/SO we are funded on the level of 6k per by IN2P3 (PICS) plus LABEX (7k$) per year. So we are fine for the next 3 years or so. But overall again I think we do not have long term solution here so things often oscillate. We were much worse off two years ago for PB. Now we are ok, but it is sometimes difficult to get committed to an experiment which takes a decade to come to fruition, if we have no long term travel support as a minimum.

HCERES Question #5

What is the current strategy, and what are the interests of group members, for CMB-E4 vs CMB-S4? What are the prospects for the mm lab contribution to CMB stage 4?

Current Strategy:

- Push the “Florence Process” in hopes of Europe-wide participation in S4 (this was the framework/spirit within which E4 was done)
- Within the IN2P3 (not just APC), leverage mmLab, QUBIC, NIKA and other explore the possibilities of contributing hardware to the Simons Observatory (an optics “tube”; which would presumably also lead to S4 contributions)

Current Strategy (cont’d.)

- Demonstrate utility of QUBIC’s bolometric interferometry for the CMB
- There is some danger with LiteBIRD & QUBIC that we lose participation in “small-scales”

mmLab Contributions:

- TES cold readout (in demand)
- Dual Color LE KIDs
- Detector Characterization

HCERES Question #6

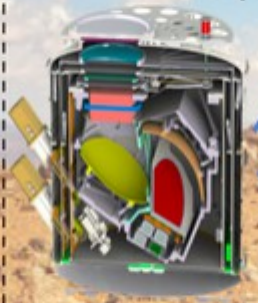
What are the financial prospects to bring the QUBIC instrument to a level/size to reach sensitivity comparable to current large ground based CMB polarization experiments?

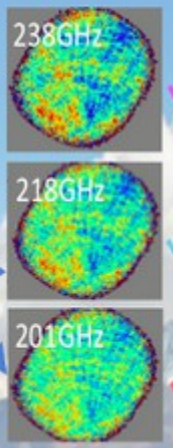
- At the moment QUBIC has 400 horns & ~2k detectors
  - To go to 3600 horns & 16k detectors would cost ~€40M
- The CMB Stage-IV Concept Definition Team has estimated the total project cost to be $412M.
- Simons Observatory has been endowed with ~$50M
- As part of the “Florence Process”, we have been discussing Europe-wide contributions of order $50-100M

QUBIC is a spectro-imager

TOD(220 GHz)

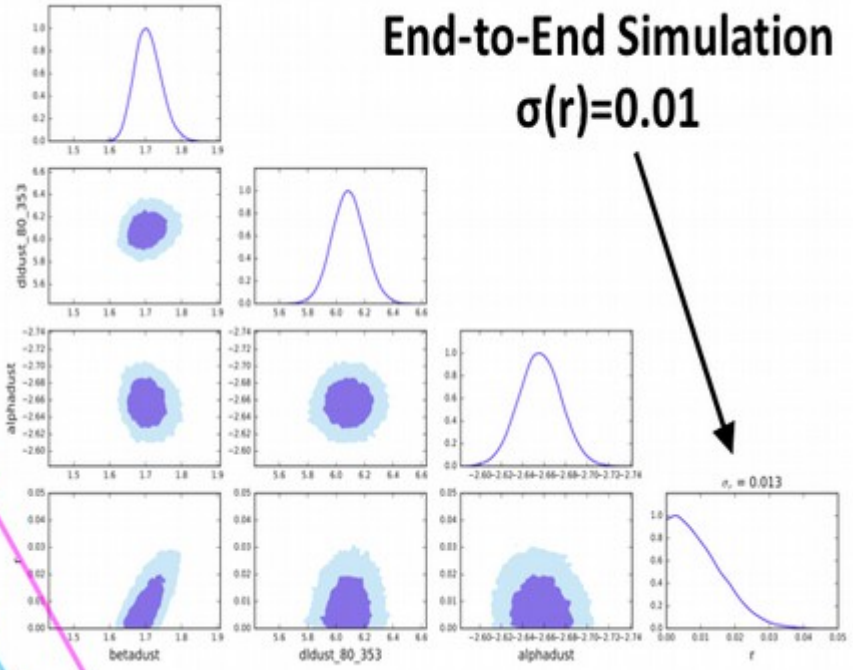
TOD(150 GHz)

