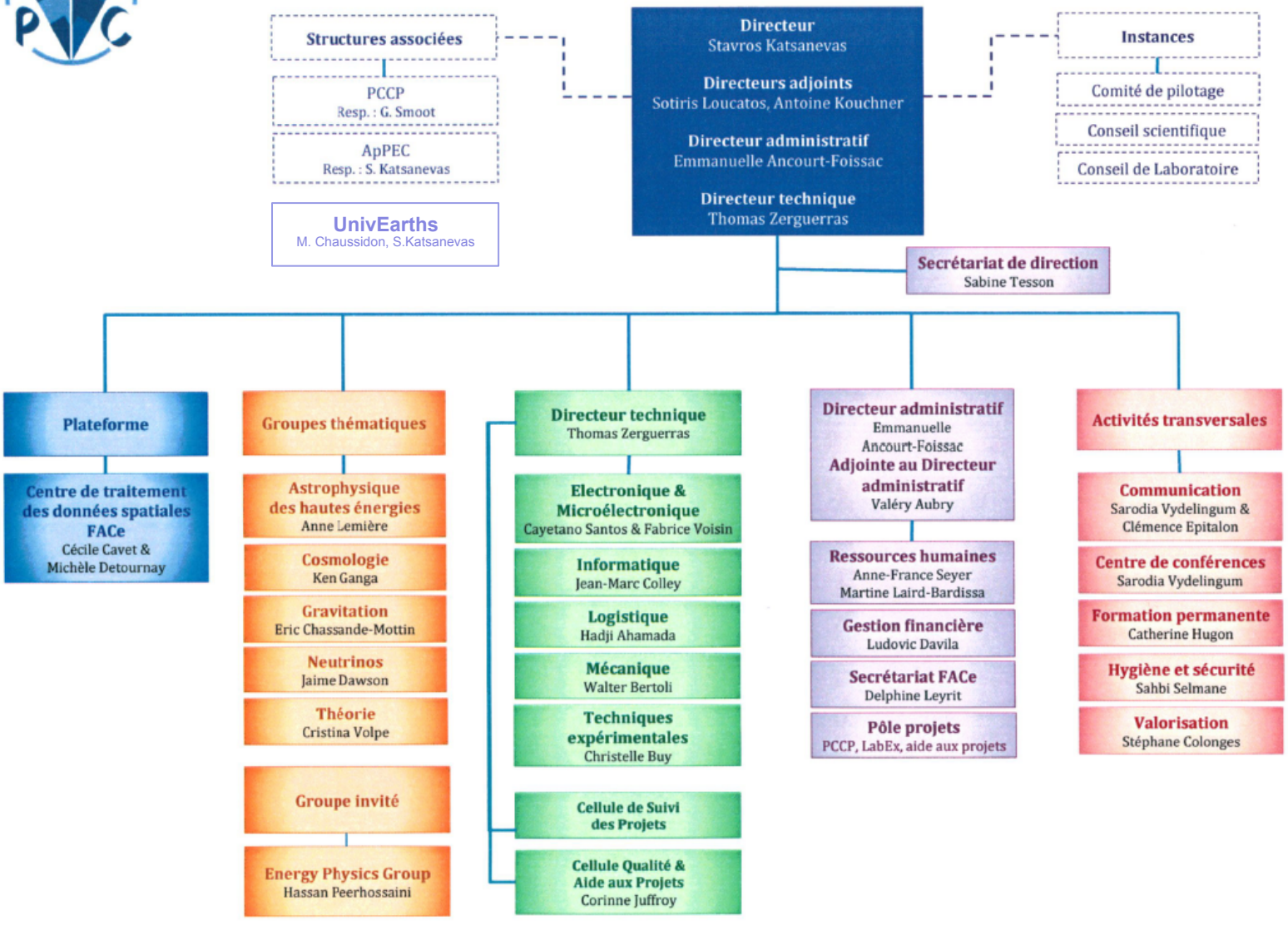
Laboratoire Astroparticule et Cosmologie (APC)
UMR 7164

IN2P3, Univ. Paris Diderot, CEA, Observatoire de Paris

Stavros Katsanevas

Créé en 2005

AstroParticule et Cosmologie - UMR 7164



Laboratory composition

Composition Labo | Répartition par organismes | Pyramide des âges | Chercheurs | IT | EAOM

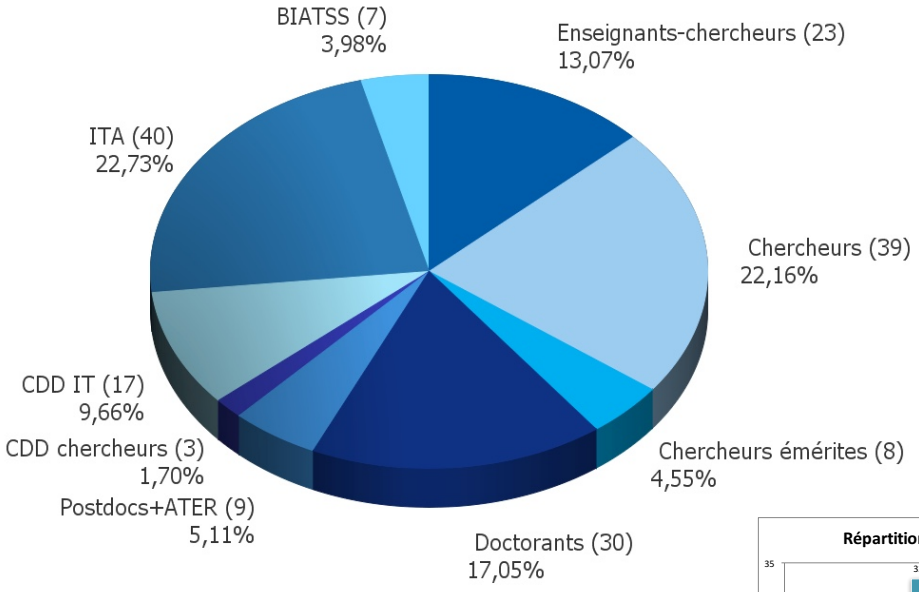
Composition Labo | Chercheurs / IT | Hommes / Femmes | Permanents / Non permanents | Permanents / CDD / Doctorants

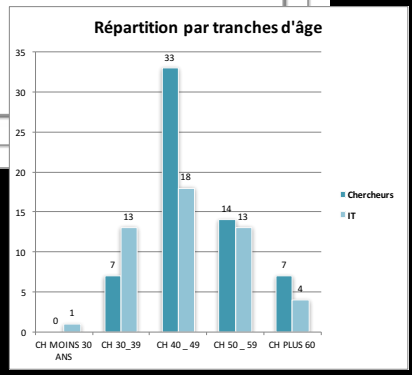
TOTAL personnel APC : 176

Total Chercheurs :	**112**
Chercheurs :	39
Enseignants-chercheurs :	23
Chercheurs émérites :	8
Postdocs+ATER :	9
CDD chercheurs :	3
Doctorants :	30

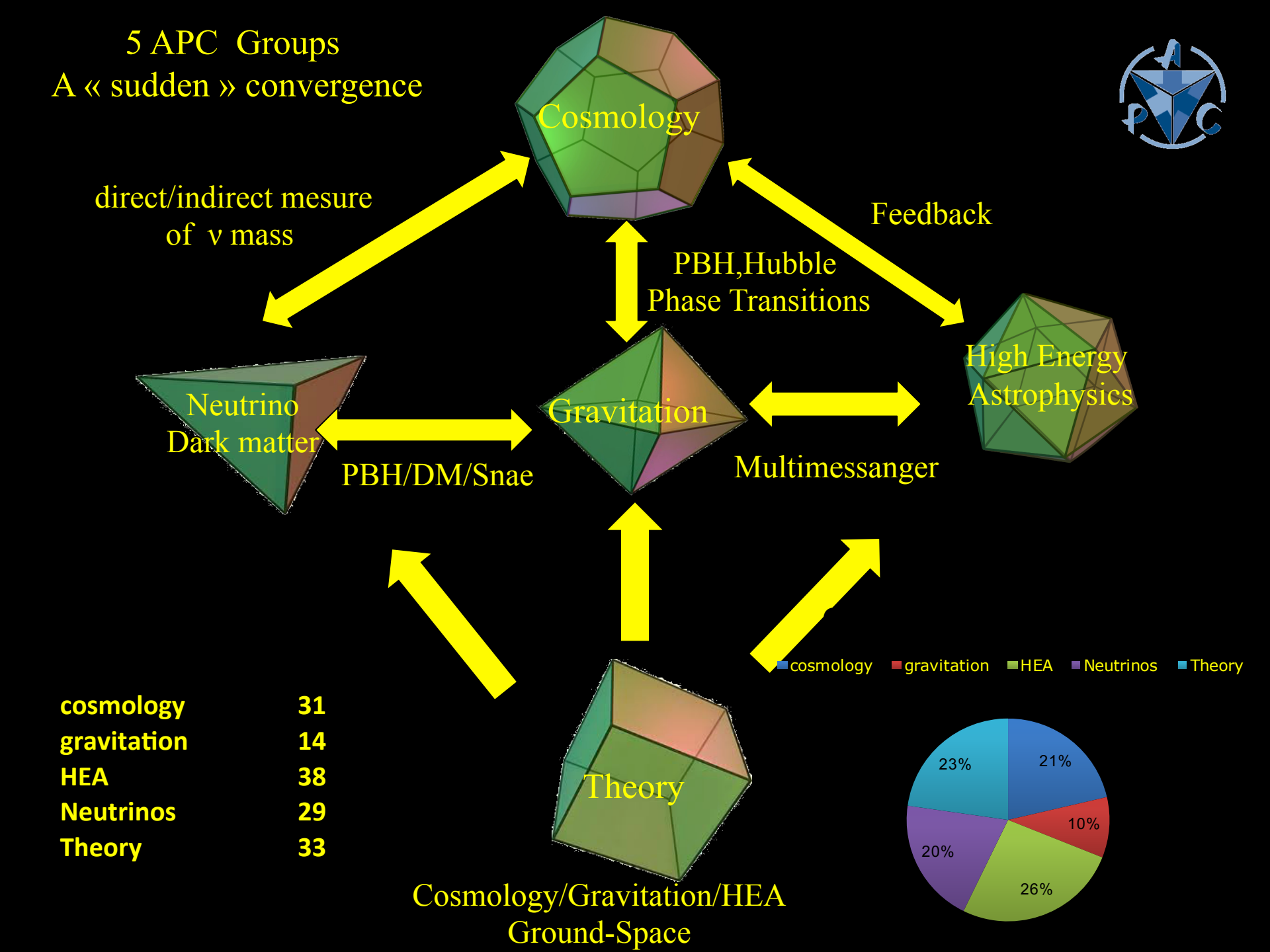
Total IT :	**64**
ITA :	40
BIATSS :	7
CDD IT :	17

Composition du Laboratoire APC (176 personnes) - 17/11/2017





5 APC Groups
A « sudden » convergence



cosmology	**31**
gravitation	**14**
HEA	**38**
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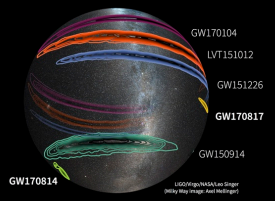
Theory	**33**



Gravitational Waves
Ground-Space complementarity @APC

The Gravitational Wave Spectrum

Sources

Big Bang

Supermassive Black Hole Binary Merger

Compact Binary Inspiral & Merger

Extreme Mass-Ratio Inspirals

Pulsars, Supernovae

age of the universe

years

hours

seconds

milliseconds

Wave Period

10^{-16} 10^{-14} 10^{-12} 10^{-10} 10^{-8} 10^{-6} 10^{-4} 10^{-2} 1 10^{2}

Wave Frequency

Detectors

CMB Polarization

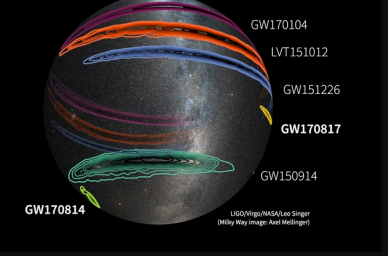
Radio Pulsar Timing Arrays

Space-based interferometers

Terrestrial interferometers

LISA

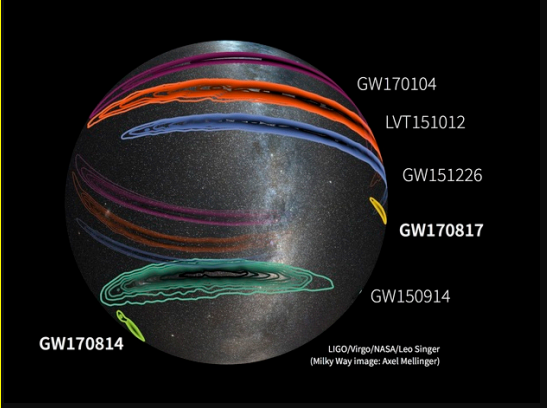
advVIRGO



Gravitational waves

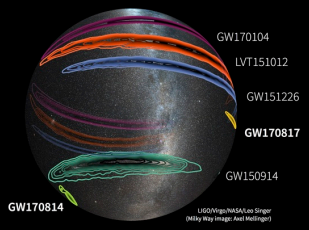
A well defined roadmap : advVirgo+ and LISA

