AstroParticules et Cosmologie

Activity Report 2013-2018

HCERES
Haut conseil de l'évaluation de la recherche et de l'enseignement supérieur

Vague D
Campagne d'évaluation 2017 – 2018

Unité de recherche

Dossier d'autoévaluation

Informations générales

Nom de l'unité :	UMR7164, Laboratoire Astroparticule et Cosmologie
Acronyme :	APC
Champ de recherche de rattachement :	Physique
Nom du directeur pour le contrat en cours :	Katsanevas Stavros
Nom du directeur pour le contrat à venir :	A déterminer

Type de demande

Renouvellement à l'identique ☑ Restructuration ☐ Création ex nihilo ☐

Établissements et organismes de rattachement :

Liste des établissements et organismes tutelles de l'unité de recherche pour le contrat en cours et pour le prochain contrat (tutelles).

Contrat en cours :
- IN2P3/CNRS
- Université Paris Denis Diderot
- CEA
- Observatoire de Paris

Prochain contrat :
- IN2P3/CNRS
- Université Paris Denis Diderot
- CEA
- Observatoire de Paris

Choix de l'évaluation interdisciplinaire de l'unité de recherche ou de l'équipe interne :

Oui ☐ **Non** ☑

In memory of Pierre Binétruy founder of APC

and APC director until 2014

Contents

PART A.

Unit evaluation

1. Presentation of the unit

1.1 Introduction

The laboratory AstroParticle and Cosmology (APC) was founded in 2005 by the CNRS, in particular IN2P3 (Institut National de Physique Nucléaire et Physique des Particules), the University of Paris Denis Diderot, the CEA (Commissariat à l'Energie Atomique et aux Energies Renouvelables) and the Observatory of Paris, to foster in France the growth of the then emergent astroparticle and cosmology theoretical and experimental activity. There was an auto-evaluation report covering only the first two years 2005-2006, then a report describing the activities during the period 2007-2012. The current report covers the period from January 2012 to June 2017.
The main themes developed at APC are:

- **Cosmology**, namely studies ranging from the study of the Cosmological Microwave Background (CMB) to the determination of the nature of dark energy using observatories on ground and in space,
- **Gravitation**, namely gravitational-wave astronomy using ground-based and spaced-based detectors, and associated fields
- **High Energy Astrophysics**, studying violent phenomena in the Universe in a multimessenger context ranging from X and Gamma rays to high-energy photons, neutrinos and charged cosmic rays.
- **Neutrino and dark matter**, in particular the determination of the nature and mass of neutrinos and dark matter and their impact on cosmological structure formation
- **Theory.** Finally, APC has a strong theoretical group on all the above themes working in contact with the experimentalists.

APC is organised since 2015[1], along **five science teams**, namely 4 thematic: **Cosmology; Gravitation; High Energy Astrophysics; Neutrinos;** and 1 transversal: **Theory.** A key aspect of APC is the presence of **6 technical departments,** which provide the technical expertise required by the projects. They are organized according to their different skills: **Mechanics, Electronics, Microelectronics, Instrumentation, Informatics, and Project Quality Procedures.** Their work develops within and around a data science plateform created in 2010 the **François Argo Centre FACe**, 4 laboratories (**Millimetric, Photodetection, Optics, Integration and Test (AIT/AIV)**) and 2 workshops (**Mechanics, Assembly Hall)**. For a detailed description of the infrastructures of the plateforme and the other equipments see appendix 2.

Furthermore, the APC hosts since January 2017, one affiliated research group, the **Energy Physics Group** whose main research concerns novel sources of energy. It is an interdisciplinary research focused on the observation and understanding of basic mechanisms underlying physical phenomena, their modeling and eventually their applications in novel energy systems.

The distribution of personnel according to team and department, on the 2nd of June is shown in table 1 below.

	Permanent	Non-permanent	Of which PhDs
COSMOLOGY	18	13	9
GRAVITATION	6	8	6
HEA	21	17	8
NEUTRINO	12	17	5
THEORY	14	19	8
ENERGY PHYSICS GROUP	2	3	3
ADMINISTRATION	11	3	
TECHNICAL DEPARTMENTS	37	15	
OTHER	1	1	
Total	**122**	**96**	**39**

Table 1. Permanent and non-permanent personnel according to team and department on June 2nd 2017

There are three associated structures to the laboratory:

[1] Before 2015 Cosmology and Gravitation were a single group, while there was another group (ADAMIS) concentrating on data science methods in all the above domains. The explosive development of cosmology and gravitation fields lead to the split of the single group to 2 different ones and their absorption of the data-science experts belonging to the ADAMIS group The current teams harbour of the order of 20 projects and 5 R&D activities.

1. **PCCP.** The Paris Centre for Cosmological Physics (PCCP)[2] founded by George Smoot, 2006 Physics Nobel Prize (G. Smoot is an APC member since February 2010) was thus created in 2010 with the strong support of the University and IN2P3. In order to provide future funding for the Centre, an endowment fund was created ("Fonds de dotation pour la Formation et la Recherche en Physique de l'Univers" FFRP), based on the model of a similar foundation created by George Smoot in Berkeley.
2. **Univearths.** A key strategic choice of APC is the interdisciplinary alliance with Geosciences in the context of the Laboratory of Excellence (LabEx) UnivEarths[3]. APC, together with IPGP and AIM have teamed up on a succesful LabEx called UnivEarthS. The amount awarded is 1 M€/year over a period of 9 years (2011-2019). This Labex is considered among the most succesful ones, since a genuine cross-cultural atmosphere has been developed.
3. **APPEC functional centre.** The Astroparticle Physics European Coordination (APPEC), founded in 2001, regroups the European funding agencies involved in astroparticle projects. Through the EU funded ERANET ASPERA (2006-2012), it has developed a roadmap for astroparticle physics in Europe which has been key in providing the adequate effort for the large projects of the discipline. The current APC director was its first coordinator. This Coordination turned into a Consortium in 2012, with a permanent structure of coordination. The current director of APC was its first president (2012-2015). APC is a functional centre[4] of APPEC hosting the strategy activities (roadmaps) and the interdisciplinary programmes. In this context, APC hosted key actions and meetings for European (Roadmap meeting in Paris in 2016) and initiated two major initiatives on European (CMB cosmology) and worldwide (neutrino) coordination.

Furthermore, APC as a "mixed unit" (UMR) of the Physics Department (UFR) of Paris Diderot University participates in the effort towards a unified Univeristy (Paris Universities Sorbonne Nouvelle, Descartes and Diderot) and the **ComUe ("Communauté Universitaire") SPC (Sorbonne Paris Cité)** gathering beyond the 3 Universities above also Paris 13, IPGP, Sciences Po, INALCO, EHESP, FMSH as well as CNRS, INSERM, INRIA, INED and IRD.

APC, which is also participating in the Council of the Observatoire de Paris (OdP), since the later is one of its funding agencies and the regional program of Ile-de-France **"Domain d'Interêt Majeur Astrophysique et Conditions d'Apparition de la Vie" (DIM-ACAV)**, has profited from funding of its actions in the past and hopes to also profit in the renewed program Dim-ACAV+ recently accepted. The OdP and DIM-ACAV are the loci of interaction and coordination with the Ile-de-France Astrophysics community. In parallel, following incitations by IN2P3, APC has started efforts of federation with the Paris IN2P3 laboratories/UMR LPNHE (Laboratoire de Physique Nucléaire et des Hautes Energies) and LLR (Laboratoire Leprince Ringuet).

At the international level, APC is embedded in a large network of international centres of excellence in Astroparticle Physics: it has a common "Associated International Laboratory" (LIA) with the Kavli Institute for Particle Astrophysics and Cosmology (KIPAC) of Stanford University and SLAC in the US, a second with the Centre of Excellence KIPMU (Kavli Institute for the Physics and Mathematics of the Universe) in Tokyo and a third with Argentina (CONICET and CNEA). In all the above cases the Director of APC is the corresponding French director. It also has a long standing LIA with Kurchatov Institute in Moscow with H. de Kerret as French Director.

A functional diagram of most of the above entities is shown in Fig. 1. For a hierarchical organization chart, see appendix 3.

[2] http://www.pariscosmo.fr
[3] http://www.univearths.fr/en/home/
[4] Other functional centres are the Gran Sasso National Lab in Italy and DESY Zeuthen in Germany.

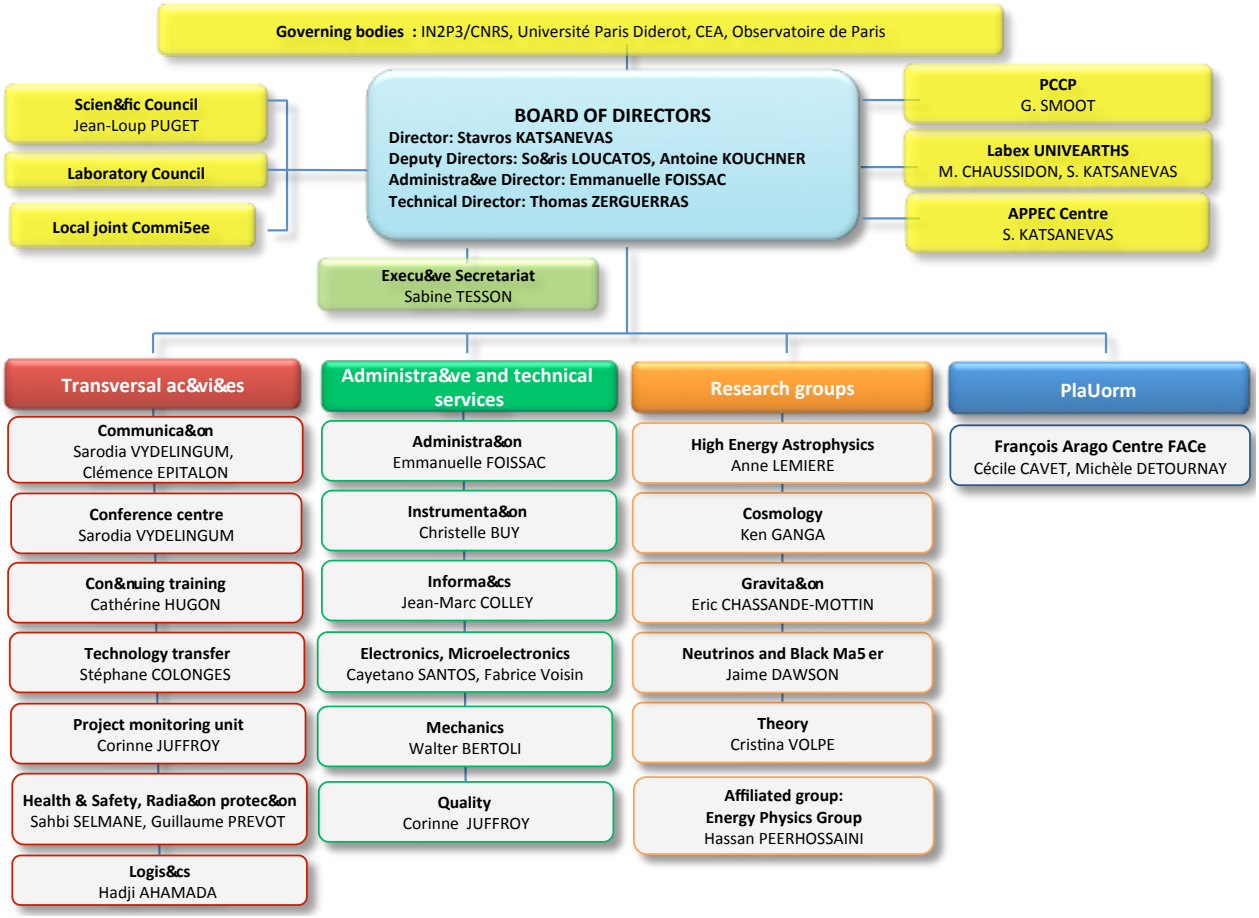


Figure 1. Functional diagram APC

1.2 Workforce and resources

The laboratory receives its basic funding from its four funding agencies, the larger part being provided by CNRS/IN2P3, then University Paris Diderot and CEA, in (approximate) proportion to their personnel, and finally the Obervatoire de Paris which started only very recently to attribute personnel to APC (1 person) but which participated actively to its creation and supports its projects. This budget provides the "soutien de base": it allows the lab to function on a daily basis, and provides support for the general activities of the groups and departments (at a rate of approximately 1 k€ per person). The projects are supported by dedicated funds, whether by IN2P3 (IN2P3 projects), by the large infrastructure funds of the ministry (through CNRS), space agencies, ANR, "Programmes d'Inverstissement d'Avenir" through the Labex UnivEarths and the Comue SPC, regional funds through DIM-ACAV, excellence grands (Institut Universitaire de France, Chaires Blaise Pascal, ERC grants), EU funds for programs (e.g. ASTERICS).

Workforce. APC on the 2nd of June 2017 has 38 researchers and 27 academics, 43 CNRS and 6 University engineers (ITA), 10 emeritus academics or researchers, 20 postodocs, 11 non-permanent technical personel and 33 doctoral students, that is a total of 192 agents. Figure 2 and Figure 3 show the total number of APC agents, according to category, their affiliation in terms of funding agencies and the age distribution:

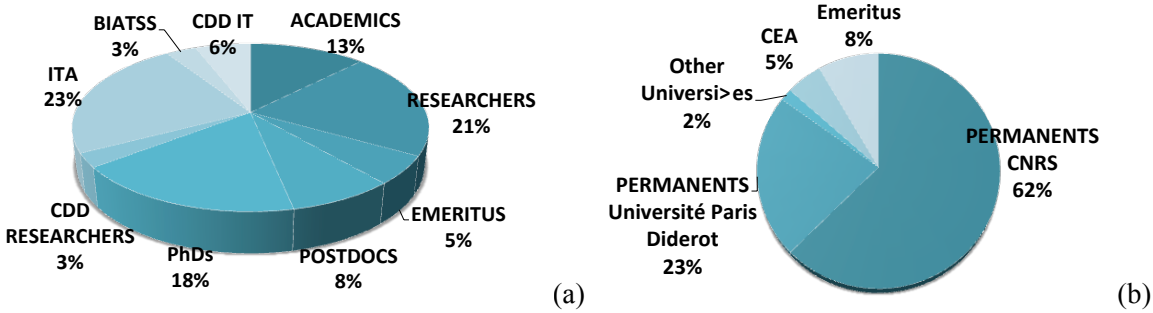


Figure 2. Composition of the lab staff on 02/06/17 according to (a) staff status and (b) organisation

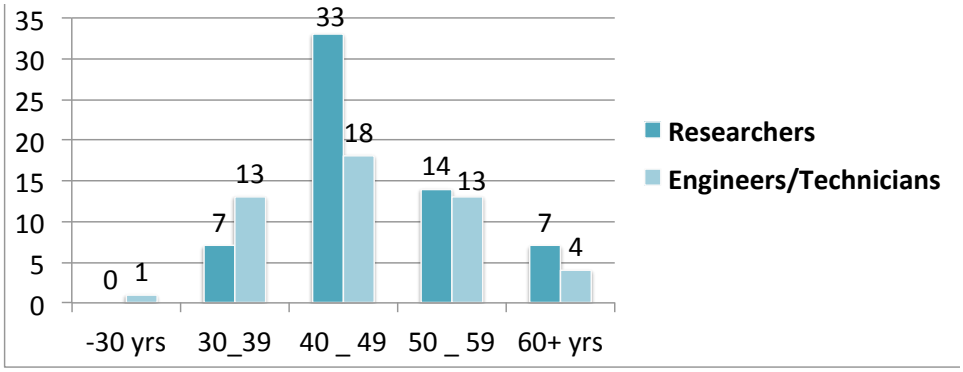
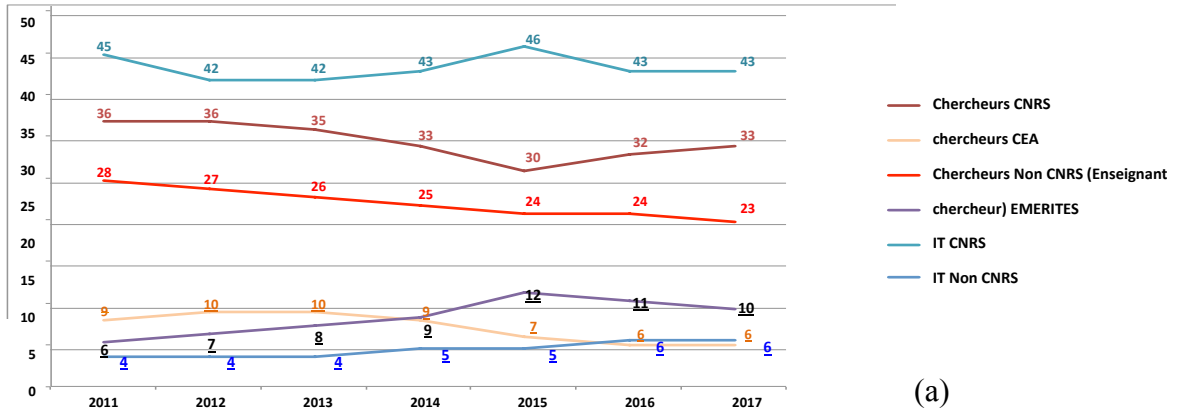
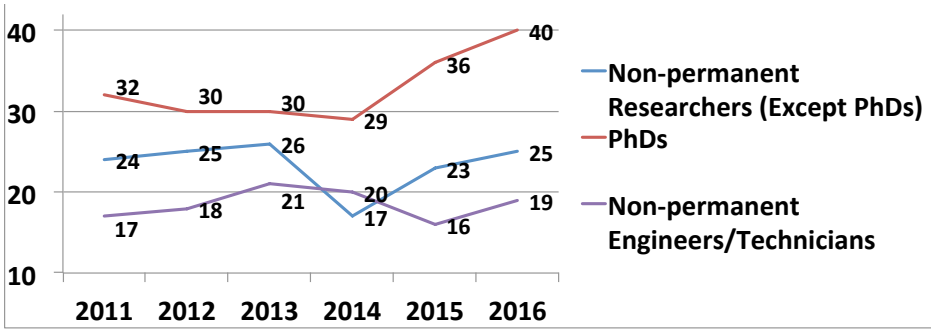


Figure 3. Research and technical staff according to age distribution

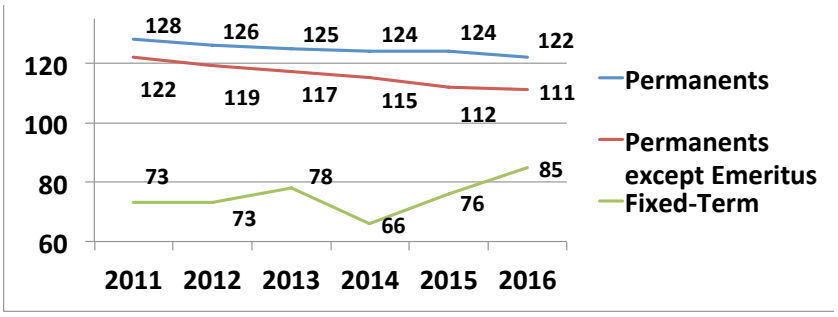
The graphs displayed in Figure 4 show the evolution of the personnel between 2012 and 2017, as well as the evolution of different sub-categories of personnel in the permanent and non-permanent categories.



(a)



(b)



(c)

Figure 4. Evolution of the number of personnel on the 31/12/2016 for (a) permanent, (b) non-permanent and (c) permanent vs non-permanent staff

One can see that between the end of 2011 and the end of 2016, 11 permanent positions were lost, and compensated with an increase of 12 persons on temporary contracts. One can also see that an almost constant

number of 45 non-permanent personnel were kept through the years (20 IT and 25 researchers), while a slight increase of doctoral students has appeared in the last 3 years. ***Thereof the order of 50 entries and 50 exits per year in the lab, representing a 25% of its personnel, and putting quite a strain on the administrative services.***

Project structure. Table 2 shows the Full Time Equivalent (FTE) for researchers, technical and administrative personnel on the 2nd of June 2017, for the 20 projects, 5 R&D (e-Graal, Compton, Gamma Cube, Muon Tomography, LiquidO) activities and personal participations (SHOOTER, SKA/PTA), active currently in the laboratory.

FTE 2017 First Quarter

	Researchers	CDD CH	PhD	Post-docs	IT	IT CDD	TOTAL
HESS-2/CTA	5,5	0,0	2,0	0,0	2	0,5	9,9
ANTARES/KM3NET	3,0	0,0	3,0	1,0	1,9	0,8	9,7
LISA/LPF	2,2	0,0	1,1	0,0	2,9	3,1	9,2
EUCLID	2,4	0,0	0,5	0,4	1,9	2	7,1
QUBIC	2,1	0,0	0,0	0,0	4,4	0,5	7,0
ADVIRGO	2,1	1,0	2,9	0,4	0,1	0	6,5
PLANCK/CORE+/S4/LITEBIRD	2,6	0,0	2,5	0,0	0,8	0	5,9
ATHENA	0,8	0,0	1,0	0,0	1,9	1,8	5,4
KIDS/BOLO	0,1	1,0	1,0	1,0	1	1	5,1
SIMULATION NUMERIQUE	1,5	0,0	1,0	1,0	1	0	4,5
JEM-EUSO	2,1	0,0	1,0	0,0	1,1	0	4,2
TARANIS	0,3	0,0	0,0	1,0	2,5	0,2	4,0
LSST	1,6	0,0	0,0	0,2	1	0,8	3,6
SVOM	1,0	0,0	0,0	0,0	2,7	0	3,6
DCHOOZ	2,4	0,0	0,0	1,0	0,1	0	3,5
WA 105/DUNE	1,6	0,0	1,0	0,0	0,2	0,5	3,3
SOX	1,9	0,0	1,0	0,0	0	0	2,9
INFIERI	0,6	0,0	2,3	0,0	0	0	2,9
NANOSAT	0,1	0,0	1,0	0,0	0,6	1	2,7
BOSS / eBOSS	1,1	0,0	1,5	0,0	0	0	2,6
POLAR BEAR	1,5	0,0	1,0	0,0	0	0	2,5
GAMMA CUBE/COMPTON	0,6	0,6	0,0	0,0	1,1	0,0	2,3
DARKSIDE	0,7	0,0	0,0	1,0	0	0	1,7
LIQUIDO	0,4	1,0	0,0	0,0	0,2	0,0	1,6
INTEGRAL/ASTRO-H	0,4	0,0	0,0	1,0	0,0	0,0	1,4
JUNO	0,3	0,0	0,0	0,0	0,2	0,5	1,0
MUON TOMOGRAPHY	0,0	0,0	0,0	1,0	0,0	0,0	1,0
E-GRAAL	0,3	0,0	0,0	0,6	0,0	0,0	0,9
SKA/PTA	0,8	0,0	0,0	0,0	0,0	0,0	0,8
X_SHOOTER	0,7	0,0	0,0	0,0	0,0	0,0	0,7
AUTRES RECHERCHES	1,9	0,0	2,4	0,0	0,0	0,0	4,3
THEORIE	10,7	0,0	8,0	4,0	0,0	0,0	22,7
ENSEIGNEMENT	10,7	0,0	0,0	0,0	0,1	0,0	10,8
WORKSHOP/Equipment	0,0	0,0	0,0	0,0	0,5	0,0	0,5
Management Support	1,2	0,0	0,0	0,0	3,0	0,0	4,2
Administration Support	0,6	0,0	0,0	0,0	13,0	4,0	17,6
IT Support	0,0	0,0	0,0	0,0	4,5	0,0	4,5
Safety Support	0,0	0,0	0,0	0,0	0,4	0,0	0,4
TOTAL	65,4	3,6	34,2	13,6	48,6	16,7	182

Table 2. FTE per project – 2017 first quarter

Faculty members. As seen in Figure 5, 38% of the researchers at APC are faculty members. The evolution of the Faculty component in the past years is also shown.

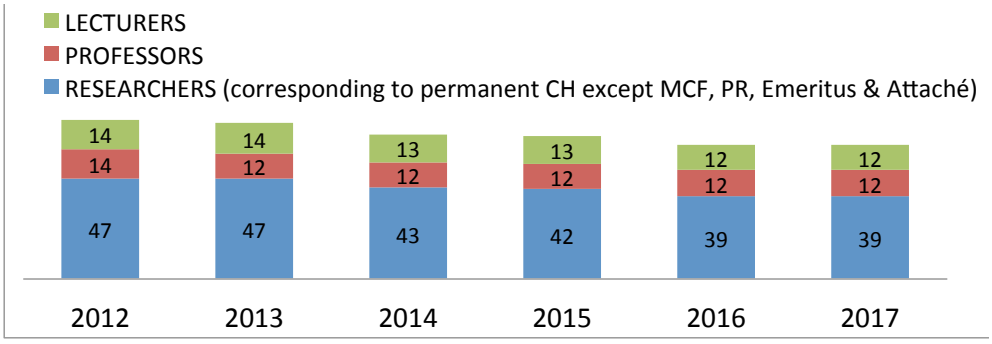


Figure 5. Evolution of the distribution of researchers according to their status

Technical department. The technical department of the lab gathers 50 agents, under the responsibility of the technical deputy director.

In 2016, the Electronics Department was renamed as the Electronics and Microelectronics Department and divided in two sub-entities: the Electronics Department and the Microelectronics Department. The latest aggregates the expertise in cryogenic microelectronics, developed during R&D on sub-K detectors and the QUBIC experiment, to increase their external visibility. The head of the Logistics Department retired in 2016 making day-to-day infrastructure management more difficult since only one technician is affected to these tasks.

Over the past few years, some skills were consolidated and new ones were developed, based on a prospective work, which takes departures and retirements into account. The figure below shows the staff evolution in terms of permanent and fixed-term position. The growing involvement in space and on-ground experiments requires even more flexibility and reactivity. This renders necessary the hiring of fixed-term staff, which represents between 25 and 30% of the laboratory technical manpower, to fulfil the projects requirements. The French space agency CNES is the principal funder for these contracts. The French research organization CNRS/IN2P3 contributes for fixed-term contracts on other priority programs such as large-size on-ground detectors projects. Maintaining and consolidating the acquired technical skills of non-permanent engineers and technicians in the laboratory is the main concern of present and coming years. In the last five years, the total technical staff oscillates between 60 and 50 (as seen in Fig. 6) whereas project requests keep growing.

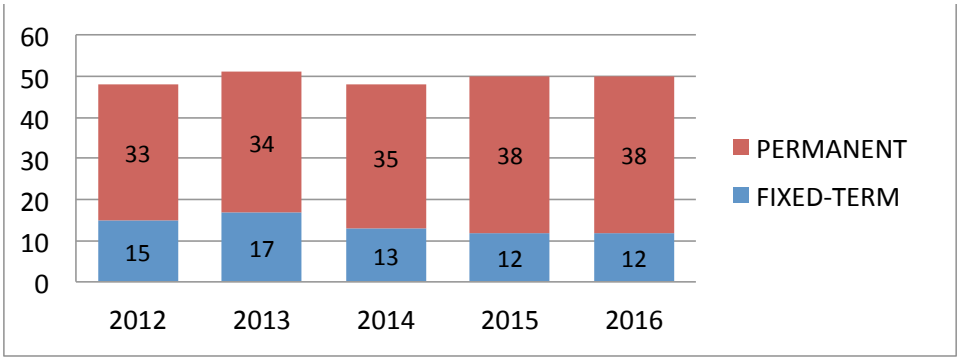


Figure 6. Evolution of the technical department staff

Fig. 7 shows the staff evolution in terms of technical profession: research engineers (IR), conception and studies engineers (IE), assistant for technical studies (AI), and technicians (T). Between 2012 and 2015, the AI staff was divided by 2 due to departures by internal mobility and retirements. The APC laboratory hired a technician for the mechanics workshop through the CNRS internal mobility procedure in 2015 and thus keeps capabilities for producing mechanics components. A cabling technician joined also the Electronics Department in 2013 through a CNRS hiring program dedicated for people with disabilities. Despite efforts to keep constant the T and AI staff, it is generally more and more difficult to find sufficiently skilled candidates on the labor market, principally because of the competition with the private sector, which offers higher wages.

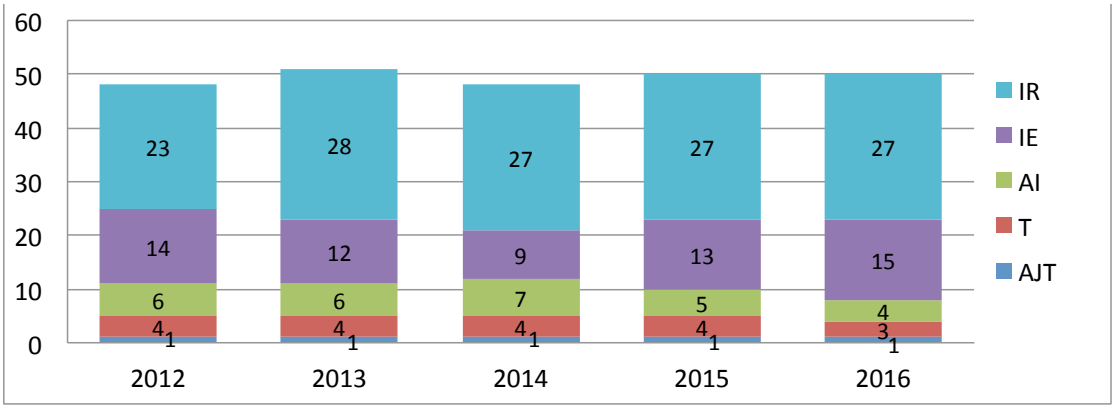


Figure 7. Technical staff evolution by status

Fig. 8 illustrates the age distribution in the technical departments on December 31st, 2016. The members of staff below 30 are mostly hired on fixed-term contracts. The main ratio of permanent positions is between 30 and 50 years old. However, 10 members of the permanent staff are above 50 and retirements are foreseen in the five coming years. Consequently, the APC laboratory has a high priority to preserve and renew the corresponding skills, particularly in mechanics, electronics and logistics.

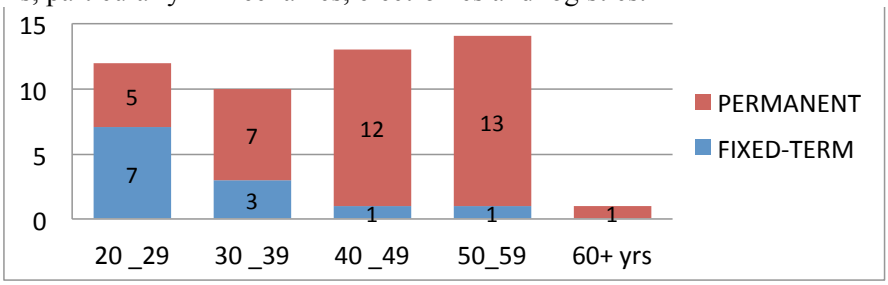


Figure 8. Technical staff age distribution – 31/12/2016

Women represent around 20% of the manpower and this ratio remains rather constant between 2012 and 2017. They are divided between the Instrumentation (Experimental Techniques), the IT and the Quality departments.

Administration. The administrative department of the lab gathers 13 officers, under the responsibility of the administrative deputy director. The evolution of the administration service is mainly characterised by its involvement in the project structure adopted since the re-organisation of the lab. The project structure is present in all fields of activity of the lab, for instance: the financial management revolves around a physicist ("physicien référent"), a project manager and a designated administrator. From this year, this organisation has been reinforced with the reallocation of all the spending categories of the lab according to the thematic groups. Henceforth, the person in charge of a thematic group (High Energy Astrophysics, Cosmology, Gravitation, Neutrino, Theory) has only one designated intermediary for the financial management who is also his contact officer for all projects or contracts stemming from the group theme.