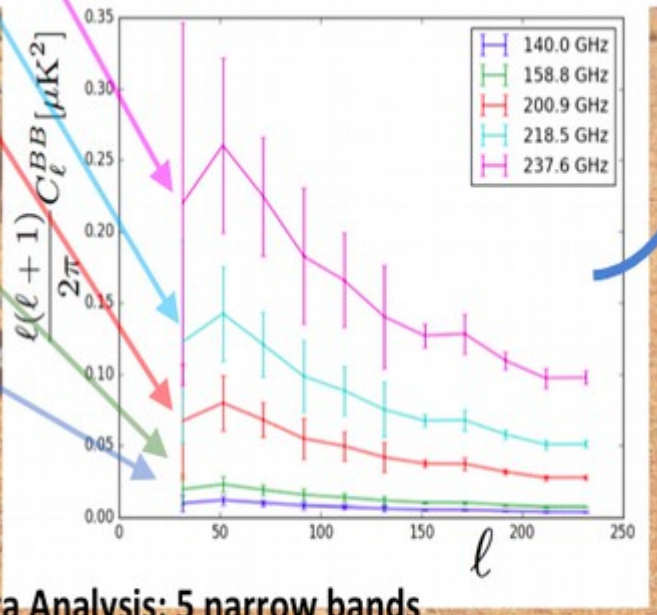




End-to-End Simulation

σ(r)=0.01





Sky:
« Infinite # bands »

Instrument:
2 wide bands

Data Analysis: 5 narrow bands
=> Increased Spectral Resolution
=> Improved Dust subtraction

QUBIC Deployment plan

- **2017-2018 : at APC**
  - Integration started
  - Early 2018: Technological Demonstrator (reduced QUBIC)
    - 1/4 focal plane, 64 horns, small mirrors
  - April 2018: Upgrade to full size mirrors and 400 horns

→ In-lab Demonstration of Bolometric Interferometry

- **2018 : Argentina**
  - mid-2018: Integration with mount, Installation on site
  - First Light Sept. 2018 with ¼ focal plane

→ On-Sky Demonstration of Bolometric Interferometry

- **2019 : Argentina**
  - Upgrade to QUBIC 1st module (2 focal planes 150 and 220 GHz)
  - First Light March 2019
  - Data taking: 2-3 years σ(r)=0.01

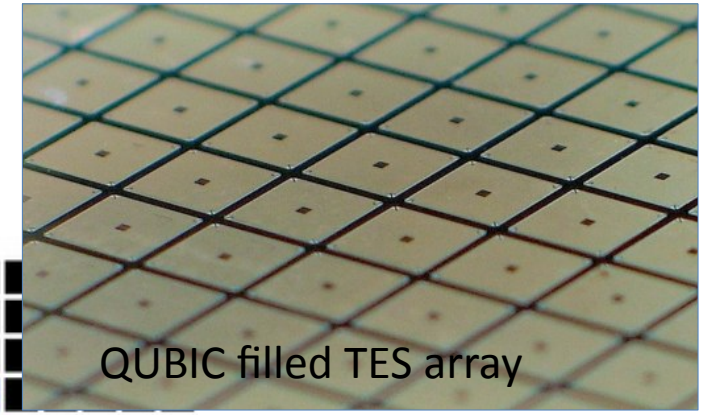
→ Stage III σ(r)=0.01

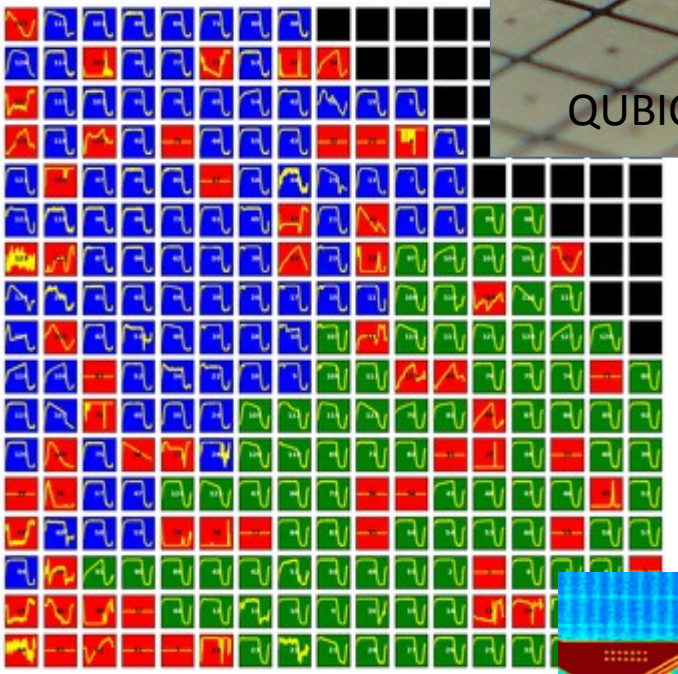
- **2020-… : QUBIC evolves towards Stage-IV**
  - European extension of the collaboration
  - Improved designs already being investigated
  - Excellent quality site open to development