- ✓ **Highlights of APC contributions**
  - ✓ advVIRGO
    - ✓ Beam adaptation telescopes
    - ✓ Leadership in comissioning and analysis groups
    - ✓ Organisation responsibility of many seminal papers since 2015
    - ✓ Interdisciplinarity with Geosciences
  - ✓ LISA
    - ✓ Introduction and leadership of French participation to LISA (since 2004)
    - ✓ Tests and data analysis for LISAPathfinder
- ✓ **Future perspectives and short term milestones**
  - ✓ advVIRGO
    - ✓ ***Preparation of O3***
    - ✓ Analysis implication in multimessenger physics (ASTERICS)
    - ✓ R&D for advVirgo+ : Laguerre-Gauss , FDS
    - ✓ Interdisciplinary studies with Geoscience
  - ✓ LISA
    - ✓ ***Phase A LISA***
    - ✓ Responsibility of Data Processing Centre
    - ✓ Participation in AIT/AIV
    - ✓ LOT , scattered light R&D



SWOT
Gravitational Waves

Forces	**Weaknesses**
• Ground-Space Complementarity • High Visibility • Role in LISA-France	• Manpower group advVIRGO • Loss of P.Binetruy
Opportunities	**Threats**
• Start of Multimessenger Astronomy • APC scientific environment • Interdisciplinarity with Geosciences	• Loss of FACe expertise for LISA



A “sudden” new convergence

Cosmology

Measurement of cosmological parameters
Primordial Black Holes
CMB Polarisation
Cosmologial phase transitions

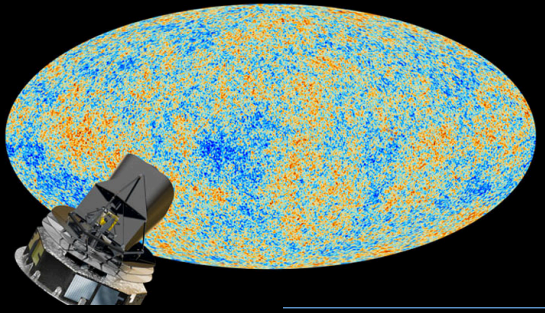
Gravitation

Theory

Modified Gravity tests
Cosmic strings,
mass of the graviton
primordial GW backgrounds

High-energy astrophysics & neutrinos

Multimessenger Astronomy
Understanding of Violent phenomena
Tests of fundamental laws

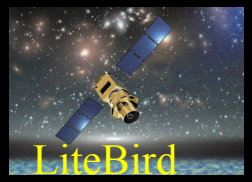


Cosmology
Ground-Space and « near »-« far » complementarity @APC

$z < 2 \times 10^6$
Thermal history
(energy injection into the CMB)

$z \approx 6\text{-}11$
Reionization

$z \approx 0\text{-}1$
Integrated Sach Wolfe:
Accelerated expansion


LiteBird


Simons Array

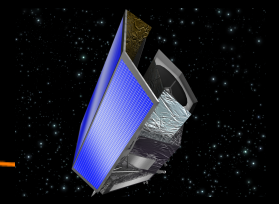

QUBIC

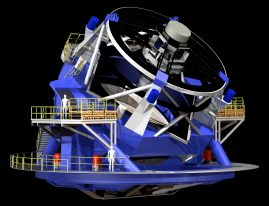
CMB emission

Inflation

Quantum Fluctuations

1st Stars


Euclid

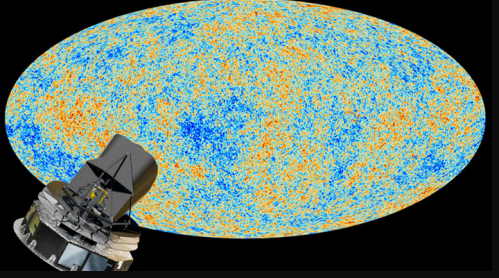

LSST

Inflation
Physics at $\approx 10^{16}$ GeV
$E > 10^{12} \times E_{LHC}$

$z \approx 1\text{-}3$
Gravitational lensing
Dark matter distribution

$z \approx 0\text{-}2$
Sunyaev-Zeldovich effect:
Distribution of the hot gas
and velocity field

- A well defined roadmap for dark energy
- Uncertainties in the European roadmap for CMB on ground and space (CMB-E4,CORE)

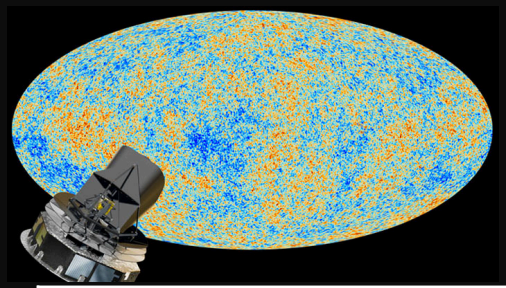


Cosmology

Well defined roadmap for dark energy

Roadmap under construction for CMB

- ✓ **Highlights of our contributions**
  - ✓ Planck contributions to construction/analysis (leadership in key papers 2018)
  - ✓ Leadership in seminal publications in eBOSS, Polarbear
  - ✓ TES test readout and multiplexing ASIC
  - ✓ LSST control and command soft
  - ✓ EUCLID Platform CODEEN
  - ✓ Responsibility of SGS Euclid
- ✓ **Future perspectives and short term milestones**
  - ✓ CMB
    - ✓ ***G2-G3: Technical demonstrator QUBIC in 2018 and full deployment in Argentina in 2019 (technical milestone)***
    - ✓ G3: Participation in Simons Array
    - ✓ G4:
      - ✓ Ground: organisation of European CMB community (CMB-E4)
      - ✓ Space: leadership in European post CORE process (ESA, LiteBird)
  - ✓ Dark Energy
    - ✓ ***Finish LSST-EUCLID contributions by 2019***
    - ✓ LSST-EUCLID exchange of data
    - ✓ Mass of neutrino analysis cosmology vs ground measurement

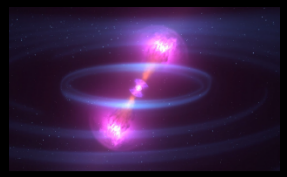


SWOT Cosmology

Forces	**Weaknesses**

• CMB
  • Detector and Readout expertise
  • Data analysis expertise
• LSST
  • Control and command
• EUCLID
  • Pipeline software and SGS
	• DE analysis effort not yet at fulll speed although better than in other french labs
	• CMB: recent losses of key instrumentalist personnel

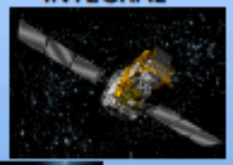
Opportunities	**Threats**
• Forthcoming LSST-Euclid agreement • Large-survey– CMB complementarity • Leadership in many European efforts • High visibility at non-European efforts (e. Simons array, Litebird)	• Not well defined status of QUBIC • No clear European roadmap for CMB, uncertainty encourages dispersion



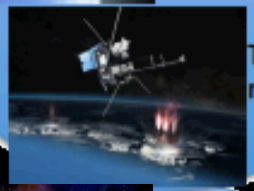
High Energy Astrophysics

1 keV 1 MeV 1 GeV 1 TeV 1 PeV 1 EeV 1 ZeV

INTEGRAL



ASTRO-H



TARANIS microsat

SVOM

SVOM Eclairs GRB trigger

ATHENA

ATHENA

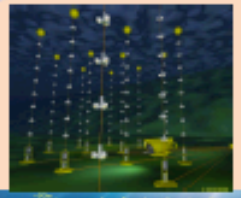
R&D Compton
R&D Gamma Cube

HESS & CTA

HESS- phase II

CTA

Antares & KM3Net



KM3Net

EUSO-ballon & JEM-EUSO

JEM-EUSO

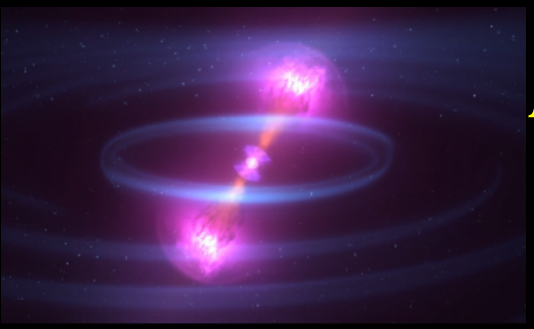
High energy Astrophysics
Space : A rich program (SVOM/ATHENA)
Ground : 2 large ESFRI infrastructures CTA/KM3NeT

✓Highlights of our contributions

- ✓ Multi-wavelength studies of AGNs and Galactic Center
- ✓ Multimessenger studies of GW
- ✓ AHE theoretical studies and simulation
- ✓ TARANIS Leadership in XGRE integration (flight model in 2018)
- ✓ SVOM : coded mask
- ✓ ATHENA Responsibility of WFEE ASIC (end of phase A 2019)
- ✓ HESS : papers on legacy, galactic centre, Vela pulsar, link FERMI
- ✓ CTA : timing distribution and PHP software
- ✓ ANTARES Spokemanship, GW followup
- ✓ EUSO : PDM Integration , technical project manager SPB and mini-Euso
- ✓ R&D Compton DSSSD detectors

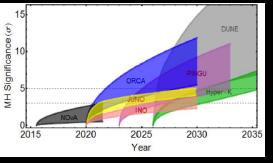
✓Future perspectives and short term milestones

- ✓ ***TARANIS Deliver flight model in 2018***
- ✓ ***Min-EUSO 1 PDM on ISS, launch end 2018***
- ✓ SVOM flight model in 2019
- ✓ ATHENA ASIC WFEE @TRL6 , end of phase A in 2019
- ✓ CTA/KM3NEt: Tics, PHP demonstrators, calibration prototype
- ✓ EUSO SPB2, K-EUSO, POEMMA discussions and selection



High Energy Astrophysics SWOT

Strengths	**Weaknesses**
• Ground-Space complementarity • Space Quality procedures • Large GW followup exeprtise	• Unbalanced ratio of engineers and researchers (inverse on ground and space) • Role of low energy γ , not yet well understood by our agencies
Opportunities	**Threats**
• Multimessenger Astronomy	• TARANIS construction uncertainties • EUSO roadmap uncertainties



Neutrinos (invisibles I)
Reactor, accelerator and cosmic

Flux (cm^{-2} s^{-1} MeV^{-1})

10^{20}
10^{16}
10^{12}
10^{8}
10^{4}
10^{0}
10^{-4}
10^{-8}
10^{-12}

CMB

solar

Supernova

Géological

Reactors

Atmospheric

Cosmic

Energy(eV)

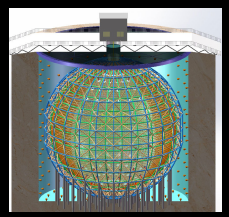
10^{-6} µeV
10^{-3} meV
1 eV
10^{3} keV
10^{6} MeV
10^{9} GeV
10^{12} TeV
10^{15} PeV
10^{18} EeV