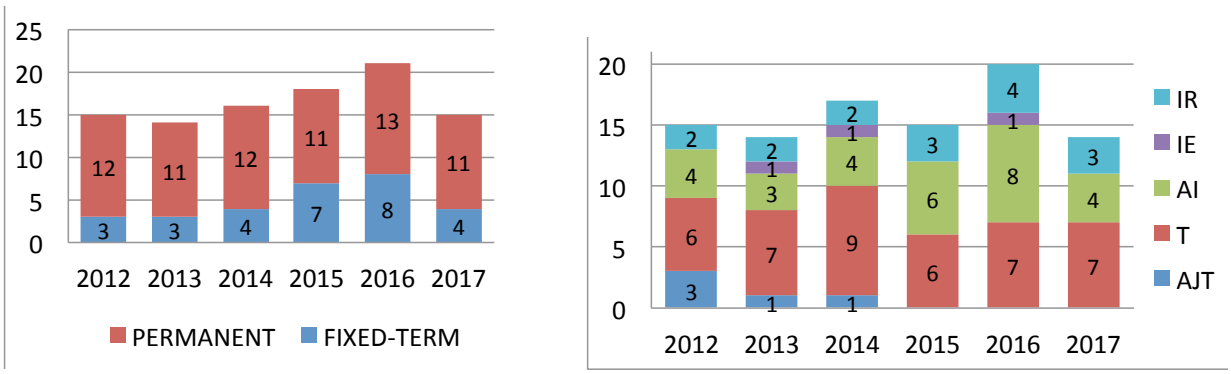


Figure 9. Evolution of administrative staff by contract term (left) and by status (right)

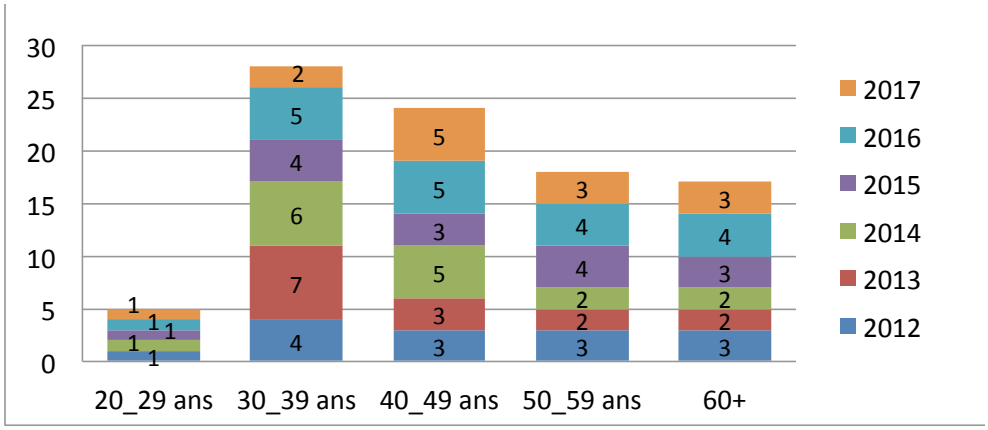


Figure 10. Evolution of the age distribution of the administrative staff

Resources. The total annual budget of the unit including salaries of the permanent staff (an approximation is used for faculty and CEA members, the exact salaries are not known) is of the order of 15 M€. The evolution of the budget from 2012 to 2017 (without counting the salaries of the permanent personnel plus the non-permanent personnel belonging to CNRS) is shown in Fig. 11 (in euros):

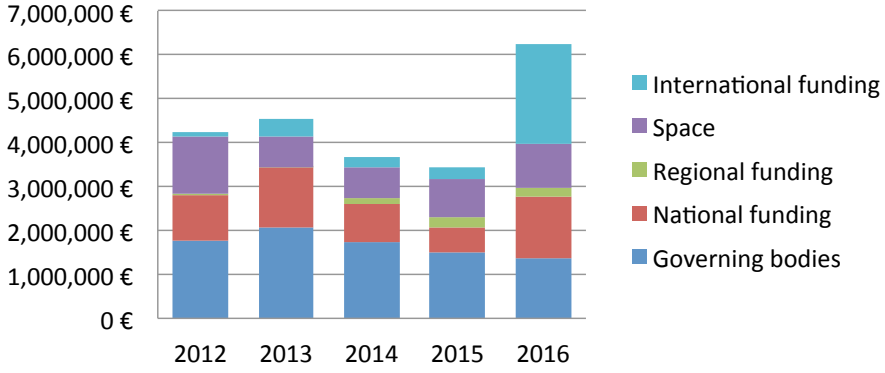


Figure 11. APC budget evolution according to the funding sources

Furthermore, as an exemple of the diversity of sources of funding we show in the graph below the percentage of resources obtained in 2012 and 2016 (excluding permanent and non-permanent CNRS, University and CEA salaries). The "proper ressources" (that is ressources not obtained through the "tutelles") have increased from 72% in 2012 to 91% in 2016 (although this presentation is biased from the fact that in the GBCP budgeting mode the multiannual budget is notified in the first year, so the budget is "forward loaded"). If one includes the salaries of the permanent and non-permanent salaries of CNRS agents these percentages become 30% (of a total of 12 M€) in 2012 to 47% (of a total of 13.7 M€). In the same period the invoices have increased by 50% and the agent missions by 33%.

The appropriations received at APC lab in 2012 and 2016, and their distribution are shown in Fig. 12.

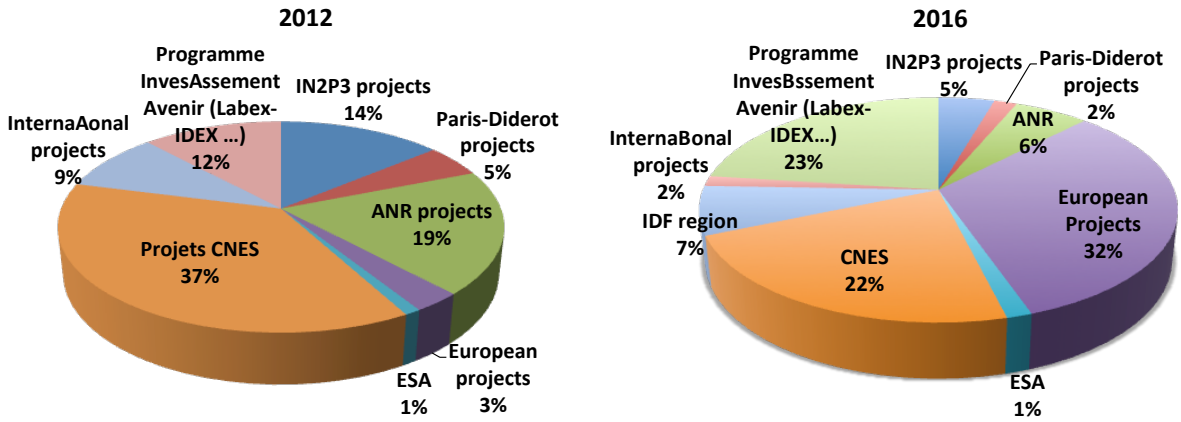


Figure 12. Distribution of the appropriations received at APC in (left) 2012 and (right) 2016

1.3 Scientific policy

Mission and scientific objectives. The main scientific objectives and the infrastructures used to attain them are:

Cosmology. After significant contributions to the **PLANCK** CMB mission, we are now developing **QUBIC**, able in principle to probe a tensor-to-scalar ratio, r, indicative of the mechanism of inflation, of 0,01. QUBIC will be deployed in Argentina. In this context, the APC millimeter laboratory is developing both cryogenic detectors (Kinetic Inductance Devices -- KIDs) and also their ASIC readouts (for both KIDS and Transition Edge Sensors -- TESs). In the near future we hope to have a leadership role in the 4th generation instruments either on ground e.g. CMB-E4 (the European analog of CMB-S4). Members of the laboratory participate both in preparation for the **LiteBIRD** satellite mission, and in **Polarbear and Simons Array**. APC is also participates in the next generation of large surveys attempting to determine the equation of state of dark energy through observatories both on the ground (**LSST**) and in space (**Euclid**). This will be a large part of the cosmology activities in the next 5 years. In parallel, researchers of the laboratory also work in **eBoss/DESI**.

Gravitation. APC is involved in the two main gravitational-wave search experiments, advanced **Virgo** on the ground, and **LISA** in space. APC develops a wide range of activities going from instrument science (R&D, instrument design and simulation, commissioning), data analysis (methods, software implementation) and astrophysics (source physics, models, multi-messenger astronomy in connection to high-energy or neutrinoastronomy).

High-Energy Astrophysics (HEA). The HEA team dedicates itself to the study of physical processes accelerating particles to relativistic energies in the Universe. Its main topics are the origin of cosmic rays, acceleration and propagation of particles, accretion/ejection processes, and all associated radiations: photons, neutrinos, cosmic rays themselves and the connection with gravitational waves. The team participate actively to many experiments at several wavelengths and using several messengers, in particular in the field of high-energy photons (X-rays, MeV and TeV gamma-rays), high-energy neutrinos and cosmic-rays hadrons notably at ultra-high energy, in close collaboration with gravitational waves experiments. The HEA projects range from "low energy" X and Gamma rays, using space satellites **(Integral, TARANIS, SVOM, ATHENA)** to high-energy photons **(HESS2/CTA)** neutrinos **(ORCA/ARCA/KM3Net)** and charged cosmic rays **(EUSO/POEMMA)**.

Neutrino. APC concentrates here on the issues of determination of the mass hierarchy of neutrinos and the search for dark matter. The neutrino group is based on its solid experience, in liquid scintillator methods in **Borexino** and **DCHOOZ** and projects its activities in the experiment **JUNO** in China, as well as the search for sterile neutrino (**SOX** using the **Borexino** tank). The DCHOOZ team has also initiated recently an ambitious R&D **(LIQUIDO)** supported by the Blaise Pascal chair of Prof. F. Suekane. Another part of the neutrino group is concentrated on Liquid Argon as a means of detecting neutrinos, participating in the **WA105** prototype in view of the global experiment **DUNE**, in the US, proposing to measure the mass hierarchy and CP violation in the neutrino sector. Last but not least, the detector **ORCA/KM3Net** aims to

measure the neutrino mass hierarchy in the coming years. **Dark matter.** Follow ing the experience existing in the neutrino group working with low energy (keV-MeV) signals and at low background (highly radio-pure detectors located deep underground), the dark matter effort is located in the neutrino group. In keeping with the long-term interests of the group (DUNE) and the techniques of Liquid Argon, and forseeing future synergies, **DarkSide,** an experiment using dual-phase liquid argon was selected.

Theory. APC has a strong theoretical group on astroparticle physics (transition galactic/extragalactic, cosmic ray anisotropy and sources, origin of cosmic neutrinos); physics and astrophysics of neutrinos (role of neutrinos in supernovae and binary neutron stars, sterile neutrinos); cosmology (inflation, effective theories for dark energy, quantification and cosmology); gravitation theories (Horndeski and beyond, quantum gravity, massive gravity, gravitational waves); quantum field theory (renormalization in anti-de Sitter, confinement); duality gravity/gauge theory.

The existence of teams working in the above themes in the same place is an extraordinary asset on many transversal studies that are currently at the forefront of research. One can for instance. cite 4 of them relating the above domains:

I. the coverage of a large spectre of frequencies in the analysis of cosmology and gravitation permitted by the presence of experiments both on space and ground in these domains;
II. the measurement of the neutrino mass hierarchy indirectly through CMB and large dark energy surveys and directly though experiments on ground as a portal to new physics beyond the standard models of Cosmology and Particle Physics;
III. the search of dark matter both indirectly from combined studies of astrophysical signatures and direct measurements through underground experiments;
IV. the study of violent phenomena and their impact on structure formation using multi-messenger studies (photon, neutrino, cosmic ray, gravitational wave) and in particular the followup of gravitational wave events with the other messengers giving an exquisite handle on the underlying physics.

Finally, APC hosts an activity on energy physics developed within the recently affiliated Energy Physics Group which combines a traditional emphasis in fluid mechanics, heat transfer, and statistical physics with an understanding and application of molecular physics, physical chemistry and biology. Research activities are particularly focused on two main fields: Hydrodynamics of active matter and Physics of transport phenomena; both with final application to Energy Challenges of Tomorrow. The Energy Physics Group has also a strong link with the energy industry through which new challenges are detected and the related research is funded.

Transverse interdisciplinary strategic elements:

Data science. Data science, ranging from simulations to the analysis of large data sets (maps of the universe) and data-mining methods (e.g. machine learning, wavelet analysis), as well the preparation of computing software environments for code creation and user interaction are key ingredients of the research in all the above fields. This was the reason of the creation of dedicate group till 2015 on data-science and above all for the creation of the François Arago computing Centre (FACe) in 2010. FACe became the focus and interaction place of about 10 engineers and an equivalent number of scientists working on data-science. The future of FACe is a central item in the next 5-year plan, and we have submitted to the region Ile de France a SESAME project federating FACe with the equivalent IPGP data science centre (S-CAPAD).

Space program. APC since its inception made a special effort to become a key player in the space science program, a relatively rare ambition at the time in the context of the IN2P3/CNRS Institute, but closely related to Astroparticle Physics and Cosmology thematic and priority choices. APC also profited enormously in this effort from the expertise of its CEA related members. This effort has given its fruits, since: a) today nearly half of the projects of APC are connected with space (Planck, Euclid, LISA/LisaPathfinder, Integral, SVOM, ATHENA, TARANIS, JEM-EUSO); b) CNES recognises APC as a space lab; and c) APC publications together with the publications of other space labs connected to Paris Diderot have given to the University Paris Diderot the first position[5] in France with respect to Space Science

[5] This was till 2015. In 2016 Paris Diderot became second, with a very small difference, to UPMC.

in published "Shangai type" analyses. The consolidation of the role of APC in national and international space missions is a pilar of our scientific policy.

Education and outreach connected to research on cosmology and Gravitation. A key element of the APC strategy is the development of the activities of the Paris Centre for Cosmological Physics (PCCP) founded by George Smoot. His goal was to create a Cosmology Centre in order to attract young and excellent researchers in cosmology to the Paris area. PCCP has various activities: hiring of postdocs in cosmology, visitors programme, organisation of workshops on topical subjects, development of innovative detectors, organisation of training sessions for high school teachers (these sessions called "Teaching the Universe", co-organized with the Palais de la Découverte science museum, and are part of the official training programme of the three Paris academies), last but not least using innovative methods to disseminate science (MOOC Gravity launched by the late Pierre Binétruy with 96000 registered).

Interdisciplinarity with Geosciences. The interdisciplinary alliance with Geosciences in the context of the Laboratory of Excellence (LabEx) UnivEarths is a strategic choice of APC. In the last years, there appeared many areas of natural synergy between Geosciences and Astroparticle Physics. Earth and Astroparticle sciences share a mutual scientific culture based on common objects of study, methods and approaches. First, the geosphere, a direct object of study of the geosciences, is both the target and the detecting medium for astroparticle observatories. Then, 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 develop models relying on the state of the art in fundamental physics, chemistry, biology and informatics. This Labex UniveErths is considered among the most succesfull ones, since a genuine cross-cultural atmosphere has been developed. The Labex (Laboratoire d'Excellence) allowed the development of innovative interdisciplinary projects, assembling three founding members (laboratories IPGP, APC and AIM) as well as the French aerospace lab ONERA. Many important research results have been obtained. Among these results one can cite: a) neutrino imaging for fundamental physics and astrophysics as well as the radiography of the earth's interior (geoneutrinos, high energy neutrinos); b) gravitational imaging for seismology (eg early warnings) using gravitational wave detection techniques; c) deep-sea observatories for neutrinos and geoscience monitoring; d) muon imaging for volcano muon tomography and archaeology; e) nanosatellites and space weather… and in the future e.g. acoustic imaging for seismology, cosmic neutrinos, deep sea biology. The Labex Univearths is currently submitting a project of a Graduate School[6] (Earth-Plantes-Universe) that would complement research with education; it will be a central part of our policy for the next 5 years.

Institutional insertion. APC works proactively in view of a federation of Paris IN2P3 laboratories (APC, LPHNE, LLR). APC participates in an effort of federation of its activities with these of other laboratories of IN2P3 in the Paris area. This is still a very recent project, with a program under definition. **APC also proactively participates in the formation procedures of the ComUe and IDeX USPC.** APC as a "mixed unit" (UMR) of the Physics Department (UFR) of Paris Diderot University participates in the effort towards a unified Univeristy and the ComUe ("Communauté Universitaire") SPC. The ComUe has obtained significant funds (2012-2016) in view of the creation of a unified university structure (IdEx). This effort was stopped in 2016 and the ComUe was asked to argument for an eventual resubmission of a new project. It is interesting to note that among the 4 domains of international excellence described in the letter asking the possibility of resubmission there was the Earth and Universe domain corresponding to the partners of the LabEx UnivEarths. The demand was succesfull and the Comue is currently preparing for a resubmission, of both the unified university structure and the future IdEx gathering all the Comue Partners. Furthermore, four "colleges" ("pôles") have been created in the context of SPC covering the 4 large domains of the SPC: a) exact sciences and technology (SET); b) biomedical; c) social sciences; and d) art and humanities. The director of the APC is coordinating since 2015 the first college SET, and in this context an initiatiave covering all 4 poles has been developed projecting the creation of an Institue of Data Science with thematic content covering all 4 colleges. This is an initiative in the spirit of the emphasis of APC on data science and all SPC establishments consider it a key project of the future IdEx. Furthermore, the leader of the Energy

[6] Essentially the Master part since the Doctoral part has already been unified in the context of UnivEarthS.

Physics group initiated and manages the "Programme Interdisciplinaire des Energies de Demain", a key program of USPC.

Regional Insertion. APC is also participating in DIM-ACAV, has profited from funding of its actions in the past and hopes to also profit in the renewed program Dim-ACAV+ recently accepted. The Dim-ACAV is the place of convergence of all astrophysics and astroparticle efforts in Ile-de France; it is therefore the natural environment of work for APC and the place to elaborate future synergies and convergence.

European Insertion. APC being one of the functional centres of APPEC, it plays a proactive role in the European convergence of Astroparticle Physics. Key actions and meetings for European (Raodmap meeting in Paris on 2016) and world-wide (on neutrino and cosmology) coordination are due to APC initiatives. These initiatives will continue in the next years, e.g. in the interdisciplinary front, of convergence with geosciences, following the model of UnivEarths. A meeting between APPEC and the consortium of key Geoscience agencies (GEO-8) is planned in the fall of 2017 as a first step in this road.

International insertion. APC is embedded in a large network of international centres of excellence of Astroparticle Physics: it has a common LIA with the Kavli Institute for Particle Astrophysics and Cosmology (KIPAC) of Stanford University and SLAC in the US, a second with the Centre of Excellence KIPMU (Kavli Institute for the Physics and Mathematics of the Universe) in Tokyo and a third with Argentina (CONICET and CNEA). It also has a long standing LIA with Kurchatov Institute in Moscow. Furthermore, APC has a long-term collaboration with the University of Chicago and its Kavli Institute of Cosmological Physics (KICP); Princeton University (Visiting Professor C. Galbiatti); New York University; the German Helmholtz Allianz for Astroparticle Physics (HAP) and Karlsruhe Institute of Technology (KIT); Albert Einstein Institute (Hannover) on the detection of gravitational waves in space; Technische Universitaet Muenchen (TUM); Hamburg in the context of a collaboration APC-Oxford-Hamburg; Sapienza in Rome and Milano Bicocca; NCBJ (Nuclear Center for Nuclear Research) in Poland; the Perimeter Institute (Canada) and Solvay Institutes (Belgium). In the context of PCCP, there are also important relations with the Energetic Cosmos Laboratory (ECL) at Nazarbayev University, Astana, Kazakhstan.

It is also important to note that an International Mixed Unit (IMU) between Paris (APC and LPNHE) and the Bay Area of the US (Berkeley, Stanford) is under construction. The APC director is the current coordinator of this action. APC is also the foreign partner, ready to provide expertise for the creation of a Center for Astroparticle Physics (AStroCENT, head L. Roszokwski), close to the APC themes in Warsaw. APC also participates to 3 itenrational doctoral programs (see section on education). Last but not least, APC hosts annually over ten international conferences and workshops and also has a rich outreach program, including **art-science** actions (APC-Foundation of France cofounding of the work of art "Squaring the Circle" by the Hungarian artist Attila Csorgo).

Technical and infrastructure policy.

The APC laboratory is strongly involved in scientific experiments using on-ground instruments and detectors embedded on satellites. The technical departments of the laboratory contribute to associated instrumental developments, including design studies, construction, tests and validation. They gather dedicated skills and are under the global supervision of a technical director, member of the laboratory direction office. Each technical department is hierarchically structured with a department head and his or her deputy. It gathers all related skills in a given field (Electronics, Microelectronics, Software and Network Administration, Instrumentation, Quality and Product Assurance). The department head is appointed for a renewable two years term to allow a turnover of responsibilities. Each member of a technical department is generally involved in a main project (for a Full-Time Equivalent around 80%) plus a second one. However, in the IT and the Quality Departments, many of them embrace support activities (QA/PA, system and network administration, command and control, algorithmic) in more than two projects. All technical departments fit in the matrix organization of the laboratory. Each member of the technical staff is attached to a Department according to his/her skills and assigned to projects.

Project Organization. All APC scientists who benefit from technical skills for hardware and software developments comply with a standardized project management structure:

- Projects are divided in phases tagged by reviews, internally (the CSP is the APC internal review structure) or under external agencies supervision (national French research agency IN2P3, French space agency CNES…)

- The Quality Department provides several kinds of template documents for schedule control, reporting, finance monitoring, quality assurance, product assurance and reliability.
- Project managers use Electronic Document management tools to store critical documentation or various reports. Since 2016, the new IN2P3 ATRIUM tool replaces EDMS.

A Scientist manager and an Engineer Technical manager share project management.

Education policy. The fields of expertise for lecturing of faculty members are centered on particle and astroparticle physics, theoretical physics, signal and data processing and instrumental developments, particularly in the space domain. APC members actively participate to the administrative boards of Paris-Diderot University and of its Physics Department: the Department Coucil (5 members) the Scientific Council (5 members), the Teaching Council (4 members). Since the international dimension of education is very important for APC, one of its professors has taken the responsibility of coordinating international student exchanges (Erasmus programme).

APC members lecture and are involved in undergraduate labs for all the programmes proposed by the Paris-Diderot University. In *Licence*, APC Faculty members are coordinating and lecturing the major courses on general physics topics for up to 300 students in 1st year (L1). They have also been very implicated in the discussion and modification of the *Licence* programs during the past 5 years. APC PhD students and postdocs participate in the tutoring (*Travaux Dirigés*) and lab works (*Travaux Pratiques*). APC Faculty members are responsible for various courses leading to a specialization for the first year of the Master course (M1): Field theory, Nuclear and Particle Physics, Astrophysics. For the second year (M2), « specializations » of Paris-Diderot most tightly related to APC are: a) Nuclei, Particles, Astroparticles and Cosmology (NPAC); b) Astronomy, Astrophysics and Space Engineering (AAIS); Fundamental Concepts of Physics (CFP); Physics Engineering of Energies (IPE).

APC members have had a leading role in the coordination of two Master 2 Programmes:

- "NPAC: Nuclei, Particles, Astroparticles and Cosmology" Master. Since 2016, the 2 co-responsibles for Paris Diderot are faculty members at APC.
- "Space and Applications" Master at the French-Vietnamese University of Science and Technologies. Since 2012, APC members have participated to the definition of the program.

IGOSat: a students' nanosatellite project. IGOSat is the first educational 3U CubeSat (10x10x30 cm) developed at Paris Diderot University with main objective to give university students hands-on experience of a real satellite project. So far, more than 200 students have been working on IGOSat. Each year, about 15 interns (from bachelor to master level) are supervised by about 10 scientists and engineers from APC and IPGP (Institut de Physique du Globe de Paris).

Students' internships. All lab members are involved in "Training through research" at all stages of education:

- High-school students regularly spend one or two weeks to learn about research activities and how a research lab operates. Students from technical schools spend one or two months.
- Students from different origins (technical institutes, university, etc.) perform their internship within one of the support units: electronics, mechanics, administration, etc.
- University students come to APC for internships of different kinds. Some of the 3-rd year Licence students of Paris-Diderot University joined a research team for two months, to start familiarizing with research activities a few hours a week. The mandatory one-month internship for 3-rd year Licence students at Paris-Diderot University, at the end of the L3 year, is regularly taken in research groups at APC.
- 141 Master students (M1+M2) were hosted at APC in the past 5 years with an average of 28 students per year, ranging from 13 students in 2015 to 42 students in 2016.

Graduate Level Education. A dozen of PhD students and post-docs are enthusiastically involved in teaching and training. There is a tight connection between research and training at graduate level. Since 2012 the PhD students at APC are enrolled in the Doctoral School STEP'UP (ED 560), which covers a vast scientific area, ranging from the disciplines of Geosciences, Environment and Planetology to the Physics of Two Infinites. The STEP'UP doctoral school is organized in two components: Earth Sciences and the Environment and Physics of the Universe. PhD students of APC are assigned the component Physics of the Universe. The APC participates to this doctoral school for both pedagogical and organizational matters. The

head of the "Physics of the Universe" component is member of the APC. Another member is part of the bureau of the doctorate school, and another one also takes part in the recruiting committee as expert.

PhD students at APC. From 2012 to 2017, 55 PhD candidates were enrolled and 50 PhD theses were defended. APC research teams were capable of funding 2/3 of PhD allowances through projects grants (ANR, ERC, Europe, etc.). The remaining students received scholarships from the Doctoral School. About a dozen of PhD students join APC every year. The follow-up of theses is ensured with tight connection with the doctorate school. Since 2013, the lab organizes the *PhD students' day*. Throughout the day, APC PhD students present their thesis activities through oral presentations and posters. All members of the laboratory are invited to participate. The PhD students of the Lab organize a weekly Journal Club with discussions based on recent articles related to diverse themes covered in the laboratory.

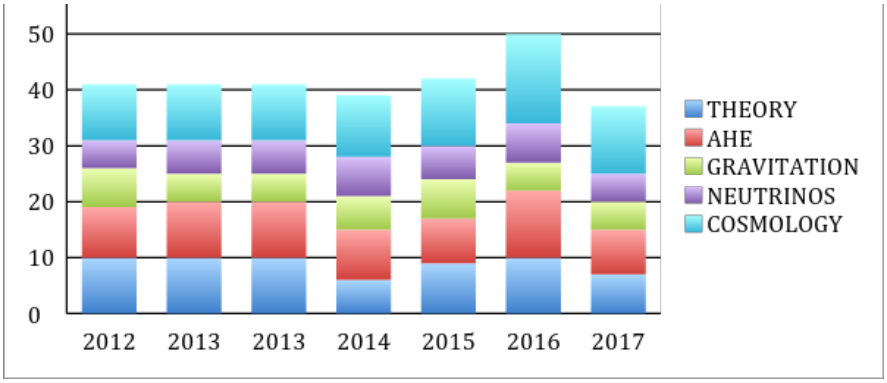


Figure 13. Total number of PhD students per year and per team.

International Doctoral programmes. APC has been a leader in the creation of international doctoral programmes:

- IDAPP, International Doctorate on AstroParticle Physics allowed for several official co-tutorships involving APC and Italian Universities.
- IDPASC, International Doctorate in Particles, AStroparticles and Cosmology (http://www.idpasc.lip.pt) is an interdisciplinary network whose purpose is to create new high-level experts in the fields of Particle Physics, Astrophysics and Cosmology and facilitate ERASMUS exchanges.
- The Oxford-Hamburg-Paris International Doctorate on Astroparticle Physics with Multiple Messengers (http://www.desy.de/~sigl/ap-hamburg-paris-oxford.html) is a research project for exchanging Ph.D. students.

Thematic and summer/winter schools. An important part of training of graduate students comes from thematic schools. APC members participate to the organization of several summer or winter schools:

- ISAPP, International School of AstroParticle Physics (http://isapp.ba.infn.it/) is a network of European Doctorate Schools with a common curriculum in Astroparticle Physics. Two schools are organized per year. Since 2012, 2 schools were organized in APC.
- *"Ecole de GIF"* (http://ecole-de-gif.in2p3.fr/une.htm) An APC Professor is member of the scientific organising committee and chair of the committee since 2013. The 2011 edition on "Neutrinos" and the 2014 edition on "Cosmology" were organised at APC in September.
- The "*Rencontres de physique de l'infiniment grand à l'infiniment petit*" are regularly organized. APC is a supporting institute sending students and providing lecturers and participating in the Organizing Committee.
- Since 2014, the LabeX UnivEarthS organizes an *autumn school* that brings together about 30 students during a week of classes in an exceptional setting. The school is open to students studying at APC.

Massive Open Online Courses. The APC lab is at the origin of the Massive Open Online Course (MOOC) *Gravity!* The course, which was originally developed in French, is now available in English. It is a course for the general public aiming at presenting the various aspects of gravity in the Universe, featuring Pierre Binétruy and the 2006 Nobel Prize winner G. Smoot. The latest edition has been followed by 96 000 subscribers.

Projects for the future. The projects for future developments of teaching activities in which APC wishes to have an important role are mainly related to the aim for internationalization and to the new dynamics created around the collaboration with Earth science mainly in the context of the UnivEarths LabEx programme and the doctorate School STEP'UP. Following this approach APC intends to play a leading role in in the development of the future Graduate School (***Ecole universitaire de Recherche***) gathering Earth-Planets-Universe sciences. The project is expected to set up a unique high-level teaching and training platform related to those domains, and furthermore to achieve efficient technology transfer between the partners as well as towards other institutes and industry. Finally, novel outreach initiatives will be promoted, in addition to a reinforcement of Master formation towards Astroparticle physics. An effort will be made in association with the Physics department to provide a formation in English, so to ensure attractivity to foreign students.

Outreach policy.

APC is very active in outreach on different domains. The main actions concerning this period are: a) website redesign and video presentations, b) participation in science fairs, c) demonstration tools for science, d) Teaching the Universe actions, e) art and science actions, f) MOOCs, g) Physics Masterclasses, h) Univearths Fall school and i) exhibitions. They are presented below in more detail:

Website redesign, APC video and Youtube channel. The laboratory website has been completely updated (structure and design), in order to be more user friendly and easier to use both internally and for the external visitors. APC has hired in 2014 a private company (Websedge) to make a video showing the APC scientific themes and activities. This video has been shown in APS conferences and can be see at the first page of the website. Over the last years, video clips were recorded and have actively been uploaded to the APC lab Youtube Channel, which now counts 40 video recordings, with in particular films on the TARANIS satellite, LISA Pathfinder, neutrinos and gravity.

Science Fair. The APC has been participating to the science festival "Fete de la Science", held at Paris Diderot University every year, with a stand for demonstrations on: Gravitational waves, Cosmic rays, Cosmological background and the student nanosatellite IGOSat project. The animations included a scientific presentation of the subjects, adapted to the level of the students (high school, master) or the general public, using presentation panels and videos, as well as a time of exchange with the researchers. The animations have been completed by conferences given by researchers on the last advances of our domain.

Demonstration tools. Outreach activities have been carried out with the instruments listed below:

- Radio telescope demonstration or the cosmological background detection. The radio telescope has also been used at the observatory of Paris for master students.
- Cosmic Ray Balloon. For 3-4 years, outreach activities have been carried out towards senior high schools, with the support of CNES and the assistance of Planete Science. Following a selection process, 10 high schools had the opportunity to participate in the detection of cosmic rays. Thus, cosmic balloons equipped with a basket containing a detector and a GPS were sent at 30 km of altitude. This set-up also allowed live transmissions to the high school students on the ground.
- Since the first observation of gravitational waves, activities related to this theme were more frequent, in-house demonstrators to explain gravitational waves and space-time curvature were developed.

Teaching the universe. This action, part of the training programme of teachers from the regional education authorities of Ile-de-France, has carried on with the participation of Prof. Pierre Binetry and the Nobel Prize laureate George Smooth. About 50 high school teachers participated in this three-day training on cosmology every year.

Art and Science. APC hosts annually over ten international conferences and workshops and also has a rich outreach program, including **art-science** actions (APC-Foundation of France cofounding of the work of art "Squaring the Circle" by the Hungarian artist Attila Csorgo and an action on gravity "Universe 2.0 funded by the foundation Carasso).

Physics Masterclass. On the occasion of the UN World Day for Women and Girls in Science, a Masterclass of Physics was organized in 2017 in partnership with the European GENERA project. 30 students from Parisian high school were welcomed to the laboratory to discover our domain, to visit the place with the PhD students, including the millimeter room and the clean room, and to participate in a computer analysis of CERN data analysis about neutrinos. Given the success of the day, similar events will be implemented in the coming months.

UnivEarthS Fall School. Since 2014, the Labex UnivEarthS has organized in partnership with APC an autumn school that brings together about 30 students during a week during a special place. The school is open to students in master's or PhD, to the scientists working on the UnivEarthS thematic, and it also hosts high school science teachers via the association "Les cordées de la réussite". The school brings together researchers from different disciplines, creates interfaces between Earth Sciences and Physics of the Universe, and confronts the resarchers to a different public with the high school teachers.

Exhibitions. A photo exhibition was held on the Double Chooz experience on neutrino oscillations in 2014. An exhibition of ancient instruments was organized during the 2016 Science Fair to present the advances and methods used since 1700 to the current day in the discovery of the universe and cosmology.

Valorisation policy.

The Valorisation correspondent, appointed by the lab director, is a researcher or engineer well informed on the work of the different research teams and able to build a relationship of trust with each colleague. They encourage the communication between the lab and its governing bodies and partners and facilitate the technology transfer process. The tools put in place in APC are laboratory workbooks (distribution and management) while a reflection is underway on the electronic lab notebook. Other axes of possible improvements are: welcoming procedure at the lab to be completed in order to better inform on the issues of innovation, technology transfer and commercialisation, and the rules to be respected. A connection seems necessary with the personnel training on the computer security rules.

Key accomplishments of the laboratory on valorisation. Currently a project is in its maturing phase with the support of the SATT IDFINNOV. It concerns an idea of Gamma Plenoptic Camera whose principle has been filed for patent. A collaboration has been set up with a neighbouring lab in order to mobilize the resources essential to the maturing phase of this project. It reveals that accessing available resources and the associated means is an obstacle for actions to exploit the research results.

2. Scientific production and activities

2.1 Scientific output

The unit is a fundamental science unit, therefore its main scientific output are publications and conferences, as well as responsabilities in key technological and data-science parts of large scientific infrastructures. The scientific output is presented in detail in appendix 4. Here we present only a concise summary of the activities.

First, on what concerns prizes and distinctions, the laboratory counts in its premises:

- A nobel laureate (G. Smoot) on cosmology
- 4 members of the Institut de France (J. Bartlett, A. Kouchner, V. Van Elewyck, T. Patzak)
- 1 ERC advanced grant (E. Kiritsis) and 2 ERC Starting Grant (T. Lasserre and C. Deffayet)
- 3 Gruber Prize and Special Breakthrough prizes in Fundamental Physics (Virgo team: M. Barsuglia, E. Chassande-Mottin, E. Porter)
- 1 Prix Descartes for H.E.S.S. (M. Punch, 2013)
- 1 Chevalier de l'Ordre National du Mérite (2012, S. Katsanevas)
- A Prix Montpetit, Académie des Sciences (E. Chassande Mottin)
- 2 Unesco-Loreal prizes for women in science (E. Capocasa, V. Domcke)
- 1 Prix du Magazine de la Recherche (N. Busca)
- Lewis F. Moody Award of the American Society of Mechanical Engineers (2013, H. Peerhossaini)

Publications and Conferences. In the years under examination (2012-2107) the unit has produced 1105 publications, which if normalised to the number of permanent researchers and high level engineers would give an average of 3,5 publications per year (see Appendix 4 for a characteristic list of 20% of publications). These publications, although still relatively « recent » have obtained over 50000 citations, giving an average of 50 citations per publication (source INSPIRE). Among the publications there are: *12 « renowned » papers* (> 500 citations) coming essentially from PLANCK, VIRGO, DCHOOZ and BOSS, *18 « famous » papers* (250-500 citations), where, apart from the previous experiments, one finds also the CTA concept paper, *53 « very well known »* (100-250 citations) and *94 « well known »* (50-100 Citations).