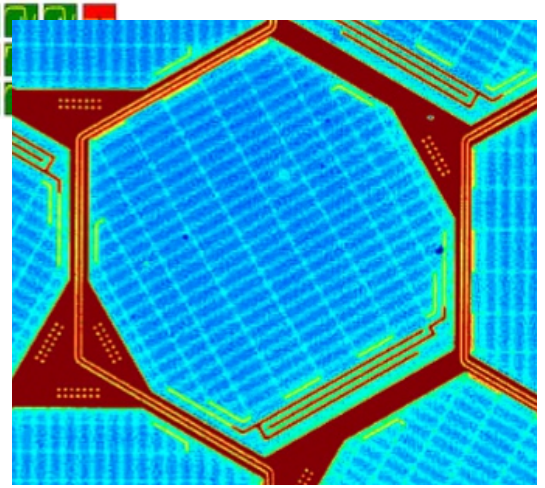
→ Evolution to Stage IV σ(r)=0.001

Millimeter-Wave Laboratory Activities

- QUBIC:
  - Instrument definition
  - Detection chain architecture
  - Cold readout electronics
    - Cryogenic SiGe ASIC
    - TDM 128->1: **world premiere**
  - TES characterisation
- Polarisation sensitive KIDs
  - Test set-up
  - First samples