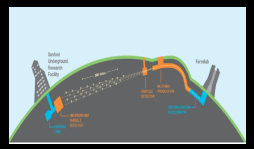
DCHOOZ/JUNO
CeSOX

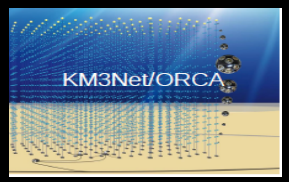
DUNE/ORCA

KM3NEt/ARCA

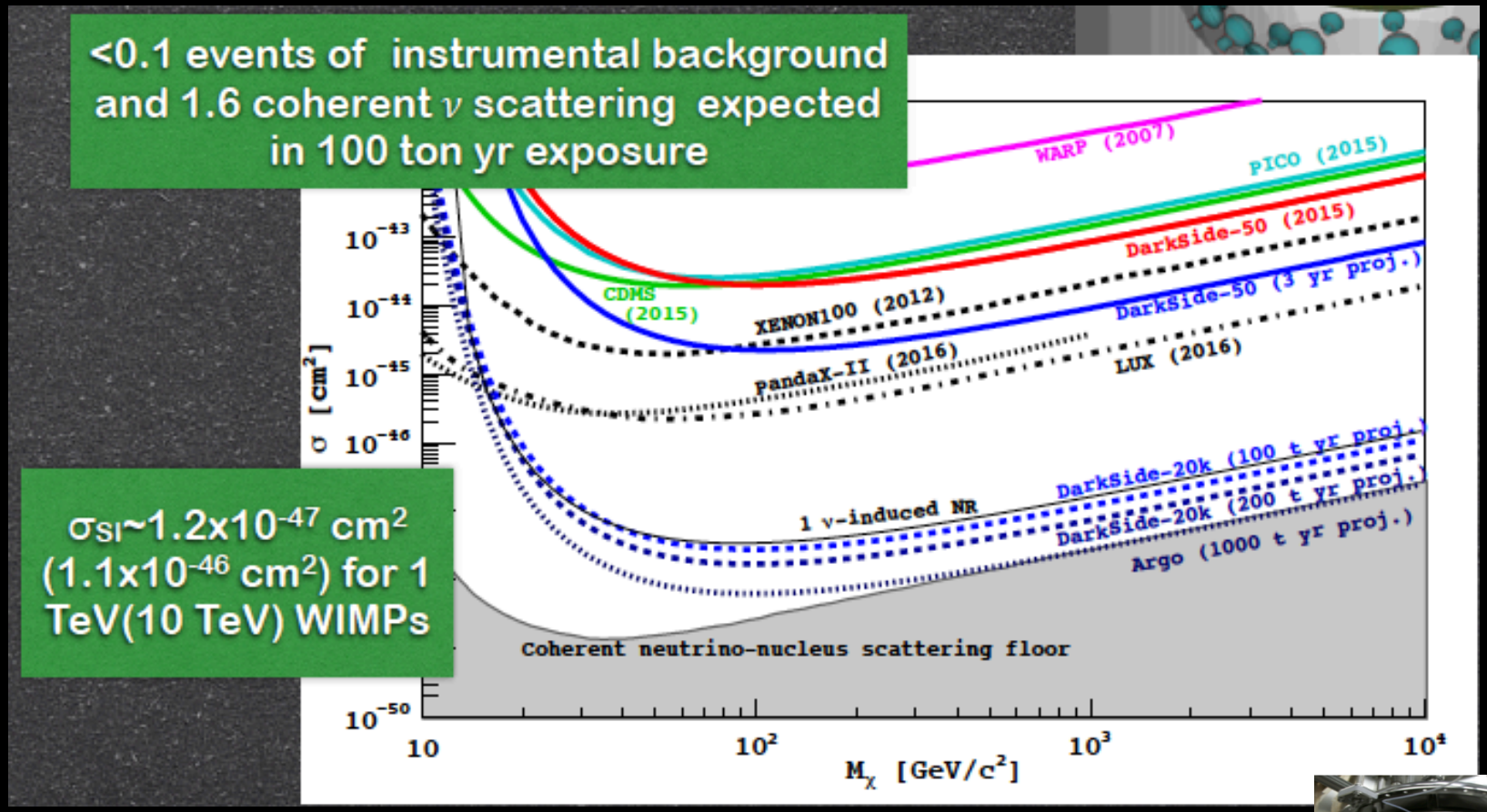
3 techniques:H_2O/Liq Scint/Liq Ar

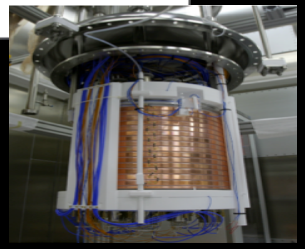






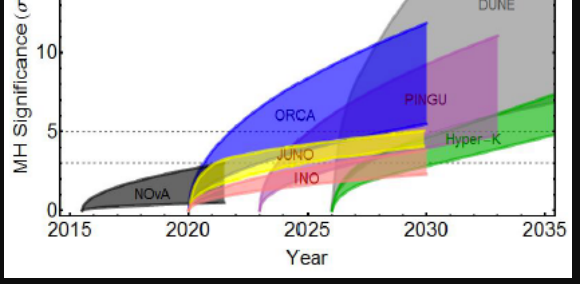
Dark matter (invisibles II)





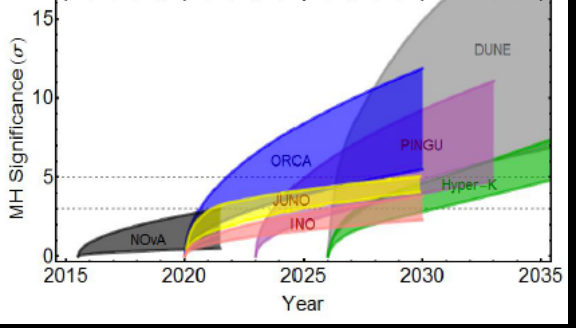
Dark Side

Liq Argon: Dark-Side➔Ds-20k ➔Argo



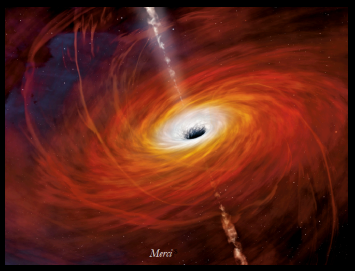
Neutrinos and Dark matter
APC contributions and prospectives

- ✓ **Highlights of our contributions**
  - ✓ DCHOOZ : Spokesmanship, mechanics, analysis
  - ✓ JUNO : The idea of multicalorimetry, DACQ card X-ROC
  - ✓ WA105/DUNE, Global convergence role, Physics coordination, PM DACQ card
  - ✓ KM3Net, NH/IH mass analysis, interdisciplinarity with Geosciences
  - ✓ Borexino/CeSOX, DarkSide detailed simulation
  - ✓ R&D Darkside directionality ARIS
  - ✓ R&D LIQUIDO , chair Blaise Pascal Suekane
  - ✓ Interdisciplinarity Geoneutrinos, Muonic tomography
- ✓ **Future perspectives and short term milestones**
  - ✓ ***DCHOOZ , final results and decomissioning in 2018***
  - ✓ ***WA105 Start of data taking in 2018-2019***
  - ✓ JUNO/WA105/DarkSide CATIROC electronics card (synergies)
  - ✓ R&D advances LIQUIDO, ARIS
  - ✓ Deployment of ARCHE (muography)



Neutrinos and dark matter SWOT

Strengths	**Weaknesses**
• Expertise Liquid scintillators • Electronics card expertise • Simulation • Visible responsibilities	• Small number of researchers per project (except KM3NEt) • Insufficient manpower in electronics engineers
Opportunities	**Threats**
• Synergy of measurements of neutrino mass hierarchy in neutrino and with cosmology • Good position in Argon Global collaboration for Dark matter • Interdisciplinarity with Geosciences	• Budget ORCA and DUNE • Liquid Argon for DM not yet a national priority



Theory

- **Cosmology, Gravity, String Theory (1ERC senior) :**
  - **Inflation, dark energy and cosmological perturbations**
  - **Topological defects**
  - **General relativity, modified gravity theories**
  - **Gravitational waves**
  - **Duality, Holography**

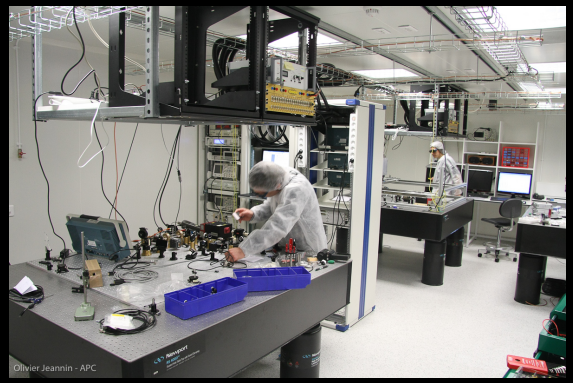
- **Astroparticle physics and neutrino:**
  - **Neutrino physics and astrophysics**
  - **MHD and propagation simulations**
  - **Cosmic rays**

- **Quantum Field Theory (QFT) :**
  - **Non-abelian gauge theories and deconfinement,**
  - **QFT in curved geometries,**

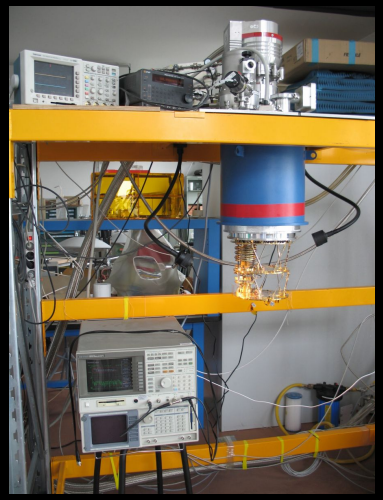
Theory SWOT

Strengths	**Weaknesses**
• Good internal organisation • International Visibility • APC very active meeting place, international insertion • Among largest theory groups in IN2P3	• The phenomenological bridge although in good progress needs further strengthening given the opportunities
Opportunities	**Threats**
• New environment after GW discovery • Multi-messenger context	• Not enough career opportunities of promotion for our Maitres de Conference

Technical labs



Salle blanche ISO8 (128m²):
- **Salle intégration**
- **Salle LISA**
- **Salle VIRGO**



Laboratoire Millimétrique: Cryostat à dilution 100mK (Oxford Instrument)
(Puissance de refroidissement : 160µW @100mK,
Pas de fluide cryogénique)

Laboratoire Photodétection

Hall de montage

Atelier mécanique

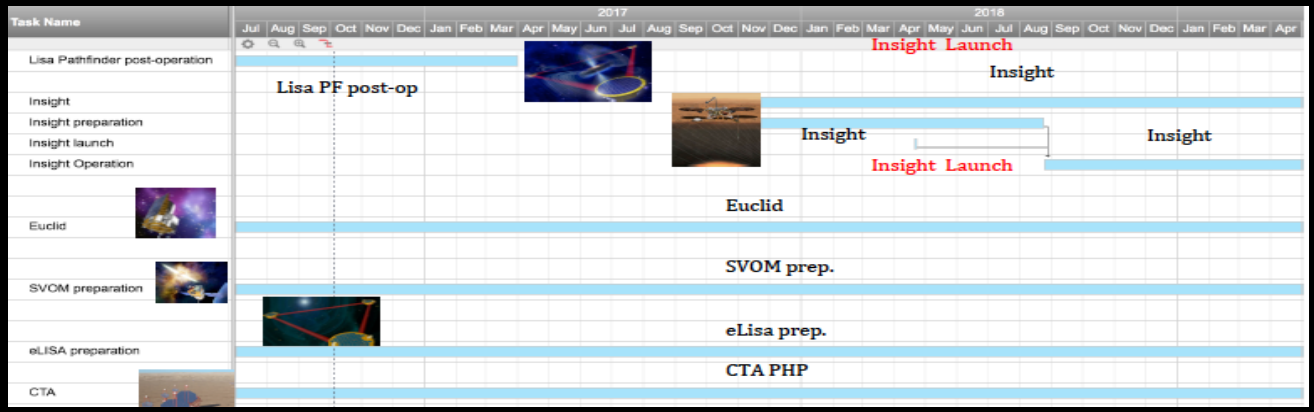
Salle bas bruit (37,5 m²) avec cage de Faraday pour tests de composants et circuits électroniques (0.1mHz et 10Hz)

Imprimante 3D Stratasys Fortus FDM250mc
(thermoplastique ABS stable)

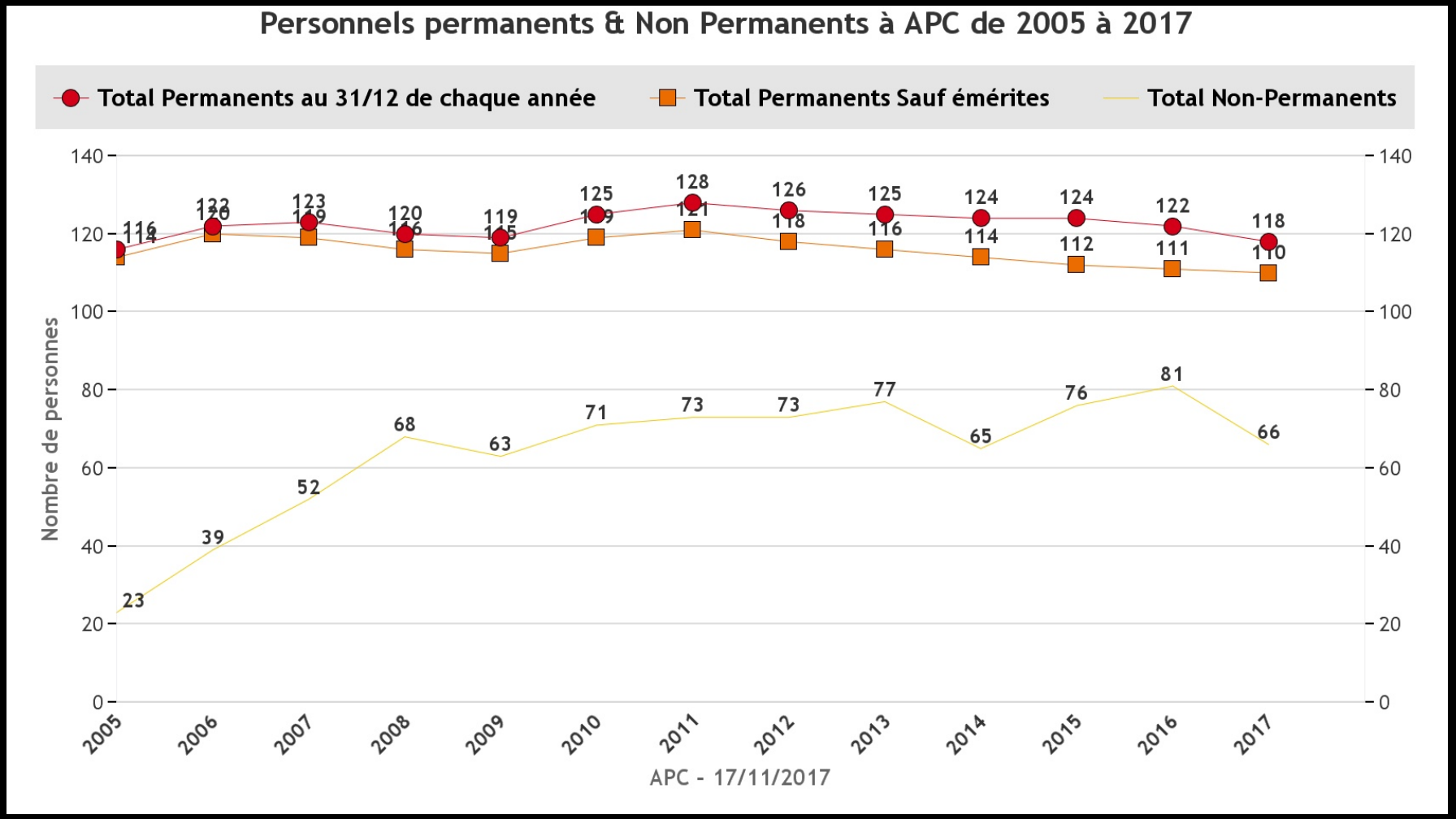
FACe (François Arago center)
Data Science Platform