There have also been 13 published monography books and 7 chapters in multi-author books. In addition, there were numerous invitated presentations to international conferences (293 published proceedings). We present in appendix 4 a selection of 50 characteristic published presentations, plus a selection of non-published ones. A conservative estimate of the invited presentations conferences per year and per permanent scientist or high-level engineer is of the order of 2 per year. The members of APC have also a good share in the organisation of international conferences.

Scientific Responsabilities and technological achievements. A long list of responsibilities is also presented in Appendix 4, among them, one can note that nearly 10 high responsablity positions are held by APC members (3 spokesmen, 1 co-spokesman, 2 data-center responsibles and 3 co-PIs or co-spokesmen, 1 project coordinator) while APC members occupy close to 40 positions of responsibility of parts of major infrastructures.

Nearly 40 members of APC are evaluators in the many scientific journals of the domain, and half of them participate in editorial commitees and around 50 members of APC participate in evaluation bodies on behalf of national and international agencies, on projects and in view of recruitment of researchers and/or academics. There are 5 characteristic R&D efforts in progress while in the last five years, one patent was granted. The laboratory is also a rich source of information technology products. In appendix 4, we present near 20 products covering simulation and analysis codes and the setting up of pipelines.

2.2 Quantitative data

Ces données chiffrées concernent la totalité de la production et des activités de l'unité de recherche.

5 – Produits et activités de la recherche - Données chiffrées

			Équipe 1 Cosmo	Équipe 2 Grav.	Équipe 3 HEA	Équipe 4 Neutr.	Équipe 5 Theory	Équipe 6 Ener. Phys.	SC Tech. Depts
Journaux / Revues	Articles scientifiques *(pour le domaine SVE, préciser le nombre d'articles en premier et/ou dernier auteur entre parenthèses)* Articles de synthèse / revues bibliographiques Autres articles *(articles publiés dans des revues professionnelles ou techniques, etc.)*	1105	297	114	235	71	280	40	68
Ouvrages	Monographies et ouvrages scientifiques, éditions critiques, traductions	13	1				12		
	Direction / édition scientifique	4		1			3		
	Chapitres d'ouvrage	7		3	2	2			
	Thèses publiées / éditées	2						2	
Colloques / congrès, séminaires de recherche	Éditions d'actes de colloques / congrès Articles publiés dans des actes de colloques / congrès Autres produits présentés dans des colloques / congrès et des séminaires de recherché	318	43	27	98	77	48	25	
Développements instrumentaux et méthodologiques	Prototypes et démonstrateurs **(1)**	oui	oui	oui	oui	oui	non	non	oui
	Plateformes et observatoires **(1)**	oui				oui	oui	non	oui
	…								
Produits et outils informatiques	Logiciels	20	4	3	11	1	0	0	1
	Bases de données / Cohortes							0	
	Corpus **(1)**					?			
	Outils présentés dans le cadre de compétitions de solveurs								
	Outils d'aide à la décision	1				1			1
	…								
Brevets, licences, déclarations d'invention		1	0	0	1	0	0	0	
Rapports d'expertises techniques, produits des instances de normalisation		4	1	1		2			
Produits des activités didactiques	Ouvrages	3		1		1	1	0	
	E-learning, moocs, cours multimédia, etc.	32	6	11	3	3	6	0	3
Produits destinés au grand public	Émissions radio, TV, presse écrite	36	10	10	5	5	5	0	1
	Produits de vulgarisation : articles, interviews, éditions, vidéos, etc.	128	21	6	4	62	32	0	3
	Produits de médiation scientifique **(1)**	oui	oui	oui	oui	yes	oui	0	oui
	Débats science et société	19	1	4	4	3	7	0	
Autres produits propres à une	Créations artistiques théorisées	0	0	0	0	0	0	0	

discipline	Mises en scènes	0	0	0	0	0	0	0	
	Films	1	0	0	0	1	0	0	
	…								
Activités éditoriales	Participation à des comités éditoriaux (revues, collections)	27	3	3	2	5	7	2	5
	Direction de collections et de séries	1	1	0	0	0	0	0	
Activités d'évaluation (1)	Responsabilités au sein d'instances d'évaluation	oui	oui	oui	oui	7	oui	oui	
	Évaluation d'articles et d'ouvrages scientifiques	oui	oui	oui	oui	10	oui	oui	
	Évaluation de laboratoires (type HCERES)	oui	oui		oui	4		oui	
	Évaluation de projets de recherche	oui	oui	oui	oui	6	oui	oui	Oui
Activités d'expertise scientifique (1)	Activités de consultant	oui						non	Oui
	Participation à des instances d'expertises (type Anses) ou de normalisation	oui						oui	Oui
	Expertise juridique	non	non	non	non	non	non	non	
Organisation de colloques / congrès		61	16			16	22	7	
Post-doctorants et chercheurs accueillis		67	15	5	28	8	11		
Interactions avec les acteurs socio-économiques	Contrats de R&D avec des industriels	1						1	
	Bourses Cifre	0							
	Créations de laboratoires communs avec une / des entreprise(s)								
	Création de réseaux ou d'unités mixtes technologiques								
	Création d'entreprise, de start-up	1			1				
Contrats de recherche financés par des institutions publiques ou caritatives	Contrats européens (ERC, H2020, etc.) et internationaux (NSF, JSPS, NIH, banque mondiale, FAO, etc.)	10	2	1	1	3	3		
	Contrats nationaux (ANR, PHRC, FUI, INCA, etc.)	10	1	2	2	1	4		
	Contrats avec les collectivités territoriales	1				1			
	Contrats financés dans le cadre du PIA	2			1			1	
	Contrats financés par des associations caritatives et des fondations (ARC, FMR, FRM, etc.)	0							
Indices de reconnaissance	Prix	11	0	6	0	1	2	1	1
	Distinctions	14	1	0	4	6	3		
	Invitations à des colloques / congrès à l'étranger, séjours dans des laboratoires étrangers	387	94	14	61	35	179	4	
	Responsabilités dans des sociétés savantes (1)	oui	oui	non	oui	oui	oui	non	

(1) Ne pas indiquer le nombre mais "oui" ou "non"

Table 3. Research products and activities at the APC

2.3 Selected production and research activities

The cosmology group responsibilities and products of research are the following:

Planck. Coordination responsibilities both for the instrument development (deputy instrument scientist) and for the data analysis (in Pipeline Running and Checking group). Responsibility for the scientific simulation of the sky (Planck Sky Model). Understanding cosmic ray interactions with the detectors, modelling the zodiacal light signal, development of the component separation method «SMICA» (selected to produce the official Planck maps). Contributions to the scientific analysis of the data.

QUBIC. Leadership of the design, fabrication and management of the project since its beginning.

Polarbear. Major contributions and co-leadership of the data analysis process of the experiment.

Millimetre laboratory. Coordination of the B-mode Superconducting Detectors (BSD) national collaboration to develop superconducting detector (TES & KID) arrays, along with associated readout electronics and planar detection architectures for accurate polarisation measurement. APC researchers developed the QUBIC superconducting bolometer readout system based on time domain multiplexed electronics with a multiplexing factor of 128:1, which was a world first.

LSST. APC's largest technical contributions to LSST are focused on the architecture and development of the camera control and command systems and development of the filter-change sub-system. APC aresearchers also assume scientific coordination for the French camera construction.

Euclid. Responsibility for the scientific coordination of the French Science Data Centre (at CC-IN2P3). Responsibility for the CODEEN collaborative platform. In the coming years, processing of the external LSST data. Studies of the impact of cosmic rays on the infrared detector behaviour (a natural extension of what has been done on Planck).

eBOSS. APC has a leading role on the analysis of Lyman-α data. An APC researcher coordinates the eBOSS Lyman-α cosmology working group.

International coordination on CMB, ground and space. Researchers of APC have led the efforts for the M4 space proposal CORE+ and ground space European Generation 4 CMB coordination (CMB-E4). Both proposals were not accepted.

The gravitation group responsibilities and products of research are the following:

advVirgo. Responsibility for the realization of the "mode-matching" telescopes. These telescopes were designed, constructed, tested and integrated to the detector by the group. The group is also involved in R&D activities, in particular they studied the possibility to reduce the impact of thermal noise through the use of non-Gaussian laser beams, and they are now contributing to a frequency-dependent squeezing experiment, to reduce the quantum noise. The AdVirgo group participates actively to the analysis of LIGO and Virgo data. Members of the group asure the co-responsibility of the transient search group and currently with the compact binary search group. The group made major contributions to the discovery papers released in 2016 (a member of APC one of the 2 analysis coordinators of the paper). The group develops a range of projects, including fast Bayesian methods for binary parameter estimation and advanced search methods for transient sources that expand the signal space covered by the current template-based searches with support from the ANR, for an interdisciplinary collaboration on "Wavelet graphs for chirp searches". The AdVirgo group completed searches for joint sources of gravitational wave and neutrinos in collaboration (joint PhD thesis) with the ANTARES group, and the coordination of the LIGO-Virgo electromagnetic follow-up program (2012-2014) leading to a worldwide network of over 90 astronomer groups.

LISAPathfinder. The team includes the PI of the French contribution to LPF (Laser Modulator Unit, LMU) an essential part of the optical metrology system. The team developed Monte Carlo Markov Chain and Multinest algorithms to measure the instrument parameters and to characterize noise glitches in the LPF data. The team contributed to the LPF performance characterization over a wide

range of aspects including the drag-free and attitude control system, crosstalk effects, micro-thrusters analysis and glitches fit and subtraction, all studies using the FACe computing facility.

LISA. The team is involved in the LISA mission led by ESA, it was led by Pierre Binétruy until he passed away in April 2017. Pierre Binétruy was Co-PI and member of the mission executive board. He was also the coordinator of the French participation to LISA. The team contributed to the major mission definition reports, including "The Gravitational Universe" white paper, the reports of the Gravitational Observatory Advisory Team and the L3 mission proposal. With CNES support, the team initiated a Data Processing Center. The DPC is the entity that receives calibrated data from the Science Operations Center (SOC) at ESA, processes them to identify gravitational wave sources and their parameters, and sends the results back to the SOC. The APC also assumes leadership of the mission simulation effort in the LISA Consortium in collaboration with AEI-Hannover as well as co-chairing of the LISA Working Groups 'Cosmology' and 'Data Analysis'. The team contributes to the development of search algorithms, as well as the development of advanced algorithms for parameter estimation using Bayesian Inference for different astrophysical sources. They also developed a new algorithm that quickly and accurately searches for white dwarf galactic binaries. It is the first galactic binary search developed in Europe since 2008. An APC memeber co-chairs the LISA Working Group 'Science of Measurements'. The team built a table-top electro-optical experiment able to mimic the propagation delay of laser phase noises between spacecraft and generate interferometric signals representative of the ones onboard LISA; an experiment that allowed demonstrating that Time Delay Interferometry (TDI) can reduce the laser noise level by 8 orders of magnitude on realistic signals. In collaboration with ARTEMIS (Nice) and LMA (Lyon) and with the financial support of CNES, the team is involved in the study and characterization of scattered and diffused light, a crucial problem for the LISA optical system.

Connection to geophysics. Similar scientific and technological problems have to be addressed in the context of gravitational-wave detection and geophysics. These similarities have motivated several interdisciplinary projects in collaboration with IPGP. This collaboration has led to the new idea of inferring earthquake properties from the prompt gravity signal induced by mass redistribution. (P. Montagner et al., Prompt gravity signal induced by the 2011 Tohoku-Oki earthquake, *Nature Communications* **7**, 13349 (2016)). This can potentially lead to faster, gravity-based earthquake early-warning systems under study with the ANR project E-GRAAL.

The High Energy Physics group responsibilities and products of research are the following:

Galactic Center with X Rays. Members of the group have carried out between 2012 and 2017 several large projects of observations of the central molecular zone at the Galactic Center with XMM-Newton and with Chandra. This large set of data has allowed continuing the investigation on the propagation in the clouds of the X-ray echoes of Sgr A* outbursts. Theoretical work and further analysis of the light curves and the spectra of this reflected emission are setting crucial constraints on the light curve of the black hole over several centuries. The detailed mapping of the central molecular zone with XMM have on the other hand put in evidence several large bubbles and loops of hot gas that again indicate ancient large energetic activity in the very centre of the Milky Way, possibly linked to black hole or to star formation bursts

Integral. HEA is deeply involved in the analysis and understanding of the Integral missions observations. APC hosts the IBIS Co-Principal Investigator. In collaboration with the Virgo group at APC, they have published a paper on searches with Integral the hard X-ray/gamma-ray counterpart of a gravitational wave and in the paper of Savchenko et al. (2016) they have demonstrated that Integral will be the best observatory to detect this possible counterpart.

ATHENA. The ESA L2 mission **ATHENA** is foreseen for launching in 2028. It consists of a large X-ray telescope concentrating 0.1-12 keV X-rays on a new generation high-resolution spectrometer (the X-ray Integral Field Unit, X-IFU) and on a Wide Field Imager (WFI). APC contributes to the integrated circuits (ASICs) of part of the readout detection chain of the X-IFU, the warm front-end electronics (WFEE).

SVOM. The HEA group is also involved in the bilateral Chinese-French **SVOM** mission dedicated to Gamma-Ray Bursts (GRB) and to the variable and transient sky. Launch is planned for end 2021. APC has responsibility for the design and development of the ECLAIRs X/hard X-ray instrument coded mask and for part of the software development of the French Science Center (FSC). In addition to these technical contributions, APC hosts the leading scientists for the General Program and for the Target of Opportunity.

TARANIS. The laboratory has almost completed a high-energy space mission instrument XGRE in the context of **Taranis** devoted to the study of terrestrial gamma-ray flashes. XGRE will aslo be used also as a GRB detector; most useful at the time of the gravitational wave astronomy emergence.

R&D Compton and Gamma Cube. APC initiated, an R&D program in order to design, optimise and test double-sided silicon striped detectors (DSSSD) in view of making a space **Compton** telescope. The preparation of a new concept of instrument for a gamma-ray mission in the MeV range has also lead to the development of the **Gamma Cube** project. This R&D aims to localize charged particle interactions and tracks in a scintillating detector thanks to a plenoptic, or light-field, measurement. A patent was filed in 2013 with an application to a medical gamma camera.

H.E.S.S/CTA. HEA team is one of the pioneering groups in the field of very high-energy gamma ray with significant technical and scientific contributions to the **H.E.S.S**. array of Imaging Atmospheric Cherenkov Telescopes (IACTs), as well as to the **CTA** project. Scientific topics with major contributions by the HEA team cover both galactic and extragalactic domains. The published results are presented in the Highlights session. The team's know-how in Galactic science has also allowed to APC to have the leadership for the CTA working group on the subject (2013-2016), as well as for the 'cosmic ray, supernova remnants and molecular clouds' task (2009-2013). The team also actively participates to the extragalactic science with HESS and CTA as well: through the responsibility of the systematic search for AGN in HESS (2012-2013) and that of corresponding author for two papers. The team is also involved in redshift determination of BLLs that are likely to be detected with CTA. APC team members are active in the 'AGN population' and 'grpropa' CTA working groups, and have been initiators of the 'redshift determination' working group within CTA.

On the technical side, the team has been at the front-line of development of both low- and high-level analysis methods, relying on state-of-the-art multivariate algorithms (neural networks, boosted decision trees) with particular attention paid to the extreme ends of the HESS II array energy range. They are also actively involved in the data-model definition and formats, as well as high-level use cases of the future observatory, especially in the context of its planned public data release. CTA will be open to guest observing programs and the APC team has taken the responsibility of the 'Proposal Handling Platform', which is meant to facilitate the submission, selection and real-time viewing of proposals, and will be integrated in the central CTA WebPortal. On the hardware side, they are working on the clock distribution and trigger time-stamp, for the CTA's array's software coincidence trigger system.

ANTARES/KM3NeT. The HEA team is also involved in the design, construction and exploitation of the large-scale neutrino Cherenkov detectors in the Mediterranean Sea: ANTARES and KM3NeT. The team has acquired a strong visibility in both ANTARES and KM3NeT collaborations, with contributions at the scientific, technical and institutional levels. A member of the group is the elected Spokesperson of the **ANTARES** Collaboration since June 2014, and other members serve in the Steering, Publication and Conference Committees of ANTARES or KM3NeT. The group is responsible for the calibration, monitoring and data quality of the detector, and is strongly involved in the searches for cosmic neutrinos: emission from the Galactic Plane, multi-messenger searches with GRBs, gravitational waves (LIGO/Virgo), cosmic rays (Auger/TA) and neutrinos from IceCube. The period 2012-2016 has been particularly fruitful for the scientific exploitation of ANTARES data, in light of the recent results from the IceCube collaboration, which has reported several indications of a cosmic neutrino component, yet without a clear identification of the sources. Besides the standard searches for diffuse neutrinos fluxes and cosmic neutrino sources, the ANTARES Collaboration has developed an ambitious multi-messenger program to which the APC group has made important contributions. In particular, the ANTARES and Virgo teams at APC have pioneered the development of joint searches of neutrinos in coincidence with gravitational waves. A post-doc in the group has

been in charge of the ANTARES follow-up of the first gravitational wave event GW150914 detected by LIGO. The results have been integrated in one of the companion papers of the GW discovery article.

JEM-EUSO. In this period, the main experimental activities have taken place in the framework of the international JEM-EUSO collaboration, whose prime goal is to develop a space-based instrument to detect the fluorescence light of UHECR-induced atmospheric showers. The members of the APC group are recognized leaders within the JEM-EUSO collaboration, with 3 members of the Executive Committee, the head of the science working group and responsible of the science case, the French P.I., and the project manager of the EUSO-Balloon mission. EUSO-Balloon consists of the first fully operational pathfinder of JEM-EUSO coronated with a successful flight under a stratospheric balloon in August 2014, under responsibility of the APC team. Its success triggered further instrumental developments, which led to the realization of an upgraded instrument: the EUSO-SPB mission, approved, funded and operated by NASA, with participation of CNES. EUSO-SPB, was a success on the instrument side, took data under analysis, but a flaw in the balloon itself made it fall into the ocean 6 days after launch. APC played a major role in the EUSO-SPB mission, whose focal surface has been integrated, tested and calibrated in the photo-detection laboratory. The HEA team also contributed significantly to a third pathfinder, the mini-EUSO mission, at ISS, with the integration and tests of the focal surface. Mini-EUSO will be launched in early 2018.

UHECR Theory. HEA group members are also recognized leaders in the domain of UHECR theory, with key contributions to the study of the propagation of UHECRs from their extragalactic sources to the Earth, as well as original works on particle acceleration.

Galactic cosmic rays. The study of galactic cosmic rays is amongst the main lines of research carried out by the High Energy Astrophysics group at APC. These theoretical/phenomenological investigations are focused on the acceleration of cosmic rays at supernova remnant shocks, on their propagation in the turbulent interstellar magnetic field, and on the study of the radiative signatures (espacially in the gamma ray domain) resulting from the interactions of cosmic rays with ambient matter and background radiation fields. The origin of the cosmic rays responsible for the diffuse TeV emission at the Galactic Center and the connection with the high SNR rate in the region and SgrA is also investigated within the HEA team.

High performance computing. The high performance computing (HPC) team's main interest lies in the study of astrophysical plasmas in the vicinity of compact objects as well as in the particle acceleration processes at work in astrophysical shocks. Over the last five years, the team's work has been centred on the development of two innovative numerical tools for both the astrophysical high-energy and astroparticle physics communities.

The neutrino and dark matter group responsibilities and products of research are the following:

Neutrino physics using liquid scintillators.

Double Chooz. The Double Chooz (DC) experiment measures the mixing angle θ_{13} using anti-neutrinos from the Chooz nuclear power station (Ardennes, France). APC plays a leading role in the experiment, with members in key positions; the experiment spokesperson and the IN2P3 national co-ordinator, director of the LNCA laboratory and analysis/detector co-ordinator. During the period 2012 to 2017, the Near Detector was constructed and commissioned. APC mechanical engineers, were greatly involved in the construction; responsible for the main vessel, upper shielding and platform, and electronics hut. APC members are also responsible for the Flash-ADC cards, electronics installation, on-site computers, data acquisition, and participated actively in the commissioning.

Borexino. APC members have been involved in Borexino since its conception. Borexino has produced a wide range of results related to the observation of solar and geo–neutrinos, and APC members have been deeply involved in the analyses, in particular leading the first measurement of the ^{8}B neutrino rate with the lowest energy threshold (3 MeV) among real-time experiments.

SOX. During 2018, a ~150 kCi of ^{144}Ce anti–neutrino source will be deployed in a tunnel below the center of the Borexino detector in order to for an oscillation pattern L/E, testing the existence of sterile

neutrinos. APC/CEA members lead the procurement and calibration of the source. APC is involved in studying potential contaminants in the ^{144}Ce source, which could alter the calorimetric measurement of the source activity.

JUNO. The JUNO experiment, in China, will be the largest liquid scintillator detector in the world, with a 20 kton detector located in a dedicated underground laboratory at 700m depth. The APC neutrino group members, and engineers have pioneered the concept of 'Double Calorimetry'; conceiving, designing and now leading the construction of the Small PMT (SPMT) read-out system, in order to control to highest precision the systematics on the calorimetry of the detector. An APC member is the co-ordinator of the SPMT system and French responsible for the SMPT read-out electronics and another APC member is the technical co-ordinator.

Neutrino and dark matter physics using liquid argon.

LAGUNA: Towards WA105 and DUNE. APC members have been critical in the conception and design of DUNE, and the formation of the collaboration. Results from the European design studies LAGUNA and LAGUNA-LBNO, completed in 2014, have formed the experimental concept. Members of APC were heavily involved in the low energy performance studies and also assured the scientific coordinator of the project (chair of the science board and leader of the physics task force), contributing to the 4000-page report with a technical design of the detector, the infrastructure and the beam line and the 300-page report on the physics performance and leading the writing of publications.

Dual-Phase ProtoDUNE (WA105). The LAGUNA, LAGUNA-LBNO efforts resulted in the proposal to the CERN SPSC of a large-scale demonstrator, WA105. An APC member is chair of the Institutional board. APC contributes to the detector by providing the light read out front-end electronics based on fast µTCA technology in collaboration with OMEGA. The collaboration is ready to install the detector and will be ready to take data in April 2018.

DUNE. The proposed far detector (at 1300 km from FNAL) will be located deep underground at the SURF 4850L with a fiducial mass of 40 kt of liquid argon. The size and costs of the DUNE experiment are so important that it can only be realized with a strong international organization and coordination. In 2014, an APPEC meeting was organized by the APC director to bring together all major funding agencies from Europe, Americas and Asia to coordinate the effort. This resulted in the merging of LAGUNA-LBNO and LBNE collaborations to realise DUNE, hosted by Fermilab, USA. In August 2014, a member of the APC joined the international interim Executive Board tasked to form the proto-collaboration, leading to the formation of the new international collaboration, DUNE, in January 2015. Two members of APC were nominated co-coordinators of the atmospheric neutrino working group and the long baseline physics working group respectively. The director of APC is a member of the International Neutrino Committee hosted at Fermilab to supervise DUNE construction.

DarkSide. DarkSide is a direct dark matter search programme using dual-phase liquid argon Time Projection Chambers installed at LNGS. Group members successfully introduced this project to APC and France. They were joined by DarkSide PI, C. Galbiati, who was awarded with a Paris-7 chair in 2016 and continues to be associated to the group. The members of the group are the authors of the DarkSide simulation and lead several aspects of the DarkSide-50 analysis (e.g. sensitivity to WIMPs and to solar neutrinos), which impact key results. The group is driving the design of this detector via the simulation. The group aslo conceived ARIS (Argon Response Ionization and Scintillation) - a small-scale dual-phase LAr TPC which was exposed to interaction of neutrons at the ALTO facility (IPNO) in 2016, and successfully measured the quenching of nuclear recoils and the argon response dependence on the electric field.

Neutrino physics using sea water.

KM3NeT – ORCA. The scientific activities of the APC group on KM3NeT are currently focused on the development of simulation and reconstruction tools for the ORCA feasibility study, and on the processing and analysis of the data from the first detector prototypes and lines. An APC member

coordinates the relevant ANR Projet DAEMONS partnering APC, CPPM and IPHC Strasbourg. At the technical level, the APC team is responsible for the Calibration Unit of KM3NeT/ORCA, to be deployed in 2018. The scientific activities of the APC group on ORCA are currently focused on the development of simulation and reconstruction tools for the feasibility study. The group also operates two test benches for the characterization of KM3NeT Digital Optical Modules (DOMs).

Interdisciplinary neutrino applications.

Sea observatory interdisciplinary applications. The KM3NeT detector offers new opportunities for Earth and Sea sciences, thanks to its unique location and capacity to continuously monitor the abyssal environment. The atmospheric neutrinos detected by ORCA can also be used for studies of Earth composition by using the neutrino oscillation tomography method. To exploit these synergies, the KM3NeT group is developing new collaborations with experts, geophysicists and marine scientists from IPGP, one of the partner institutes of APC within the LabEx UnivEarthS.

Muons for Archaeology. Following the successful study of muons in the Double Chooz detectors, an interdisciplinary project was formed to study archeological structures with muon tomography. Preliminary studies based on MonteCarlo simulations indicate the capability of this technique applied to the so-called Appolonia tumulus (in northern Greece). The first detector will be installed in the following months.

The theoretical group responsibilities and products of research are the following:

The theory group research activity is centered on key open questions at the forefront of research in astroparticle physics, cosmology, gravitation, quantum field theories and its applications. Their research work focuses both on theoretical and on phenomenological aspects of fundamental interactions, some being closely related to international experimental projects and more generally to observations. The latter puts the theory group in close symbiosis with the high-energy astrophysics, cosmology, gravitation and neutrino experimental groups of the APC laboratory.

Astroparticle Theory. The astroparticle physics activity concerns mainly cosmic rays and neutrinos. In particular, they have shown that a recent local supernova gave significant contribution to the measured cosmic ray flux, explaining the dipole anisotropy measurements and anomalies in antiparticle (positrons and anti-protons) spectra; secondly galactic and extragalactic contributions to the astrophysical neutrino flux have been studied in several models accounting for both cascade and muon Icecube neutrino data.

Neutrino Theory. Amongst the different lines of research developed in the group are to unravel how neutrinos change their flavour in astrophysical and cosmological environments, to study indirect effects, or to propose signatures of key unknown neutrino properties, in experiments running or under study and to establish links with other domains. In particular they have established a formal connection between the collective modes and the dynamics of neutrinos propagating in astrophysical environments and other many body systems, such as condensed matter and atomic nuclei. Their investigations in accretion disks around binary neutron star merger remnants have clarified that helicity coherence from the neutrino absolute mass contributions cannot induce flavor conversion effects.

Cosmology Theory. Cosmological observations, in particular the CMB anisotropies, point to the existence of primordial fluctuations, with a spectrum close to but distinct from scale-invariance (inflation). The group also works on dark energy. In particular they have deveopped an approach based on effective field theory capable of including most of the models with a scalar field, of giving a formulation that identifies different classses of models, even apparently different, furnishing a common theoretical framework to compare theoretical predictions with observations. They have also been working on theories of modified gravity, in particular scalar-tensor theories, formulations of massive gravity (e.g. ghost free, or its holographic link to quantum field theory).

Gravitation Theory. 2016 saw the first obervation of gravitational waves from a binary black hole merger event by the LIGO/Virgo Collaborations. Among the main results of the theory group in this domain are e.g: a) the spectral shape of a stochastic gravitational wave background from a first-order phase transition and from inflation has been determined, in the LISA frequency band and the study of the propagation of gravitational wave signals from compact massive binaries.

Formal aspects of quantum field theory. APC theory group members have performed studies in curved spacetime, high spin theories, quantization methods, holographic principle - and its applications to cosmology, condensed matter and strong interactions. Among the main results: a mechanism that can "hide" the cosmological constant due to quantum effects of the Standard Model in the holographic/braneworlds context; a detailed study of the renormalisation group in the "holographic" theories; application of holographic ideas to inflation, in cosmology, towards a unified framework of inflation models, based on Wilsonian ideas.

2.4 Highlights

Highlights of scientific achievements between 2012 and 2017

We present below the main scientific achievements by group, for a more detailed description as well as the precise responsabilities of APC in the achievement see section 2.3.

Cosmology. On what concerns the CMB, the previous 5 years are characterised by the publication, starting 2013 of the PLANCK data, that gave the definitive and ultimate values for the non-polarised CMB analysis, defining key values of the Standrad model of Cosmology.

During the post-mission period, the APC has had responsibility for the scientific simulation of the sky (Planck Sky Model), modelling the zodiacal light signal, development of the component separation method « SMICA » (which was selected to produce the official Planck maps), and contributions to the scientific analysis of these data (using galaxy clusters as a probe for cosmology, putting constraints on Inflation models and on non-gaussianity features, and doing joint analysis of the data with other cosmological probes such as BOSS).

In parallel and in 2014 the POLARBEAR collaboration published its first round of results, including the first direct constraints on the presence of B-mode polarization on small angular scales, consistent with the signal expected to be generated by gravitational lensing due to large-scale structure in the Universe acting upon the CMB photons. The analysis was largely due to an APC agent.

Another highlight of cosmology was the confirmation that the Universe was decelerating before it started to accelerate, obtained through the work of N. Busca with Lyman-α data of the BOSS survey.

Gravitation. 2016 will be remembered as the year when GW astronomy began. In February 2016, the LIGO/Virgo collaboration announced the detection of gravitational waves from the merger of a binary black hole system quickly followed by a second one. These detections resulted in the publication of about twenty articles in prestigious journals, co-authored by 10 members of the Gravitation team who also share in the “2016 Gruber prize in Cosmology”, and the “Special breakthrough prize in fundamental physics”. Eric Chassande-Mottin was one of the two coordinators of the paper writing team of the discovery paper published in Phys. Rev. Letters.

2016 has also seen the great success of the LISA technology demonstration package, LISA Pathfinder (2015). This mission validated key technologies for LISA, specifically for drag compensation and interferometry. The team participates to the data analysis activities remotely from FACe or in person at ESA’s Mission Operation Centre in Darmstadt. The LPF results have surpassed the goals. The publication of LPF results includes eight co-authors from APC. Those very good results strengthen the L3 mission proposal submitted to ESA in Jan 2017.

In parallel to the research on gravitational waves, the team pursues activities in connection to (“Newtonian”) gravity measurements and their application to geosciences in collaboration with Institut de Physique du Globe de Paris (IPGP). This collaboration has led to the new idea of inferring

earthquake properties from the prompt gravity signal induced by mass redistribution. (P. Montagner et al., Prompt gravity signal induced by the 2011 Tohoku-Oki earthquake, Nature Communications 7, 13349 (2016)). This can potentially lead to faster, gravity-based earthquake early-warning systems under study with the ANR project E-GRAAL.

High Energy Astrophysics. HESS I and HESS II reaching maturity gave many important reults and the team members were for many the corresponding authors. In particular, the completion of the Galactic survey with HESS I has provided 78 objects with 10 new discoveries among which two new shell type supernova remnants (SNR). Members of the team have been actively involved in analyses and writing of 6 papers to be published in the A&A special issue of the HESS I legacy.

The center of the Galaxy is also at focus of APC member activities.

It has been shown by the APC team that the spectrum of the diffuse gamma-ray emission does not present any cutoff, indicating thereby that the parent population of cosmic rays extends up to the PeV energy domain. This is the first evidence of a PeVatron in the Galaxy.

A new VHE source in the vicinity of the radio arc was also discovered. These results were published in two articles in Nature and A&A with members of the team as corresponding authors. The detection of pulsed emission from the Vela pulsar, under one of APC team member's leadership, has opened the field of pulsar physics to HESS.

The addition of a fifth and large dish at the center of the HESS I array was meant to push down the threshold of the latter from above 100 GeV to below 50 GeV. HEA team members have shown that the measurement of the Vela pulsar spectrum down to energies of 20 GeV, in full agreement with the signal obtained with the Fermi-LAT instrument, has validated the design of the fifth telescope and represents a major breakthrough in gamma-ray astrophysics from ground.

The past 5 years have been of course also rich in developments for the scientific community involved in neutrino telescopes. The discovery of a signal of cosmic neutrinos by the IceCube detector has opened the way to high-energy (TeV-PeV) neutrino astronomy and reiterated the need for new telescopes with significantly improved sensitivity. Despite its smaller size, ANTARES made valuable contributions thanks to its excellent angular resolution in both the muon channel and the cascade channel. Beside the standard searches for diffuse neutrinos fluxes and cosmic neutrino sources, the ANTARES Collaboration has developed an ambitious multi-messenger program to which the APC group has made important contributions. In particular, the ANTARES and Virgo teams at APC have pioneered the development of joint searches of neutrinos in coincidence with gravitational waves. More recently, a post-doc in the group has been in charge of the ANTARES follow-up of the first gravitational wave event GW150914 detected by LIGO. The results have been integrated in one of the companion papers of the GW discovery article.

A second article of follow-up of the GW signal has also been written with APC leadership, searching with Integral the hard X-ray/gamma-ray counterpart of a gravitational wave. Furthermore, the group has published work demonstrating that Integral will be the best observatory to detect this possible counterpart.

Neutrino. The last 5 years were also critical for the measurement of neutrino parameters.

With only the Far Detector in operation, DC was the first reactor experiment to provide positive evidence for a non-zero value of θ_{13} at 2σ's (2011) which when combined with that of T2K, yielded evidence at the level of 3σ. This was quickly followed in 2012 by the Daya Bay experiment (China) providing evidence at $\sim 5\sigma$, and later by RENO (South Korea). Since then, DC has provided several further key results to the field. In 2013, DC provided an independent θ_{13} measurement in the same detectors using a H-capture based technique, and in May 2014,

DC provided the first evidence for a spectral distortion (up to +10% amplitude at ~4MeV), demonstrating that the accuracy of today's best ILL based predictions (originally claimed uncertainties ~3%) is not fully consistent with data. Similar spectral distortions were reported by RENO (June) and Daya Bay (July) of the same year.