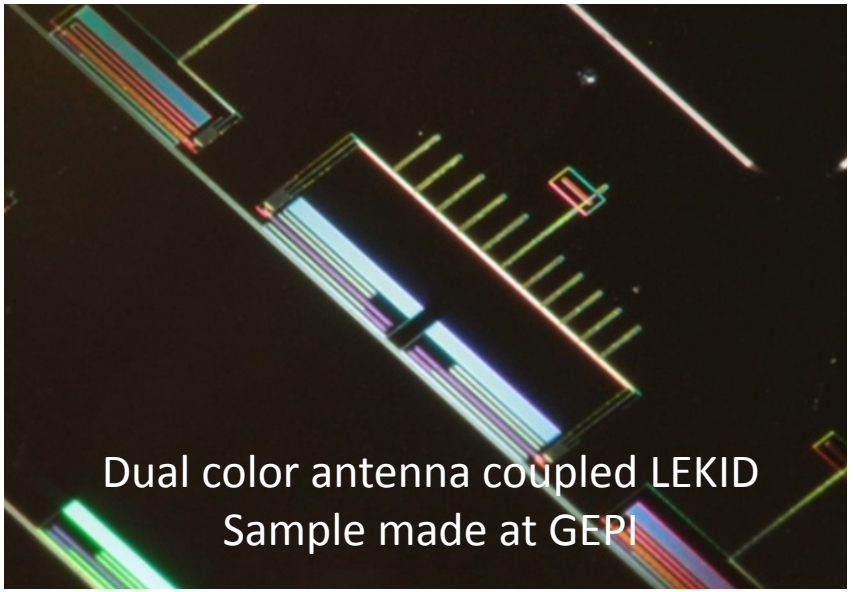

QUBIC filled TES array

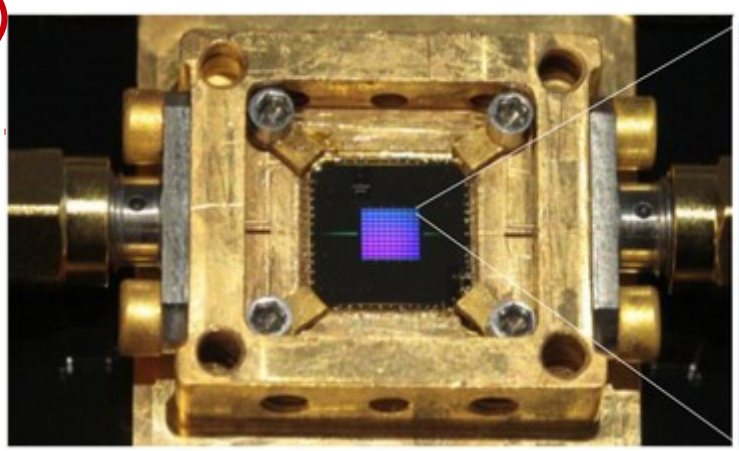

C fiber signal on QUBIC TESs

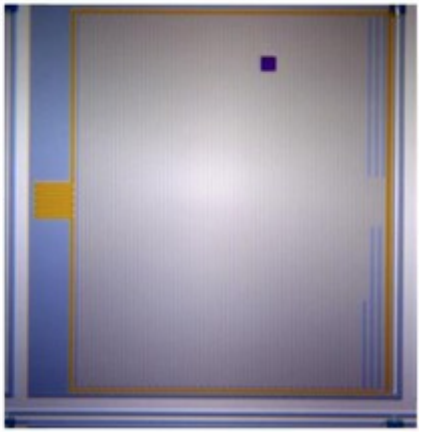

Polarisation sensitive LEKIDs

Millimeter-Wave Laboratory Future

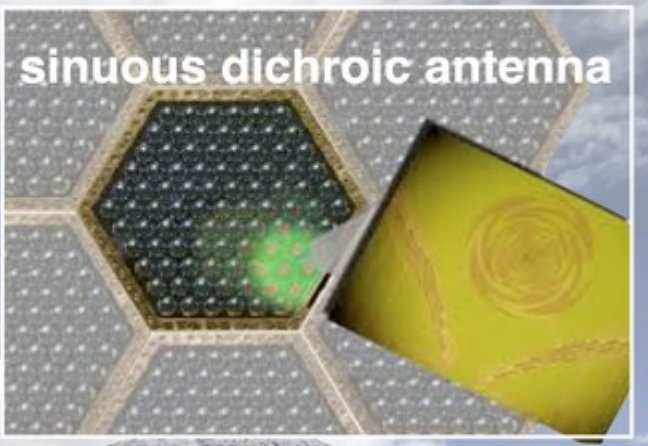
- Faster TDM ASIC
- Antenna coupled multichroic LEKIDs
- Projects:
  - Near term: QUBIC
  - Medium/Long term:
    - ground-based experiment S4-like
    - space mission (LiteBird, CORE)
- Visible and near-IR KIDs
  - GEPI leader







Simons Array (2018-2020)
(= POLARBEAR phase II)



+ continuously rotating HWP

Basic facts

- "extended POLARBEAR";
- 3 x 3m Gregorian telescopes ➤ 3.5'@150GHz,
- multifrequency: 95, 150, 220, 270GHz
- ~25,000 multichroic, polarization-sensitive, TES detectors;
- Operations: 2018 till 2020
- Science goals: $\sigma(r) = O(10^{-2})$, $\sigma(\Sigma m_\nu) = O(40meV)$

POLARBEAR telescope

95+150GHz

220+270GHz

95+150GHz

APC involvement

- remote observations;
- pipeline development and validation;
- leadership of the component separation effort (J.Errard);
- co-leadership of the map-making effort (R.Stompor);
- co-leadership of the lensing estimation work (D. Beck).

Simons Observatory

- A new project supported by Simons Foundation and combining two major current experiments: POLARBEAR/Simons Array and advACT.
- It will feature multiple telescopes with range of apertures (1- 6m) and O(10^5) multi-chroic detectors.
- It will operate from the Atacama Desert in Chile;
- The first light is expected in 2020.
- It will be a precursor for Stage IV experiments.
- It targets: $\sigma(r) << 10^{-2}$, $\sigma(\Sigma m_\nu) < O(35meV)$, but it science ranges from clusters to primordial gravitational waves.
- It is an open collaboration actively searching for foreign partners.

@APC

- The PB/SA group at APC involved since 2016 and has an 'essential' member status (absolved of yearly 'buy-in' fees);
- Involved in (co)-coordination of the science activities (membership of the *Scientific Planning and Pipeline and Data Management Committees, coordination of the Working Groups*);
- Discussion started with SO about a potential APC/IN2P3 hardware involvement.
- Could be a stepping stone for the APC, IN2P3 and French CMB community to S4.

LiteBIRD- CMB polarization satellite mission

JAXA-led CMB polarization mission which is undergoing phase A study in Japan (PI. M. Hazumi) as part of JAXA's strategic mission program. It is expected to be launched as early as in 2026/27.

LiteBIRD is an international collaboration involving researchers from Japan, US (PI: A. T. Lee) and Canada (PI: M. Dobbs).

LiteBIRD's main science objective is to characterize large-scale CMB polarization with unprecedented precision enabling it setting an upper limit on the tensor-to-scalar ratio of $\sigma(r) \sim 10^{-3}$.

LiteBIRD is designed to measure what really has to be measured from space, providing opportunities for numerous and fruitful synergies with suborbital CMB and other (21 cm, galaxy survey) efforts.

LiteBIRD at APC

At APC the LiteBIRD group is composed of 7 permanent researchers and 2 research engineers.

The involvement of the APC researchers in LiteBIRD dates back to 2014. Since then we have made major contributions to the project via LiteBIRD's Joint Study Groups studying impact of instrumental effects (HWP, etc) and astrophysical foregrounds on performance of the mission.