- ✓ APC data analysis center for space missions (since 2010).
  - ✓ 650 CPU, 40 TB, team of 10 agents
  - ✓ Offices, meeting rooms, video-conference rooms, computing room, CDF.
  - ✓ Location: Biopark but moving to Condorcet and IPGP in 2018
  - ✓ Strong link with the **CC-IN2P3.**
- ✓ **Achievements, exemples of activities and projects**

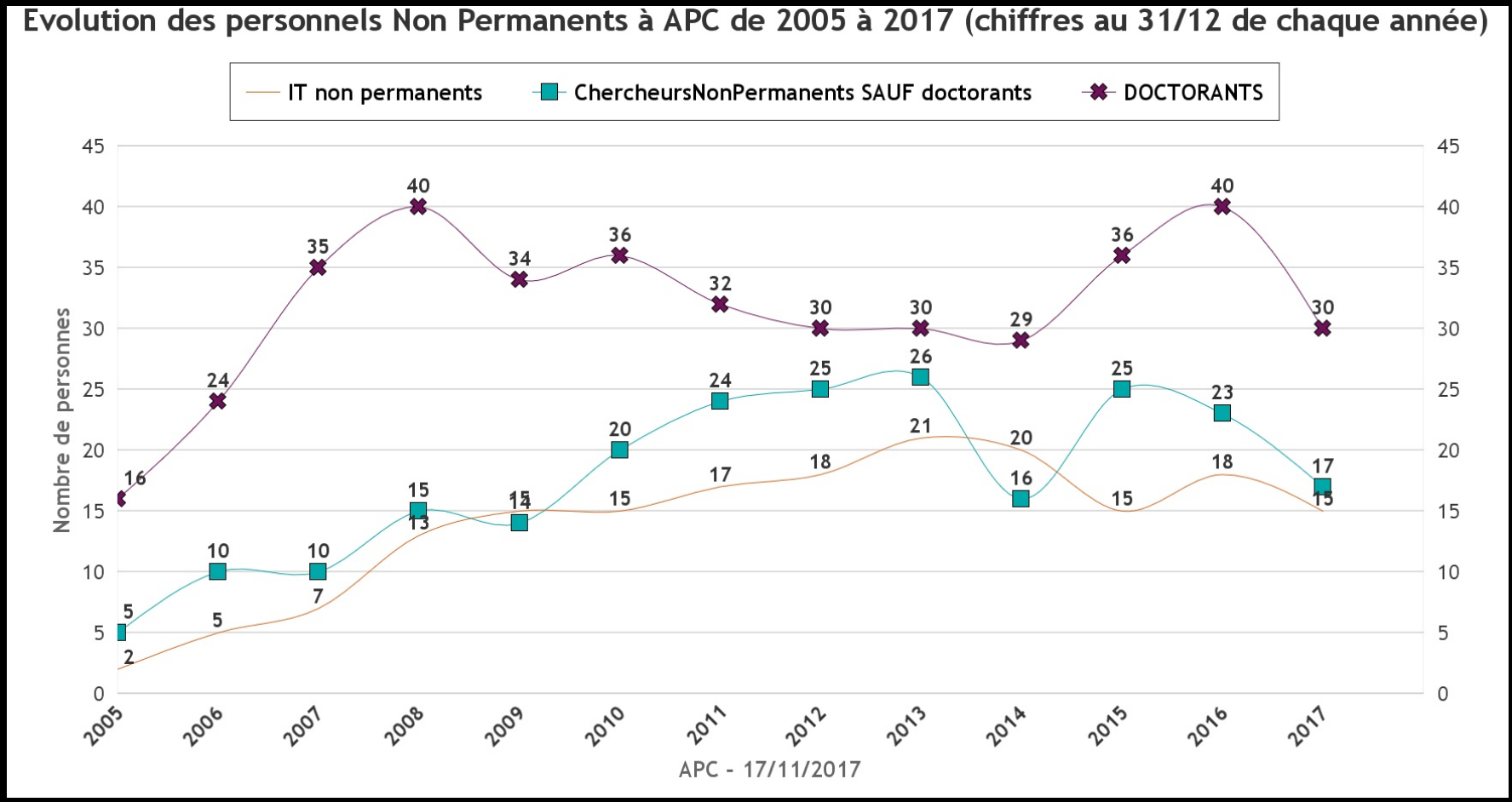
- PLANCK Sky model , and QUBIC preparation
- EUCLID Collaboration platform CODEEN, LSST Slow Control software
- CTA Proposal Handling Platform,
- VIRGO Mutimessenger studies: ASTERICS (I3, EU), INTEGRAL Follow-up GW ,
- MHD computing
- Future
  - LISA Phase A and DPC
  - SVOM ➔ ÉCLAIR pipeline et quick look



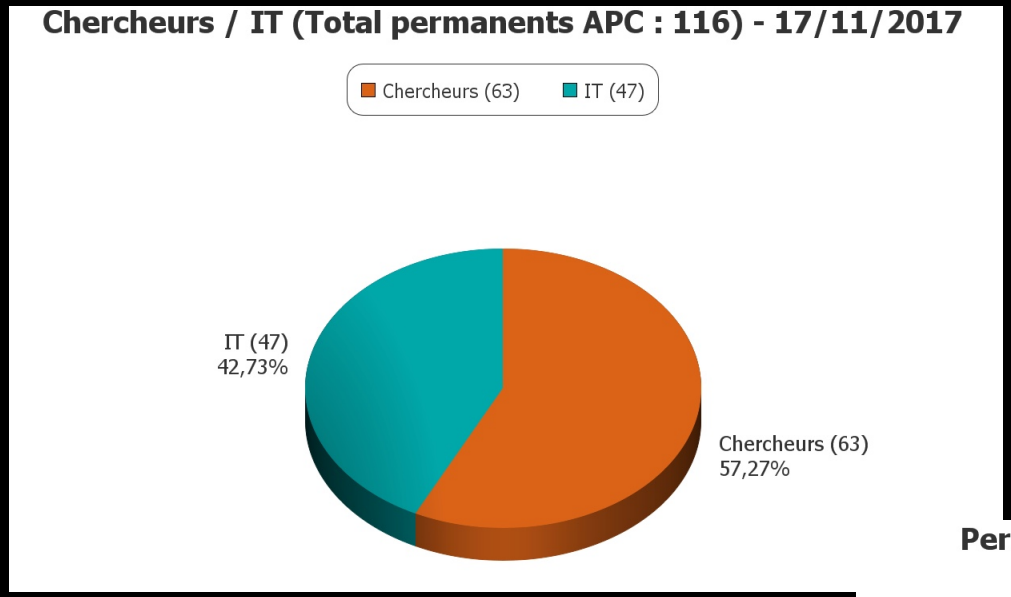
Permanent personnel overall stability

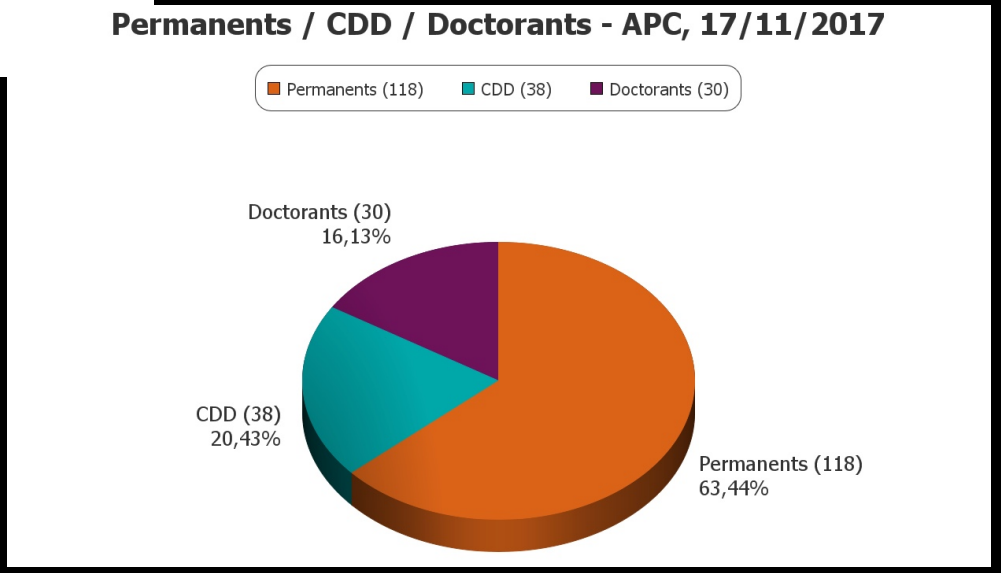


Doctorates , postdocs and non-permanent engineers
Temporary, epochal diminution ?

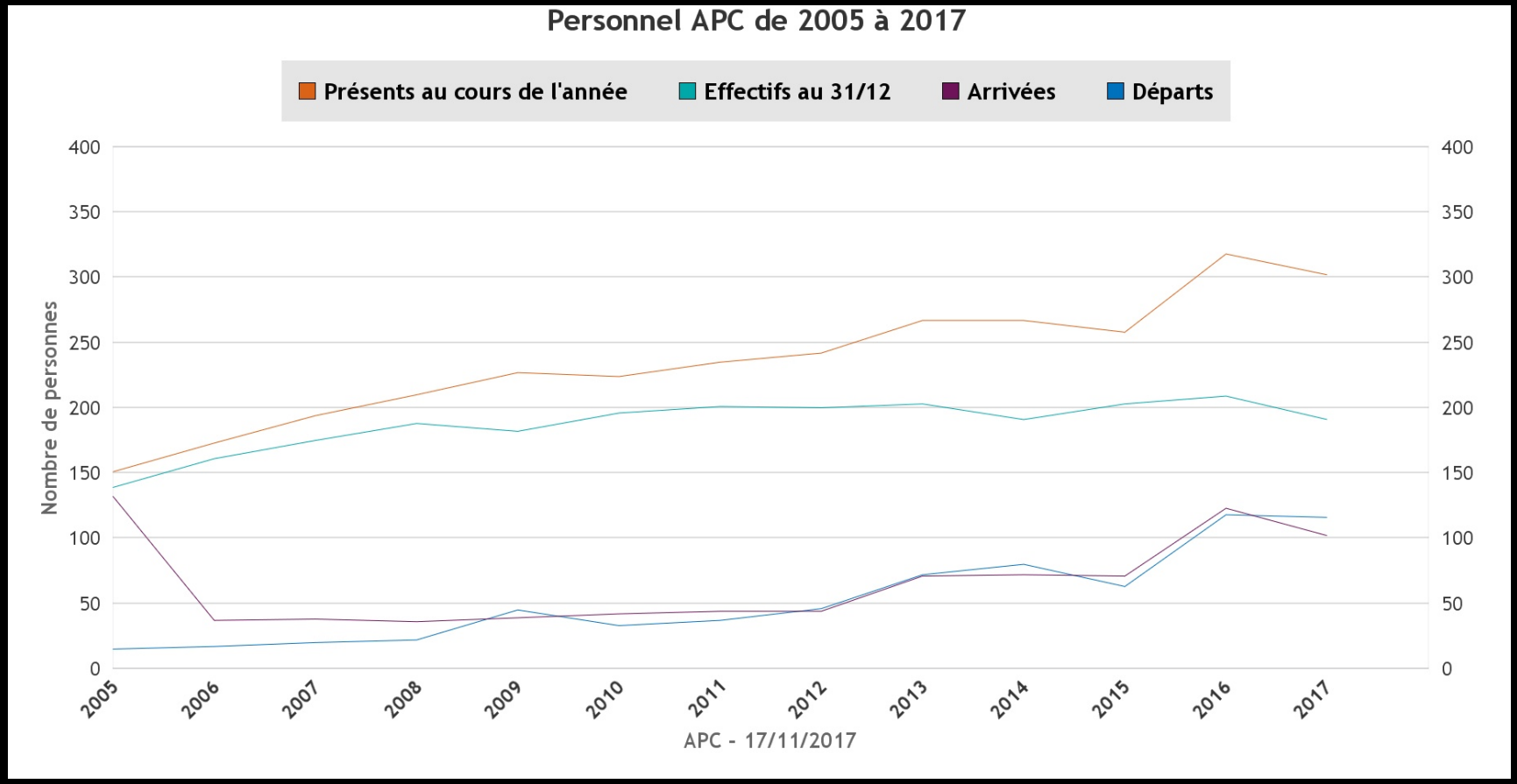


The smallest ratio of engineers to researchers in permanent stuff And the highest ratio of non-permanent to permanent in IN2P3