In 2016, DC announced its first result with both Near and Far detectors, using a novel analysis which includes all observed Inverse Beta Decay interactions (with neutron captures on H, C and Gd) which increases the statistics by a factor of 3. The result suggests a ~40% larger value of θ_{13} than that of Daya Bay, providing a tension of 2.2σ. Should this trend be confirmed with higher significance, this would have implications to the indirect prediction of CP-violation when reactor results are combined with T2K+NOvA experimental results.

Within the 2016 release, DC has also provided two novel results: the world most precise IBD-directionality measurement and the world most precise rate+shape reactor spectral characterisation. A new result is to be released for publication in 2017.

Last but not least on the scientific side, DarkSide-50 run in 2014 with atmospheric argon, demonstrating its capability to operate in a background-free mode, and in 2015 DarkSide-50 ran with 150 kg of argon extracted from deep underground, demonstrating the possibility to reduce the 39Ar contamination by more than 3 orders of magnitude.

Highlights of scientific achievements between 2012 and 2017

The near detector for the **Double Chooz** experiment was installed and ready for operation in 2014 to complete the already existing far detector. The APC laboratory undertook the complete mechanical design and production management. The tank was made stiff at the bottom to support a water pressure of 45 tons without consequent deformation.

The APC laboratory took in charge the design, production, integration and validation of the telescopes for the **Advanced VIRGO** experiment. The telescopes were installed on–site in 2014 and 2015. This achievement combines optics and mechanics skills to fulfil the strong requirements in terms of light transmission, beam size adaptation, optical aberration minimization and reproducibility. Moreover, a R&D activity demonstrated the interest of higher-order Laguerre-Gauss modes for next-generation gravitational waves on-ground detectors, leading to a publication in the Physical Review D in 2015.

The **QUBIC** project, dedicated to the detection of CMB B-modes, met major changes and progressed in the last five years. QUBIC, which will be the first Bolometric Interferometer to map the CMB sky and which aims at measuring the B-mode polarisation of the CMB with high sensitivity and accuracy over large angular scales. From its Argentinian site (San Antonio de los Cobres, 5000m above sea level), it will put strong constraints on Inflation models (σ(r)=0.01) and demonstrate this novel technology as a possibility for future CMB Polarization observatories such as CMB Stage-4 or E4. A quarter focal plane was integrated and validated during the summer 2015 at the APC laboratory and a second version of the ASIC dedicated to TES (Transition Edge Sensor) time-multiplexed readout and SQUID (Superconductive Quantum Interference Device) biasing was delivered in June 2016. In the context of QUBIC a superconducting bolometer readout system based on time domain multiplexed electronics with a multiplexing factor of 128:1, was developed; a world first. The APC project team is now focused on the completion of a technological demonstrator, whose size is one-eighth of the final instrument.

The APC laboratory contributes to the implementation of the central trigger system for the **CTA** experiment, including a clock distribution and a time stamping. After the development of a first card model MUTIN, the system migrated to the UCTS (Unified Clock Time Stamp) standard with White Rabbit in 2015. The TiCKs card, completed at the end of 2016, is the redesign of the Spec White Rabbit card in the CTA standards and integrates the CTA daughterboard. The PA engineer of the Quality Department brings also its expertise to the RAMS (Reliability Availability Maintainability Safety) studies for NectarCAM.

The Control & Command for the Filter Changing System and the JAVA development framework for the CCS camera are the technical contributions of the APC laboratory to the **LSST** telescope, whose construction started in April 2015 in Chile. The CCS and FCS softwares are implemented on test benches in the USA and France since 2012. The successive project reviews by the NFS (National Science Foundation) and the DOE (Department of Energy) led in 2015 were successful.

The APC laboratory is in charge of the design, production and integration of the XGRE instrument for the **TARANIS** mission, dedicated to the detection of TLE (Transient Luminous Events) occurring during large storms. The APC project team produced and validated the QM (Qualification Model) XGRE sensors in august 2015 and completed the whole reading electronics, combining analogic and numeric circuits following the ECSS and RadHard standards. Unfortunately, major anomalies on the LaBr3 scintillators, manufactured by the Saint-Gobain company, were reported on the FM (Flying Model) sensors after vibration and shock tests in 2016, leading to a new development plan for a launch in 2019.

The APC laboratory's technical involvement in the WFEE (Warm Front-End Electronics) for the X-IFU sensor of the **ATHENA** mission started in 2015. In summer 2016, a first version of the reading ASIC was designed and delivered to test the radiation hardness of several architectures in the framework of the Phase A.

The APC laboratory is the one French laboratory, which contributes to the in-flight data analysis of the **LISAPathfinder** mission successfully launched in December 2015. LISAPathfinder validated the choice of laser interferometry as the embedded detection technology for a gravitational waves space observatory and opens the way to the future LISA mission. Furthermore, the LOT (LISA On Table) R&D advances the realization of an electronic/optical simulator for space based long-arm interferometry and its application for LISA.

The APC laboratory leads radiation hardness studies of the EM (engineering Model) NISP H2RG detector, manufactured by the Teledyne company, for the **EUCLID** mission. Activities include the building of a cryogenic test-bench, a thermal regulation system and cabling. Successful tests with a proton beam took place at the Louvain-la-Neuve accelerator facility in December 2016.

The **JEM-EUSO** collaboration achieved a successful balloon flight under the CNES aegis in 2014 validating the technology for the detection of UV fluorescence induced by the interaction of high-energy particles with the atmosphere. Two years of preparation were necessary, during which the APC laboratory managed the overall project and took in charge the integration and calibration of the focal plane. A long duration NASA flight (EUSO-SPB) was launched with an upgraded instrument in April 2017. The instrument worked as specified for 6 days, but a flaw in the construction of the ballon, under NASA responsibility, stopped the mission at the 6th day.

3. Organisation and life of the unit

3.1 Management, organisation and scientific animation

The director and the directors office. The direction of the laboratory, formally the responsaibility of the director of the laboratory, is assured on a day-to-day basis by an executive office: the director, two deputy directors one for science and one for education, an administrative deputy director and a technical deputy director. There are two statutory committees with respect to the directorate of the lab: the Steering Committee ("Comité de Pilotage") overseeing it and the Scientific Committee advising it.

Steering Committee. The Steering Committee is composed of a representative of CNRS, a university of Paris Diderot University, a representative of CEA and a representative of the Observatory of Paris, with a deliberative vote. Members of the Steering Committee can be assisted by the experts of their choice if necessary. The presidency of the Steering Committee is exercised by CNRS. The Director of the Unit, assisted by the Deputy Director(s), participate in the meetings of the Steering Committee in an advisory capacity. The CNRS Regional Delegate for the region where the Unit belongs and the Director of the UFR of Physics of the Paris Diderot University, or their representatives, attend meetings in an advisory capacity, as necessary. The Steering Committee meets at least once a year, convened by its Chairperson or at the request of one of the Parties. The Steering Committee, a decision-making body, is responsible for: laying down the orientations of the scientific programs of the Unit; proposing to the Parties the appointment and termination of the functions of the Director and the Deputy Director; adopting the annual budget of the Unit and monitoring its implementation; approving the changes made to the list of staff assigned by the Parties to the Unit; proposing to the Parties, for agreement, the association of a third party with the Unit.

Scientific Committee. The scientific committee, chaired by Jean-Loup Puget, advises the director and the lab on the scientific programme that it reviews during its meetings that take place at least once a year. It consists of six external members (besides the chair, presently Roger Blandford Stanford University, Eugenio Coccia, Gran Sasso Science Institute Director, INFN, Nathalie Roe, Director, Physics Division, LBL Berkeley, André Rubbia, ETH Zürich, Gabriele Veneziano, CERN), the director and deputy director(s), the heads of the 5 teams and 3 elected members (two researchers and one ITA (engineers, technicians and administrative staff)).

Science teams. The APC science is organised around five science teams, namely 4 thematics: Cosmology; Gravitation; High Energy Astrophysics; Neutrinos; and one transversal: Theory. The teams organize the common issues related to their thematic, e.g. define the priorities of the thematic science policy, the recrutement priorities and have a primary role in the scientific animation. They organize seminars, discussions, initiate new projects, welcome students for internships or PhDs, and fund travel for general conferences. In a recent rearrangement of the administration teams, they now have a unique correspondent at the administration level. The teams have a specific annual budget and are lead by a responsible and its deputy. These last form the primary interlocutors of the direction on what concerns human ressources issues and participate in monthly meetings with the direction and the heads of the technical and administration departments and the Scientific Council.

Technical departments. A key aspect of APC is the presence of 6 technical departments, which provide the technical expertise required by the projects. They are organized according to the different trades: Mechanics, Electronics, Microelectronics, Instrumentation, IT, Project Quality Procedures. The technical departments of the laboratory contribute to associated instrumental developments, including design studies, construction, tests and validation. They also have a hierarchical structure, the head of the department making propositions for promotions and "primes"; she(he) also participates at the monthly lab orientation meetings. They are all under the responsibility of the technical director.

Administration department. The administration department, under the responsibility of the administrative director, is in charge of managing and assisting the research activities. This service manages the funding allocated to the lab as well as the human resources. They also manage associated research structures and activities.

Laboratories. The team and department activities are supported by 4 laboratories: Millimetric, Photodetection, Optics, Integration and Test and 2 workshops: Mechanics workshop and Assembly Hall (for details see Appendix 2).

Projects, the role of CSP and QA. If teams and departments are the vertical dimension of the matrix structure, projects represent its horizontal or transverse dimension. Each project is run by a team consisting of one physicist ("physicien référent" in the lab language) and one project manager ("chef de projet"). The "physicien référent" expresses the scientific needs, interacts with the whole collaboration, identifies the financial supports, etc. The "chef de projet" (project manager) translates the needs into technical needs, manages the project and drives the technical team. Throughout its lifetime, the project undergoes a certain number of reviews, from the initial review of opportunity to the final closure review. The review board, called "Cellule de suivi des projets" or CSP, consists of the directorate, the heads of departments, few senior physicists of the lab, and a member of the QA team. The needs are discussed with the heads of departments prior to each review and human and hardware resources are granted after the review. The CSP board meets 6 to 10 times a year, depending on the status of on-going projects or the incoming requests to start new projects, to review one of two projects, which means that major projects are reviewed at least once a year. These reviews are internal and are complementary to the project reviews at national or international cases. The QA Team is advising the projects on quality assurance. It also has a labwise role, identifying the processes and providing a certain number of documents, such as the quality manual, a detailed desciption of processes or a set of indicators (see part B for more information).

Monthly meetings of the heads of the groups and departments. Most discussions and decisions regarding the life and orientation of the lab are made at monthly meetings of the heads of teams and departments with the directorate. Every other month, project physicists and managers join the meeting in order to discuss specific issues concerning the projects in general. Every two months this meeting is extended to include the responsibles of projects.

There are also two councils working at the interface between the direction and the laboratory agents: the **Laboratory Council** and the "**Comité Paritaire local**". First, the **Laboratory Council** deals with all aspects of laboratory life. It has an advisory function, its opinions are translated into conclusions and are known to all. The sessions of the laboratory council are open to all. The Unit has a laboratory council of nineteen (19) members, which meets at least three (3) times a year. It comprises: the Director of the Unit and the Deputy Director(s); five members elected by and from the research staff of the Unit; five members elected by and from the ITA-BIATSS staff of the Unit; five members appointed by the Director of the Unit; one member elected by and representing doctoral students; one member elected by and representing post-doctoral fellows. The Lab Council, which is the main representative assembly, meets approximately every two months to review all the lab activity and discuss a certain number of issues regarding both scientific and non-scientific aspects. Its agenda is discussed in a pre-meeting open to everyone and its meetings are also open to all lab members. A written report is also published each time and sent to everyone. The other elected body is the "**Commission Paritaire Locale**" which reviews the propositions for promotion coming from the director, and deals with all personal problems regarding careers.

Scientific and non-scientific animation. The exchange of information in a lab of some 200 persons is important but has to be organized. For a long period a periodic "Lettre du vendredi" advertised information of relevance to some or most of the lab members: issue of various calls, deadlines for proposals, etc. These functions have been transferred recently to the web site, and deliberations are in place for the optimal way to assure this communication (eventually a monthly letter). Once every month, on a Friday morning, the "Vendredi de l'APC" offers an opportunity to present, in a non-technical way, scientific highlights of the lab teams, outreach events, films about the laboratory, pictures of one of the many sites where lab members go for their experiments. This is also the occasion for the lab director to inform about the latest news.

Scientific seminars are the APC colloquium held at the lab level, plus seminars organized by the teams, often on the occasion of their regular meeting. In particular the theory team organizes a weekly

theoretical seminar. Younger physicists are organizing journal club meetings (see e.g. the cosmology journal club, as well as the doctoral student club).

Finally, every other year, the lab organizes a retreat called “biennale” outside Paris in order to discuss topics of relevance to the functioning and evolution of the lab. About half of the lab participates and working teams are organized by the lab council to prepare the discussions. In 2012, it was held in Dourdan near Paris, focused on the scientific vision for the next decade 2015-2025, and was dedicated to the preparation of the previous autoevaluation exercise. The next one, January 2015, was in Fontainebleau and focused on the laboratory organisation, after the first year of a new director. The last one was in April 2017 and it was a biennale to discuss of scientific policy and update of the scientific strategy in view of the present autoevaluation exercise.

Conferences. Like many large laboratories abroad, APC has a strong policy of developing conferences and workshops. With this aim, a conference and workshop unit was created in 2009, when its coordinator was hired. APC thus hosts scientists from all over the world. The conference and workshop unit consists of two members, its coordinator and an agent in charge of logistics aspects. The conference unit offers a large range of services (dedicated website, poster, video, research of providers, registration of participants, financial aspects...). Moreover, since the retirement of the communication manager, the coordinator of the conference unit is in charge of several aspects of the outreach of the laboratory. Over the last five years, twenty out of the sixty conferences and meetings, organised by the unit, had more than 100 participants.

3.2 Parity

Male/Female distribution from 2012 to 2017. The APC lab is aware that the large discrepency of representation between male and female within physics is reflected amongst its staff. This is also true at the doctoral level. Over the last five years, the female staff have counted for less than a fourth of the total APC staff. About a third of the ITA & BIATSS staff and a fifth of academic staff have been female employees. Despite a low female representation within the lab, the direction board supports the empowerment of its female staff. For instance, three out of five team leaders are currently women. In addition, the APC lab participates to actions tackling the gender inequality such as GENERA program and Gender in Physics Day. The lab also aims to encourage the next generation of women to engage in physics studies and access scientific careers. This commitment to help increasing women’s employment in physics is shown through the Physics Masterclass.

Actions for gender equality

Membership in the GENERA program. At the initiative of the management, the APC laboratory volunteered to be the bearer within the CNRS of the European Union project GENERA. GENERA is a a Horizon 2020 project aiming at continuing, monitoring and improving the Gender Equality Plans of Research Institutions and Organisations specifically in the physics research field. These three actions will be performed by a Consortium of 13 beneficiary partner Research Performing and Research Funding Organisations. A professor researcher of the APC is national coordinator and implementation manager for the CNRS, and a scientific mediation officer was recruited part-time to help with implementation and dissemination of the project. An assessment was carried out in the laboratory and among the partners, including individual interviews and reporting to the European Commission to measure the opinions of the researchers and the actions to be implemented.

Physics Masterclass. On the occasion of the UN World Day for Women and Girls in Science, a Masterclass of Physics was organized in February 2017. 30 students from Parisian high schools were welcomed to the laboratory to discover our domain, to visit the place with the PhD students, including the millimeter room and the clean room, and to participate in a computer analysis of CERN data. Given the success of the day, new same opportunities will be implemented in the coming months

Gender in Physics Day 2017. In partnership with GENERA, a « Gender in Physics Day » will be held in November 2017 at the university Paris Diderot, organized by the laboratory APC. The aim of the Gender-in-Physics Day is to analyse the implementation of innovative activities towards gender

equality identifying gaps, barriers, as well as best practices. It will enable an exchange of experiences and information supporting an alliance of Research Performing Organizations and Research Funding Organizations, to promote gender equality in Physics. The GIP Day will include directly various levels of participants from junior and senior researchers to management level personnel, policy makers, and different stakeholders, internal or external to the APC. Figure 14 shows the female staff vs male staff ratio according to their status since 2012.

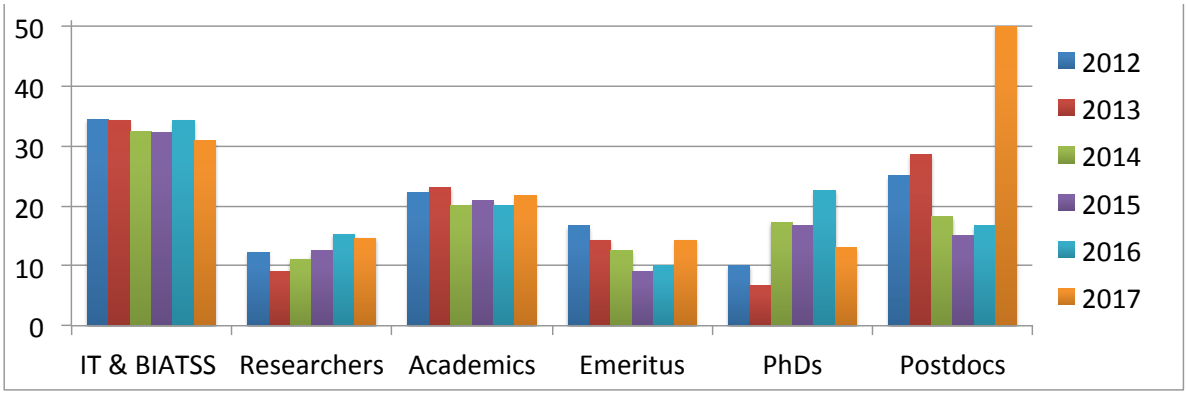


Figure 14. Evolution of ratio female staff vs total staff (in %) according to the status

3.3 Health and Safety

H&S organisation. The organisation of the Health & Safety at the APC laboratory is structured around three stakeholders:

- ***Prevention Assistant***, placed under the direct authority of the lab Director, assists and advises the Direction Board. He is responsible for the writing and the diffusion of the "Document Unique" for the risk identification and management and for the implementation of the annual action program.
- ***Radioprotection Officer*** (PCR: "Personnel Compétent en Radioprotection"), under the direct authority of the authorization Delegate, assists and advises on radioprotection. He manages the requests for authorizing the use and the purchase of radioactive sources.
- ***LASER referent***, he is in charge of the staff training for the use of the LASER devices.

H&S actions. The H&S actions carried out at APC lab are the following: carrying out accidentology analyses; defining and implementing prevention procedures: H&S sessions for incomers, handling of LASERs and cryogenic fluids; updating of the lab facilities and equipment to the existing norms; managing of the Health & Safety logbook to report incidents and accidents; training lab staff on H&S rules and procedures with sessions on radioprotection; raising awareness about H&S matters via information sessions and the section in the welcome booklet; supervising and assessing the experimental rooms as well as the labs and set-ups using radioactive sources

H&S equipment and facilities. Three safety cupboards dedicated to the radioactive sources storage, pharmaceutical and first aid kits, adapted individual protection equipment (goggles, gloves, masks…), fire alarms and oxygenometers in the labs, ventilated cupboards for solvent storage. Between 2012 and 2017, the APC lab used ULISSE logistics unit the transportation. In 2012, the French nuclear authority ("Autorité de Sureté Nucléaire", ASN) renewed the authorisation to the APC laboratory to possess and use radioactive sources. Between 2012 and 2013, the lab purchased 16 radioactive gamma sources (activities from 40 to 400 kBq) and in 2015 one beta source (activities of 100 kBq).

H&S issues. In 2016, compliance work was carried out on the ventilation system in the Condorcet building. Since, balancing problems have occurred (high noise level when operating). The freight elevator does not comply with the safety standards for hazardous fluids transportation.

Results from accidentology analysis since 2012

Accident occurrence	Main risk factors
1) Journey from home to the laboratory 2) Improper material handling 3) Falls 4) Small injuries or cuts	Machine tools Electrical devices Cryogenic fluids

Table 4. Main accidents and risks at the APC lab

Information System Security (ISS) covers all measures taken by the IT team to ensure:

The availability of services (about 30 virtual servers (DNS, mail, OSticket, VPN, BD, Web, file, LDAP, monitoring...), a computer cluster (652 cores), 300 workstations to manage, encrypt, update and backup, 300 accounts of users to be managed: procedure of open computer account via the web interface allows sending data to the database server by the different agents concerned; account closing procedure automatically triggered by scripts to clean accounts and outdated data, sensitize the 300 users via the security advisory, the letter of the service and emails, access to networks: all the mac addresses of the computer equipment must be validated by the DSI of Paris 7 (online forms and scripts executed automatically), the network is monitored by a local Znet machine installed and administered by the CC IN2P3, implementation of web applications and specific applications (CADENCE, CATIA / ANSYS) and computing tools (Mathematica, Matlab, etc.); incident management documentation via logbook (crisis management plan when there is a power outage...).

The availability and confidentiality of information. The storage server for users and projects (274TB) is well configured so that the data must be accessible to authorized persons when they need it; only those who have the right can access it.

The integrity of the systems. The services and the information (files, messages...) can be modified only by the authorized persons (administrators, owners...)

4. SWOT analysis

Strengths	Weaknesses
• Clarification of the programmatic aspects of many missions. • Cosmology, Gravitation and High Energy Astrophysics have a program both on space and ground, enhansing the detection spectrum and also allowing cross fertilization and exchange of expertise but also complementary science. Also complementary measurements in neutrino physics. • The support of a theory group including internationally renown experts with high international visibility. • Strong scientific recognition and high visibility in many projects. • APC recognised more and more as a key space laboratory by CNES. • A strong and structured support in data science. • Development of in-house technologies that become an asset in future programs. • A very strong interdisciplinary component	• Uncertainties in the European Cosmology roadmap. • Given the limited ressources, it is difficult to conciliate a strong participation in key experiments and a significative involvement in multi-messenger programs at the same time. • Strong involvement in projects limits possible commitment in generic R&D activities. • Imbalance between projects requests and available technical staff. • High turn-over of fixed term staff. • Loss of strategic skills (departure of fixed-term staff, mobility, retirement…) inducing project management difficulties. • Logistics support for the laboratory dramatically reduced after the retirement of the head of the Logistics Department. • Undersized Administrative unit, leading to a structural fragility. • Increase of the financial mangement

(Univearths) promising applications with societal impact (earthquakes, archaeology). • Excellent international network and leadership in many roadmapping exercises. • Organisation of the adminstration department on the basis of the project structure.	activities, and duality of management tools concerning the university (SIFAC tool for University vs GESLAB tool for CNRS).
Opportunities	**Threats**
• GW astronomy has a large discovery potential. • Long-term projects, RI, GDRI and space missions in the physics topics of the laboratory: CTA, LSST, KM3NET, advVirgo, Euclid, LISA, SVOM, ATHENA. • Unique multi-wavelength and multi-messengers environment allowing building a strategy for coordinate follow up observations of transient objetcs and gravitational waves; lead joint analysis between several projects, have a global view of the astrophysical processes and objects. • Complementary participation to the searches of the neutrino properties in Cosmology and Particle Physics. • Central position in European Astroparticle and historically close collaboration with Berkeley, Princeton, Stanford, Tokyo Pekin provides excellent opportunities for joint science endeavours. • Visible participation in some US experiments in cosmology that can become important if the current roadmaps in cosmology ground and space fail to give concrete results.	• Funding cuts from national institutions or partner agencies. ORCA and DUNE not completely funded. • Man power does not scale with involvement in major projects. • GW community (in France) remains limited. • Recent departure or retirement of several group members involved in the field of X-ray and MeV photons have not been replaced yet. It fragilizes this axis even though it plays a central role in our multi-messenger strategy. • Difficulties to find specific skills on the labor market. • Stricter regulations affecting project management, increase of time-consuming non-technical tasks for the team leaders. • The departures from the administrative unit, an average of one per year, due to staff's mobility or retirement, place a serious risk of loss of skills and expertise when a long time is needed to get them back.

5. Scientific strategy and projects in a 5 year perspective

Almost 10 years have passed since the first APPEC/ASPERA scientific vision of 2008, dubbed "The magnificent seven", from the 7 types of domains where progress and support was needed according to APPEC at the time. Some noticed sceptically at the time that at least 5 of the 7 infrastructures were searches for signals that had not been detected yet (gravitational waves, high energy neutrino astronomy, dark matter, neutrinoless double beta decay and ultrahigh energy cosmic ray astronomy). Well, 9 years later the "not yet a signal" areas are only 3 and huge progress in sensitivity for all have been accomplished. A rare achievement indeed for fundamental physics.

In parallel, the theoretical and experimental developments have unified further the different subdomains of the field; since:

- the whole visible Universe from the CMB to the present started to provide comparable cosmological constraints since CMB physics is now related with the large dark energy survey physics and the neutrino properties. A key aspect is the current convergence of the themes of neutrino physics (neutrino mass and nature) and cosmology. The comparison of terrestrial neutrino measurements (accelerator, reactor, atmospheric oscillations, ground and underground beta decays) with large surveys of CMB and dark energy is most probably the next portal from where inconsistencies for both standard models of particle physics and cosmology can emerge
- the beginning of the gravitational wave astronomy polarizes the whole field. We are finally at the edge of multi-messenger detections involving high-energy photons, neutrinos, high-energy charged particles and gravitational waves, which will hopefully permit the deep understanding of violent phenomena regulating structure formation in the Universe.

Despite this extraordinaly uplifting environment, some uncertainties still remain: the first is the definition of an European and/or Global roadmap for cosmology, a clarification of the major infrastructures that will play a discovery role in neutrino physics, the road to a multiton observatory of dark matter. In the context of this environment both our funding agencies and in particular IN2P3 need to take decisions, and in this process APC should play its role.

In this context the APC projections for the next 5 years are the following:

In the next five years, the APC **Cosmology** Group will move on from earlier, foundational work on Planck and BOSS. In terms of optical and near-infrared work, LSST and Euclid are expected to see first light in the coming years (ca 2020). There are essentially no programmatic constraints. One unknown though still remains, whether the two projects will agree in the coming 1-2 years on an early exchange of data for the interest of both. APC plays and will play a key role in this convergence, since it is for the time being the only French lab that participates to both. A second issue is the challenging data problem related to the amount of data to be collected. In this context the priorities are the preservation of the skills that permit the operation of LSST/Euclid data chains and the increase of the researchers that work on the analysis of LSST and Euclid.

In the CMB, the priority is to demonstrate the technical readiness of QUBIC in the lab and then deploy to Argentina for first light. It is a priority both for APC and IN2P3 as well as some foreign partners. Moreover, it is the only advanced project in Europe that could be compared with the US solutions on ground, usually much more adavanced. The Millimetre Lab will continue to furnish and test QUBIC modules, and will begin branching out into other CMB opportunities such as CMB Stage-IV, if the opportunity presents itself. The Lab is also continuing its efforts on Kinetic Inductance Devices.

Work on other projects with fewer resources, such as EBOSS and Polarbear/SA, will be continued, but need reinforcement. This should not be neglected, as they may well be the paths towards other projects such as future CMB satellites and/or the evolution towards the CMB Stage-IV. But there are certainly resource constraints that we cannot ignore. The goal is to be ready to exploit all possible synergies between LSST, Euclid, DESI/FORMOST, the Simons Observatory and CMB Stage-IV, as soon as the data are available. Last but not least, APC should continue to play a proactive role to the coming

together of the European community on CMB, both on ground (EU proposal CMB-E4) and space (followup of CORE, LiteBird…).

The next five years will be crucial for **Gravitation science** in many respects. During this period Advanced Virgo will start operations and will perform science observations jointly with LIGO. ESA will take the final decision about the projected L-class mission for gravitational-wave astronomy, and the design and construction of the mission will follow. The work program of the Gravitation team is essentially determined by this context.

During the next five years, Advanced Virgo (and eventually the Japanese KAGRA) will join LIGO for three science runs alternate with periods of commissioning. The sensitivity reached for the third and last science run will be close to design. During those years, advanced Virgo will thus produce the bulk of its science. Further upgrades that extend the initial baseline are already in preparation (such as the use of squeezed light to reduce the impact of the quantum noise). The first LIGO detections and the forthcoming entry of Advanced Virgo in the global network, open a new and dense phase of potential discoveries. During this period, the Gravitation group plans to increase its focus on the exploitation of the data, through the already ongoing activities on data analysis, but also developing links between gravitational-wave research and cosmology or high-energy astrophysics. Some of the projects we intend to complete are: a search for binary mergers in excentric orbital motion, developing multimessenger astronomy with the SVOM mission, and contributing to open gravitational wave science.

After the selection of LISA by ESA, Phase 0 started by mid 2017 and it will be followed late 2017 by a 2-yr Phase A, and then Phase B1 leading to the mission adoption in 2021. Over this period, the LISA team priorities are the mission deliverables: the LISA data processing center will gradually ramp up reaching full scale in 2028; and the payload AIVT and equipment performance validation will be completed in 2024. In parallel, the activities related to the end-to-end simulation of the mission will continue by building on the LPF experience and data. As a follow-up of the stray light studies, the LISA team and collaborators answered to ESA's Invitation To Tender for the design of the LISA telescopes.

Finally the Gravitation team is the one of the largest group in the future “Groupement de Recherche” Onde Gravitationnelle primarily funded by IN2P3, and initially led by Pierre Binétruy and currently by Chiara Caprini.

On what concerns the **High Energy Universe**, the transition phase of our key experiments (HESS/CTA, ANTARES/KM3Net, INTEGRAL/SVOM) will pursue its process, until the end of 2021, where most of our projects (CTA, SVOM, KM3Net) will be in exploitation phase and start to give their full scientific potential. During this period, the HEA team endeavours to maintain a balance between an effective participation to projects, data analysis, astrophysical interpretation and numerical simulations. The group also seeks to play a leading role in data sharing and multi-wavelengh and multi-messengers studies of the violent universe. In parallel, it will maintain its strong involvement in the definition and preparation of the next generation experiments like ATHENA and JEM-EUSO.

In the field of high-energy photon spatial detectors, the Integral mission, which is in operation since 2002 remains the best wide field instrument to search for photonic counterparts of gravitational waves and transient sky events until the launch of SVOM. After 2018, TARANIS will also provide competitive data: due to its high timing resolution, long-term studies of transient events such as TGF, GRB, pulsars, Fast Radio Bursts, black hole binaries, GW electromagnetic counterparts will be possible. Then the launch of SVOM, which is scheduled for the end of 2021, will open a wide window to the transient sky during the next five years. It is worth mentioning the importance of the SVOM ToO program in the multi-messenger context of the next years: SVOM will be one of the few observatories capable to follow the alerts of the Gravitation Waves, High Energy Neutrinos and High Energy Gamma detectors and will be crucial in the search and identification of the electromagnetic counterpart of the future multi-messanger events.

On a longer-term basis, the ATHENA mission will play a major role in the exploration of the energetic universe and the study of massive black holes. The mission should be launched in 2028.

During the next 10 years, we plan to pursue our hardware activities and grow our involvement in the mission concerning both the software aspects and the science case preparation. In parallel, on a long-term basis, a possible involvement in ASTROGAM or a recovery mission of ASTRO-H dedicated to high-energy could be envisaged if one of these missions is selected.

In the future, the HEA group will also pursue its activities at very high energy, in both Galactic and Extra Galactic fields with HESS II and CTA. The end of phase II of the H.E.S.S. experiment is planned for the end of 2019. In this context, the data analysis activities in which the group is strongly involved should be pursued during two or three more years before ending. In parallel the group will take advantage of the local skills in high level analysis tools to take strategic responsibilities and reinforce its positions in the different working groups of the CTA collaboration, in particular on catalogue elaboration, diffuse emission extraction, Galactic Centre studies and Pevatrons searches. The physics of pulsars in which the HEA group has a leading role on HESS, will also be an important science case for CTA.

In the field of cosmic neutrinos, the HEA team will maintain its astroparticles activities by participating to KM3Net/ARCA and analysing data in continuity with ANTARES. The ANTARES detector is scheduled to end its data-taking phase by 2018. The KM3NeT project has achieved important political and technical milestones in 2016, including the publication of the Letter of Intent for KM3NeT, which presents the final design for the detectors to be deployed on both KM3NeT sites: ARCA (dedicated to high-energy neutrino astronomy) and ORCA (dedicated to atmospheric neutrino oscillation studies and the measurement of the neutrino mass hiearchy: NMH). The group is committed to pursue activities related to both detectors (and both physics goals). In particular, the HEA group will pursue its involvement in the joint search program between KM3NeT and the gravitational wave interferometers LIGO/Virgo and participate in data analysis activities related to multi-messenger searches for cosmic neutrinos.

In the field of ultra-energy cosmic rays, the team will continue to have a leading and decisive role in promoting the concept of a space observatory for UHECR research through instrumental developments within the JEM-EUSO collaboration and theoretical studies. After the flight of EUSO-SPB this spring, the team will be strongly involved in Mini-EUSO, a prototype of the JEM-EUSO detector to operate inside the International Space Station as a joint ASI/ROSCOSMOS mission that will be launched in early 2018. Recently, the reflections about the future of UHECR physics led to the development of new ideas for the detection of UHECRs and high-energy neutrinos from space. In particular, important contributions are made to the CHANT concept and to the POEMMA proposal. The POEMMA proposal has just been approved as a “Probe study” by NASA, and will be studied intensively in the coming years.

Concerning the simulation activities, the HEA team has supported an intensive effort dedicated to the development of an innovative numerical tool able to produce synthetic observations from self-consistent GRMHD simulations of complex relativistic astrophysical systems. Within the next years, we will continue our unique approach of tackling the problem from the different angles of analytical and numerical studies, observations, and high-performance code development. Within our numerical observatory, the description of the interaction of these cosmic rays with the ambient medium is likely to lead to the production of secondary particles synthetic observations (HE neutrinos and HE gamma rays) that are of primary importance for gamma-ray observatory such as CTA or neutrinos telescope as IceCube and KM3NET.