The APC group has been instrumental in setting up the LiteBIRD-France collaboration and coordinating its work since its inception. APC researchers currently hold co-spokesperson and scientific coordinator functions nationally. We are also well-positioned to play important roles on the European level.

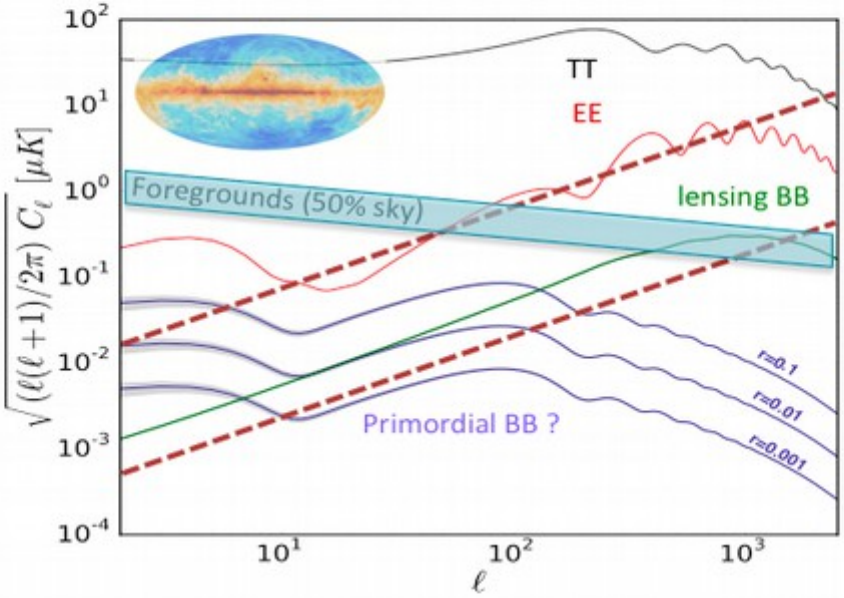
Envisaged hardware contributions from APC are in the area of warm read-out electronics, building on the extensive expertise of the Lab acquired from work on QUBIC and Athena.

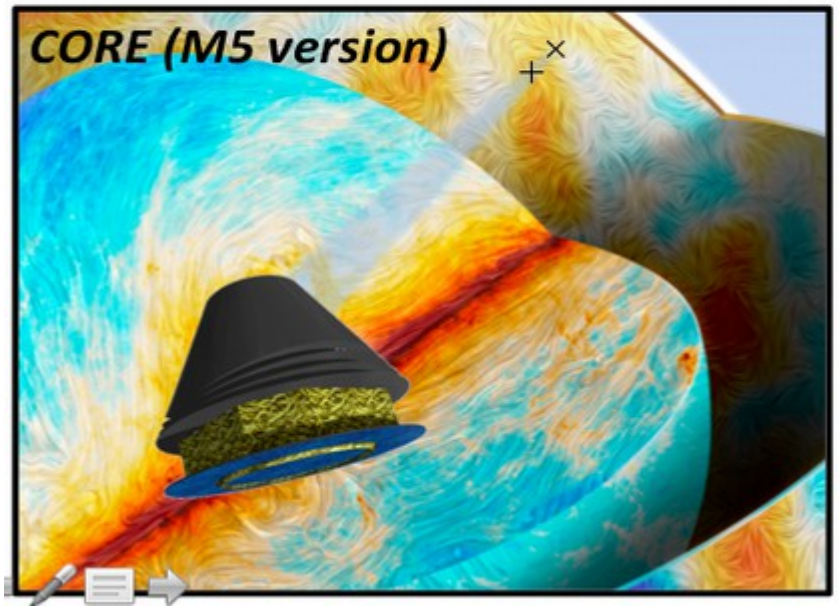
We also plan on making significant contributions to a development of data analysis pipeline and data management layer building on our experiences gained from the Planck and POLARBEAR work.

CORE and "post-CORE-M5" options

Primordial BB is uncertain (risky target):
- *foregrounds* are a potential killer at l < 10;
- *lensing* and foregrounds are issues at l≈80 ;
- *r could be << 0.001,* beyond detection capability.

CORE avoids these risks by targeting:
- primordial B-modes *down to fundamental limits,* after both de-lensing & foreground subtraction;
- *guaranteed* high-value CMB polarization science;
- *guaranteed* rich legacy.





Status in 2017

CORE did not pass the ESA technical and programmatic screening for M5 in January 2017. The main issue was cost.

Drastic reductions of mirror and focal plane sizes do not solve the issue. An international partner seems necessary.