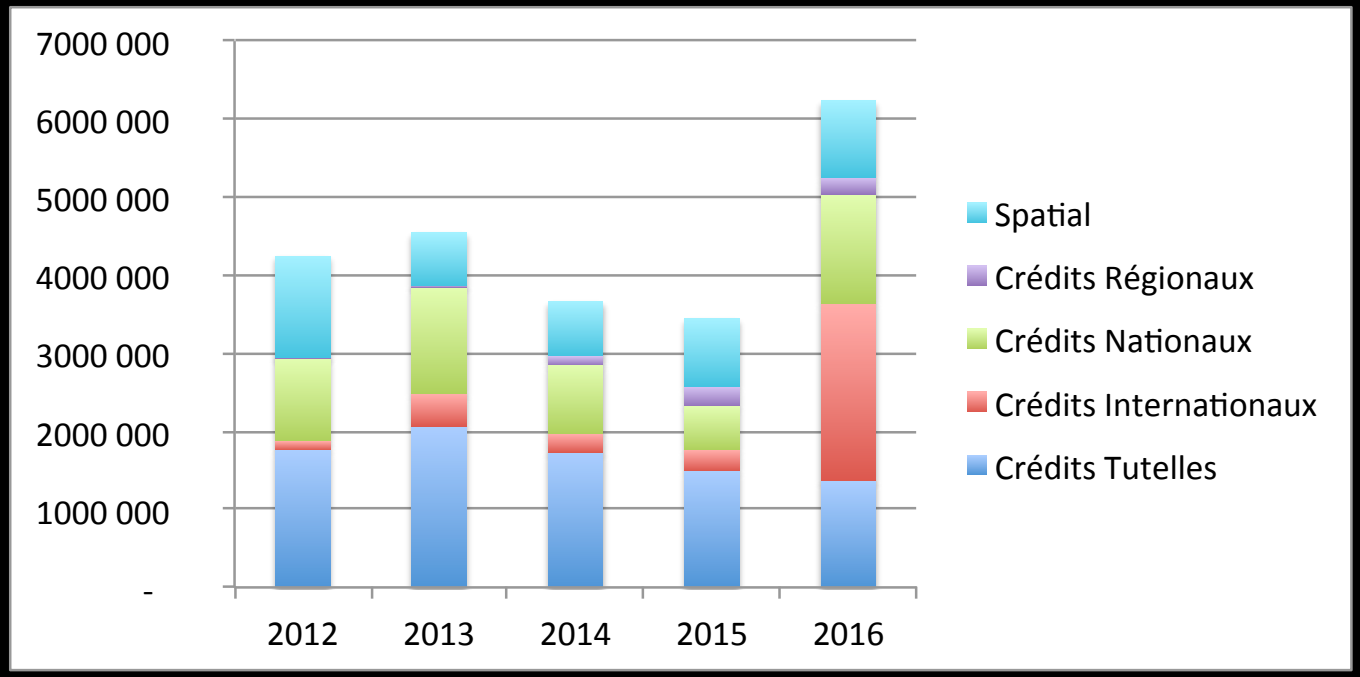




A very large annual turnover (over 100)

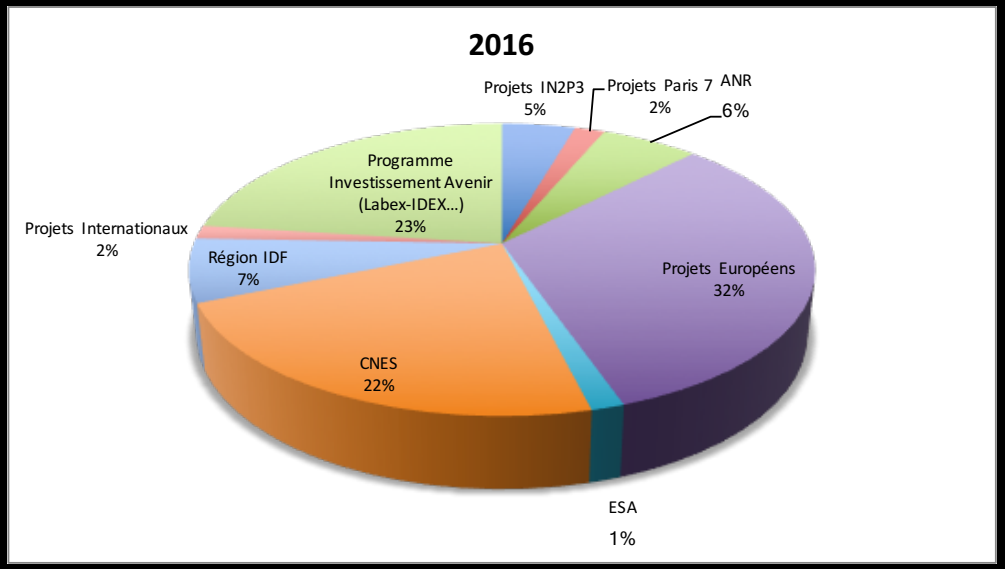


Budget evolution



In 2016
21% subventions d'Etat
79% ressources propres

A large variety of sources



Gender issues

EU funded in the frame of H2020-GERI-2014-1

- 2015-2018, 3.34 Mio Euro funding
- 14 beneficiaries from 11 countries
- Objectives: assess the status of gender issues and GEPs, support organisations in implementing
- Shall establish a long-term perspective beyond project lifetime (network, monitoring)

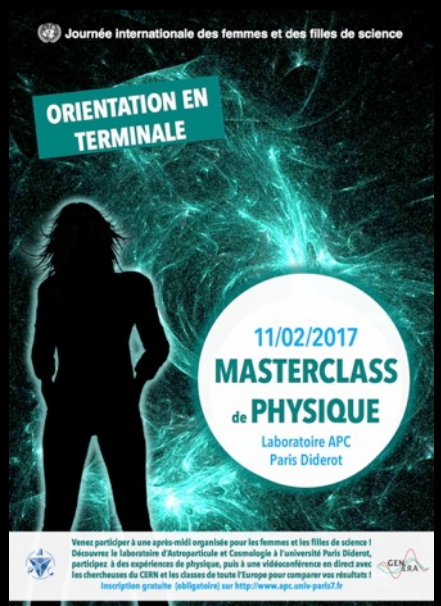
GENERA: implementation at APC

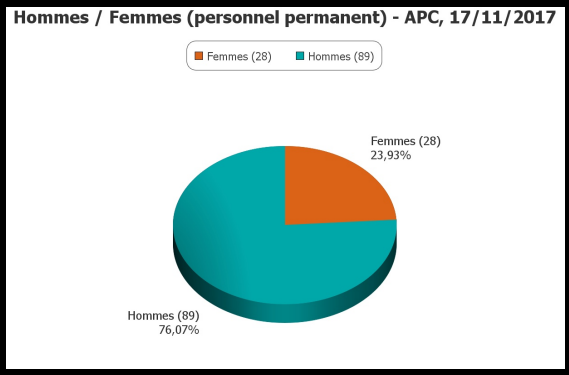
1) Actions towards students, role models

- Masterclass on UN day of women in science (11/02/2016)
- Intervention at Summer School for undergraduate students (16/07/2017)
- Discussion session at High School Teachers' school EPhyD (31/08/2017)
- Exhibit "Physique de femmes" at Fête de la Science 2017

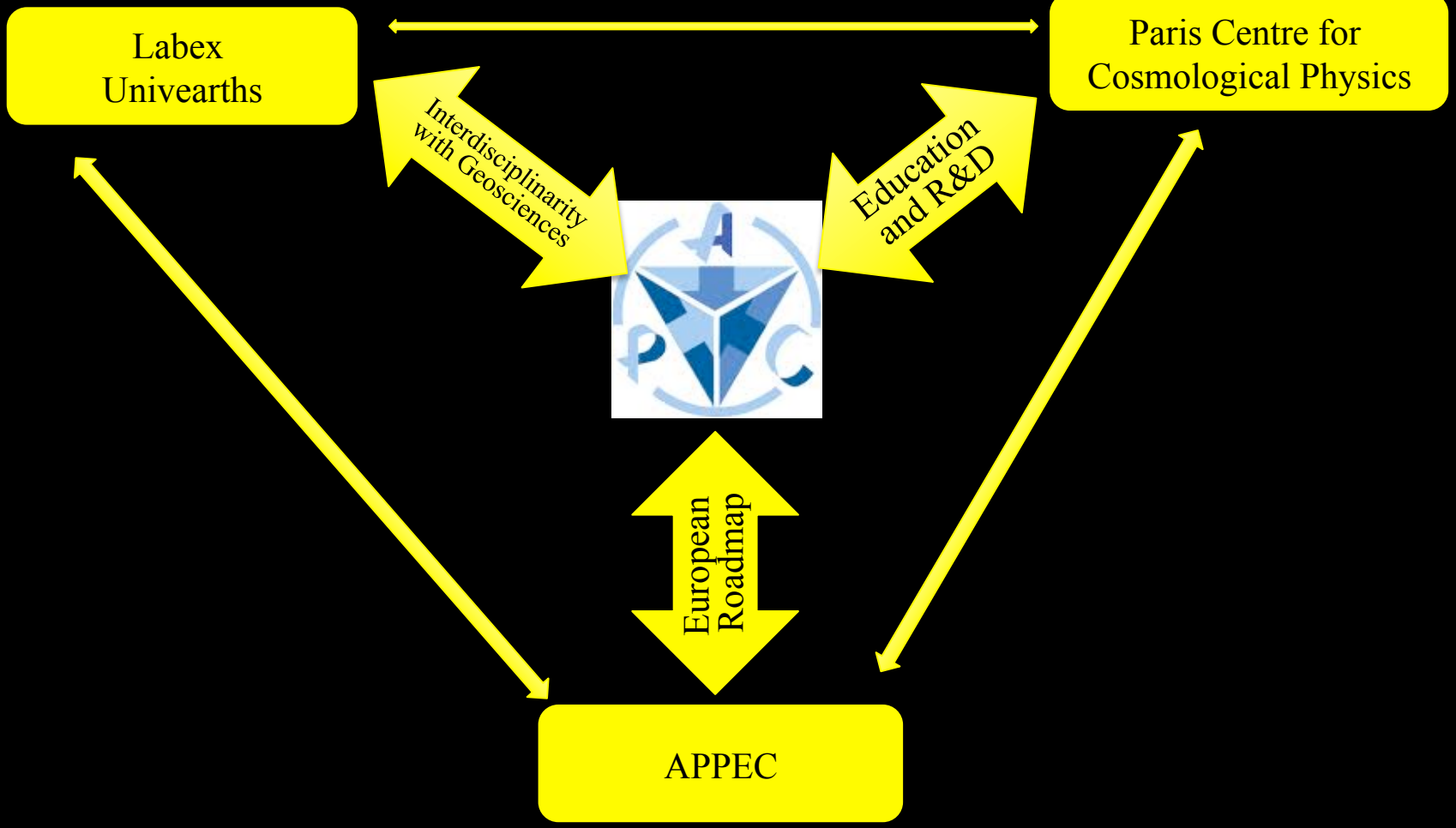
2) Encourage women to apply

- L'Oréal-Unesco Prize (E. Capocasa and V. Domcke, 2016)
- Nominations of group and service leaders
- ➔ 50% Women of group/srevice leaders at APC





Three key associated structures



Astro-geo science emerging synergy (or revival of an older alliance)

- ✓ The geosphere, a direct object of study of the geosciences, is both the target and the detecting medium for astroparticle observatories,
- ✓ They both deal with complex natural systems at a much larger scale than the human, deploy large sensor networks in sometimes hostile environments (sea, desert, underground, space);
- ✓ Use long series of precise observations acquired over a range of time scales;
- ✓ Extreme dating is a discovery instrument;
- ✓ They finally use advanced sensors and a large data manipulation and worldwide networking, including the distribution of alerts.