In the **neutrino** sector, during the next 5 years, we can expect final results and the end of the experiments Double Chooz and Borexino/SOX. The team is and will continue to be highly involved in the analysis, with the objective of obtaining the most precise measurement possible, which is expected to arrive at a 1σ error on θ_{13} of ~0.008. In order to achieve this precision, remeasurements of the liquid proton numbers are required which will occur during the detector dismantlement in 2018. Borexino, renown for the study of solar and geo-neutrinos, will end with a strong test for the existence of sterile neutrinos, and we can expect an important impact from the results expected in ~2019.

In the quest to determine the mass hierarchy, both the JUNO and ORCA experiments are currently under-construction, with the team members active in the design, optimisation and preparation of both

experiments. Data taking for JUNO and ORCA should begin in ~2020 and 2021 respectively, and early results pointing towards a preferred hierarchy could be expected during the period. Related to the group's longer-term project DUNE, the next two years will be occupied with the WA105 protoDUNE DP demonstrator, which will be tested in a beam at CERN in 2018. The results and experience from this detector will decide the ultimate design of the DUNE module.

It should be obvious that the interests of the neutrino group have a large complementarity and overlap. The group contributes to three experiments sensitive to the neutrino mass ordering which use three different types of detector technology (liquid scintillator, water Cherenkov and a liquid argon TPC), three different sources of neutrinos (atmospheric, reactor and beam) and exploit two different underlying physical mechanisms; the matter-effect and vacuum oscillations. This later complementarity will open interesting avenues for future combined analyses and the wider goal of confirming the 3-neutrino paradigm. Despite the difference in technology, we are developing synergies, in particular related to the detection of photons (KM3NeT/ORCA and JUNO) and associated electronics and acquisition (JUNO and DUNE).

The group’s interest in the direct detection of dark matter continues with the 20k detector of DarkSide. Team members are currently active in determining the design of this detector, which is planned to be operational in 2020, working towards the realisation of ARGO, which would also make precision measurements of solar neutrinos.

Furthermore, the existence of teams working in the above themes in the same place is an extraordinary advantage on many transversal studies that are currently at the forefront of research. One can e.g. cite 4 of them relating the above domains:

- the coverage of a large spectre of frequencies in the analysis of cosmology and gravitation permitted by the presence of experiments both on space and ground in these domains;
- the measurement of the neutrino mass hierarchy indirectly through CMB and large surveys and directly though experiments on ground as a portal to new physics beyond the standard models of Cosmology and Particle Physics;
- the search of dark matter both indirectly from combined studies of astrophysical signatures and direct measurements through underground experiments;
- the study of violent phenomena from neutron-star and black-hole mergers to supernova explosions and active galactic nuclei (AGN), and their impact on structure formation tackled using multi-messenger studies (photon, neutrino, cosmic ray, gravitational wave) and in particular the follow-up of gravitational wave events with the other messengers giving an exquisite handle on the underlying physics.

The same remark applies for **theoretical physics**, where a program with many points of contact with the experimental program above is in development.

In particular on what concerns cosmic ray physics, the theory group will develop a detailed model of galactic cosmic rays, study the contribution of individual nearby supernovae and their influence on Earth climate and life on Earth. Moreover, their goal will be to understand the origin of astrophysical neutrinos and develop a multi-messenger model of ultra-high energy cosmic rays, astrophysical ultra-high energy neutrinos and gamma rays.

In neutrino astro-physics, their aims will be: 1) to investigate flavor conversion phenomena, due e.g. to self-interaction effects, in astrophysical environments, to understand under which conditions they occur and if they can occur nearby the neutrinosphere so that they can influence the supernova shock dynamics; 2) to push current predictions much beyond the present status by realizing challenging simulations including the kinetic terms as well as the mean-field contributions to study the competition between timescales for flavor conversion and of collisions; 3) to determine the spectral changes due to flavor conversion, important for future observations -- from a(n) (extra)galactic supernova or the diffuse supernova neutrino background --, and their impact on the r-process in neutrino-driven winds, either in core-collapse supernovae or in accretion disks around compact binaries.

In the context of gravitational theories, they would like to continue our exploration of theories of modified gravity, in particular of scalar-tensor theories with higher order derivatives. It would be interesting to study in more detail the phenomenology of beyond Horndeski theories, and of their recent extension that we called DHOST (for Degenerate Higher Order Scalar Tensor), both in cosmology and astrophysics. They would also like to study gravitational waves in the context of modified gravity and see how gravity theories could be tested against the forthcoming data from the gravitational wave detectors, LIGO, Virgo or KAGRA.

Concerning gravitational waves and cosmology, they will be investigating gravitational waves as a cosmological test through the study of the stochastic backgrounds and of the propagation of the signals from binaries in the Universe expansion. As for the stochastic backgrounds, they will analyse the sources in the Universe, model the spectra and develop methods for their detection within LISA. Concerning the binaries, they will use the emission from gravitational waves to test the expansion of the Universe, with/without electromagnetic counterpart. They will study the effect of matter structures on large scales in the Univese on the propagation of the gravitational wave signals.

Finally, in the quantum field theory context, they will work on QCD, QFT in curved space. Concering the gauge/gravity duality, they will generalize the studies mentioned above and work towards understanding how gravity can emerge from field theory via the renormalization group. For this, they will generalize their results on holographic RG flows to curved space-times, and connect holography to the framework of quantum GR. They will work towards the construction of a consistent holographic model that incorporates both the standard model and gravitational dynamics and in which problems connected with physics beyond the standard model can be addressed in a novel way.

In parallel, in the next five years, the APC **technical departments** are being involved in several space projects, whose launches schedule spread from 2019 to 2034. TARANIS and SVOM, which are the two first missions to be ready in 2019 and 2021, are mobilizing substantial technical manpower even after the launches for detectors commissioning or answering to space agencies' technical requests. The ATHENA mission is starting the B1 phase in 2018 for a launch scheduled in 2028 and is mobilizing skills in microelectronics and mechanics for the conception of the Warm Front-End Electronics of the X-IFU instrument. The French contribution on AIT/AIV of LISA would be defined after the on-going Phase 0 at the end of 2017. Strategic skills already identified include mechanical and instrumental AIT/AIV, optics and QA/PA. The A phase starts beginning 2018. After the EUSO-SPB flight, the launch of mini-EUSO, a third pathfinder instrument, on the ISS is scheduled in 2018 and will be the first on-orbit detector. In parallel, large-size space missions, like K-EUSO and POEMMA, are under preparation.

The on-ground QUBIC bolometric interferometer demonstrator is expected to open the path to the full-scale instrument dedicated to the study of B polarisation mode of the Cosmological Microwave Background in Argentina, if technical and financial requirements are fulfilled. The delivery of the qualified calibration base for the undersea KM3NET-ORCA neutrino telescope for further off-shore tests is scheduled in the second quarter of 2018. First versions of the reading electronics cards, using both CATIROC chips from the Pole Omega for the WA105 and JUNO experiments are being ready in 2017 and further versions definitions will follow depending on the results obtained in this first phase. A peak of activity is expected in 2018-2019 for the LSST software framework for the Camera Control System and the Filter Control System, including deliveries and tests at Stanford. At the end of 2017, the TiCKs card will be tested with a telescope on the CTA north-site in the Canaria islands. If the technological solution proposed by the APC is selected by the CTA collaboration, production including test benches building and subcontracting management would start and last around five years.

The APC laboratory is leading efforts to keep and strengthen strategic skills to fulfil all these commitments. Therefore, the laboratory will continue a policy for recruiting fixed-term technical members of staff on permanent position in the coming years. The Microelectronics Department must reach a critical size by hiring a permanent engineer to contribute to future research programs (LiteBIRD, S4, E4) and also fully fulfil current commitments.

The Electronics Department needs to reinforce skills in printed-circuit board design, analogic electronics and FPGA programming to meet technical requests for building reading electronics for

detection set-ups. At the interface with computing, skills in Command & Control are necessary to develop acquisition software and automatic procedures for testing and validating electronics cards. Moreover, retirements will occur in the five coming years and care must be taken to replace these departures so that the department keeps a critical size.

The Experimental Techniques/Instrumentation department is facing a huge challenge with the oncoming LISA project and needs to strengthen its capabilities to answer varied requests in optics, AIT/AIV and system engineering. Besides, projects like DUNE/WA105, JUNO and EUSO need skills in photodetection in a next future. Future developments of instruments for the CMB studies require also an increased back up for support in sub-K detection techniques.

Activities of the PA/QA engineers are spread in a lot of projects and the hiring of an engineer is mandatory to keep an efficient commitment.

The Mechanics Department is facing the retirement of a skilled engineer in mechanics integration for space instruments in a two years-term and its replacement is thus essential for on-going and future activities.

Another major concern is to secure skills in Control/Command and development at the IT department, currently held by a fixed-term engineer, to meet the needs of projects such as LSST and LISA.

A technician is needed to back up transport and logistics operations, including installation and management of large size equipment, assistance to project teams and interface with the Infrastructure Department of the Paris-Diderot University.

Last but not least, the next 5 years will be years of full development and extension of the interdisciplinary links with our IPGP and AIM UnivEarths colleagues on the interface between geoscience and astroparticle physics and cosmology. The recently resubmitted program for a Graduate School “Earth Planets Universe”, that if succesfull would last till 2027 contains an upgraded program of synergies with societal impact and not only, a close association of research with education through measures at the master level. It will be hopefully (SESAME proposal) be based on a federation of the computing centres FACe and S-CAPAD of IPGP and a development of data-science skills, also a part of a future Institute of Data Science supported by the Comue SPC. It will also be based on measures towards a federation of our space-oriented labs and platforms in the context of a Space Campus.

The laboratory will also develop the actions of PCCP, on research and detector development, development of new tools for education (MOOC, Teaching the Universe) and “art and science” actions.

Finally, it will continue the tradition of a rich European and International coordination program. The program that gave to APC a leading position among international centres in the same domain.

PART B.

Teams & departments' evaluation

1. Cosmology team

General Presentation.

The APC Cosmology group was created in January of 2016, when the previous Cosmology & Gravitation group was split into separate Cosmology and Gravitation units. We retain our close ties with the Gravitation group, and also share interest and some talks and meetings with the APC Theory group. The Cosmology group is composed of 18 permanent researchers (9 from the CNRS, 5 from the University, one from CEA, and 3 emeritus), 7 doctoral students, and 3 postdocs. Another 20 or so APC members are affiliated with the Cosmology group (i.e. this is their "second affiliation"). We have a mailing list with of order 50 recipients, which includes group members as well as others such as external affiliates, associates, and the like, and we have nominally weekly meetings, though we will skip meetings where there is nothing significant to report or a number of people are out of the office. The team works on a number of aspects of cosmology, from theory to instrumentation. There are two overarching themes to the group: "Wide-Field Astronomy", which covers optical and infrared work, and "Cosmic Microwave Background", obviously covering the CMB. In addition, there are various smaller efforts.

Products and activities

Wide-Field Astronomy. As noted above, roughly half the group work involves the Euclid Satellite, the LSST Survey and the BOSS experiment and its descendants, eBOSS and DESI.

LSST. There are six permanent researchers and professors in the APC LSST group: three permanent engineers, one postdoc, one non-permanent engineer, and one student. Our largest technical contributions to LSST are focussed on the construction of its camera: the architecture and development of the camera control and command systems and development of the filter-change sub-system. We also do scientific coordination for the French camera construction. Principal scientific themes are galaxy clusters, joint analyses and cross-correlations between different probes, and gravitational lensing.

Euclid. In June of 2010, the APC Cosmology group joined the consortium which proposed Euclid. ESA selected Euclid for its M2 call in 2012, anticipating a launch that is now scheduled for the end of 2020. Euclid will survey the sky at optical and infrared wavelengths, observing more than a billion galaxies for gravitational lensing studies and obtaining spectra for 50 million of those galaxies, thereby allowing the team to reconstruct a three-dimensional map of the Universe. Euclid's focus on studying the nature of Dark Energy is complementary to work which will be done by the ground-based LSST. Just as the group has done in the CMB, using a combination of the space-based Planck and ground-based QUBIC and Polarbear, we anticipate that the combination of the Euclid and LSST platforms will allow us to do both better.

Besides the two primary probes developed by the Euclid consortium (gravitational lensing and galaxy clustering) to put constraints on the nature of the Dark Energy, the APC team has chosen to develop its efforts using galaxy clusters as an additional probe, and on the joint analysis of a variety of other cosmological probes, which is a natural extension of work that has been done while using Planck. Eight APC CNRS or faculty researchers are involved in Euclid, three post-docs are working on scientific investigations, one Ph.D. student is involved, and twelve technicians and engineers (among them two CDD engineers funded by CNES) work with the group. The APC's involvement in the preparation of the Euclid project is:

- responsibility for the CODEEN collaborative platform, with FACe engineers providing work without which CODEEN could not be done;
- a "To Be Defined" processing of the external LSST data which is needed mainly for Euclid's photometric redshift estimation of the over one billion galaxies which will be detected by Euclid;
- responsibility for the scientific coordination of the French Science Data Centre (at CC-IN2P3);
- studies of the impact of cosmic rays on the infrared detector behaviour (once again, this is a natural extension of what has been done on Planck).

- **eBOSS/DESI. eBOSS** (extended Baryon Oscillation Spectroscopic Survey) builds on the BOSS survey, filling the redshift region between 1 and 2, which had not been previously observed with observations of quasars and emission line galaxies. eBOSS will also increase the statistics of Lyman-α forest data by both increasing the high-redshift (z>2) quasar density with observations of new quasars and by re-observing known quasars, in order to increase the signal-to-noise ratio. eBOSS has been running since 2014 and is expected to finish observing by 2019.
- **DESI** (Dark Energy Spectroscopic Instrument) will take the BOSS/eBOSS concepts to the Stage-IV level by obtaining the redshifts of several tens of millions of objects in the redshift range 0<z<4. DESI will build the most comprehensive direct measurements if the expansion rate of the Universe well before, during and after the transition from matter to dark energy domination. The APC has a leading role on the analysis of Lyman-α data (N. Busca coordinates the eBOSS Lyman-α cosmology working group). These APC activities are widely recognized within the community. The participation of the APC in DESI is ensured via a technical in-kind contribution.

Cosmic Microwave Background

Planck. The APC Cosmology group has been involved with ESA's Planck mission since this was selected in 1996. Planck was launched in 2009 and the High Frequency Instrument, with which the APC was most involved, took observations until January 2012. The main objectives of Planck were to map the full celestial sphere in both polarisation and temperature in nine frequency bands from 30 GHz to 857 GHz, to put constraints on the standard cosmological model, and to explore possible extensions of this model. This was done and today, thanks in part to Planck, the cosmological parameters are known at the per-cent level. After the publication of more than 150 scientific papers, the consortium will disband in mid-2017 after releasing a final set of papers. During the 21 years of Planck work at APC, 17 researchers (including 13 CNRS researchers and 4 associated or full professors from the Paris-Diderot University), 11 post-docs and 21 technicians and engineers contributed to Planck. 20 PhD theses were (or will be) defended between 2000 and 2017. During this time, the APC team contributed to the project with coordination responsibilities both for the instrument development (deputy instrument scientist) and for the data analysis (in Pipeline Running and Checking group). During the post-mission period, the APC has had responsibility for the scientific simulation of the sky (Planck Sky Model), contributions to the data processing such as understanding cosmic ray interactions with the detectors, modelling the zodiacal light signal, development of the component separation method « SMICA » (which was selected to produce the official Planck maps), and contributions to the scientific analysis of these data (using galaxy clusters as a probe for cosmology, putting constraints on Inflation models and on non-gaussianity features, and doing joint analysis of the data with other cosmological probes such as BOSS). The Planck mission was the first spatial project in which APC has been involved and it opens a new experimental approach for the APC teams.

QUBIC. QUBIC (http://qubic.in2p3.fr) has been part of the APC Cosmology Group for the last 10 years, first as the BRAIN project, before evolving into its present, international incarnation in 2008. QUBIC will be the first Bolometric Interferometer and aims at measuring the B-mode polarisation of the CMB with high sensitivity and accuracy over large angular scales. From its Argentinian site (San Antonio de los Cobres, 5000m above sea level), it will put strong constraints on Inflation models (σ(r) = 0.01) and demonstrate this novel technology as a possibility for future CMB Polarization observatories such as CMB Stage-4 or E4. The APC group has been leading the design, fabrication and management of the QUBIC project since its beginning, and the integration of the QUBIC First Instrument will take place at APC in 2017/2018. The APC QUBIC team brings together cosmologists and physicists with expertise ranging from theory and data analysis to instrumentation; there is one permanent researcher, one non-permanent researcher, one emeritus researcher and one professor from APC involved in the project, as well as well as eight permanent and one non-permanent electronics, mechanical and managerial engineers.

Main activities from 2012 to mid-2017: The "Detailed Design" of the QUBIC instrument was realized from 2012 through 2014. This involved R&D for the detectors, including their design and that

of the multiplexed SQUID readout, R&D for the platelet horns, the thermo-mechanical engineering of the focal plane, simulations and data analysis development specific to bolometric interferometry, as well as project management. Since 2014, the IN2P3, INSU, the UnivEearthS LabEx, and the DIM-ACAV have supported QUBIC at the APC for fabricating the QUBIC first module. The QUBIC Technological Demonstrator will be integrated in 2017 at APC and will demonstrate the bolometric interferometry technique. Originally intended to be located in Antarctica, QUBIC will start observations in 2018 from a site in Argentina that offers comparable sensitivity and improved logistical support, as well as a strong collaboration with scientific teams in Argentina, in addition to our traditional collaborators in Italy, the United Kingdom and Ireland.

Polarbear. POLARBEAR/Simons Array (PB/SA) is a CMB B-mode experiment operating from a site at the Atacama Desert in Chile. The experiment is supported by the US National Science Foundation and the Simons Foundation and is led by the University of California at Berkeley (PI: A. T. Lee). Our group, consisting of two permanent researchers, a research engineer and a thesis student (there have been 5 PhD students over the period from 2009 to today), is a major contributor and co-leader of the data analysis process of the experiment. In 2014, the POLARBEAR collaboration published its first round of results, including the first direct constraints on the presence of B-mode polarization on small angular scales, consistent with the signal expected to be generated by gravitational lensing due to large-scale structure in the Universe acting upon the CMB photons. It also set first constraints on the gravitational lensing potential using only CMB polarization data and one of the first using the CIB measurements as a mass tracer. The experiment is currently being upgraded and from 2017 until 2019, redubbed as the Simons Array, will observe the sky in multiple frequency bands using over 20,000 multi-chroic detectors on three different telescopes. The goal will be to set new limits on the amplitude of the primordial, large-scale CMB B-Modes.

Millimetre Laboratory. The Millimetre Laboratory contributes to the development of superconducting detectors and detection chains for future ground-based and suborbital CMB polarisation missions. As of February 2017, the team consists of one professor, two CNRS research engineers, two technicians, and one graduate student. **Main activities from 2012 to mid-2017**: APC is the coordinator of the B-mode Superconducting Detectors (BSD) national collaboration to develop superconducting detector (TES & KID) arrays, along with associated readout electronics and planar detection architectures for accurate polarisation measurement. In particular, we have developed the QUBIC superconducting bolometer readout system based on time domain multiplexed electronics with a multiplexing factor of 128:1, which was a world first. The Millimetre Laboratory is also involved in the development of a multi-frequency architectures based on a broadband antennae in the framework of an ESA contract between several European universities (with Maynooth university – project coordinator – as well as Manchester, Cardiff, Rome and Chalmers).

Other Activities. While not a lab priority, members of the group are, of course, involved to lesser extents in other projects as well. In addition to CMB experiments such as LiteBIRD, Spider and EBEX there is interest in 21 cm cosmology -- we have members of both the SKA and HIRAX consortia in the group. We even have members using the tools of astrophysics in the service of Egyptian archaeology.

Members of the Cosmology Group are, of course, referees for journals, both French and international funding agencies and scientific monograph series. We are regularly invited to speak at international conferences, and regularly give lectures at summer schools and the like. We are also members of the organizing committees of such conferences and schools -- Moriond, Vietnam, etc. Our members have worked on national-level working groups such as the Millimeter/Sub-Millimeter Detection Road Map and the French CMB Perspectives group.

We advise graduate students, give presentations to Paris-area school children, work on software that others freely use, such as HEALpy mapping code and Lyman-α cosmology analysis, participate in outreach activities such as Enseigner l'Univers and CERN's Origins program, and have won "primes" and prizes such as the Prix du Magazine La Recherche Lauréat Astrophysique 2013. The Cosmology Group actively participated in the Future-Learn MOOC Gravity! and hosts the Cosmology Virtual Institute of Astrophysics lecture series.

SWOT analysis

Strengths	Weaknesses
• Euclid and LSST at APC are well-defined and funded through the next decade. • EBOSS/DESI, QUBIC and Polarbear/SA have well-defined APC contributions. • The Millimeter Laboratory is well-furnished with CMB-necessary equipment. • The Cosmology group has a number of projects with very similar themes, which allows us to share scientific resources. Each of EBOSS/DESI, Euclid, LSST, Polarbear/SA and other possible high-resolution CMB missions all study the evolution of the Universe through observations of its structure. This opens the door to complementarity and synergies across a number of these experiments. • The QUBIC potential for using bolometric interferometry to increase foreground knowledge. • Deep understanding of the LSST command and control system. If the LSST control software engineer gets a long-term position, the APC will have a well-defined, major, long-term role in the maintenance of LSST.	• Most of the projects associated with the APC Cosmology Group are strained to have the resources they need. • Some projects associated with the APC Cosmology Group, such as EBOSS/DESI, Polarbear/SA/CMB Stage-IV and LiteBIRD lack dedicated funding, which prevents us from making long-term commitments and taking on more leadership and responsibility positions in the collaboration.
Opportunities	**Threats**
• The Simons Observatory, South Pole Telescope and the longer-term CMB Stage-IV are growing, and would be amenable to APC participation, were the necessary resources found. The same can be said for the LiteBIRD satellite project. • Historically close collaboration with Berkeley, Princeton and Stanford provides excellent opportunities for joint science on DESI, Euclid, LSST, the Simons Observatory and CMB Stage-IV.	• LSST, CMB Stage-IV and other US-led experiments with which we collaborate are very dependant from the US federal funding. • The subject of "joint analyses", in which we are interested, is becoming very competitive. • QUBIC is a smaller project than others in the group in terms of financing, and thus is more vulnerable to changes occurring on external teams. • As with other resources, many of the Cosmology Group Projects are strained financially.

Strategy and the five-year plan

In the next five years, the APC Cosmology Group will move on from earlier, foundational work on Planck and BOSS.

In terms of optical and near-infrared work, LSST and Euclid are expected to see first light in the coming years. LSST commissioning data will arrive in 2020 and science data will begin to be taken in 2022. We are preparing for the data analysis using simulations and data from precursor telescopes such as SDSS, HSC and Planck, among others. The goal is to be ready to exploit all possible synergies

between LSST, Euclid, DESI/FORMOST, the Simons Observatory and CMB Stage-IV as soon as the data are available.

In the CMB, QUBIC will show technical readiness in the lab and then deploy to Argentina for first light. The Millimetre Lab will continue to furnish and test QUBIC modules, and will begin branching out into other CMB opportunities such as CMB Stage-IV, if the opportunity presents itself. The Lab is also continuing its efforts on Kinetic Inductance Devices.

Work on other projects with fewer resources, such as EBOSS and Polarbear/SA, will be continued, but need reinforcement. This should not be neglected, as they may well be the paths towards other projects such as future CMB satellites and/or the evolution towards the CMB Stage-IV. But there are certainly resource constraints that we cannot ignore.

Below we give a few more specifics.

Millimeter Laboratory Scientific activities for the next 5 years:

- Development of millimetre Lumped Element Kinetic Inductance Detectors (LEKIDs) that are intrinsically sensitive to polarization.
- Development of a multi-chroic architecture based on LEKIDs detectors.
- Participation in the definition and construction phases of an EU S4 instrument.
- Participation in KIDs detector tests for the visible and near IR, in collaboration with GEPI/ Observatoire de Paris.

QUBIC Scientific activities for the next 5 years:

- 2017: Technical Demonstration integration and testing
- 2018: First Instrument Integration and Commissioning
- 2018-2021: First Instrument exploitation and data analysis
- 2017-2022: Design of future QUBIC-like modules and participation to Preliminary Design Study of CMB-E4 and/or contribution to CMB-S4.

EUCLID Scientific activities for the next 5 years:

- 2017-2018: Simulations of ground-data for the “Scientific Challenge 3”
- July 2017: Final report for the radiation testing of the detectors of the NISP
- End of 2018: NISP and VIS instruments to be delivered to ESA
- 2020-2022” Commissioning phase of LSST
- Mid-2021: EUCLID launch

LSST

- Integration phase for SLAC and Chili
- Commissioning phase (Chili) and beginning of data collection
- Preparation of the joint analysis of the LSST and EUCLID data

Polarbear/Simons Array

- 2017-2019: Deployment of PB2 telescopes
- 2017-2022: Preparation for the deployment of Simons Observatory
- 2019-2021: Analysis of data from Simons Array with CMB observations and optical lensing
- 2021-2022: Analysis of data from Simons Observatory with CMB observations and optical lensing

2. Gravitation team

General presentation.

The Gravitation team was created in January 2016 to gather in a single team all researchers involved in gravitational wave science, formerly distributed in various groups. The team is composed of 6 permanent researchers (2 University/MCF, 3 CNRS and 1 emeritus), 5 PhD students and two postdoctoral fellows. Four other PhD students are co-advised in the context of a collaboration with colleagues from other groups at APC or with other institutes (in particular, IPGP). This sets the "training ratio" to 1.5, the largest across all groups at APC. About 12 researchers and students are associated with the Gravitation team as a "second affiliation".

The Gravitation team meets twice a month. It possesses a mailing list and a wiki page[7] for internal communication. Team meetings include exchanges of general information, discussions of scientific news, updates from the various components of the team, and presentations by group members or visitors. There are good connections with other teams at APC. Members of the Theory team are regularly participating to the team meetings. We organized multiple joint meetings with the High-Energy Astrophysics and Cosmology teams to discuss and address topics of common interest.

The team core scientific interest is gravitational-wave astronomy. The team is involved in the development and exploitation of both ground-based observatories with advanced Virgo, and the space-based observatory LISA (and related technological space platform LISA Pathfinder). All team members are involved in the international collaborations that develop and exploit those instruments. As detailed in the activity report below the team includes members with leading responsibilities in the framework of those collaborations.

The team develops a wide range of activities going from instrument science (R&D, instrument design and simulation, commissioning), data analysis (methods, software implementation) and astrophysics (source physics, models, multi-messenger astronomy in connection to high-energy or neutrino astronomy).

The team is also involved in activities connected to the above core priorities that are possible seeds for future main projects. The team participates to the development of future detector generation (Einstein Telescope), and contributes to the gravitational-wave science using other windows, specifically pulsar timing array with the EPTA and IPTA.

In parallel to the research on gravitational waves, the team pursues activities in connection to ("Newtonian") gravity measurements and their application to geosciences in collaboration with Institut de Physique du Globe de Paris (IPGP), with the support of the LabEx UnivEarthS.

Products and activities.

2016 will be remembered as the year when GW astronomy began. In February 2016, the LIGO/Virgo collaboration announced the detection of gravitational waves from the merger of a binary black hole system [1] quickly followed by a second one. These detections resulted in the publication of about twenty articles in prestigious journals, ranging from the detections themselves, to astrophysical implications and tests of General Relativity co-authored by 10 members of the Gravitation team who also share in the "2016 Gruber prize in Cosmology", and the "Special breakthrough prize in fundamental physics". 2016 has also seen the great success of the LISA technology demonstration package, LISA Pathfinder. This mission validated key technologies for LISA, specifically for drag compensation and interferometry [2].

Ground-based detectors – Advanced Virgo. The Virgo team includes 10 members (8 are from the Gravitation group). The members of the AdVirgo group are involved in several activities ranging from the design and development of the Advanced Virgo detector to its scientific exploitation.

7 http://apcweb.in2p3.fr/APCMediaWiki/Gravitation [wiki, apc_wiki]

The group is responsible for the realization of the "mode-matching" telescopes led by Matteo Barsuglia. These telescopes were designed, constructed, tested, integrated to the detector by the group [3,4]. They are now fully operating. The group is also involved in R&D activities meant to enhance the sensitivity of present gravitational-wave detectors. In particular we have studied the possibility to reduce the impact of thermal noise through the use of non-Gaussian laser beams [5,6], and we are now contributing to a frequency-dependent squeezing experiment, to reduce the quantum noise [7].

The AdVirgo group participates actively to the analysis of LIGO and Virgo data. Members of the group have leading role in this area, with the co-responsibility of the transient search group (Eric Chassande-Mottin, 2014-16) and currently with the compact binary search group (Edward Porter, since 2016). The group made major contributions to the discovery papers released in 2016. The group develops a range of projects, including fast Bayesian methods for binary parameter estimation and advanced search methods for transient sources [8] that expands the signal space covered by the current template-based searches. For this last point, the group has received support from the ANR, for an interdisciplinary collaboration on "Wavelet graphs for chirp searches".

APC provides a very rich environment particularly favourable to the development of multi-messenger astronomy. The AdVirgo group completed a number of projects in this area, including searches for joint sources of gravitational wave and neutrinos [9] in collaboration (joint PhD thesis) with the ANTARES group, and the coordination of the LIGO-Virgo electromagnetic follow-up program (2012-2014) leading to a world-wide network of over 90 astronomer groups [10]. These activities now continue in the context of the H2020 project ASTERICS [11] that fosters the interoperability between major astronomical infrastructures in Europe.

Space-based detector – LISA and LISA Pathfinder. The LISA team includes 20 members (7 are from the Gravitation group[8]). Though tightly connected, LISAPathfinder (LPF) and LISA are separate projects pursued by different teams but with significant staff overlap.

LISAPathfinder. The LISA team is involved in LPF since 2005. Antoine Petiteau is the current PI of the French contribution to LPF. France contribution to LPF hardware is the laser modulator unit (LMU), which is an essential part of the optical metrology system. The team developed data analysis tools, such as Monte Carlo Markov Chain and Multinest algorithms to measure the instrument parameters and to characterize noise glitches in the LPF data. During the preparatory phase the team has organized and hosted five meetings where the data analysis procedures were exercised.

LPF was launched on Dec 2015. The scientific operations started on Mar 1st 2016 and will run until May 31st 2017. The team participates to the data analysis activities remotely from FACe or in person at ESA's Mission Operation Centre in Darmstadt. The team contributed to the LPF performance characterization over a wide range of aspects including the drag-free and attitude control system, crosstalk effects, micro-thrusters analysis and glitches fit and subtraction, all studies using the FACe computing facility. The team produces daily and monthly reports about the LMU status. The LMU performed as expected. The LPF results have surpassed the goals. The residual differential acceleration between the two test masses reached < 4 fm s^{-2} Hz^{-1} at 1 mHz. This is ~8 times lower than the LPF requirements and 10 % less than the LISA specs. The publication of LPF results includes eight co-authors from APC. Those very good results strengthen the L3 mission proposal submitted to ESA in Jan 2017.

LISA mission. The LISA team is involved in the LISA mission led by ESA and a consortium of research institutes and universites. The team was led by Pierre Binétruy until he passed away in April 2017. Pierre Binétruy was Co-PI and member of the mission executive board. Antoine Petiteau took over these functions.

The team contributes to four sectors of activities:

• ***Mission definition*:** The team contributed to the major mission definition reports, including "The Gravitational Universe" white paper [12], the reports of the Gravitational Observatory Advisory Team and the L3 mission proposal [13]. Pierre Binétruy, Chiara Caprini, Hubert Halloin, Ed Porter and

8 Stas Babak (recently hired by CNRS) will join this group end of 2017.

Antoine Petiteau were active members of the writing team for the latter.

• ***National contributions to the mission*:** France is responsible of two major deliverables: LISA's data processing center and the payload AIVT and performance control. With CNES' support, the team initiated a data processing center. The DPC is the entity that receives calibrated data from the Science Operations Center (SOC) at ESA, processes them to identify gravitational wave sources and their parameters, and sends the results back to the SOC. The center currently provides continuous integration tools, support for simulation and data analysis. The center is operational and used by the LISA Consortium for the development of the simulator of the mission and of the science and noise performance tools. It also conducts exploratory studies on future technology in particular an hybrid system using both cluster and cloud. The details of the second deliverable (AIVT, performance control) are being defined by CNES.

• ***Mission simulation*:** Antoine Petiteau leads the mission simulation effort in the LISA Consortium in collaboration with AEI-Hannover. The team has a long-run expertise in this area and maintains the LISACode simulator software [14]. The team prepares the future simulation tools that will help the instrument design and the science reach evaluation.

• ***Data analysis and science*:** Chiara Caprini and Ed Porter are co-chairs of the LISA Working Groups 'Cosmology' and 'Data Analysis' respectively. The team contributes to the development of search algorithms, as well as the development of advanced algorithms for parameter estimation using Bayesian Inference for different astrophysical sources (supermassive black hole binaries, extreme mass ratio inspirals, galactic binaries, stochastic background of cosmological or astrophysical origins and cosmic strings) [15-20]. Recently, we developed a new algorithm that quickly and accurately searches for white dwarf galactic binaries [20]. It is the first galactic binary search developed in Europe since 2008. Taking advantage of the expertise on GW sources, simulation and data analysis, the team has made a strong contribution to the performance studies for ESA's L1-L3 cosmic vision program [12,13].