Activity for the coming 1-2 years (2018-2019)

Investigate partnership with India for a joint mission to be launched post 2027 (e.g. in ≈ 2030). Encouraging preliminary contacts in 2017.

Involvement of CORE consortium members to NASA CMB Probe study, in preparation for participation in a US-led mission post-2030.

Recent LSST News

- Contribution to the Construction:
  - Camera Command Control System Architecture — Eric Aubourg
  - Development of the Core of the Code — Etienne Marin-Matholaz
    - This provides test-bed support for all sub-systems;
  - Filter changer control system (FCS) development — Françoise Virieux
    - This includes a full-scale model at LPNHE
  - Construction Coordination in France — Eric Aubourg
- Scientific Preparation:
  - Cluster analysis preparation – Bartlett, Penna-Lima, Ascaso
  - Multi-survey lensing analysis preparation & probe combination preparation – Aubourg, Rosset, Ganga, Doux, Penna-Lima, Aubourg

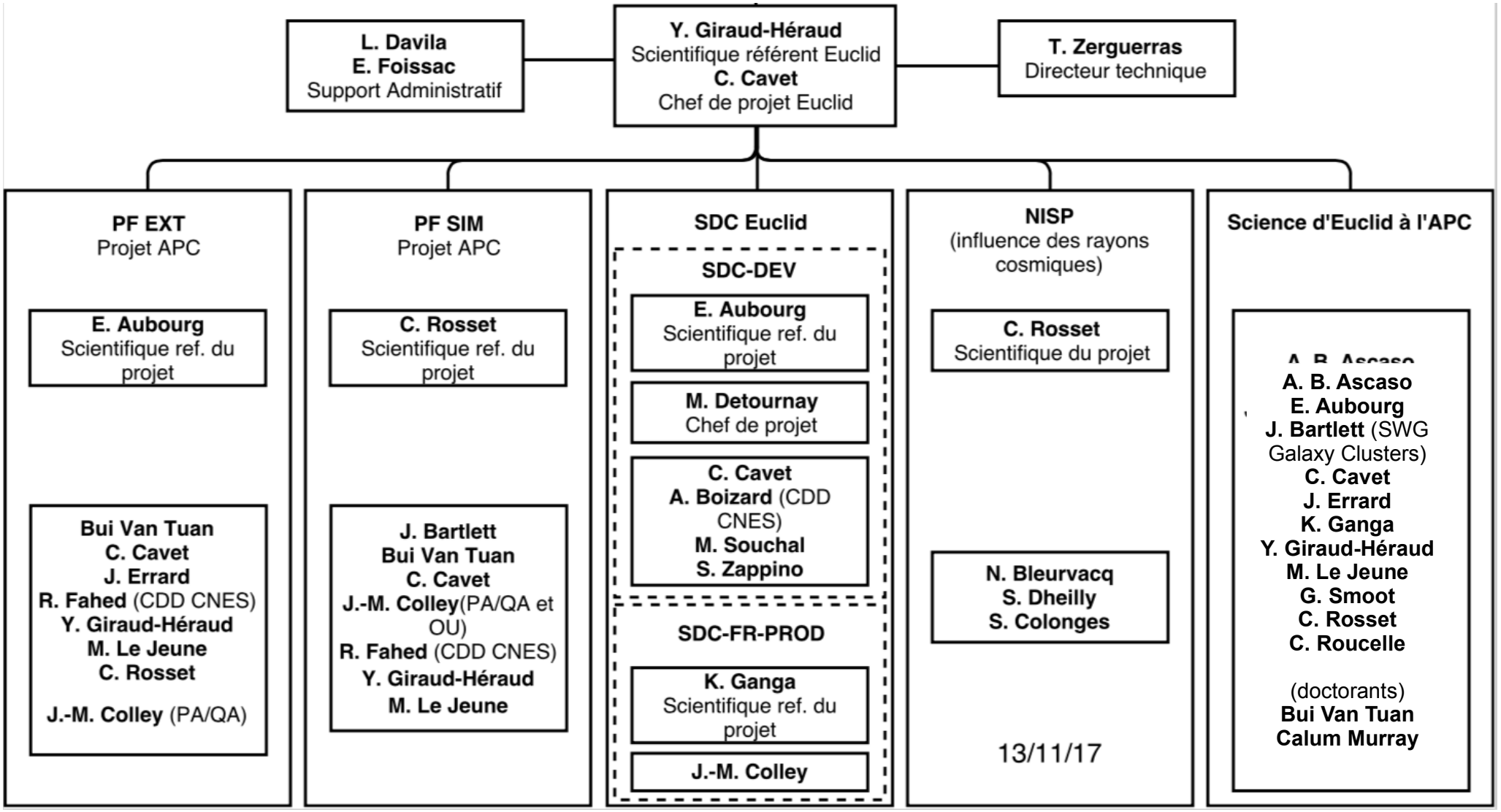
LSST 2018 –

- Construction
  - The project will soon move from construction to integration, and from SLAC to Chile
  - Construction of the filter changer at LPNHE, Filter Change System & Camera Command System
- Scientific Preparation
  - Cluster Cosmology (ANR project led by Bartlett)
  - Preparation of multi-survey joint LSST/Euclid analysis: deblending, combined shear measurement with machine learning (ERC project led by Aubourg)