- Seismology
  - Seismic precursors using gravitational wave technology
  - Ocean floor seismology (standard, acoustic)
- Muon Imaging
  - Volcano muon tomography
  - Archaeology, prospection
- Neutrino Imaging
  - Geoneutrinos
  - Earth Neutrino radiography
- Deep ocean
  - Parameter monitoring and bioimaging
- Space
  - Space weather (Nano satellites, Taranis, EUSO)

APPEC-APC centre organises a pan-European meeting of agencies and Pis by mid-2018

A strategic alliance
The interdisciplinarity with Geosciences Labex Univearths+

- ➢ EUR EPU (AIM,APC,IPGP) Not retained
- ✓ Data Plateforme DANTE (APC, IPGP) retained

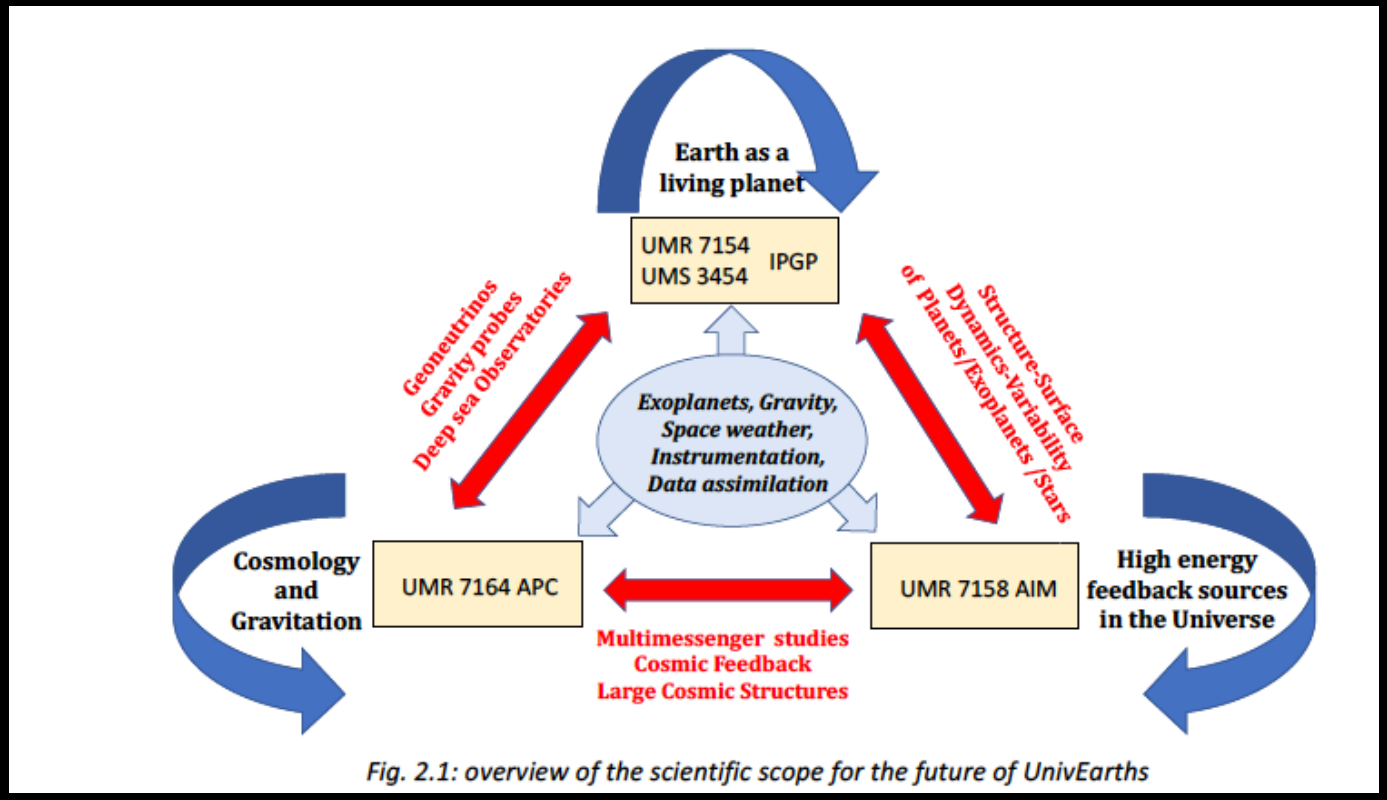


Fig. 2.1: overview of the scientific scope for the future of UnivEarths

From FACe to Project DANTE

- ✓ Context:
  - ✓ CNRS formally asked APC to move out from Biopark
  - ✓ APC together with its LabEx UnivEarthS partners IPGP submitted the proposal DANTE to the regional call SESAME of 2017: obtained 2 years funding
- ✓ DANTE a center (APC-IPGP) of innovative and multidisciplinary expertise, could become key centre of P2IDS (Paris Interdisciplinary Institute for Data Sciences)
- ✓ FACe team keeps its autonomous expertise on APC subjects

- ✓ **Key infrastructure challenge of 2018 for APC**
  - ✓ Personnel and CDF exchange with UMR SHPERE moving to Olympe des Gouges
  - ✓ Budget of restitution of offices : 309 k€
  - ✓ Machine mouvement budget : 210 KE (SESAME, PR, CS)

Paris Center for Cosmological Physics
APC ,GEPI, LPNHE, LPTENS, LuTH

Physique de l'Univers
Fonds de dotation

Foundation « Physics of the Universe »
Chair G. Smoot, Interim Director S. Katsanevas
(replacing P. Binetruy)

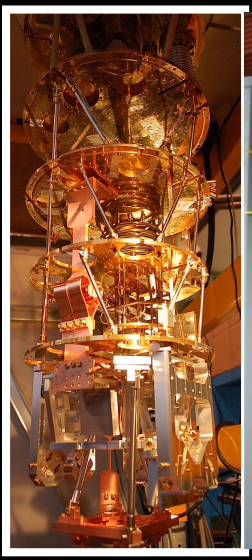
- A fellows program
- Current focus: R&D on cryogenic detectors (TES/KIDS)

- Education and Outreach
  - « Teaching the Universe »
  - MOOC Gravity (P. Binetry + G. Smoot, subscription 100.000 followers)

- A Conference program
- Art and Science Univers 2.0 (Foundation Carasso)
- International Donators (Kazhakstan)

APC mm lab (strong connection with PCCP)

- Permanents: Fabrice Voisin (10%), Damien Prêle (10%), Jean-Pierre Thermeau (40%), Steve Torchinsky (50%), Michel Piat (50%)
- Postdoc: Maria Salatino
- PhD student: Alessandro Traini
- Support of technical services
- A new instrumentalist under recruitment with Univearths funds



Dilution 20mK

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

mm cryo deepstick 4K

R&D BSD *(B-mode Superconducting Detectors)*

- Labo: APC (leader), C2N (ex-IEF), CSNSM, IAS, IN, GEPI, LPSC, L2E, IRAP
- Fundings: ANR, CNRS, CNES, ESA

Sensitivity:

- **Transition Edge Sensor arrays**
  - Superconducting NbSi
  - SiGe ASIC at 4K: TDM 128->1
  - Application to QUBIC
- **Kinetic Inductance Detectors (KIDs)**
  - Polarisation sensitive KIDs
  - Visible + NIR KIDs (GEPI)

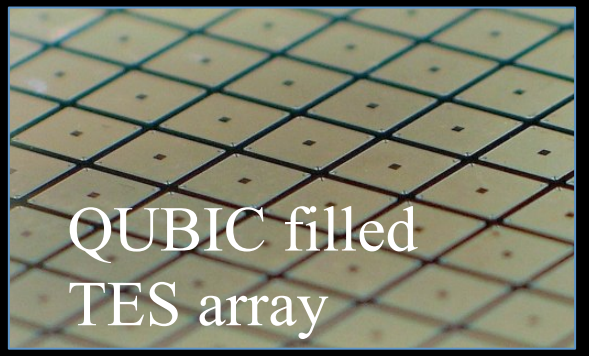
Immunity to systematic effects

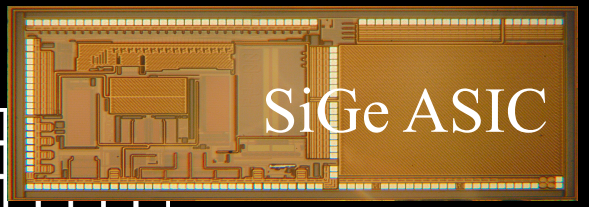
- **Planar superconducting microwave devices**
  - Nb based
  - Antennas and filters
  - Multi-chroic architecture
  - Use of radio architectures in the incoherent detection field

Perspectives: QUBIC, LiteBird, CORE, CMB-E4

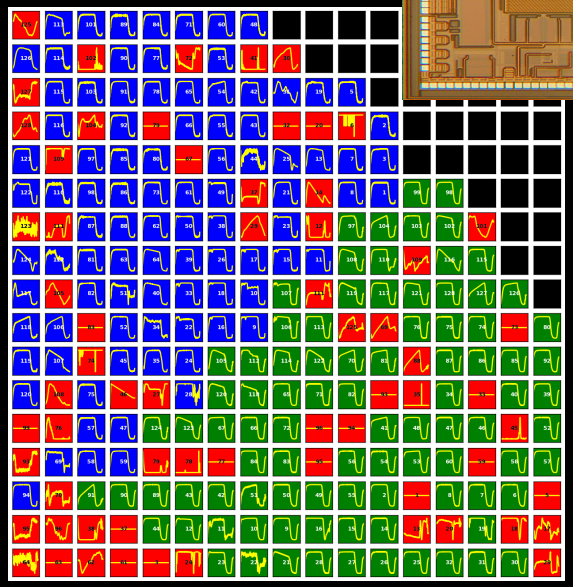
TESs developments

Lab	Responsibilities
APC	Coordination, architecture definition, cold readout, TES tests
CSNSM	NbSi, solid state physics
C2N	Microfabrication
IRAP	Warm electronics





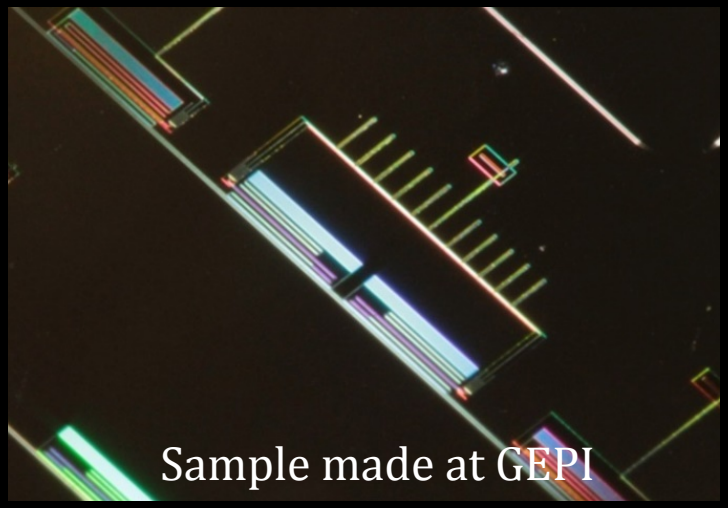
- Readout for QUBIC:
  - Cryogenic SiGe ASIC
  - TDM 128 -> 1:
    first in the world

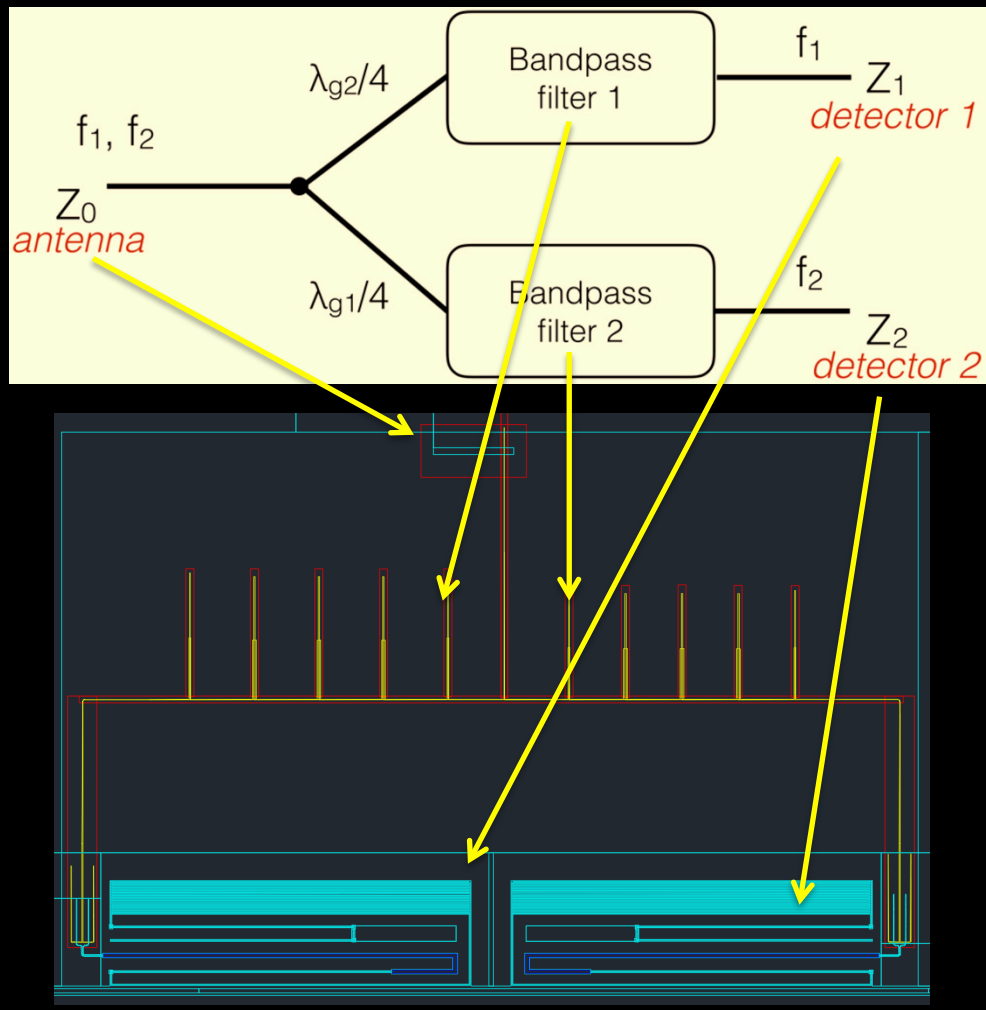


C fiber signal on QUBIC TESs

Polarisation sensitive KIDs

- Dual-color antenna-coupled LEKID
  - Single slot antenna
  - 2 filters and 2 LEKIDs
    - 140GHz and 160GHz
    - 10% bandwidth
  - Under test