• ***R&D*:** Hubert Halloin is the co-chair of the LISA Working Group 'Science of Measurements'. The team built a table-top electro-optical experiment able to mimic the propagation delay (a few seconds) of laser phase noises between spacecraft and generate interferometric signals representative of the ones onboard LISA. These signals are extracted with a phasemeter, prototype of the LISA instrument and processed using the noise reduction algorithms called Time Delay Interferometry (TDI). This experiment allowed demonstrating that TDI can reduce the laser noise level by 8 orders of magnitude on realistic signals [21]. It is also an opportunity to work on optical tests benches similar to the ones, which will be required for the instrument's performance checks.

In collaboration with ARTEMIS (Nice) and LMA (Lyon) and with the financial support of CNES, the team is involved in the study and characterization of scattered and diffused light, a crucial problem for the LISA optical system. This study benefits from the expertise acquired in the context of optical design of the AdVirgo mode matching telescopes and is a good example of competence transfer between the two main components of the Gravitation team.

Connection to geophysics. Similar scientific and technological problems have to be addressed in the context of gravitational-wave detection and geophysics. These similarities have motivated several interdisciplinary projects in collaboration with IPGP. A first project explores the potential of interferometric gravitational-wave detectors for geophysics. This collaboration has led to the new idea of inferring earthquake properties from the prompt gravity signal induced by mass redistribution [22]. This can potentially lead to faster, gravity-based earthquake early-warning systems under study with the ANR project E-GRAAL.

Space-based gravitational-wave detector requires the development of low noise, high-precision optical metrology techniques on time scales from seconds to hours. Similar technical challenges are required for the broadband planetary seismometers deployed on the Moon and Mars. A project aims at developing an interferometric readout system, inspired from techniques used in gravitational-wave metrology, which could potentially improve the sensitivity of the current, capacitive technologies by 1 or 2 orders of magnitude.

SWOT analysis

Strengths	Weaknesses
• High visibility and recognized expertise in both advanced Virgo and LISA projects. • Involvement in ground-based and space-based experiments allows cross fertilization and exchange of expertise (experimental and data analysis) ... • … but complementary science (different wavelength, different source reach)	• Man power is lacking – Does not scale with involvement in two major projects. • Age pyramid skewed (over 45 to under 45 ratio is 2) -- need young researchers!
Opportunities	**Threats**
• GW astronomy has a large discovery potential. The field will ramp up during the next 20 yrs. • AdVirgo funded, LISA phase 0 approval [Jun 2017] (strong support from CNES and ESA).	• GW community (in France) remains limited – Attracting new researchers is essential. • The future of fundamental science in space in the US is uncertain. Involvement of NASA in LISA?

Strategy and the five-year plan

The next five years will be crucial for the science developed by the Gravitation team in many respects. During this period Advanced Virgo will start operations and will perform science observations jointly with LIGO. ESA will take the final decision about the projected L-class mission for gravitational-wave astronomy, and the design and construction of the mission will follow. The work program of the Gravitation team is essentially determined by this context.

During the next five years, Advanced Virgo (and eventually the Japanese KAGRA) will join LIGO for three science runs alternate with periods of commissioning. The sensitivity reached for the third and last science run will be close to design. During those years, advanced Virgo will thus produce the bulk of its science. Further upgrades that extend the initial baseline are already in preparation (such as the use of squeezed light to reduce the impact of the quantum noise).

The first LIGO detections and the forthcoming entry of Advanced Virgo in the global network, open a new and dense phase of potential discoveries. During this period, the Gravitation group plans to increase its focus on the exploitation of the data, through the already ongoing activities on dataanalysis, but also developing links between gravitational-wave research and cosmology or high-energy astrophysics. Some of the projects we intend to complete are: a search for binary mergers in excentric orbital motion, developing multimessenger astronomy with the SVOM mission, and contributing to open gravitational wave science.

Assuming the likely selection of LISA by ESA, Phase 0 will start mid 2017 followed late 2017 by a 2-yr Phase A, and then Phase B1 leading to the mission adoption in 2021. Over this period, the LISA team priorities are the mission deliverables:

- The LISA data processing center will gradually ramp up reaching full scale in 2028.
- The payload AIVT and equipment performance validation will be completed in 2024.

In parallel, the activities related to the end-to-end simulation of the mission will continue by building on the LPF experience and data. As a follow-up of the stray light studies, the LISA team and collaborators answered to ESA's Invitation To Tender for the design of the LISA telescopes.

Finally, the Gravitation team is the one of the largest group in the future “Groupement de Recherche” Onde Gravitationnelle primarily funded by IN2P3, and initially led by Pierre Binétruy.

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3. High Energy Astrophysics team

General presentation.

Since the creation of APC, the High-Energy Astrophysics (HEA) team has been a mainstay of the laboratory and it is today its largest thematic group. Since 2014, the High Performance Computing (HPC) team has joined the HEA group and it is now part of the HEA activities. The HEA team is currently composed of 23 permanent researchers (5 University/MCF, 5 CEA staff and 13 CNRS researchers), 5 postdoctoral fellows, and 8 PhD students. During the period 2012-2017, the group has hosted 15 PhD students and 11 postdoctoral fellows.

The HEA team dedicates itself to the study of physical processes accelerating particles to relativistic energies in the Universe. Its main topics are the origin of cosmic rays, acceleration and propagation of particles, accretion/ejection processes, and all associated radiations: photons, neutrinos, cosmic rays themselves and the connection with gravitational waves. These phenomena take place within a wide variety of objects that the team study directly, such as supermassive black holes, gamma-ray burst, Supernovae remains, Pulsars, or indirectly through their interaction with their environment (the interstellar medium or the Galaxy). The team also participates actively to many experiments at several wavelengths and using several messengers, in particular in the field of high-energy photons (X-rays, MeV and TeV gamma-rays), high-energy neutrinos and cosmic-rays hadrons notably at ultra-high energy, in close collaboration with gravitational waves experiments also present at APC. We are strongly involved in many international collaborations through instruments developments, observation campaigns and data analysis and interpretation, but we also perform high performance computing, phenomenological and theoretical modelling. In parallel, the team pursues activities in connection with geosciences in collaboration with the Institut de Physique du Globe de Paris (IPGP), with the support of the LabEx UnivEarthS.

One of the assets of the group lies in the interrelations between all these activities and the creation of an effective synergy between the different energy domains and messengers, and the phenomenology and simulation. Some progresses has been made these last years towards this goal, mainly through the establishment of a regular scientific meeting. Indeed, the HEA team meets every week for a group meeting that includes general informations, discussions of scientific news and presentations by group members or visitors, but also dedicated seminars or journal clubs. This appointment has become essential for the cohesion of the team, the scientific exchanges and the interactions with PhD students and postdoctoral fellows. It is also an important tool for setting up our multi-messenger strategy. Joint meetings with the Gravitation team are regularly organized and benefit a lot to the scientific exchanges. In the following we will describe the group activities and recent results by messenger axis.

Products and activities

The X-ray and soft gamma-ray photons axis. Since its creation, the APC laboratory has been heavily involved in the field of high energy photons collected by space from X-rays to MeV gamma-rays. The group has a long-standing expertise in instrumentation, data analysis and related physics topics. During the time period 2012-2017, 3.5 permanent researchers have been involved (V. Beckmann (left the team in 2016), A. Goldwurm, C. Lachaud, P. Laurent, F. Lebrun (retired since 2016)), as well as various PhD students (D. Chuard, M. Clavel, M. Khalil, G. Trapp) and postdocs (D. Maier, K. Kretscmer, D. Sachenko, S. Soldi, D. Sarria).

One of the most dynamic and prolific research topics studied concerns the **high energy activity of the Galactic Centre** (GC) supermassive black hole, Sgr A*, explored through the study of the X-ray emission from the central regions of the Galaxy. Members of the group have carried out between 2012 and 2017 several large projects of observations of the central molecular zone with XMM-**Newton** and with **Chandra**. This large set of data have allowed them to continue the investigation on the propagation in the clouds of the X-ray echoes of Sgr A* outbursts that occurred more than hundreds years ago (Ponti et al. 2013). The thesis work of Maïca Clavel has shown in particular that the variability of the 6.4 keV line emission and the associated continuum in the region is produced by at

least two separate events originated by Sgr A* in the past, one of few year duration the other lasting at least 10 years (Clavel et al. 2013, 2014). More theoretical work (Walls et al. 2016) and further analysis of the light curves (Terrier et al 2017) and the spectra (Chuard et al. 2017) of this reflected emission are setting crucial constraints on the light curve of the black hole over several centuries. The present Sgr A* flaring activity was also monitored with several multi-wavelength campaigns involving XMM, Chandra, Nu-STAR, VLT, VLA (Neilsen et al. 2015, Ponti et al. 2015b, Ponti et al. 2017) which provided important constraints on the flare rate and on the flare radiation mechanism. The detailed mapping of the central molecular zone with XMM have on the other hand put in evidence several large bubbles and loops of hot gas that again indicate ancient large energetic activity in the very centre of the Milky Way (Ponti et al. 2015), possibly linked to black hole or to star formation bursts.

HEA is also deeply involved in the analysis and understanding of the **Integral mission** observations. APC hosts the IBIS Co-Principal Investigator (P. Laurent). Concerning calibration, the team has strongly contributed to the improvement of ISGRI imaging and spectral analysis. In the recent years, we have developed software and calibration files, which now enable astronomers to recover the absolute flux of the observed source over the whole energy range. Concerning science, the HEA team has collected numerous results during the five past years, the most impressive being related to the observation of radioactive lines from SN 2014J (Isern, 2016), the study of the gamma-ray tail observed in Cygnus X-1 and its polarization (Rodriguez, 2015), the study of the spectral variability and polarisation of the bright nova V404 Cygni (Laurent, 2017). Last but not least, we have signed the MoU in order to have a direct access to the LIGO/VIRGO alerts and demonstrated in the Savchenko et al. (2016) paper that Integral will be the best observatory to detect this possible counterpart.

HEA is also involved in the **Hitomi mission**. Following the lost of the mission on April 28th, 2016, the APC team has decided to concentrate his efforts on 3 of the six sources observed: the Perseus cluster, the Crab pulsar and the X-ray binary IGR J16318-4848. From the Perseus observations, we have contributed to give an upper limit to the 3.5 keV emission, hypothetically resulting from the sterile neutrinos annihilation. Presently, we are also looking at the polarization properties of the Crab pulsar and will also participate to the interpretation of the 6.4 keV fluorescence iron line observations from IGR J16318-4848.

The HEA group is also involved in the proposal of the **Athena space mission** concept, which foresees the launch in 2028. A coherent, ambitious but realistic proposal, was set up beginning 2014 with the micro-electronic team of the laboratory, to contribute to the integrated circuits (ASICs) of part of the readout detection chain of the X-IFU, the so called warm front-end electronics (WFEE). The proposal was accepted by the X-IFU system team, led by CNES and IRAP, that finally assigned full responsibility of the entire WFEE subsystem to APC. Led by A. Goldwurm, the project involves now about several APC engineers and several members of the HEA group and it is presently in the phase A study within the Athena/X-IFU consortium. The team counts two formal X-IFU co-Is, a member of the X-IFU science Advisory Team, a co-Chair of the Athena Working Group on the background estimation and several members of other Athena WGs. A thesis on the ASICs circuits for low noise amplifiers of the X-IFU readout chain has started in 2016 along within several associated studies (Prêle et al. 2016).

The HEA group is also deeply involved in the next large high-energy space mission of France, the bilateral Chinese-French **SVOM mission.** The project is presently in Phase C, and the launch is planned for end 2021. France is responsible for the coded mask X/hard X-ray instrument ECLAIRs and for the X-ray telescope MXT, along with the development and operation of the French Science Center (FSC) that will handle the real time information on the detected GRBs sent by the satellite and the analysis of the data in particular of the French instruments. APC has responsibility for the design and development of the ECLAIRs coded mask and for part of the software development of the FSC, in particular the ECLAIRs data analysis pipeline. In addition to these technical contributions, APC hosts the leading scientists for the General Program (A. Goldwurm) and for the Target of Opportunity (C. Lachaud).

The laboratory has also almost completed a high-energy space mission in the context of the **Taranis mission**. Following the withdrawal of a US team, CNES contacted APC to realize the XGRE

instrument (X, Gamma rays and Relativistic Electrons) under the direction of F. Lebrun. Beginning of 2016, while testing the space model, a major failure appeared. After in-depth studies with CNES and the detector manufacturer it appeared that the sealing of the hygroscopic detectors has been broken during vacuum tests allowing humidity penetration afterward. CNES decided to redo identical detectors but to skip vacuum tests. XGRE is now behind the global TARANIS planning and the APC team has to rush to deliver a new flight model by the end of the year 2017. XGRE will be the first complete space system integrated at APC; with its hazards it has proved to be an excellent experience for the project APC staff.

The group has also constantly looked at the future of the discipline by getting involved in the high-energy space projects proposed by the European community and in associated R&D. Since 2012, we have initiated (P. Laurent), with the help of CNES, a R&D program in order to design, optimise and test double-sided silicon striped detectors (DSSSD) in view of making high-energy telescopes. The team is also involved in the development of the Gamma Cube project (F.Lebrun, R.Terrier). This R&D aims to localize charged particle interactions and tracks in a scintillating detector thanks to a plenoptic, or light-field, measurement. The SATT IdF-Innov has granted a maturation project to help test this prototype and to evaluate the feasibility and performances for a medical gamma camera. The former is done at LPNHE (Paris) and the latter is done, thanks to numerical simulations, at APC.

The Very High Energy gamma-ray photons axis. The HEA team is one of the pioneering groups in the field of very high energy gamma-ray. It has with significant technical and scientific contributions to the **H.E.S.S**. array of Imaging Atmospheric Cherenkov Telescopes (IACTs), as well as to the **CTA** project. During the time period 2012-2017, 8 permanent researchers have been involved (A. Djannati, S. Gabici, P. Goldoni, B. Khélifi (joined the team in 2014), A. Lemière, S. Pita, M. Punch, R. Terrier), as well as several post-docs (J. Kraus, M. Naumann-Godot, L. Nava, S. Reccia, I. Reichards) and PhD students (S. Celli, P. Cristofari, L. Jouvain, J. Lefaucheur, M. Spir-Jacob, T. Tavernier).

Scientific topics with major contributions by the HEA team cover both galactic and extragalactic domains. In particular, the completion of the Galactic survey with HESS I has provided more than 2000 hours of observation of the Galaxy. A detailed catalog has been built. It provides a uniform analysis of the full dataset and contains 78 objects with 10 new discoveries among which two new shell type supernova remnants (SNR) (Donath A. et al. 2015, Pulhofer et al. 2015). This also leads to the discovery of diffuse Galactic emission in the VHE domain and allowed systematic studies of the Galactic population of SNR and pulsar wind nebulae (PWN) (Abramowski A. et al. 2014). These studies are fundamental to understand the physical processes at play, e.g. the recently accepted PWN catalog paper demonstrates that PWN evolve with time and confirms the picture of ancient nebulae populating the TeV sky. Members of the team have been actively involved in analyses and writing of 6 papers to be published in the A&A special issue of the HESS I legacy (A. Djannati, B. Khélifi, A. Lemière, R. Terrier). The center of the Galaxy is also at focus of our activities. Detailed analysis of the diffuse emission in the central 200 pc has shown that the cosmic ray density is maximal in the inner ten parsec of the Galaxy and decreases with the distance to the centre. This is consistent with the presence of a steady accelerator in the vicinity of the supermassive black hole at the centre of the Galaxy. Moreover, it has been shown that the spectrum of the diffuse gamma-ray emission does not present any cutoff, indicating thereby that the parent population of cosmic rays extends up to the PeV energy domain. This is the first evidence of a PeVatron in the Galaxy. A new VHE source in the vicinity of the radio arc was also discovered. These results were published in two articles in Nature and A&A with members of the team as corresponding authors. (S. Gabici, R. Terrier, A. Lemière) (Abramowski A. et al. 2016, Lemière et al. 2015, Abramowski A. et al. 2017). The detection of pulsed emission from the Vela pulsar, under one of APC team member's leadership, has opened the field of pulsar physics to HESS. The addition of a fifth and large dish (28 m equivalent diameter) at the center of the HESS I array was meant to push down the threshold of the latter from above 100 GeV to below 50 GeV. The measurement of the Vela pulsar spectrum down to energies of 20 GeV, in full agreement with the signal obtained with the Fermi-LAT instrument, has validated the design of the fifth telescope and represents a major breakthrough in gamma-ray astrophysics from ground. This has been among the highlights of the HESS II results (TeV-PA 2014, Cospar 2014, CNRS press release 2014…) (A. Djannati). The team's know-how in Galactic science has also allowed us to have

the leadership for the CTA working group on the subject (2013-2016), as well as for the 'cosmic ray, supernova remnants and molecular clouds' task (2009-2013) (S. Gabici).

The team also actively participates to the extragalactic science with HESS and CTA as well. We have assumed the responsibility of the systematic search for AGN in HESS (2012-2013) (Abramowski A. et al. 2012, Abramowski A. et al. 2013, Abramowski A. et al. 2014) (S. Pita, J. Lefaucheur). The team is also involved in redshift determination of BLLs that are likely to be detected with CTA. In 2011 eight carefully selected Fermi BLL without Redshift were observed with the new ESO spectrograph X-shooter taking advantage of the GTO time obtained thanks to the institute participation to its development (DRS, P. Goldoni). The results (published in 2012 in preliminary form and in 2014 in final form) show the very good performances of this instrument in this task (Pita S. et al. 2012, Goldoni P. et al. 2014). Our team members are also active in the 'AGN population' and 'grpropa' CTA working groups, and have been initiators of the 'redshift determination' working group (S. Pita, P. Goldoni).

On the technical side, our team has been at the front-line of development of both low- and high-level analysis methods, relying on state-of-the-art multivariate algorithms (neural networks, boosted decision trees). At low level, particular attention has been paid to the extreme ends of the HESS II array energy range, i.e. 10-100 GeV in monoscopic mode, e.g. used for the Vela pulsar detection, and 10-100 TeV. Since few years, high-level analysis tools for HESS are improved and new tools are conceived by the team in view of the CTA project, benefitting from our three-decade experience in the field. Thanks to a funding from the Labex UnivEarthS we developed a set of python tools to perform spectral analysis of HESS data with the Sherpa and XSpec packages, widely used in X-ray astronomy. We merged our efforts with the GammaPy team, which aims to provide a complete framework for VHE data analysis in python using the fits standard file format. After developing spectral and image analysis, we now implement 3D or cube analysis, which is fundamental for complex environments and which will be heavily used for CTA. We are also actively involved in the data-model definition and formats, as well as high-level use cases of the future observatory, especially in the context of its planned public data release. CTA will be open to guest observing programs and the APC team has taken the responsibility of the 'Proposal Handling Platform' which is meant to facilitate the submission, selection and real-time viewing of proposals and will be integrated in the central CTA WebPortal (B. Khélifi). Thanks to the APC Electronic Department know-how and facilities, the team is also contributing to hardware aspects for CTA. In particular, we are working on the clock distribution and trigger time-stamp, for the CTA's array's software coincidence trigger system (this contribution is detailed in the CTA-Hardware section, in the technical department chapter), as well as on the CTA Camera Test facility designed as part of the 'CTF Camera Acceptance Test Plan' (M. Punch) (Glicenstein J.F. et al. 2013, 2015).

The « Neutrinos axis ». The HEA team is also involved in the design, construction and exploitation of the large-scale neutrino Cherenkov detectors in the Mediterranean Sea: **ANTARES and KM3NeT**. The team has acquired a strong visibility in both ANTARES and KM3NeT collaborations, with contributions at the scientific, technical and institutional levels. During the periode 2012-2017, 5 permanents members (B. Baret, C. Donzaud, A. Kouchner, S. Loucatos, V. Van Elewick), 5 Ph.D. sudents (T. Avgitas, B. Bouhou, S. Bourret, R. Gracia Ruiz, T. Gregoire) and 1 postdoctoral fellow (J. Coelho) have been involved in ANTARES and KM3Net. A member of the group (A. Kouchner) is the elected Spokesperson of the ANTARES Collaboration since June 2014, and other members serve in the Steering, Publication and Conference Committees of ANTARES or KM3NeT. The group is responsible for the calibration, monitoring and data quality of the detector (B. Baret, V. Vallage, C. Donzaud), and is strongly involved in the searches for cosmic neutrinos: emission from the Galactic Plane, multi-messenger searches with GRBs, gravitational waves (LIGO/Virgo), cosmic rays (Auger/TA) and neutrinos from IceCube (B. Baret, J. Aublin, T. Grégoire, A. Kouchner, V. Van Elewyck).

The period 2012-2016 has been particularly fruitful for the scientific exploitation of ANTARES data. Despite its smaller size, ANTARES makes valuable contributions thanks to its excellent angular resolution in both the muon channel and the cascade channel (induced by all neutrino flavours).

Besides the standard searches for diffuse neutrinos fluxes and cosmic neutrino sources, the ANTARES Collaboration has developed an ambitious multi-messenger program to which the APC group has made important contributions (B. Barret et al. 2012). In particular, the ANTARES and Virgo teams at APC have pioneered the development of joint searches of neutrinos in coincidence with gravitational waves (B. Barret 2013). The result of the first search of coincident events in ANTARES and Virgo/LIGO data taken 2007, based on the thesis work of B. Bouhou, have been published in 2013 (ANTARES collab. 2013). More recently, a post-doc in the group (A. Coleiro) has been in charge of the ANTARES follow-up of the first gravitational wave event GW150914 detected by LIGO. The results have been integrated in one of the companion papers of the GW discovery article (ANTARES collab. 2016). The ANTARES detector is scheduled to end its data-taking phase by 2018. While analysis activities will continue on the complete dataset for a couple of years, it is expected that the activity of these group members will progressively shift to KM3NeT.

The KM3NeT project is recognized as a major astroparticle experiment on the 2016 Roadmap of the European Strategy Forum for Research Infrastructures (ESFRI). The scientific activities of the APC group on KM3NeT are currently focused on the development of simulation and reconstruction tools for the ORCA feasibility study, and on the processing and analysis of the data from the first detector prototypes and lines (KM3NeT collab. 2016, S. Bourret et al. 2016). At the technical level, the APC team is responsible for the Calibration Unit of KM3NeT/ORCA, to be deployed in 2018. The group also operates two test benches for the characterization of KM3NeT optical modules. The team is also strongly involved in the calibration and data quality activities for the first KM3NeT/ARCA detection units (KM3NeT collab. 2016, S. Bourret et al. 2016). We are also responsible for the operation of two test benches at APC dedicated to the characterization of KM3NeT Digital Optical Modules (DOMs). The scientific activities of the APC group on ORCA are currently focused on the development of simulation and reconstruction tools for the feasibility study (S. Bourret, J. Coelho, P. Gay, A. Kouchner, V. Van Elewyck) and are fully described in the section related to the Neutrino team activities.

The "UHECRs axis". Since its creation, the HEA team has been heavily involved in the study of ultra-high-energy cosmic rays (UHECRs). The dedicated group develops activities in all aspects of UHECR research: instrumental, experimental, phenomenological and theoretical. Over the last five years it has involved 5 permanent researchers (D. Allard, J.N. Capdevielle, P. Gorodetzky, E. Parizot, C. Lachaud) and 3 PhD students (S. Bacholle, C. Blaksley, A. Jung).

In this period, the main experimental activities have taken place in the framework of the international **JEM-EUSO** collaboration. The members of the APC group are recognized leaders within the JEM-EUSO collaboration, with 3 members of the Executive Committee (out of 14), the head of the science working group and responsible of the science case, the French P.I., and the project manager of the EUSO-Balloon mission. EUSO-Balloon consists of the first fully operational pathfinder of JEM-EUSO, approved, funded and operated by CNES, and recognized as the main activity of the international JEM-EUSO collaboration up to its successful flight under a stratospheric balloon in August 2014, under French responsibility. EUSO-Balloon has represented a considerable effort of the APC team. Its success allowed continuing the global efforts towards JEM-EUSO and triggered further instrumental developments, which led to the realization of an upgraded instrument: the EUSO-SPB mission, approved, funded and operated by NASA, with participation of CNES to support the activities of the French groups and cover its workpackages. EUSO-SPB has been launched the 17th of April 2017 under a super pressure balloon for a long duration flight. APC played a major role in the EUSO-SPB mission, whose focal surface has been integrated, tested and calibrated in the photo-detection laboratory. The HEA team also contributed significantly to a third pathfinder, the mini-EUSO mission, with the integration and tests of the focal surface. This mission consists of a prototype of the JEM-EUSO detector, similar to the balloon instruments, to operate inside the International Space Station as a joint ASI/ROSCOSMOS mission. Mini-EUSO will be launched in early 2018.

HEA group members are also recognized leaders in the domain of **UHECR theory**, with key contributions to the study of the propagation of UHECRs from their extragalactic sources to the Earth, as well as original works on particle acceleration. In particular, the HEA members were the first to recognize and demonstrate the importance of considering composed nuclei, in addition to protons, to

understand the phenomenology of UHECRs. The inclusion of nuclei was later made unavoidable by the experimental results of the Pierre Auger Observatory. Among the main and most cited results, obtained in the last five years, are:

- A detailed study of particle propagation including energy losses, composition changes through photo-dissociation and angular deflections by Galactic and extragalactic magnetic fields, with skymap predictions and the statistical analysis of their intrinsic anisotropies for a wide range of astrophysical models (this became an important element of the JEM-EUSO science case).
- The computation and prediction for different UHECR models of cosmogenic neutrinos and photons, as secondary products of the propagation of cosmic rays in the extragalactic space.
- The first complete calculation of particle acceleration in the mildly relativistic internal shocks of GRBs. The resulting propagated spectrum and composition was shown to be compatible with the observational data under specific assumptions on the partition of energy in GRBs.
- A detailed description of the transition between Galactic (GCR) and extragalactic cosmic rays, accounting for the spectral features and the evolution of CR composition over the whole range of energy.

Finally, studies are conducted on the physics of air showers themselves, particularly in relation to the exploration of constraints related to high-energy hadronic physics (J.N. Capdevielle).

Transverse activities: phenomenology and simulations

Galactic cosmic rays: The study of galactic cosmic rays is amongst the main lines of research carried out by the High Energy Astrophysics group at APC. These theoretical/phenomenological investigations are focused on the acceleration of cosmic rays at supernova remnant shocks, on their propagation in the turbulent interstellar magnetic field, and on the study of the radiative signatures (espacially in the gamma ray domain) resulting from the interactions of cosmic rays with ambient matter and background radiation fields (Acero *et al*. 2013) (Cristofari *et al*. 2013, Gabici *et al*. 2014) (Nava *et al*. 2014). A particular attention has been devoted to the study of the interactions of cosmic rays in dense molecular clouds (Morlino *et al*. 2015) (Nava *et al*, 2013) (Vaupre *et al*. 2014). The interactions of high-energy (GeV and TeV) cosmic rays in molecular clouds produce an intense flux of gamma ray photons, observable by both ground and space borne instruments. On the other hand, low energy (MeV) cosmic rays ionise the gas and influence the dynamical evolution of clouds and thus the process of star formation. Finally, the interactions of galactic cosmic rays with the interstellar gas also result in the production of neutrinos. It has been suggested that a halo of cosmic rays surrounding our galaxy could contribute significantly to the production of the isotropic flux of multi-TeV neutrinos recently detected by Icecube (Vaupre *et al*. 2014). The origin of the cosmic rays responsible for the diffuse TeV emission at the Galactic Center and the connection with the high SNR rate in the region and SgrA is also investigate within the HEA team (Jouvin *et al*. 2017).

High performance computing. The high performance computing (HPC) team main interest lies in the study of astrophysical plasmas in the vicinity of compact objects as well as in the particle acceleration processes at work in astrophysical shocks. After restructuration, the team has joined the HEA team since 2014. During the time period 2012-2017, the HPC team has been composed of two permanent researchers (P. Varniere et F. Casse) as well as various PhD students (I. El Mellah & C. Demidem) and postdocs (F. Vincent & A.J. VanMarle). Over the last five years, its work has been centred on the development of two innovative numerical tools for both the astrophysical high-energy and astroparticle physics communities. Regarding the study of plasmas in the vicinity of compact objects, the group has developed the general relativistic MHD version of the MPI-AMRVAC in collaboration with colleagues from LUTh (Obs. Paris-Meudon). This code is the first of its kind in the French astrophysical community. This GRMHD code is able to handle any kind of GR metrics, either analytical or numerical ones. We have published several papers devoted to both the study of accretion disk instabilities in the close vicinity of Kerr black holes and to more exotic compact objects such as boson star. Our code is also unique in the sense that its outputs are directly connected to a general relativistic ray-tracing code (GYOTO) thus providing synthetic observations of the compact system. This project has produced more than fifteen publications over the last three years. The second part of our activity is devoted to the description of the self-consistent acceleration of supra-thermal particles in the vicinity of astrophysical shocks. Since this mechanism is intrinsically a multi-scale process, we

have developed an entirely new numerical code linking a large-scale description of the plasma and the magnetic field (MHD) to a particle-in-cell (PIC) framework. This innovative tool has enabled us to provide the first ever self-consistent description of the Fermi acceleration for all obliquity of the magnetic field and over large distances. This project is supported by the ANR through a collaboration with colleagues from IAP, LUPM (Montpellier), IPAG (Grenoble) and CELIA at Bordeaux.

SWOT analysis

Strengths	Weaknesses
• Unique multi-wavelength and multi-messengers environment allowing: o building a strategy for coordinate follow up observations of transient objetcs and gravitational waves. o leading joint analysis between several projects o having a global view of the astrophysical processes and objects. • Strong scientific recognition and high visibility • Guaranted funding of most of the futur projects in which the group is involved (CTA, KM3Net, SVOM, ATHENA, TARANIS).	• Given the limited ressources, it is difficult to conciliate a strong participation in key experiments and a significative involvement in multi-messenger programs at the same time.
Opportunities	**Threats**
• The large discovery potential of the new generation of large Observatory (CTA,KM3Net) and Space projects (SVOM, TARANIS, ATHENA, JEM-EUSO) in which the HEA team is involved. • The maturity of the next generation of gravitationnal waves and cosmic neutrinos detectors that makes possible a real multi-messenger astrophysics.	• Recent departure or retirement of several group members involved in the field of X-ray and MeV photons have not been replaced yet. It fragilizes this axis even though is plays a central role in our multi-messenger strategy. • The prevalence of Astrophysical questions in our field places the HEA team in a marginal position within the IN2P3, while we are neither sufficiently recognized within the INSU. • The large Observatory CTA and KM3Net are funded for the construction phase but not for the operation phase : it represents a real threat of a lack of support for our analysis and scientific activities within the next years.

Strategy and the five-year plan

In the coming years, the transition phase of our key experiments (HESS/CTA, ANTARES/KM3Net, INTEGRAL /SVOM) will pursue its process, until the end of 2021, where most of our projects (CTA, SVOM, KM3Net) will be in exploitation phase and start to give their full scientific potential. During this period, the HEA team endeavours to maintain a balance between an effective participation to projects, data analysis, astrophysical interpretation and numerical simulations. The group also seeks to play a leading role in data sharing, multi-wavelength and multi-messengers studies of the violent universe. In parallel, it will maintain its strong involvement in the definition and preparation of the next generation experiments like ATHENA and JEM-EUSO.

In the field of high-energy photons spatial detectors, the Integral mission, which is in operation since 2002 will remain the best wide field instrument to search for photonic counterparts of gravitational

waves and transient sky events until the launch of SVOM. At the end of 2016, ESA has accepted to extend its financial and technical contribution to the mission up to 2018, but the observatory may be technically able to be extended up to 2024 without loss of performances. Within the next years, we will pursue our effort analysing data and leading multi-messenger follow up observations. After 2018, TARANIS will also provide competitive data: due to its high timing resolution, long-term studies of transient events such as TGF, GRB, pulsars, Fast Radio Bursts, black hole binaries, GW electromagnetic counterparts will be possible. Then the launch of SVOM, which is scheduled for the end of 2021, will open a wide window to the transient sky during the next five years. It is worth mentioning the importance of the SVOM ToO program in the multi-messenger context of the next years: SVOM will be one of the few observatories capable to follow the alerts of the Gravitation Waves, High Energy Neutrinos and High Energy Gamma detectors and will be crucial in the search and identification of the electromagnetic counterpart of the future multi-messanger events. The HEA team has strategic responsibilities in the SVOM collaboration which will guarantee an efficient scientific return. On a longer term basis, the ATHENA mission will play a major role in the exploration of the energetic universe and the study of massive black holes. The mission is expected to enter the phase B in 2018-2019, and should be launched in 2028. During the next 10 years, we plan to pursue our hardware activities and grow our involvement in the mission concerning both the software aspects and the science case preparation. In parallel, on a long-term basis, a possible involvement in ASTROGAM or to a recovery mission of ASTRO-H dedicated to high energy could be envisaged if one of these missions is selected.

In the future, the HEA group will also pursue its activities at very high energy, in both Galactic and Extra Galactic fields with HESS II and CTA. The end of phase II of the H.E.S.S. experiment is planned for the end of 2019. In this context the data analysis activities in which the group is strongly involved should be pursued during two or three more years before ending. In parallel the group will take advantage of the local skills in high level analysis tools to take strategic responsibilities and reinforce its positions in the different working groups of the CTA collaboration, in particular on catalogue elaboration, diffuse emission extraction, Galactic Centre studies and Pevatrons searches. The physics of pulsars in which the HEA group has a leading role on HESS, will also be an important science case for CTA. The group will also participate actively to the multi-wavelengh campaigns of transient objects observations and to the program of redshift determination of AGNS in which we already have important responsibility. In parallel, synergies with SVOM and KM3Net will be reinforced in close collaboration with the Gravitational group, in the context of the fast evolution of international cooperation towards joint multi-messenger studies of the transient sky.