Euclid

- ESA's M2 cosmology mission: the near-term successor to Planck.
- Launch expected in 2021, with 7 years of operations.
- APC is contributing to the Euclid External, Simulations, Photometric Redshifts, CMB Cross-Corr...
- Pre-Launch NISP Radiation Testing
- Euclid-France's “Software Development platform” is developed by APC, the IN2P3 and others
- Co-lead of, and contributors to, Galaxy Cluster SWG
- APC provides the Euclid-France SDC Reference Scientist/CCIN2P3 scientist

Euclid@APC Organization



Work with LSST

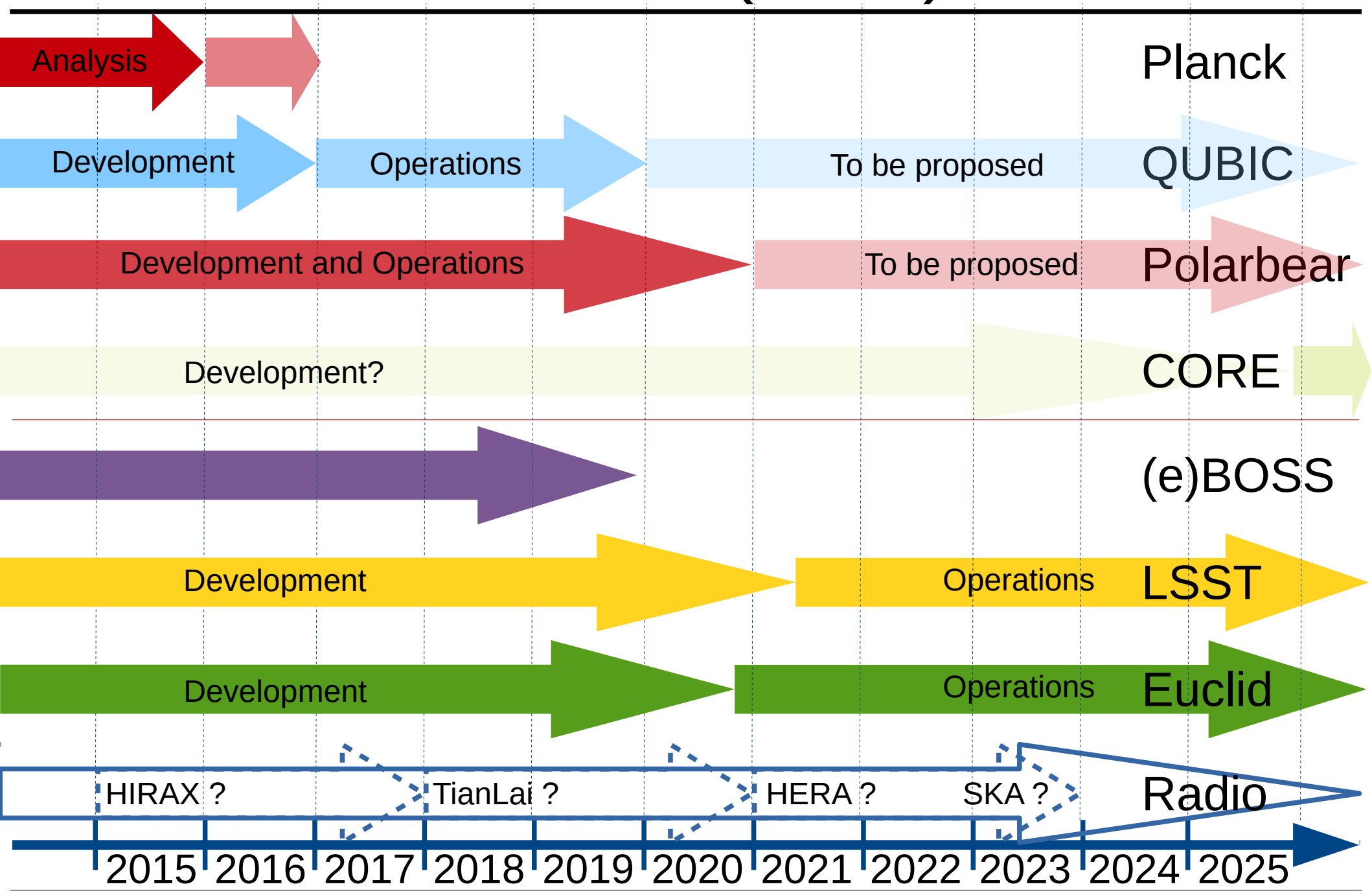
Simu-lations

Project Support

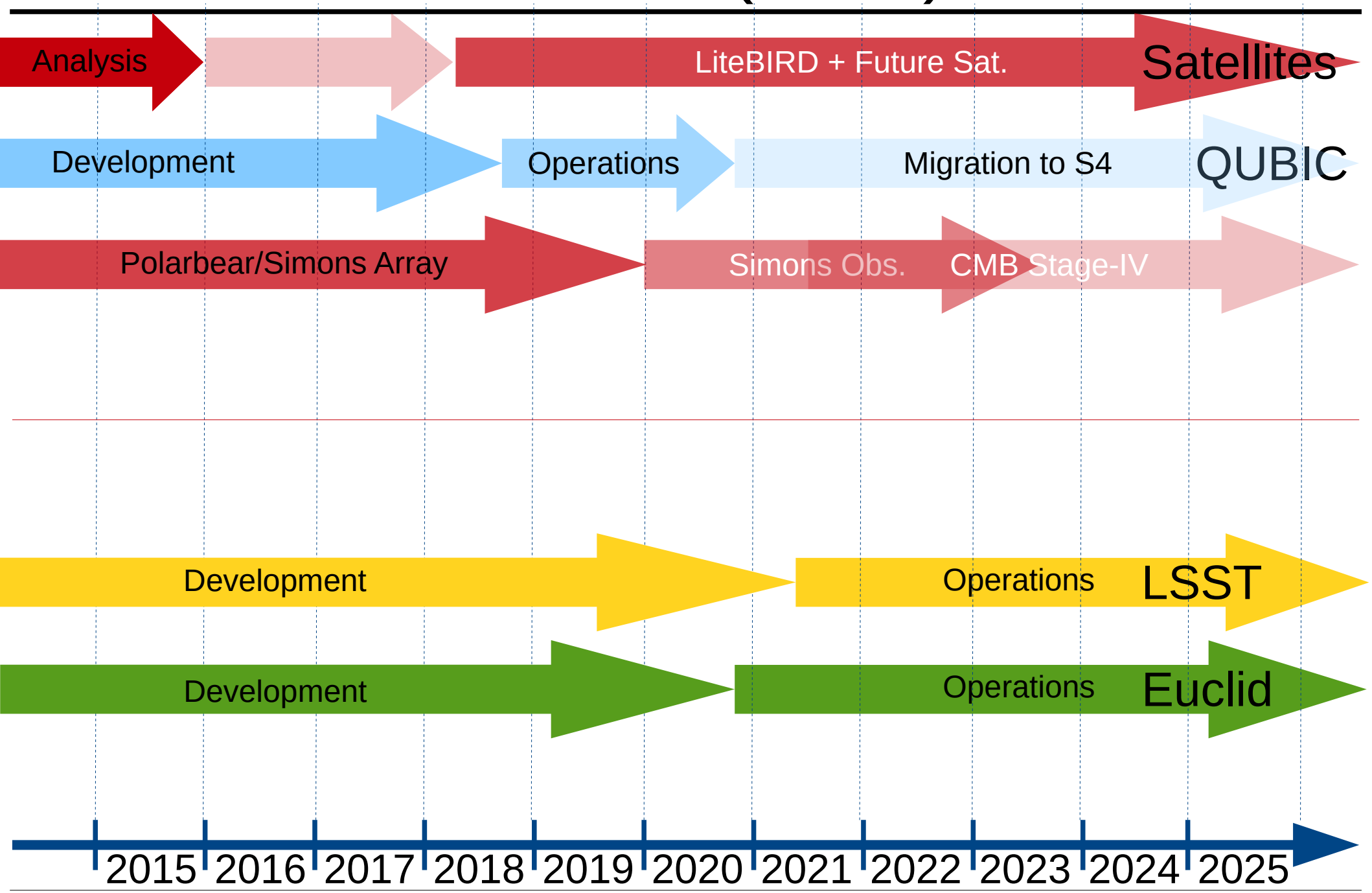
Cosmic Ray Tests

"Science"

Timeline (2015)



Timeline (2017)



Thanks!