APPEC

APPEC functional centre

Mandate of APC Functional centre

- Organize Scientific Advisory Committee
  - April 2016 APPEC town meeting
  - S.K central editor of the European Roadmap
- Interdisciplinary issues

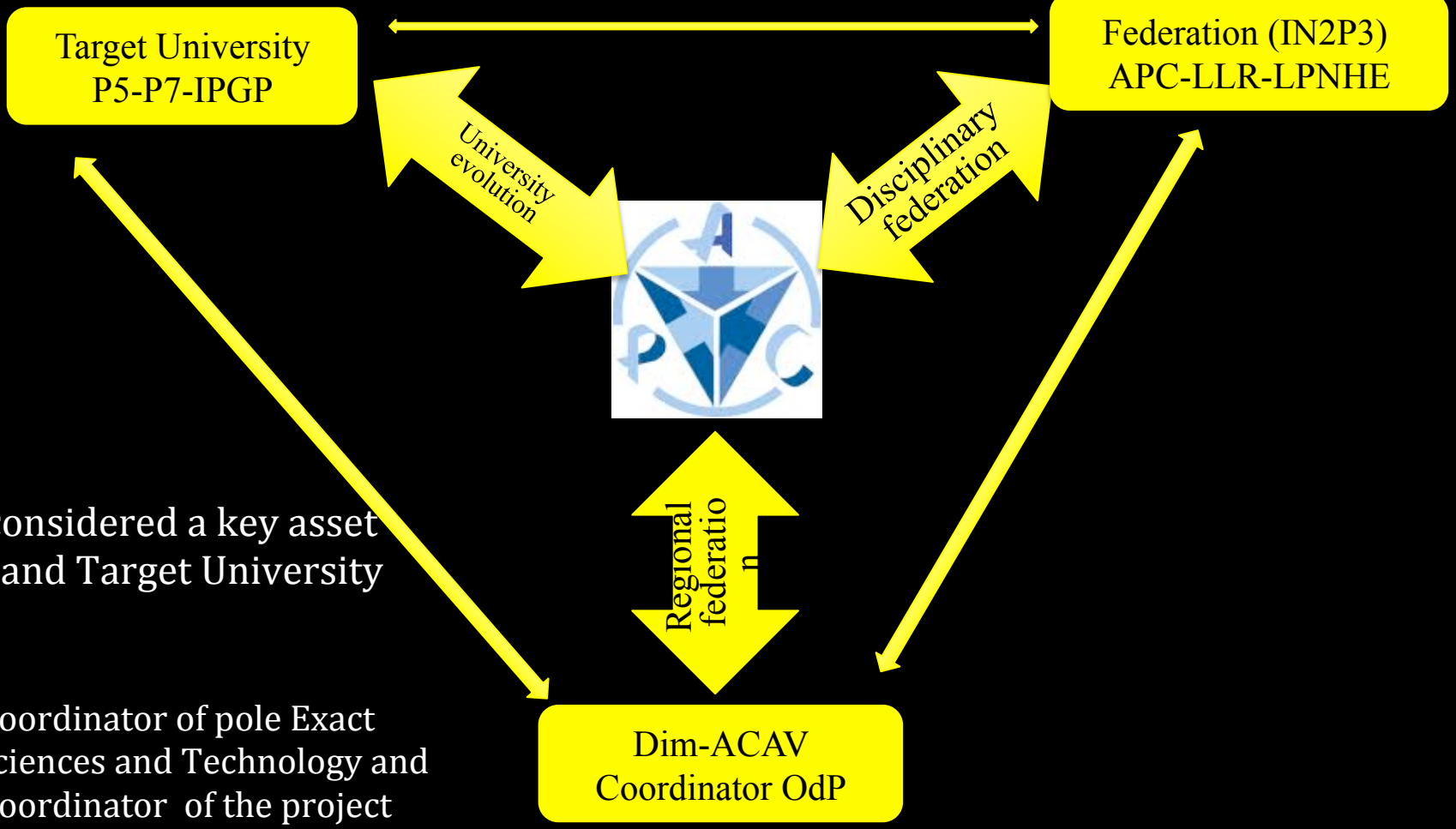
Recent Highlights

- Global Neutrino Meetings (2014,2015,2016)
- European Coordination CMB (2015,2016, 2017)

Planned

- Interdisciplinary efforts with Geosciences (2018)

Institutional insertion



APC considered a key asset of P7 and Target University

S.K

- Coordinator of pole Exact sciences and Technology and
- Coordinator of the project Paris Interdisciplinary Institute of Data Sciences

International Insertion, beyond APPEC

AstroCeNT:
Particle Astrophysics Science and Technology Centre

- The prime objective of AstroCeNT will be to develop a future oriented research and development (R&D) programme in science and technology in the area of ultra-sensitive detectors and sensors as well as large data set collection and analysis tools

- The international strategic partner of AstroCeNT will be the Laboratory of Astroparticle and Cosmology (APC) — a world-class scientific institute based in Paris.

- The main scientific field of the Agenda will initially be focused on two areas:

    1. **Gravitational wave astronomy and**
    2. **Dark matter**

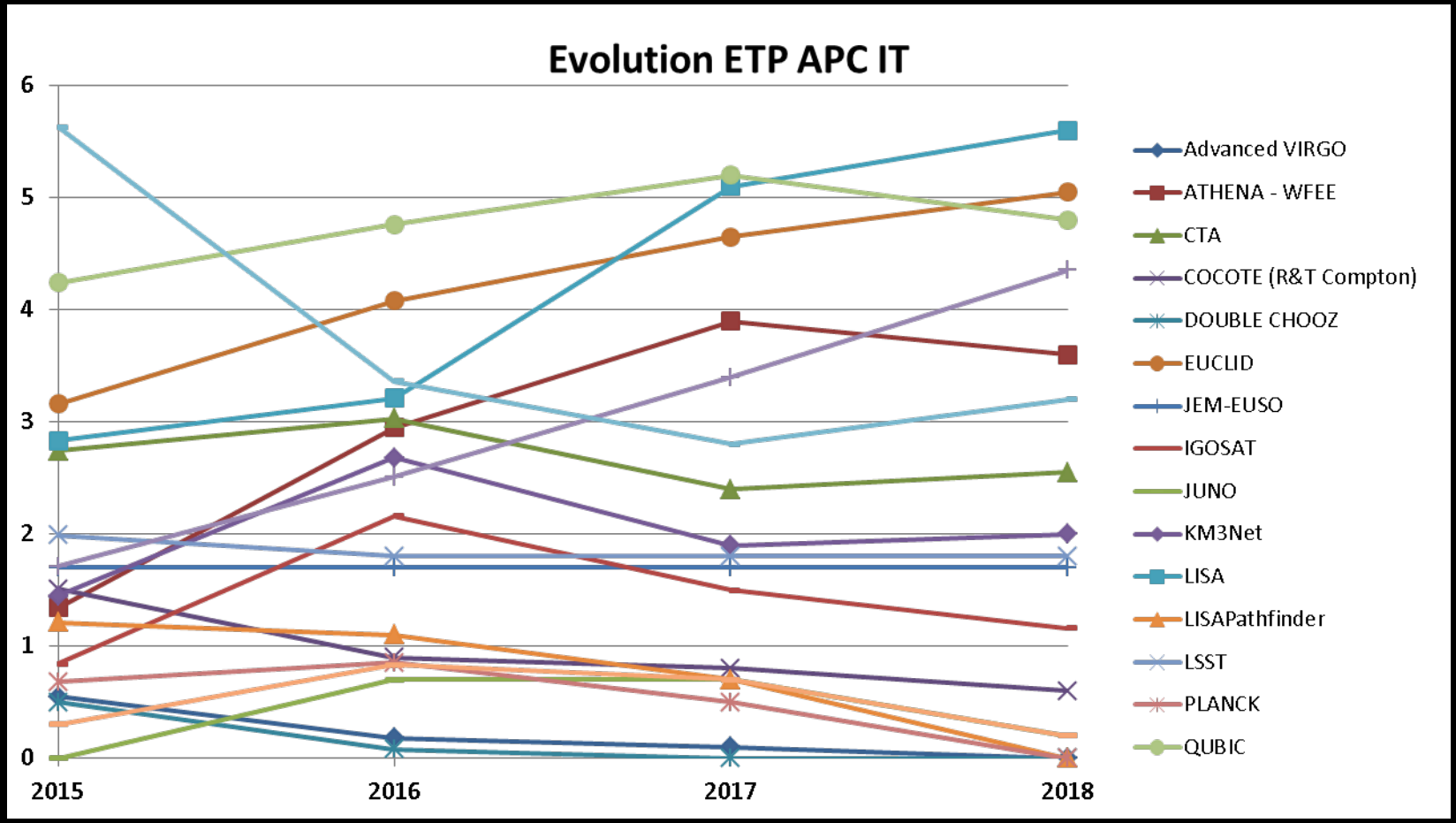
The main three science-driven technological themes initially proposed for AstroCeNT are:

1. **Silicon Photo Multiplier based systems;**
2. **seismic sensors;**
3. **data acquisition and large data set processing**

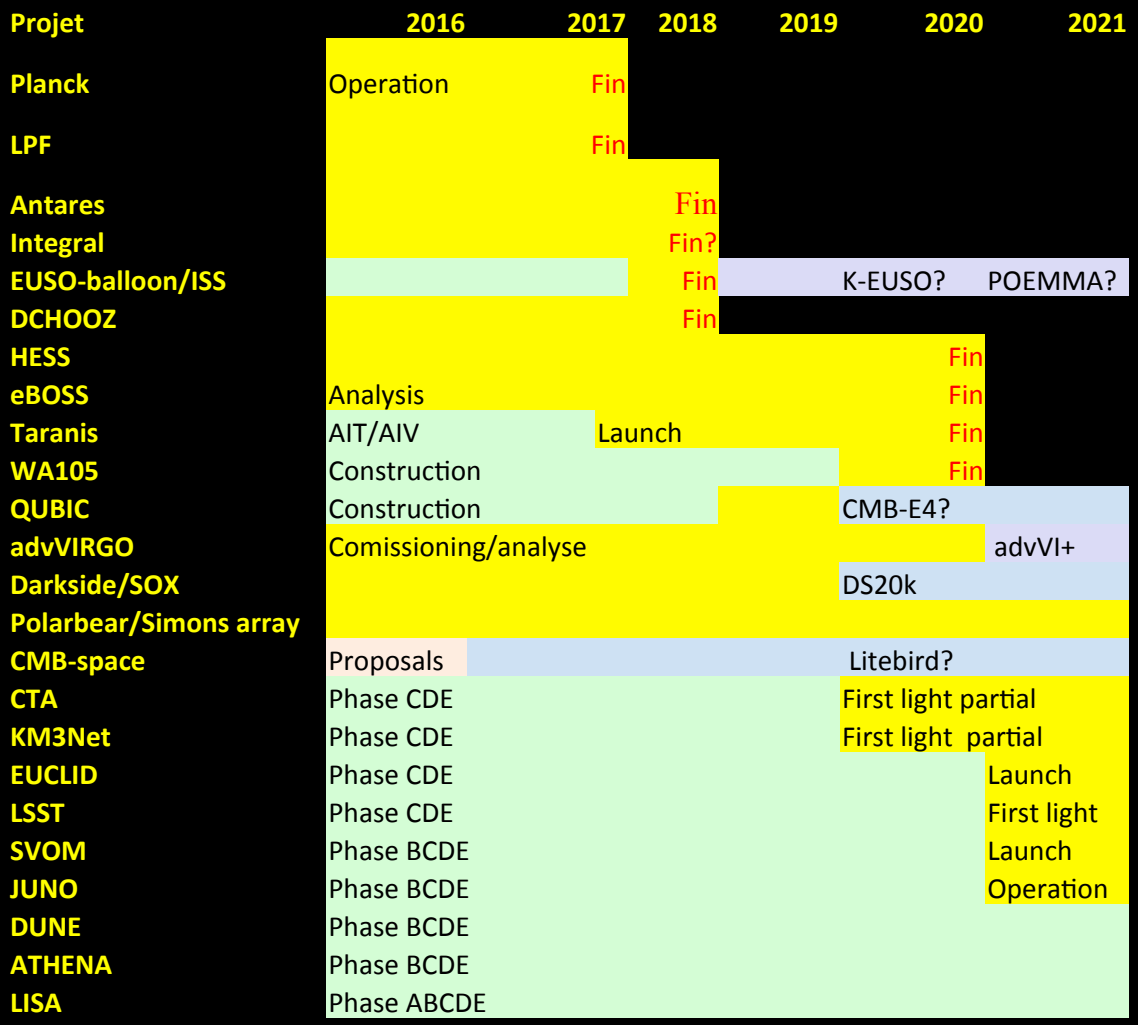
6 questions from our HCERES evaluation committee:

1. *How can you tell if a group is spread too thin to be effective, and how are priorities set and accepted? Can you please give examples of activities that groups decided not to pursue and how that worked?*
   - Context
     - Evolution from APC contributions "en amont et en aval" to key infrastructure contributions
     - The importance of our space involvement, key attractor of resources
   - 2 Evaluation Instruments
     - CSP evaluations and Scientific Council. Too close and too far ? Need an intermediate instance, a discussion in our Biennale March 2017, postponed for the new direction
     - During the first Biennale of APC, complaints that our FTE did not previously conserve unitarity, this is clearly not the case anymore
- 6 Projects stopped or downscaled to individual contributions since 2014
  - SKA and PTA, (lead to discontent of key researchers) , Xshooter, Borexino, R&D Gamma-cube (despite funds from InnovSATT), and downscaled eBOSS participation (lead to loss of a key researcher)
- 4 New projects since 2014 (in fact continuation of our expertise in new context):
  - SVOM (mask expertise from SimbolX),
  - ATHENA (follow-up of our expertise in space ASICs),
  - Dark Side (Borexino expertise)
  - DUNO (continuation of DCHOOZ expertise)
- 1 Transmutation LAGUNA ➔ WA105/DUNE
- 1 R&D project in CSP process: LIQUIDO
- By 2019, many programs end, near 40% reduction, but key involvements in the remaining
- Good time distribution, but no significant R&D due to lack of resources

A precise evolution of technical forces
CSP and CQP



Roadmap



2017 24 projects in operation and construction

2020 15 projects in operation and construction?