In the field of cosmic neutrinos, the HEA team will maintain its astroparticles activities by participating to KM3Net/ARCA and analysing data in continuity with ANTARES. The ANTARES detector is scheduled to end its data-taking phase by 2018. While analysis activities will continue on the complete dataset for a couple of years, it is expected that the activity of these group members will progressively shift to KM3NeT. The KM3NeT project has achieved important political and technical milestones in 2016, including the publication of the Letter of Intent for KM3NeT Phase 2 [5], which presents the final design for the detectors to be deployed on both KM3NeT sites: ARCA (dedicated to high-energy neutrino astronomy) and ORCA (dedicated to atmospheric neutrino oscillation studies and the measurement of the neutrino mass hiearchy: NMH). The group is committed to pursue activities related to both detectors (and both physics goals). The group has the ambition to progressively increase its technical contribution to the construction of the detector, up to a level that would match its scientific impact in the collaboration (the APC group is currently second largest French group after the hosting lab, CPPM). So far, we have taken responsibility for the design and construction of the first KM3NeT Calibration Unit, to be deployed on the ORCA site in 2018. In this context, a new Laser Beacon has been designed to be integrated on the CU as part of the calibration devices of the detector. On the analysis side, it is expected that the members of the group active in ANTARES will transfer their expertise in multi-messenger searches onto KM3NeT/ARCA. In particular, the HEA group will pursue its involvement in the joint search program between KM3NeT and the gravitational wave interferometers LIGO/Virgo and participate in data analysis activities related to multi-messenger searches for cosmic neutrinos. The HEA group naturally offers an ideal

context for such research, allowing for collaborations with members of the major next-generation experiments CTA (for gamma-ray astronomy) SVOM (for GRB detection), JEM-EUSO (for ultra-high cosmic rays) and advanced Virgo and LIGO (for gravitational waves).

In the field of ultra-energy cosmic rays, the team will continue to have a leading and decisive rôle in promoting the concept of a space observatory for UHECR research through instrumental developments within the JEM-EUSO collaboration and theoretical studies. After the flight of EUSO-SPB this spring, the team will be strongly involved in Mini-EUSO, a prototype of the JEM-EUSO detector to operate inside the International Space Station as a joint ASI/ROSCOSMOS mission that will be launched in early 2018. A possible participation to K-EUSO (a prototype of JEM-EUSO that will represent 50 unity of Mini-EUSO to be launched in 2022) is under discussions with ESA. Recently, the reflections about the future of UHECR physics led to the development of new ideas for the detection of UHECRs and high-energy neutrinos from space. In particular, important contributions are made to the CHANT concept and to the POEMMA proposal, with the important innovation of observing showers as well as their direct Cherenkov emission in the direction of the Earth's limb, with a series of Schmidt cameras operating in the UV. The POEMMA proposal has just been approved as a "Probe study" by NASA, and will be studied intensively in the coming years. A crucial pathfinder to this possible future mission is the EUSO-SPB2 long duration balloon mission, for which a proposal has just been submitted. This includes a key participation of our group, in continuity of the previous works done on EUSO-Balloon, EUSO-SPB and mini-EUSO.

Concerning the simulations activities, the HEA team has supported an intensive effort dedicated to the development of an innovative numerical tool able to produce synthetic observations from self-consistent GRMHD simulations of complex relativistic astrophysical systems. Within the next years we will continue our unique approach of tackling the problem from the different angles of analytical and numerical studies, observations, and high-performance code development. In particular, the new PIC module that we developed recently will enable us to describe the dynamics of the plasma in the vicinity of compact objects and also to provide the radiative emission coming from relativistic electrons accelerated within the plasma. It is noteworthy that this new feature opens the door to multi-messenger physics as we will also address the acceleration of cosmic rays (and associated HE neutrinos) in the vicinity of the central object. Within our numerical observatory, the description of the interaction of these cosmic rays with the ambient medium is likely to lead to the production of secondary particles synthetic observations (HE neutrinos and HE gamma rays) that are of primary importance for gamma-ray observatory such as CTA or neutrinos telescope as IceCube and KM3NET. On a longer term, another direction the group wish to explore will be to expand the ability of our code to use non-analytical metrics to be able to use time varying non-analytical metrics. This will open a new door in the study of the systems prone to emit gravitational waves. The outcome of these simulations will be a preliminary step toward the realization of multi-messenger synthetic observations.

4. Neutrino and dark matter team

General presentation.

The Neutrino group is the largest in France currently comprising: 3 CNRS researchers, 5 academic staff of Paris-Diderot (3 of whom are IUF), 4 emeritus, 2 retired members, 2 visiting academics, 5 postdoctoral researchers and 5 PhD students. The interests of the group are focussed on the determination of the parameters governing neutrino oscillation; the current measurement of θ_{13} (Double Chooz) and future experiments to make; precision measurements of oscillation parameters and tests of the three-neutrino paradigm (JUNO, DUNE), a search for sterile neutrinos (Borexino/CeSOX), determining the neutrino mass ordering (ORCA, JUNO, DUNE) and measuring the CP-violating phase (DUNE). Group members also study the sources of neutrinos; geo- and solar (Borexino), reactors (Double Chooz, JUNO) and atmospheric (ORCA, DUNE). With future massive neutrino detectors, other studies become possible such as the search for Nucleon Decay and astrophysical observations of Galactic Supernovae (JUNO, DUNE).

Since the conception of the laboratory, one astro-particle critical to cosmology has been missing, dark matter, and in 2012 APC decided to meet this experimental challenge with involvement in a direct search experiment. Following the experience existing in the neutrino group working with low energy (keV-MeV) signals and at low background (highly radio-pure detectors located deep underground), it was natural that this effort be led by members of the neutrino group. In keeping with the long-term interests of the group (DUNE) and for-seeing future synergies, an experiment using dual-phase liquid argon was favoured (DarkSide).

The interests of the group have a large complementarity and overlap. The group contributes to three experiments sensitive to the neutrino mass ordering which use 3 different types of detector technology (liquid scintillator, water Cherenkov and a liquid argon TPC), 3 different sources of neutrinos (atmospheric, reactor and beam) and exploit two different underlying physical mechanisms; the matter-effect (ORCA and DUNE) and vacuum oscillations (JUNO). This later complementarity will open interesting avenues for future combined analyses and the wider goal of confirming the 3-neutrino paradigm. Despite the difference in technology, we are developping synergies, in particular related to the detection of photons (KM3NeT/ORCA and JUNO) and associated electronics and acquisition (JUNO and DUNE).

The group also has two interdisciplinary projects; muon tomography for archeology and neutrino-oscillation tomography with KM3NeT-ORCA. Members of the group are interested in the development of future detectors, studies of argon-detectors for solar neutrino physics [1], ionisable organic liquids for neutrino detection [2] and LiquidO. The project LiquidO has been recently joined by a Marie Cure Fellow (M. Grassi), and in April 2017 Blaise Pascal chair F. Suekane joined the group and will soon bring a further two post-doctoral researchers.

Team members participate to the GDR neutrino, A. Kouchner and A. Tonazzo are working group co-ordinators, and the group hosted the GDR meeting in May 2017.

Products and activities.

Borexino/SOX. Borexino is a large liquid scintillator detector, installed at the LNGS laboratory, designed to detect neutrinos via elastic scattering on electrons. APC members have been involved in Borexino since its conception. D. Franco is now national IN2P3 co-ordinator, PhD student R. Roncin (Borexino/Double Chooz) successfully completed his thesis in 2014 and T. Houdy is due to complete his PhD in 2017. CEA/APC members T. Lasserre and M. Cribier join the activity with SOX. Borexino has already produced a wide range of results related to the observation of solar and geo–neutrinos, and APC members have been deeply involved in the analyses, in particular leading the first measurement of the ^{8}B neutrino rate with the lowest energy threshold (3 MeV) among real-time

experiments. A new ^{8}B analysis, performed by T. Houdy and D. Franco, with a factor ~7 larger exposure, will be published in fall 2017. At the beginning of 2018, a ~150 kCi of ^{144}Ce anti–neutrino source will be deployed in a tunnel below the center of the Borexino detector (SOX). Reconstructing the events from this source, Borexino will search for an oscillation pattern L/E, testing the existence of sterile neutrinos, suggested by the "neutrino reactor" and "gallium" anomalies. The results will strongly rely on the capability to keep all the systematics under control. APC/CEA members T. Lasserre and M. Cribier lead the procurement and calibration of the source. APC is involved in studying potential contaminants in the ^{144}Ce source, which could alter the calorimetric measurement of the source activity.

Double Chooz. The Double Chooz (DC) experiment measure the mixing angle θ_{13} using anti-neutrinos from the Chooz nuclear power station (Ardennes, France). The experiment relies on two identical detectors in shallow underground laboratories; one located ~400m (Near Detector - ND) and the other at ~1050 m (Far Detector - FD) from the reactor cores. The ND monitors the reactor flux and spectrum, cancelling major systematics on the measurement. APC plays a large role in the experiment, with members in key positions; H. de Kerret is the experiment spokesperson and A. Cabrera is the IN2P3 national co-ordinator, director of the LNCA laboratory and analysis/detector co-ordinator. Current neutrino group members participating are: J. Dawson, D. Franco, D. Kryn, M. Obolensky, A. Onillon, H. Gomez and A. Tonazzo. During the period, the group was reinforced by one Marie Curie fellow, P. Novella, and for long periods by visiting professors; John Losecco (Notre Dame). The group also hosted and supervised several visiting PhD students; Yosuke Abe (Tokyo Institute of Technology), Tomoyuki Konno (Tokyo Institute of Technology), Kazuhiro Terao (co-tutelle with MIT), Akira Shigemori (Nagata University), Luis Gonzalez (co-tutelle with UNICAMP), Thamys Abrahao (UNICAMP) and Guillaume Pronost (co-tutelle Nantes). APC PhD students A. Remoto, R. Roncin and A. Hourlier also successfully defended their theses in 2012, 2014 and 2016 respectively. During the period 2012 to 2017, the Near Detector was constructed and commissioned. APC mechanical engineers, W. Bertoli, A. Givaudan and M. Karakac were greatly involved in the construction; responsable for the main vessel, upper shielding and platform, and electronics hut. APC members are also responsible for the Flash-ADC cards (with electronics engineer B. Courty), electronics installation, on-site computers, Data Acquisition, and participated actively in the commissioning. Shift organisation, coordination with CCIN2P3 and regular on-site visits are also assured by the team. Historically, Double Chooz has provided several contributions to the global effort towards the measurement of θ_{13}, including the detector design and the reactor prediction (ILL based) strategy. With only the Far Detector in operation, DC was the first reactor experiment to provide positive evidence for a non-zero value of θ_{13} at 2σ's (2011) which when combined with that of T2K, yielded evidence at the level of 3σ. This was quickly followed in 2012 by the Daya Bay experiment (China) providing evidence at ~5σ, and later by RENO (South Korea). Since then, DC has provided several further key results to the field. In 2013, DC provided an independent θ_{13} measurement in the same detectors using a H-capture based technique [3], and in May 2014 DC provided the first evidence for a spectral distortion (up to +10% amplitude at ~4MeV), demonstrating that the accuracy of today's best ILL based predictions (originally claimed uncertainties ~3%) is not fully consistent with data. Similar spectral distortions were reported by RENO (June) and Daya Bay (July) of the same year. In 2016, DC announced its first result with both Near and Far detectors, using a novel analysis which includes all observed Inverse Beta Decay interactions (with neutron captures on H, C and Gd) which increases the statistics by a factor of 3. The result suggests a ~40% larger value of θ_{13} than that of Daya Bay, providing a tension of 2.2σ. Should this trend be confirmed with higher significance, this would have implications to the indirect prediction of CP-violation when reactor results are combined with T2K+NOvA experimental results. Within the 2016 release, DC has also provided two novel results: the world most precise IBD-directionality measurement and the world most precise rate+shape reactor spectral characterisation. A new result is to be released for publication by June 2017.

Data taking is expected to end at the end of 2017. By then, the 1σ error of θ_{13} is expected to be ~0.008 upon a re-measurement of the proton composition of both FD and ND during the detector

decommissioning. If the discrepancy relative to Daya Bay persists, todays difference will be >4σ's. Today's main goal of DC analysis is geared to setting and/or validating the central value of θ_{13} with highest possible accuracy.

Following the successful study of muon in the Double Chooz detectors by H. Gomez (LabEx project WP12 «Geoparticles»), an interdisciplinary project was formed to study archeological structures with muon tomography, funded by TelluS INSU/IN2P3. This work is led by postdoctoral researcher H. Gomez, with participating group members A. Tonazzo and S. Katsanevas. Preliminary studies based on MonteCarlo simulations [4] indicate the capability of this technique applied to the so-called Macedonian tumulus. The first detector will be installed around a tumulus in Apollonia (northern Greece) in the following months.

JUNO. The JUNO experiment, in China, will be the largest liquid scintillator detector in the world, with a 20-kton detector located in a dedicated underground laboratory at 700m depth. JUNO is a high precision neutrino oscillation experiment based on reactor neutrinos. It will measure oscillation angles and mass splittings of both the solar (θ_{12}, δm^2) and reactor (θ_{13}, Δm^2) sectors and the sign of $\pm\Delta m^2$ — the Mass Hierarchy (MH). JUNO is expected to improve the precision on θ_{12}, δm^2, Δm^2, respectively, by up to 10x, 5x and 5x, allowing direct tests of the PMNS matrix unitarity. The detector should also achieve world leading sensitivities to supernovae and geo neutrino observations as well as proton decay via a unique set of channels, such as the Kaon one.

The experiment is in its final design phase (end of 2017), and detector construction will begin in 2019 with data taking expected in 2021. In order to determine the Mass Hierarchy the detector is designed to achieve the energy resolution of 3 % at 1 MeV, requiring 18,000 20" PMTs with Flash-ADC read-out. Towards this goal, neutrino group members, A. Cabrera (APC responsible), M. Obolensky and H. de Kerret with C. Volpe (Theory) and engineers A. Noury and C. Santos, have pioneered the concept of 'Double Calorimetry' ; conceiving, designing and now leading the construction of the Small PMT (SPMT) read-out system. This additional and independent system, comprises up to 36,000 3" PMTs and electronics readout (including DAQ), in order to control to highest precision the systematics on the calorimetry of the detector. The electronics readout is based on the OMEGA ASIC CatiROC with an industrial liaison with CAEN (Italy). A. Cabrera is the co-ordinator of the SPMT system and French responsible for the SMPT read-out electronics, with C. Santos as technical co-ordinator. Beyond calorimetry purposes, the SPMT is capable to address leading physics channels in JUNO such as complementary measurements of θ_{12}, δm^2, deadtime-less supernova readout, proton-decay, high precision and accuracy 4π muon reconstruction (i.e. cosmogenic background active vetoing) as well as readout complementarity handled to aid the LPMT maximal sensitivity.

KM3NeT – ORCA. The scientific activities of the APC group on KM3NeT are currently focused on the development of simulation and reconstruction tools for the ORCA feasibility study, and on the processing and analysis of the data from the first detector prototypes and lines [5,6]. The presence at APC of other experts in neutrino physics has allowed the group to be at the forefront of establishing the physics case for ORCA [7], and one member of the group (A. Kouchner) is the coordinator of the KM3NeT/ORCA sensitivity study since 2013. He also coordinates the ANR Projet DAEMONS (Demonstrating the Ability of Estalishing the Mass Ordering of Neutrinos in the Sea) partnering APC, CPPM and IPHC Strasbourg. He and V. Van Elewyck have also served in the Editorial Board of the recently published KM3NeT Letter of Intent. At the technical level, the APC team is responsible for the Calibration Unit of KM3NeT/ORCA, to be deployed in 2018. The group also operates two test benches for the characterization of KM3NeT optical modules. The scientific activities of the APC group on ORCA are currently focused on the development of simulation and reconstruction tools for the feasibility study (S. Bourret, J. Coelho, P. Gay, A. Kouchner, V. Van Elewyck):

- development of a full Monte-Carlo simulation framework based e.g. on the OscProb neutrino oscillation tool developed by J. Coelho, designed to perform sensitivity studies for the neutrino mass hierarchy and detector optimisation
- development of new reconstruction tools : one former post-doc of the group (S. Galatà) was responsible for the implementation of reconstruction strategies for track-like events (generated by muon neutrino charged-current interactions). The interest of the group has now shifted to a more

general approach on reconstruction and particle identification based on deep-learning techniques (J. Coelho, S. Bourret, P. Gay)

The KM3NeT detector also offers new opportunities for Earth and Sea sciences, thanks to its unique location and capacity to continuously monitor the abyssal environment. The atmospheric neutrinos detected by ORCA can also be used for studies of Earth composition by using the neutrino oscillation tomography method. To exploit these synergies, the KM3NeT group is developing new collaborations with experts, geophysicists and marine scientists from IPGP, one of the partner institutes of APC within the LabEx UnivEarthS. V. Van Elewyck has recently obtained two fundings for this purpose, one from IdEx SPC (ONSET: Oscillation Neutrino Studies and Earth Tomography) and one from LabEx UnivEarthS (ARGOS: Astroparticle Research, Geophysics and Oceanographic Studies).

DarkSide. DarkSide is a direct dark matter search programme using dual-phase liquid argon Time Projection Chambers installed at LNGS. Group members D. Franco (national IN2P3 co-ordinator) and A. Tonazzo successfully introduced this project to APC and France. They were joined by DarkSide PI, C. Galbiati, who was award with a Paris-7 chair in 2016 and continues to be associated to the group. The group's activity was also strengthed by the arrival of Q. Riffard as post-doctoral researcher. During the period, one PhD thesis (P. Agnes) was successfully completed. P. Agnes remains associated to the group.

The group members are the authors of the DarkSide simulation and lead several aspects of the DarkSide-50 analysis (e.g. sensitivity to WIMPs and to solar neutrinos) which impact key results: in 2014 the first DarkSide-50 run with atmospheric argon, demonstrating its capability to operate in a background-free mode, and in 2015 DarkSide-50 ran with 150 kg of argon extracted from deep underground, demonstrating the possibility to reduce the 39Ar contamination by more than 3 orders of magnitude. These two extraordinary results are at the basis of DarkSide-20k, using 20 tonnes of 39Ar-depleted argon, which is foreseen to start in 2020. The group is driving the design of this detector via the simulation. The ultimate detector in the DarkSide program is ARGO, a 300 tonne dark matter detector also capable to measure with high accuracy solar neutrino rates from CNO, pep, 7Be, and 8B reactions.

The group conceived ARIS (Argon Response Ionization and Scintillation) - a small scale dual-phase LAr TPC which was exposed to interaction of neutrons produced by the ^{7}Li(p,^{7}Be)n reaction at the ALTO facility (IPNO) in 2016, and successfully measured the quenching of nuclear recoils and the argon response dependence on the electric field. The project was funded by Labex UnivEarthS with D. Franco as PI, the post-doctoral researcher Q. Riffard led the experimental effort on-site.

LAGUNA towards DUNE and its prototype, the ProtoDUNE-Dual-Phase experiment WA105.

APC members have been critical in the conception and design of DUNE, and the formation of the collaboration. Results from the European design studies LAGUNA and LAGUNA-LBNO, which were completed in 2014, have formed the experimental concept. A. Tonazzo was heavily involved in the low-energy performance studies (as part of the LAGUNA science board) and T. Patzak was the scientific coordinator of the project (chair of the science board and leader of the physics task force), contributing to; the 4000 page report with a technical design of the detector, the infrastructure and the beam line, the 300 page report on the physics performance and leading the writing of publications. During this period one PhD thesis was successfully completed, under the supervision of T. Patzak; L. Agostino, who is now a high school teacher. Post-doctoral researcher, M. Buizza Avancini, was recruited by CNRS as CR-2 and relocated to LLR.

Dual-Phase ProtoDUNE (WA105). The LAGUNA, LAGUNA-LBNO efforts resulted in the proposal to the CERN SPSC of a large-scale demonstrator, WA105 in 2013 (approved CERN experiment from August 2013) and the TDR in 2014 [8,9]. T. Patzak is chair of the Institutional board (22 institutions from 10 Countries, ≈ 130 physicists). APC contributes to the detector by providing the light read out front-end electronics based on fast µTCA technology in collaboration with OMEGA. The construction of the cryostat in the CERN North Area is ongoing and will be finished in April 2017. The collaboration is ready to install the detector and will be ready to take data in April 2018, just before LS2. The APC team has been recently reinforced by new members; PhD student A.

Scarpelli, started in October 2016 (funded by INSPIRE COFUND), preparing for the analysis of data and J. Dawson contributes to the development of the light read out.

DUNE. The proposed far detector (at 1300 km from FNAL) will be located deep underground at the SURF 4850L with a fiducial mass of 40 kt of liquid argon. It consists of four cryostats instrumented with Liquid Argon Time Projection Chambers (LArTPCs). LArTPC technology provides excellent tracking and calorimetric performance. The full imaging of events in the DUNE detector will allow the study of neutrino interactions and other rare events with unprecedented detail.

The size and costs of the DUNE experiment (order 2 billion $) are so important that it can only be realized with a strong international organization and coordination. In 2014, an APPEC meeting was organized by S. Katsanevas, to bring together all major funding agencies from Europe, Americas and Asia to coordinate the effort. This resulted in the merging of LAGUNA-LBNO and LBNE collaborations to realise DUNE, hosted by Fermilab, USA. In August 2014, T. Patzak joined the international interim Executive Board tasked to form the proto-collaboration, leading to the formation of the new international collaboration, DUNE, in January 2015.

A. Tonazzo and T. Patzak were nominated co-coordinators of the atmospheric neutrino working group and the long baseline physics working group respectively. The major accomplishments are the CD reports on the detector and physics performance of the DUNE experiment [10,11,12] . A very important change in the measurement strategy has been imposed with respect to the LBNE strategy, namely the importance of the second maximum for detecting CP violation and the tau neutrino appearance measurement to check for unitarity and to distinguish the CPV signal from Non-Standard Interactions (NSI).

SWOT Analysis

Strengths	**Weaknesses**
• High visibility and internationally recognized expertise • Diverse experiments • Attempts to find synergies between experiments (sharing of electronics engineers between protoDUNE (WA105) and JUNO, future possibilities related to liquid argon - DarkSide/protoDUNE) • Complementary measurements (for example 3 future experiments can measure the mass hierarchy) • Future projects well defined - for neutrinos (ORCA, DUNE, JUNO), and continuation of DarkSide	• Not enough resource given for the electronics development of the card for protoDUNE (WA105) • Too many postdocs, need to recruit at least one young researcher in the next few years (CR-2). Last CNRS recruitment was in 2012.
Opportunities	**Threats**
• Interesting opportunities related to joint analyses (JUNO/ORCA/DUNE)	• Future projects ORCA and DUNE are not completely funded

Strategy and the five-year plan

During the period, we can expect final results and the end of the experiments Double Chooz and Borexino/SOX. The team is and will continue to be highly involved in the analysis, with the objective of obtaining the most precise measurement possible, which is expected to arrive at a 1σ error on θ_{13} of ~0.008. In order to achieve this precision, remeasurements of the liquid proton numbers are required

which will occur during the detector dismantlement in 2018. Borexino, renown for the study of solar and geo-neutrinos, will end with a strong test for the existence of sterile neutrinos, and we can expect an important impact from the results expected in ~2019.

In the quest to determine the mass hierarchy, both the JUNO and ORCA experiments are currently under-construction, with the team members active in the design, optimisation and preparation of both experiments. Data taking for JUNO and ORCA should begin in ~2020 and 2021 respectively, and early results pointing towards a preferred hierarchy could be expected during the period.

Related to the group's longer-term project DUNE, the next two years will be occupied with the WA105 protoDUNE DP demonstrator, which will be tested in a beam at CERN in 2018. The results and experience from this detector will decide the ultimate design of the DUNE module.

The group’s interest in the direct detection of dark matter continues with the 20k detector of DarkSide. Team members are currently active in determining the design of this detector, which is planned to be operational in 2020, working towards the realisation of ARGO, which would also make precision measurements of solar neutrinos.

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5. Theory team

General presentation.

The theory group is composed by 14 permanent researchers of which 6 University researchers (E. Huguet, J. Mourad, F. Nitti, J. Renaud, D. Steer, J. Serreau), 6 CNRS researchers (C. Caprini, N. Deruelle, E. Kiritsis, D. Langlois, D. Semikoz, C. Volpe) and 2 Emeritus: (J.-P. Gazeau and M. Lachièze-Rey).

Chiara Caprini (CNRS), formerly at IPhT Saclay, has joined the group the 1st of September 2016. During 2016-2017, Karim Noui, an University researcher (LPT Tours) is a member of the group thanks to a "demi-délégation CNRS". D. Langlois and C. Volpe have been heads of the group during 2012-2013 and 2014-2017 respectively, with D. Steer the adjoint. The group has typically 5-6 associate researchers from other institutions, including H. Bergeron (ISMO Orsay), K. Noui (Tours U.), U. Reinosa (Polytechnique), B. Van Tent (LPT Orsay), F. Vernizzi (IPhT Saclay). P. Binétruy sadly deceased in Spring 2017.

During 2012-2017 the group has supervised: 15 PhD thesis (A. Chatelain, J. Ben Achour, F. Julié, F. Gautier, J. Ghosh, M. Guilleux, A. Helou, J. Maelger, F. Lamy, W. Li, T. Marchand, M. Pieroni, L. Silva Pimenta, A. Tresmontant, D. Väänänen), 11 postdocs (A. Belokogne, M. Cardenas, V. Domcke, D. H. Kumar, E. Joung, P. Malkiewicz, S. Mizuno, A. Naruko, N. Merino, R. Saito, L. Witkowski) and 15 trainings of students at different University levels (L3, M1, M2).

Products and activities.

The theory group research activity is centered on key open questions at the forefront of research in astroparticle physics, cosmology, gravitation, quantum field theories and its applications. Our research work focuses both on theoretical and on phenomenological aspects of fundamental interactions, some being closely related to international experimental projects and more generally to observations. The latter puts the theory group in close symbiosis with the high-energy astrophysics, cosmology, gravitation and neutrino experimental groups of the APC laboratory. Some group members are involved, or develop research, in close connection with experiments - Planck, LSST, EUCLID, LISA, Virgo, CTA, JEM-EUSO, JUNO.

Astroparticle. The astroparticle physics activity concerns mainly cosmic rays and neutrinos. The origin of cosmic rays is a puzzle over 100 years old, but the current wealth of precision data is paving the way to its solution. We have been developing demanding simulations to explain the spectra, the composition and the source of cosmic rays as well as their propagation in the intergalactic medium. Among our main results:

We have shown that a recent local supernova gave significant contribution to the measured cosmic ray flux, explaining the dipole anisotropy measurements and anomalies in antiparticle (positrons and anti-protons) spectra. M. Kachelriess, A. Neronov and D. Semikoz, "Signatures of a two million year old supernova in the spectra of cosmic ray protons, antiprotons and positrons", PRL 115, 181103 (2015).

Both galactic and extragalactic contributions to the astrophyscal neutrino flux have been studied in several models. Our investigations have shown that the data contains evidence of contribution of a galactic component of the astrophysical neutrino flux. Such an approach accounts for both cascade and muon Icecube neutrino data. A. Neronov and D. Semikoz, "Evidence the Galactic contribution to the IceCube astrophysical neutrino flux", Astropart. Phys. 75, 60 (2016).

Neutrino physics. Neutrino physics has made an impressive progress since the discovery of the neutrino oscillation phenomenon in 1998. Neutrinos are weakly interacting particles capable of bringing information from stellar cores, violent phenomena such as supernova explosions and leaving an imprint in primordial or stellar nucleosynthesis in supernovae, in accretion disks around black hole-neutron star and binary neutron star merger remnants. Amongst the different lines of research developed in the group are 1) to unravel how neutrinos change their flavour in astrophysical and cosmological environments, 2) to study indirect effects, or to propose signatures of key unknown

neutrino properties, in experiments running or under study, 3) to establish links with other domains. Among our main results:

Using the theoretical framework of the Born-Bogoliubov-Green-Kirkwood-Yvon hierarchy, we have established a formal connection between the collective modes and the dynamics of neutrinos propagating in astrophysical environments and other many body systems, such as condensed matter and atomic nuclei. C. Volpe, D. Väänänen, C. Espinoza, "Extended evolution equations for neutrino propagation in astrophysical and cosmological environments", PRD87 (2013) 113010.

Our investigations in accretion disks around binary neutron star merger remnants has clarified that helicity coherence from the neutrino absolute mass contributions cannot induce flavor conversion effects. We have given a perturbative analysis explaining why non-linearity does not increase adiabaticity, contrarily to what shown in a previous study. This gives the final answer to this recently debated question. A. Chatelain, C. Volpe, "Helicity coherence in binary neutron star mergers and non-linear feedback", Phys.Rev. D95 (2017) 043005.

Cosmology. Cosmological observations, in particular the CMB anisotropies, point to the existence of primordial fluctuations, with a spectrum close to but distinct from scale-invariance. The best current explanation for the origin of these fluctuations is a phase of accelerated expansion --- inflation --- in the early universe. This scenario was proposed more than 30 years ago and has survived the tremendous improvement of observations. We have studied different models of inflation, such as models of Dirac-Born-Infeld type. The group also works on dark energy. Among our main results:

An approach has been developed, based on effective field theory, capable of including most of the models with a scalar field, of giving a formulation that identifies different classses of models, even apparently different. It also furnishes a common theoretical framework to compare theoretical predictions with observations. J. Gleyzes, D. Langlois, F. Piazza, F. Vernizzi, "Essential Building Blocks of Dark Energy", JCAP 1308 (2013) 025.

The study of possible modifications of general relativity (GR) is of major theoretical and phenomenological importance. Such theories should be mathematically consistent, e.g. free of instabilities and ghosts, experimentally viable, that is consistent with GR at least on scales ranging from ~1mm to solar system and explain the observed late time acceleration of the universe today. We have been working on several theories of modified gravity, in particular scalar-tensor theories, formulations of massive gravity (e.g. ghost free, or its holographic link to quantum field theory). Among our main results:

A new class of scalar-tensor theories has been identified, called "beyond Horndeski", whose Lagrangian depends on second order derivatives. It generalises Horndeski theories as the Euler-Lagrange equations are formally of third order. But there is only one scalar degree of freedom, thus avoiding Ostrogradsky instability. We have studied such theories in detail and in a gauge-invariant way, given its Hamiltonian formulation and calculated the number of degrees of freedom. These theories have the interesting consequence that gravitation inside stars deviates from GR, as has been shown explicitly for neutron stars. D. Langlois, K. Noui, "Degenerate higher derivative theories beyond Horndeski: evading the Ostrogradski instability", JCAP 1602 (2016) 034 and C. Deffayet, G. Esposito-Farese, D. ASteer, "Counting the degrees of freedom of generalized Galileons", Phys.Rev. D92 (2015) 084013.

Gravitation. 2016 saw the first obervation of gravitational waves from a binary black hole merger event by the LIGO/Virgo Collaborations. The LISA (Laser Interferometer Space Antenna) has an enormous potential to provide cosmological tests, either by detecting the stochastic gravitational wave background from the primordial Universe (inflation, phase transitions, topological defects and primordial black holes) or by using the signal from massive black hole binaries to examine the redshift-distance relationship and determine the cosmological parameters. The former would furnish unique information about the status of the primordial Universe and help discriminating among models. Among our main results:

The spectral shape of a stochastic gravitational wave background from a first-order phase transition and from inflation has been determined, in the LISA frequency band. An analysis method of the signal

has been developed, which will furnish crucial information about the origin of the stochastic gravitational background observed by LISA. C. Caprini et al., "Science with the space-based interferometer eLISA. II: Gravitational waves from cosmological phase transitions", JCAP 1604 (2016) 001.

The propagation of gravitational wave signals from compact massive binaries has been studied, as well as the imprint of matter inhomogeneities on the waveforms, in order to assess LISA potential to determine the acceleration of such sources, eventually the one due to the Universe expansion and therefore the cosmological parameters. C. Bonvin, C. Caprini, R. Sturani, N. Tamanini, "Effect of matter structure on the gravitational waveform", PRD95 (2017), 044029.

The LIGO/Virgo detectors will allow testing, e.g., scalar-tensor theories of gravity. As a first step, the conservative part of the two-body dynamics in scalar-tensor theories in 2PN has been developed within an extended effective one-body approach. F. Julié, N. Deruelle, "Two-body problem in Scalar-Tensor theories as a deformation of General Relativity: an Effective-One-Body approach", arXiv:1703.05360.

Formal aspects of quantum field theory - in curved spacetime, high spin theories, quantization methods, holographic principle - and its applications to cosmology, condensed matter and strong interactions. Among our main results:

In relation with the crucial question of de-confinement, a novel approach with massive gluons is being developed. A new quantization procedure, which consistently deals with Gribov ambiguities and yields a modified perturbative expansion (with an effective gluon mass term) with no Landau pole. A perturbative calculation has been performed of the phase diagram and of the deconfinement phase transition of Yang-Mills theory and of QCD with heavy quarks at nonzero temperature and chemical potential in this massive perturbation theory, in good agreement with lattice results. U. Reinosa, J. Serreau, M. Tissier, "Perturbative study of the QCD phase diagram for heavy quarks at nonzero chemical potential", PRD92 (2015) 025021.

The research activity in the context of gauge/gravity correspondence has followed multiple directions, all of which can be linked to improving our understanding of the connection between gravity (GR) and field theory. Among our main results:

We have proposed a mechanism that can "hide" the cosmological constant due to quantum effects of the Standard Model in the holographic/braneworlds context. C. Charmousis, E. Kiritsis, F. Nitti, "Holographic self-tuning of the cosmological constant", arXiv:1704.05075.

We have performed a detailed study of the renormalisation group in the "holographic" theories (large N, strong coupling) and discovered several properties and novel non-perturbatif phenomena such as the presence of "branch cuts" in the beta function. E. Kiritsis, F. Nitti, L. Silva-Pimenta, "Exotic RG Flows from Holography", Fortsch.Phys. 65 (2017) 1600120.

We have applied holographic ideas to inflation, in cosmology, and provided a unified framework of inflation models, based on Wilsonian ideas. This has given a classification of the fluctuation properties, as a function of critical exponents and solved some of the puzzles concerning scalar fields with heavy masses. P. Binétruy, E. Kiritsis, J. Mabillard, M. Pieroni, "Universality classes for models of inflation", JCAP 1504 (2015) 033.