6 questions from our HCERES evaluation committee:

2. The agreements and connections with international groups are admirable and impressive. Could you please list some specific results or opportunities that are a consequence of these

1. UMI Berkeley, many synergies from CMB detectors (BCCP-PCCP), to data science (BIDS-P2IDS), science: Polarbear, LSST, discussions for gravitation ?
2. LIA Japan, Litebird, Neutrino, dark matter
3. LIA Argentina, CMB deployment in Salta
4. Chicago, UHECR, Labex Univearths
5. Astrocent, building synergies
6. KIT, Hambourg-Oxford, Solvay, essentially theoretical interactions

European Strategy for Astroparticle Physics (2017)

- *Two emergent characteristics of the present era :*

I. *We are at the edge of multi-messenger detections involving high energy photons, neutrinos, high-energy charged particles and gravitational waves, that will give us a deeper understanding of violent phenomena regulating structure formation in the Universe as well as eventually hints for new laws of physics .*

II. *The visible Universe from the CMB to the present started to provide comparable constraints to the standard models of cosmology (inflation, dark energy) and particle physics (neutrino, dark matter).*

6 questions from our HCERES evaluation committee:

3. What connections are foreseen with the upcoming European Strategy for Particle Physics?

1. Large scale multi-messenger infrastructures:
   - CTA/KM3Net, advVirgo➔ET, upgrade Auger
2. Medium scale Dark Matter and neutrino experiments
   - DM (DS-20k), Neutrinoless-2beta
3. Synergies with astronomy particle physics and cosmology
   - Neutrino DUNE , HK
   - Cosmology DE : LSST/EUCLID
   - Cosmology CMB roadmap: G4 on ground and space

Large-scale multi-messenger infrastructures

To improve understanding of our Universe, APPEC identified as a very high priority those research infrastructures that exploit all confirmed high-energy 'messengers' (cosmic particles that can provide vital insights into the Universe and how it functions). These messengers include gamma rays, neutrinos, cosmic rays and gravitational waves. European coordination is essential to ensuring timely implementation of such infrastructures and enabling Europe to retain its scientific leadership in this field.

Medium-scale Dark Matter and neutrino experiments

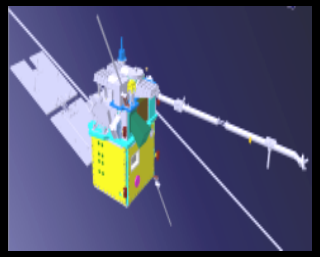
APPEC considers as its core assets the diverse, often ultra-precise and invariably ingenious suite of medium-scale laboratory experiments targeted at the discovery of extremely rare processes. These include experiments to detect the scattering of Dark Matter particles and neutrinoless double-beta decay, and direct measurement of neutrino mass using single-beta decay. Collectively, these searches must be pursued to the level of discovery, unless prevented by an irreducible background or an unrealistically high demand for capital investment.

Synergies with astronomy, particle physics and cosmology

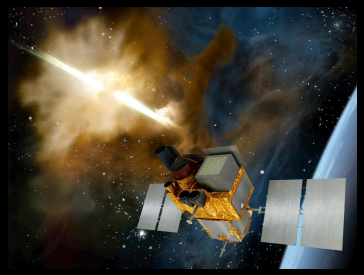
To shed light on neutrino mixing and the neutrino mass hierarchy, APPEC is a long-term proponent of experiments using natural neutrinos from the Sun and from Earth's atmosphere as well as neutrinos from nuclear reactors and accelerators. Recognising the increasingly interdisciplinar reach of astroparticle physics, APPEC has broadened the scope of its roadmap to include explicitly two topics referred to in it 2008 science vison: the CMB and Dark Energ These are flourishing fields of research, as demonstrated by Nobel Prizes awarded in 2006 and 2011. They not only complement core astroparticle physics topics but also yield stringent constraints on neutrino mass and on the role of neutrinos in the early Universe. So far in these recommendations, the focus has been on projects primarily funded by European astroparticle physics agencies. By contrast, for the three topics addressed in this subsection, the main funding is likely to come from US and Asian agencies or from the European particle physics and astronomy communities.

Multi-messenger Universe

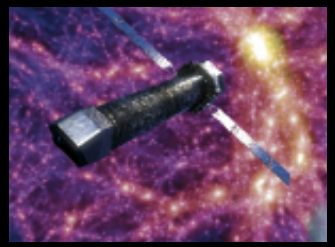
LISAPF



TARANIS

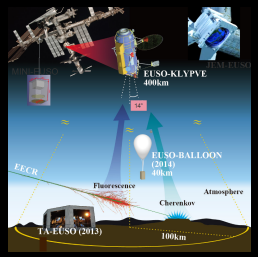


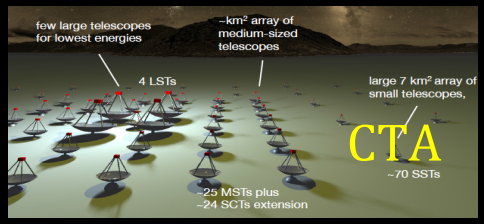
SVOM



ATHENA

INTEGRAL



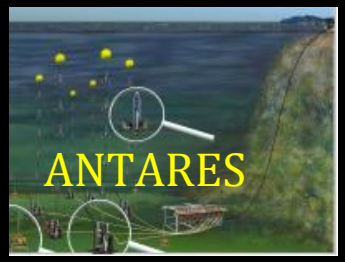


EUSO ballon

EUSO LDB-ISS

HESS

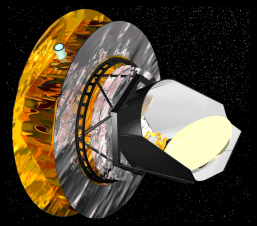
advVIRGO



ANTARES

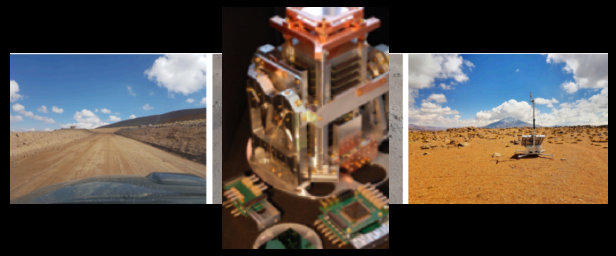
2018 | 2020 | 2022 | 2024 | 2026 | 2028 | 2030 | 2032

Mesure of the Universe (Cosmology, DM,neutrinos)

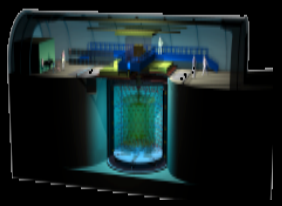


Planck

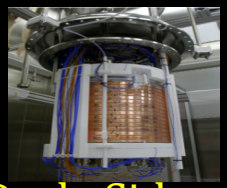
PolarBear/Simons Array



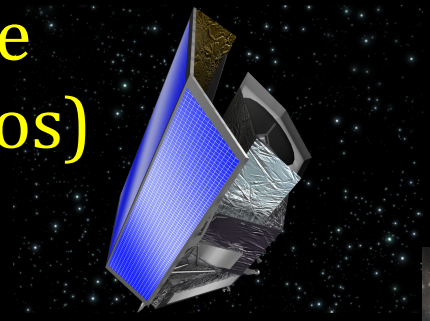
QUBIC



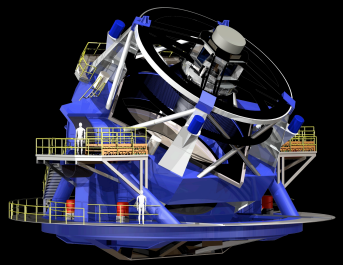
DoubleChooz



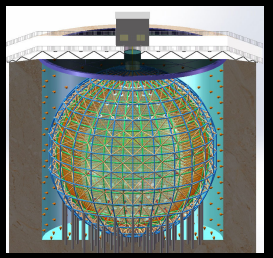
Dark Side



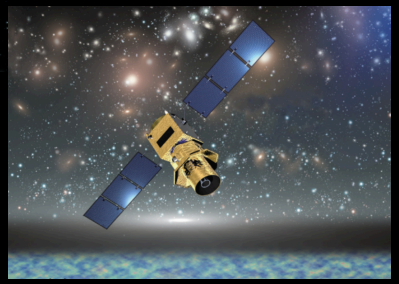
EUCLID



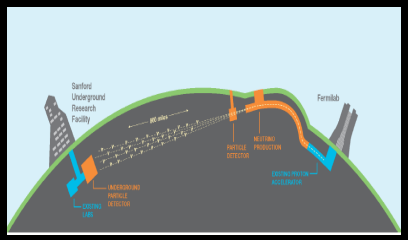
LSST



JUNO



LiteBird



DUNE

2018	2019	2020	2021	2022	2025	2030	2032

6 questions from our HCERES evaluation committee:

4. FACe : The François Arago Center is presented as a platform to host DPC (Data Processing Centers) or DAC (Data Access Centers) for space missions or ground based projects with heavy computing needs. Please show how this platform is organized and the workforce needed to operate it. If the workforce is shared with the IT department, how is this managed?

5. PCCP: What are the organizational and financial relations between The Paris Center for Cosmological Physics (PCCP) and APC? Is there coordination between the PCCP scientific program and the APC physics group (Cosmology, Theory …)?

6. The Energy Physics Group has recently joined the laboratory. The scientific activity of this is clearly of high level and with high societal impact. However, It is not a priori obvious that APC would offer the best development environment to this research activity. In addition, many of the research themes of this group are rather managed by departments of the CNRS (or CEA) which are not the ones which are the “tutelle” of APC. Would you please further explain the strategy for welcoming this new group at APC?

Key scientific short and medium term objectives

- Prepare O3 / Virgo and phase A of LISA
- Finish the Technical Demonstrator and the first module of QUBIC
- Leadership participation to a European ground / space roadmap for CMB
- Fulfil obligations to Euclid and LSST, increase APC weight to analysis
- Advancing the construction of major CTA / KM3Net infrastructures
- Finish our technical implication to TARANIS
- Continue the tradition of low energy photons in space, persuade agencies of it renewed role, until the coming of SVOM / ATHENA who will have a rich multi-messenger potential
- Measure mass hierarchy and neutrino CP violation in a complementary way (DUNE / JUNO / ORCA)
- Defend th erole of Liquid Argon techniques in DM search in French context
- Exploit the synergies between multi-messenger domains and cosmology
- Continue to develop
  - Interdisciplinarity with the geosciences (UnivEarths)
  - Innovative education techniques (PCCP)
  - Data science (FACe and DANTE)
  - European and international links (APPEC, LIAs and UMIs)

SWOT, APC

Forces	**Weaknesses**
• Very proactive researchers and engineers • Leadership in IN2P3 in search of new resources (from ANR to EU) • Adaptation to a new funding environment • Recognition as a space laboratory • Technical and data-science expertise • High Visibility in the University envt. • International recognition	• Differential ratios researchers/engineers per project, in general lack of technical forces (among the smallest IN2P3 ratios) • Administration HR fragility, given the multiplicity of the funding sources • Large CDD turnover • Not anymore dedicated European project manager, communication officer
Opportunities	**Threats**
• Start of GW and Multi-messenger Astronomy • Unique APC group structure in the current scientific context • Interdisciplinarity with Geosciences	• Tight schedule for FACe relocation • Fragility to loss of key expertise