SWOT Analysis

Strengths	Weaknesses
• The Theory group includes internationally renown experts in these fields and has high international visibility. The group is also heavily involved in teaching and the	• The lack of young researchers. Only one young researcher (less than 40 years old).

supervision of students at all levels of the LMD, of PhD students and postdocs. Finally the group has strong connections with the 4 experimental groups in the laboratory.	
Opportunities	**Threats**
• Interesting opportunities might be offered by the creation of a theoretical network among different laboratories within Paris	• This year one young CNRS researcher has been hired, after ten years without hiring any. The age pyramid having a peak at around the age of 50, it is absolutely necessary to hire more young researchers. • Recurrent funding (SBNA) has significantly decreased since the AERES evaluation. The funding for trips has been on average between 1000 and 1500 euros/researcher. The allocated amount is definitely too low.

Strategy and the five-year plan

For the future, we will keep investigating the novel methods and ideas we have been proposing and their consequences, and developing challenging simulations in order to bring important elements to solve the crucial open questions in the four research domains of the group. Here we mention some of our main goals.

Astroparticle physics. In cosmic ray physics, we will develop a detailed model of galactic cosmic rays, study the contribution of individual nearby supernovae and their influence on Earth climate and life on Earth. Moreover, our goal will be to understand the origin of astrophysical neutrinos and develop a multi-messenger model of ultra-high energy cosmic rays, astrophysical ultra-high-energy neutrinos and gamma rays.

In neutrino astro-physics, our aims will be: 1) to investigate flavor conversion phenomena, due e.g. to self-interaction effects, in astrophysical environments, to understand under which conditions they occur and if they can occur nearby the neutrinosphere so that they can influence the supernova shock dynamics; 2) to push current predictions much beyond the present status by realizing challenging simulations including the kinetic terms as well as the mean-field contributions to study the competition between timescales for flavor conversion and of collisions; 3) to determine the spectral changes due to flavor conversion, important for future observations -- from a(n) (extra)galactic supernova or the diffuse supernova neutrino background --, and their impact on the r-process in neutrino-driven winds, either in core-collapse supernovae or in accretion disks around compact binaries.

Gravitation. In the context of gravitational theories, we would like to continue our exploration of theories of modified gravity, in particular of scalar-tensor theories with higher order derivatives. It would be interesting to study in more detail the phenomenology of beyond Horndeski theories, and of their recent extension that we called DHOST (for Degenerate Higher Order Scalar Tensor), both in cosmology and astrophysics. We would also like to study gravitational waves in the context of modified gravity and see how gravity theories could be tested against the forthcoming data from the gravitational wave detectors, LIGO, Virgo or KAGRA.

Concerning gravitational waves and cosmology, we will be investigating gravitational waves as a cosmological test through the study of the stochastic backgrounds and of the propagation of the signals from binaries in the Universe expansion. As for the stochastic backgrounds, we will analyse the sources in the Universe, model the spectra and develop methods for their detection within LISA.

Concerning the binaries, we will use the emission from gravitational waves to test the expansion of the Universe, with/without electromagnetic counterpart. We will study the effect of matter structures on large scales in the Univese on the propagation of the gravitational wave signals.

Quantum Field Theories.

Concerning strong interactions, we shall compute the spectrum of light mesons in QCD within our modified perturbative approach (with massive gluons). We will also explore the phase diagram of QCD with realistic quark mass in this approach.

For QFT in curved space, we will implement advanced nonperturbative methods to compute the two-point function of a scalar field in de Sitter space. We shall study the question of the backreaction of the nonperturbative quantum fluctuations of a scalar field on the classical geometry.

Concering the gauge/gravity duality, in the upcoming years, we will generalize the studies mentioned above and work towards understanding how gravity can emerge from field theory via the renormalization group. For this, we will generalize our results on holographic RG flows to curved space-times, and connect holography to the framework of quantum GR. We will work towards the construction of a consistent holographic model that incorporates both the standard model and gravitational dynamics and in which problems connected with physics beyond the standard model can be addressed in a novel way.

6. PCCP

The Paris Centre for Cosmological Physics is a place of educational research and of exchanges related to the physics of the Universe. In 2010, George F. Smoot, 2006 Nobel Prize winner, was recruited by the University Paris Diderot. He saw the opportunity to create a large Parisian centre dedicated to cosmology. Together with the University Sorbonne Paris Cité, the CNRS and the Paris Observatory, among others, the PCCP is developing a synergy between laboratories in the Paris area to contribute in answering essential questions, like that of the origin of matter and of the structure of space and time. The PCCP wishes to address also teachers and enthusiasts, to share this great adventure to the frontiers of knowledge.

PCCP activity 2011 - 2016

Education & Outreach. PCCP is keen on raising within the general public the interest for the study of the Universe, its concepts and methods. Specific programs and dedicated tools are developed for the young public, students, teachers, and anyone who is potentially an enthusiast:

"Enseigner l'Univers" – Teaching the Universe. Ran by G. Smoot and Pierre Binétruy, course adressed to college professors, yearly edition, in Paris usually in November and have also run one in Malta 2014 and one in Greece 2015. In June 2016, ran the Berkeley Teachers' Academy, which is to train middle and particularly high school teachers how to teach science (and math). With the participation of K. Ganga, G. Patanchon, E. Porter

The on-line course / MOOC: Gravity! From the Big Bang and Black Holes to Gravitational Waves and the website. This on-line course was offered 5 times, twice in French on the French platform FUN and three times in English on the English platform FUTURELEARN, with a total of 96.800 registered learners. It is a 6 weeks course presented by Pierre Binétruy and George Smoot, with the participation to an educator team of PCCP and APC postdocs and Ph.D. students. The course includes videos, quizzes, tests, hangouts, readings and a forum. It was specifically designed for a general public without any formula. Final results for this on-line course are repeatedly recognized to be unseen for scientific courses. As an example, 25% of the registered learners on the French course are finishing it successfully. A course designed for high-school students, with calculations and formulas is being built with the very active participation of international school, and involvement of young students. The students can extend their studies through Gravity.paris, an internet site created to inform enthousiasts and learners on gravitational actuality, give more detail information and specific training for high-school students.

Students: 3 Master students and 2 Ph.D students were housed at PCCP

Fellows programme. This programme is dedicated to attract excellent postdocs and give them high scientific visibility. The PCCP has the privilege of being a centre doing the most advanced research, interacting with world-class faculty and students, while enjoying the cultural opportunities found only in Paris. We have strong international partners and collaborators, an outstanding research program, and excellent young researchers and postdoctoral fellows. At the same time, our constant commitment to creating direct contacts between the society and the scientific community shapes our education and outreach programs. **Present fellows**: Valerie DOMCKE (*L'Oréal-UNESCO fellowship for women and science 2016*), Dhiraj Kumar HAZRA, Ivan DEBONO, Andrea TARTARI. **Past Fellows**: Mark JACKSON – CEO Fiat Lux, Singularity University 2016, Federico PIAZZA – Université de Marseille professor 2016, Giulia GUBITOSI, Marc BETOULE – CNRS since 2014.

Workshops, Conferences. We believe that understanding the Universe fosters exchange, discussion, and greater comprehension of the human experience and the world. Cosmology is the science of the Universe, how the Universe came into being, developed and evolved. 11 workshops and conferences were organized between 2011 and 2016.

Endowment Fund Physics of the Universe – RFPU. RFPU-*Physique de l'Univers* is a private entity designed to collect donations to fund PCCP's activities. The past years activities of the Fund allowed financing research programmes like the collaboration with the Narzabayev University in Kazakhstan, partial funding of the annual programme *« Teaching the Univers »,* the development of the online course *« Gravity ! »* and connections with international high schools. The fund is also interested in

developing links between artists and scientists and presented successfully its project *Universe 2.0* to the *Carasso foundation.*

7. Energy Physics Group

General presentation.

Search for novel sources of energy for tomorrow is the main driving force of research in the Energy Physics Group. Interdisciplinary research is focused on the observation and understanding of basic mechanisms underlying physical phenomena, their modeling and eventually applications in novo energy systems. At the interface of physics, biology and chemistry, this cross-disciplinary research includes also socio-economics aspect.

The Energy Physics Group is composed of 4 senior researchers (1 professor, 2 associate professors (research affiliates) and 1 CNRS research engineer) as well as 3 PhD candidates. One of the PhD candidates is co-supervised by the WINDEE Institute of the Western University in Canada. The Energy Physics Group has a wide range of collaborative research with other French as well as International universities.

The Energy Physics Group moved from another laboratory of the Université Paris Diderot and officially joined the APC in January 2017. The small size of the Group allows vigorous interaction among its members, however, formal meetings are organized every two weeks.

From the disciplinary point of view, the research in the Group combines a traditional emphasis in fluid mechanics, heat transfer, and statistical physics with an understanding and application of molecular physics, physical chemistry and biology. Research activities are particularly focused on two main fields, in each of which a rich set of topics are explored: Hydrodynamics of active matter and Physics of transport phenomena; both with final application to Energy Challenges of Tomorrow.

Energy Physics Group has also a strong link with the energy industry through which new challenges are detected and the related research is funded.

The group is also actively involved in the research initiatives of the Université Sorbonne Paris Cité (USPC). It has initiated and manages the "*Programme Interdisciplinaire des Energies de Demain*". This interdisciplinary program funded by the USPC brings together researchers of different laboratories of USPC from a wide range of hard science (engineering, physics, chemistry, biology information technology) and soft science (sociology, geography, history) around the challenges that energy faces the humanity.

Products and activities.

Both main domains of investigation of the Energy Physics Group have been active in the period of evaluation under examination and have produced knowledge in their corresponding fields.

Hydrodynamics of active matter. In this field, the main trust has been put on the understanding and modelling of the behaviour of microorganisms and their reaction to different stresses aimed at producing by photosynthesis biofuels or other bio-molecules of interest in photobioreactors. Two main topics have been addressed:

(Hydro)Dynamics of bio-suspensions. Dynamics of motile cells (bacteria and microalgae) inside a fluid flow or on a solid surface has become a topic of intensive research due to its vast applications in biotechnology and biomedical engineering in addition to its fundamental hitherto unknown aspects in physics. Our research projects on dynamics and hydrodynamics of cyanobacteria and microalgae suspensions aim at providing promising solutions, based on analytical and experimental lab studies in physics, for optimization of industrial systems such as bioreactors and biofacades. A summary of theses activities and major results obtained so far is given below:

Effects of hydrodynamic stress on the growth, motility and dispersion of microorganisms. The interest in developing a third generation of biofuels produced from microalgae and cyanobacteria have clearly increased due to the current global energy crisis. Thus, the design and construction of novel culturing systems under optimal conditions is crucial to benefit from the energy content of these species

produced under photosynthesis effect. It is observed that microorganisms produce more secondary metabolites under stress. This project investigates the effects of shear stress, generated by stirring in agitated photobioreactors and bubbling in airlift photobioreactors, on the growth, motility and dispersion of two species of microorganisms, the cyanobacterium *Synechocystis* and the microalgae *Chlamydomonas reinhardtii*. The results show that *Synechocystis* is highly resistant to shear stress; the variation in exponential growth rate is limited to the breakdown of cellular colonies, while the carrying capacity appears to increase as a function of shear stress up to a maximal value. On the other hand, *C. reinhardtii* shows to be more sensitive; the exponential growth rate increases with shear stress intensity, while the carrying capacity seems to be less affected (1). We have proposed a logistic growth model featuring two growth parameters, the exponential growth rate and the carrying capacity, to describe the growth of microorganisms with time. Another aspect of this work is the study of the motility of the two microorganisms during their growth cycle when different levels of shear stress are applied. The results show that the motility of *C. reinhardtii* follows three different phases; a rising phase starting in the middle of the exponential growth phase, a decay phase and finally a damped phase during the stationary growth phase. It is shown that agitation increases the magnitude of the average velocity and advances the cellular motility. The current phase of this project focuses on the dispersion of *C. reinhardtii* in the fluid flow in order to propose new mechanisms for separation (harvesting) of the microorganisms from suspension.

Diffusive behavior of cyanobacterium Synechocystis sp. PCC 6803 on a surface. The interaction of motile microorganism with a solid surface is an important issue in their culture process inside photobioreactors. In this project, the diffusion dynamics of *Synechocystis* on a surface under isotropic conditions is studied. A global Fickian behavior has been found, despite the clear intermittence of the motility, which results in run and tumble periods. We have managed to separate these two components and show that the diffusion takes place only during the run periods, whereas during tumbles period it appears as the microorganisms are trapped in a closed area (2). An analytical formula inspired by the CTRW theory provides a good agreement with the experiments, and makes appear three parameters to characterize diffusion: the runs and tumbles durations, and the travelled distance during runs. Numerical simulations show that our model recovers closely the experimental results. Moreover, a model for the temporal evolution of the diffusivity is proposed. This model, based on an adaptation of the bacteria's motility to their new environment when they land on the observation surface, leads to results that are consistent with experiments.

Solar bioenergy. The growth of microorganisms such as cyanobacteria and microalgae in engineering systems is a promising technology for production of biofuels and other valuable bio-products. These microorganisms undergo photosynthesis utilizing solar energy and carbon dioxide (CO_2) to yield those products. This process through engineering systems has two key benefits: utilization of clean and free energy resource (sunlight) and the consumption of CO_2 (a contribution to the curtailment of CO_2 emissions in the environment).

Buildings are one of the largest consumers of energy and also receivers of a large amount of incident solar light. Energy efficiency in building is becoming a primary goal in moving towards sustainable communities and fighting the climate change. This project is focused on an innovative approach of integrating cyanobacterium/microalgae growth with building sustainability. The specific focus of the project is on the development of a system of plate photoreactors that can be integrated with the building façade, called “biofacades”. This concept has several key benefits; first, the water-filled photobioreactors will absorb a large fraction of the solar energy incident on the building and hence will prevent its conduction into the building, resulting in a lower demand for air conditioning. Second, the CO_2 in air generated by conventional human and industrial activities could be fed to the microorganism inside the biofacade, resulting in a significant reduction in the carbon footprint of the building. Third, the clean bio-product from microorganisms can be utilized in various applications contributing to sustainable living. In the framework of this work we have contribute to a large project of construction of innovated buildings in Paris (Réinventer Paris) in which boifacade is chosen as the main elements covering the building external walls.

Physics of transport phenomena. In its second field of activities, the Energy Physics Group has conducted research on advanced thermal energy system. It includes dynamical system approach to heat transfer intensification, thermoacoustic and low temperature heat transfer.

Dynamical system approach to heat transfer intensification. Multifunctional heat exchangers/reactors are devices for thermally active chemical synthesis processes and energy systems with high safety and efficiency requirements demanding good flow mixing properties and often manipulating fragile fluid structures. In addition, a primary challenge in this type of technology is to increase the heat removal, or supply, in the system while working in the laminar regime to maintain sufficient residence time for reactive chemistry, or, in the case the microsystem dimensions, hinder turbulence. In these cases transport phenomena including mixing, heat transfer, and dispersion can be difficult and cause large energy costs.

In the Energy Physics Group, we have studied experimentally and numerically chaotic flux recombination reactors for intensifying transport phenomena in laminar regime and therefore increasing the energy efficiency of the systems. It creates particular three-dimensional chaotic structures in the steady state flow reaction path (3-5). The configuration is composed of repetitive elementary units characterized by a number of splits and recombinations that exploit the flow laminarity to fold the flow lamella repeatedly and double concentration gradients deterministically. This results in fast and efficient mixing by diffusion in very compact heat exchanger/reactors.

Thermal and chemical probe techniques have been used to assess the increase in the energy efficiency gains of these kinds of heat exchanger/reactors (6-8).

Thermoacoustics and low temperature heat transfer: applied research. Two topics are developed in the framework of applied research; the first concerns thermoacoustic machines, the second focuses on cryogenic refrigeration.

The thermoacoustic machines have become the focus of intensive research due to its vast applications in energy efficiency and energy recovery. The projects in this field in which the Energy Physics Group is involved are carried out in the framework of collaborative research with a small company HEKYOM. The work is focused on the development of refrigerators or electric power generation machines based on an innovative thermoacoustic design. The applications for energy recovery include installations of this system on industrial plants consuming large amounts of energy, releasing part of this energy at intermediate temperatures (300-400 °C) and having high refrigeration requirements. The work aimed at electric power generation is developed more particularly for spatial applications.

Thermoacoustic cooling device is an innovative alternative to the classical vapor-compression refrigeration. Thermoacoustic refrigerators use acoustic energy to transfer heat from a cold source to a hot source, with an inert gas as working fluid. They include an acoustic resonator coupled to an acoustic source. Inside the gas column is inserted the thermoacoustic core, which consists of an open cell porous medium, referred to as regenerator, at the extremity of which heat exchangers are set for connection with the hot and cold thermal sources.

Even if numerous fundamental studies have led to significant progress in the study and design of thermoacoustic devices, several physical phenomena are still not well understood because of their complexity: acoustic streaming, aerodynamical and thermal edge effects, acousto-thermal couplings, etc. These effects limit the performance of thermoacoustic systems.

With HEKYOM, we have decided to carry out at the same time fundamental studies to better characterize nonlinear effects, and experimental studies to validate the new models deduced from the fundamental research. These items will be addressed in strategy and the 5-year plan of the group.

Several experimental devices have been designed with HEKYOM, such as a small electric power generator and low-temperature engine. HEKYOM constructed and tested this engine in different acoustic geometries. It was composed of the four engine stages of the low temperature engine associated with a two-directional turbine coupled to an electric generator.

Another study is motivated by the need for electricity generation in space applications. A demonstrator was designed and constructed in collaboration with HEKYOM for this purpose. This thermo-acoustic

machine is fed by an external heat source using a high-temperature heat pipe. Its working mechanism is based on a non-resonant configuration; the acoustic source and the electric generator are linear generators (a kind of loudspeaker) connected by a thermoacoustic amplifier (the acoustic amplification is proportional to the temperature ratio of the hot and cold heat exchangers) which amplifies the acoustic wave supplied by the acoustic source before transmitting it to the electric generator. This demonstrator gave results and efficiencies close to those obtained by Stirling machines.

The current activities are focused on the improvement of the numerical models and the comparison with the experimental results.

The second topic in applied research is linked to the cryogenic applications, in particular in the field of cosmological detectors or particle accelerators.

The Energy Physics Group is involved in the study of a thermal model of the QUBIC technical demonstrator. The goal of this model is an evaluation of the transient thermal phases during the cooling and the warm-up of the low temperature stages. This work requires knowledge of the physical characteristics of the materials used in the design of QUBIC as a function of temperature. Several measurement campaigns have been conducted to obtain thermophysical properties of anisotropic composite materials such as carbon-epoxy. The thermal expansion factor (at 80K), thermal conductivity (in the temperature range from 0.8K to 20K) and mechanical elasticity modulus (80K and 4.2K) were measured in APC and SACM (CEA at Saclay). A first model including the main characteristics of the materials used for the design of QUBIC low temperature stages (1K and 0.3K) is now available. It allows estimating the durations of the cooling sequences, the steady states as well as the impact of the regeneration phases of the adsorption pumps on the detectors temperature. The Energy Physics Group has also contributed to the design of the cryogenic circuits of the elliptical cavity cryomodules of the future ESS accelerator.

SWOT analysis

Strengths	**Weaknesses**
• Attractiveness of the field of investigation: energy, • High visibility and international recognition of the group in its fields of research, • Leadership of the group in the interdisciplinary energy research.	• Reduced number of permanent researchers in the group that is not compatible with its ambition.
Opportunities	**Threats**
• Large international collaboration network of the group, • Importance of the energy as a challenge to the humanity.	• Lack of funds for fundamental research. Most of the institutional research funds are directed to the technological research.

Strategy and the five-year plan

The Energy Physics Group has entered its early operational phase in 2014. Its new laboratory space became available in early 2015 and experimental facilities were completed and commissioned in 2016. Full attention has been paid since to the perfection of the biological expertise of the group ensuring that the team has acquired equipment necessary for its operation and has obtained the mastery of most biological experimental techniques. Networking with chemistry and biology research affiliates on the university campus is now completed and we mutually make available our experimental and measurement equipment to each other.

Meanwhile, with interdisciplinary brainstorming sessions, breakthrough research topics have been identified.

In the 5 years to come, research in hydrodynamics of active matter will be focused on the understanding and modeling of microorganism motility, mechanisms of microorganism interaction with solid surface and biofilm formation, and in general microorganism colonization.

Another important issue is harvesting. The current phase of this project focuses on the dispersion of *C. reinhardtii* in the fluid flow in order to propose new mechanisms for separation (harvesting) of the microorganisms from suspension.

Concerning Solar Bioenergy, one major issue faced in this configuration is the temperature control of the biofacade photobioreactor. It has been shown that the growth of cyanobacteria and microalgae is sensitive to the reactor temperature. Maintenance of a certain temperature range substantially enhances the microorganism growth and hence the bio-products. However, a temperature rise beyond a certain threshold can kill these microorganisms. The temperature of the photobioreactor in building-integrated applications is expected to rise above the threshold, or be subjected to high variations due to the weather changes, which are not suitable for the culture of the microorganisms. Hence, a novel approach is introduced into the project to integrate thermal storage media to control the temperature of the photobioreactor to the optimal value. Micron-size encapsulated phase change material (PCM) mixed with microorganism suspension will be used as thermal storage media that have high-energy storage density and narrow operating temperature range.

The specific focus of the project in the 5 coming years is:

- to investigate and design the optimal configuration of PCM storage to maintain the acceptable temperature range in the photobioreactor for building application,
- to study the adaptation of microorganisms and their colonization in the PCM-integrated photobioreactor,
- to conduct a field-testing of the prototype design.

Prospects for 5 coming years in the field of physics of transport phenomena will concern numerical modeling of heat transfer intensification in chaotic reactors. Flow pulsation will be superposed on the chaotic advection to enhance the hea transfer intensification above and beyond those of chaotic advection. Outcomes of this research will be also applied to the photobioreactors in enhance microorganism growth.

Future work in the field of thermoacousctics will concern:

- acoustical characterization of thermoacoustic core (regenerator with hot and cold heat exchangers) at high acoustic levels in the presence of temperature gradient,
- matching conditions between the different elements of the device: regenerator and heat exchangers, themoacoustic core and acoustic load,
- phenomenological analysis, numerical simulation and experimental studies of different thermal flows that occur as consequences of thermoacoustic heat pumping in each element of the thermoacoustic machine.

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8. IT department

General presentation.

The IT team is made up of about 17 people between 2012 and 2017.

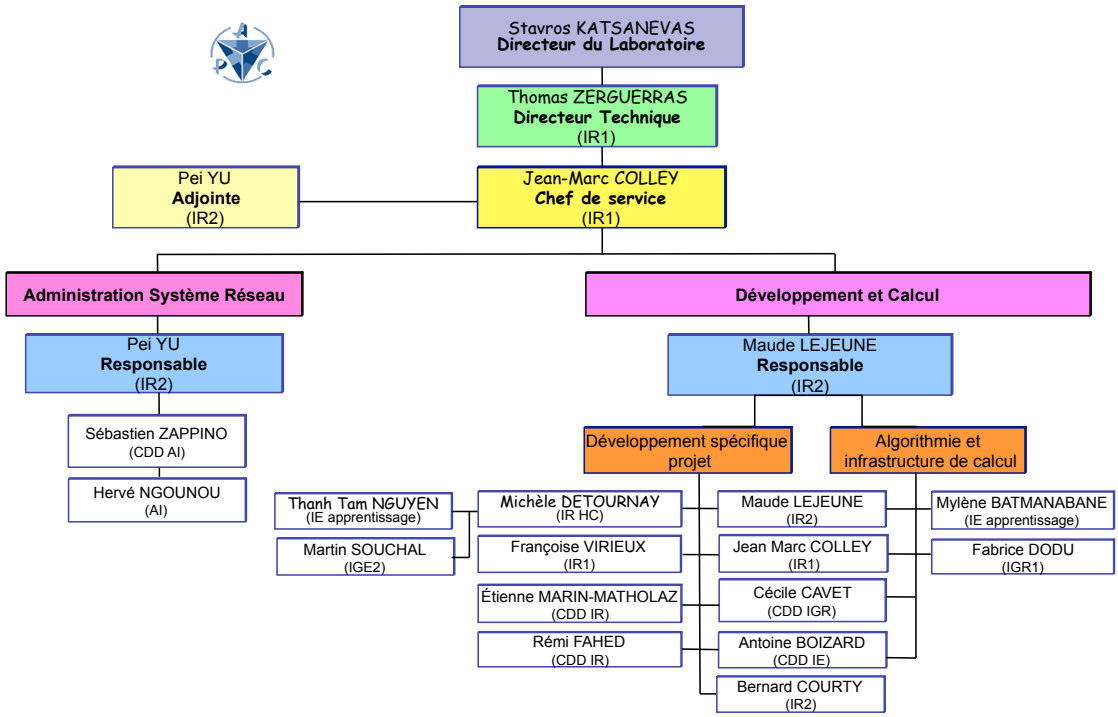


Figure 15. Informatics department organization chart

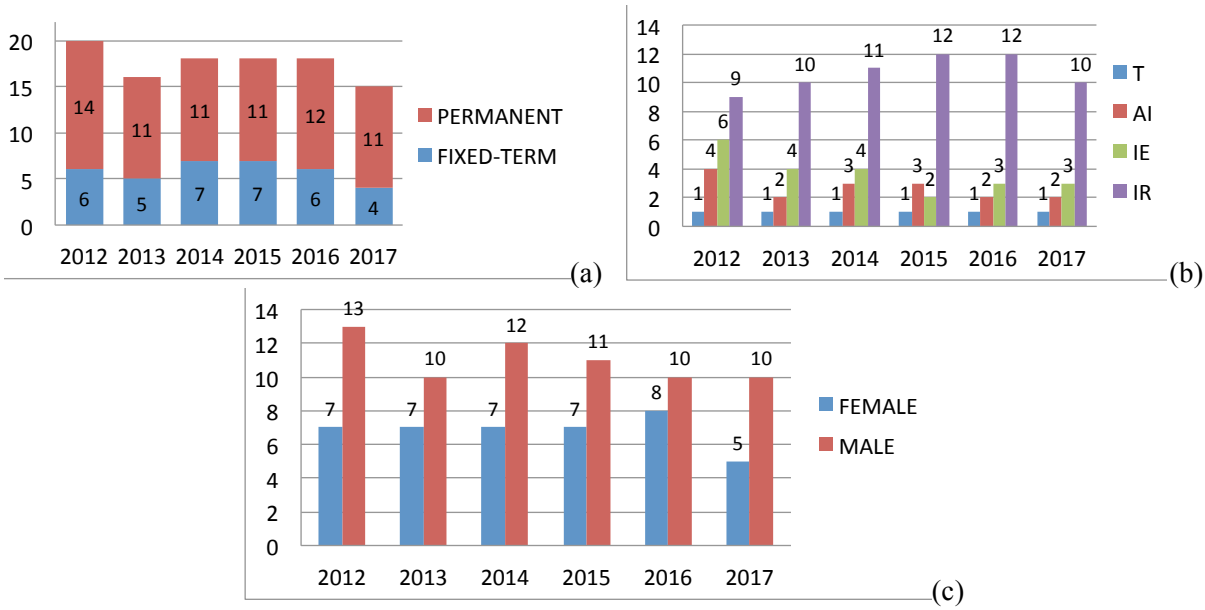


Figure 16. IT Department Staff evolution per (a) contract term, (b) status and (c) gender

The activity of the IT Department is shared between the two following items:

- Network and system administration
- Development and scientific computing.

Network and system administration. The Information Technology team of APC is committed to providing effective technology support (about 30 servers, 300 computers), computing and networking infrastructure.

The IT team is in charge of installing and maintaining consequent resources such as computer cluster (652 cores), computer-aided design for electronics (CADENCE) and mechanics (CATIA/ANSYS), facilitating the collection, storage, security and integrity of electronic data (274To storage). The IT team gives also a major effort to advise users on bug report, web applications, mailing, printing and provide every user what he needs in terms of hardware.

The IT team cooperates with the University and the IN2P3 facilities (CCIN2P3) on network management for enabling and securing access to the computing resources inside the laboratory and to/from the Internet for about 300 users of the APC.

Since 2012, several tasks have been carried out: set up the Filemaker server, update the Active Directory Server, replace the Netapp Storage Server, change the platform user ticket OSticket, upgrade the mail server from Horde to Zimbra that allows the IT team to administer directly the local accounts, mailing list and alias. The IT team implemented also the VPN service and a portal for vehicle reservation, redesigned and updated the laboratory and FACe website and the Intranet. The IT team added a new storage server for laptop backups and internal server backups replace three virtual servers and create two vlans: server and instrument.

Code programming and scientific computing. The software engineers of the IT department are involved in many aspects of the laboratory projects. Concerning code programming, they develop dedicated software and tools for data acquisition and command control (on-line programming) as well as for data analysis and simulation (off-line programming). For these two activities, they share an expertise in application development and code optimization. They master a large panel of programming languages including their interfacing and parallelization techniques, along with the standard development tools such as content management system, automatic documentation and construction tools, profiling and debugging tools. In addition to these skills in programming, the team has also a deep knowledge on the computing infrastructure on which codes are executed. Members of staff have significant expertise in the use of supercomputing facilities (the CCIN2P3, the CINES, the IDRIS, and the CCRT) and master the administration of the FACe (François Arago CEnter) small-size (less than 1000 cores) clusters. The team brings support on using computing resources such as HPC/HTC clusters and cloud computing.

Development Competences and Evolution

New Competences of IT Department acquired between 2012-2017

Many new skills revolve around virtualization and big data side administrator and user. The OpenStack software suite for cloud computing is dedicated to:

- the Euclid CODEEN project at the CC-IN2P3 Lyon computing center
- the data processing center (DPC) prototype of the future LISA project
- the FG-cloud cloud computing federation.

Slipstream is a tool which deploys automatically software solutions for cloud computing on different infrastructures. The IT Department uses two types of configurator manager: Puppet and Ansible including configuring a Torque cluster on the cloud. As for the lightweight containers, we are familiar with Docker for example to create the local development environment for Euclid LODEEN on the cloud, but also we have studied the Singularity solution under the HPC.

On the development side, we were led to choose the framework of graphical user interface Qt to realize the man-machine interface managing the network of detectors of muons GATE. In the field of Web technologies, the Django python framework is implemented for the CTA web portal Proposal Handling Plateform and for the LISA proto-DPC. Finally, a specific effort was made for an object-oriented database with Hibernate for the LSST camera control system project.

SonarQube is a standard tool commonly used at the IT Department to assess code quality in projects where continuous integration is required.

Products and activities.

Developments on project

Development software slow control or real time

LSST. The LSST Camera Control System (CCS) controls and coordinates the various camera subsystems (Filter Exchanger, Schutter, Refregiration, Power management, etc.) in order to check that camera operations proceed efficiently during the operation modes (science, calibration and engineering). The CCS also monitors camera performance to help maintaining a stable camera environment and to report errors, to interact with the LSST observatory, telescope, and data management. Moreover, the CCS sends and receives the necessary data for proper operations coordination. Finally, it provides human interfaces for status information display which is crucial for test, diagnosis and debugging.

The APC IT Department has a strategic position in the CCS development and gives a major contribution to the initial design concept of the software, in close connection with the American partners of the LSST collaboration. The conceptual and design reviews for the NFS and the DOE were successful milestones and validated these developments. Beside its responsibility of the CCS core, the APC IT team is in charge of the Filter Control System (FCS) software for the Filter Exchanger system.

The main components of the CCS software are designed and implemented into extended prototypes used by subsystem developers (FCS, refrigeration control system, power management control software, CCD test benches, Raft subsystem, shutter subsystem). The APC IT team provided documentation on the software architecture and a user manual. A simulation of the Filter Exchange System was implemented as a test-tool for the FCS. Each time a new FCS version is committed on the Jenkins integration server, a bunch of tests is executed on the simulator.

Since the change of a filter between the Autochanger and the Carousel is a high-risk operation, two mechanical prototypes were designed and built: a single-filter-test at the CPPM in early 2012 and a scale 1 prototype in 2017 at the LPSC Grenoble, the LPNHE Paris and the CPPM Marseille. The FCS provides the control software for these prototypes as well as for the final product.

CTA MUTIN+GATE. In the early phases of the CTA project definition, the real time detection of coincidences events between telescopes with 1 to 10 nanosecond accuracy appears as a crucial requirement. The MUTIN system (Multi Usage Telescope INterface) was developed at the APC through collaboration between the Electronics and the IT departments to meet these specifications. A first subsystem is an optical fiber clock distribution box that can drive more than 100 telescopes and continuously monitor the DT between them. A second subsystem collects the events from the telescopes and achieves the online real time coincidence reconstruction so that the main DAQ system provides a fast retrieve of telescopes data. In 2016, this system was successfully tested with accuracy better than 1ns.

GATE is a regional program (Ile de France) to support technical developments for gamma-ray astronomy. The MUTIN team benefited of a GATE funding to implement a portable muon detector, made of 8 suitcases, working with the MUTIN coincidence system for Cosmic Ray detection or muon calibration with optimized time precision. The IT Department developed the full real time acquisition system and the graphical user interface. The system validation relies on a simulator implemented to generate time-marked events signals corresponding to muon interactions taking the detector noise into account.

The full set-up has been installed at the Meudon observatory since April 2017 and connected to a new camera of the Gamma-Ray telescope.

IGOSAT. Currently developed in the framework of the Spatial Campus Paris 7 and an APC-IPGP collaboration, the IGOSAT nanosatellite is a student project to measure the electron density in the

high atmosphere. Its main feature is to offer the opportunity for many students to access to the Space community and its technical specificities. The IT Department supervises the students in charge of the On Board Flight Software, assuming the main responsibility for this satellite subsystem. The IT Department also provides the Web and the Data servers for the experiment.

Software development for infrastructure

CTA: Proposal Handling Platform. CTA is a large gamma-ray observatory which offers several services including access to the scientific data stored through the Virtual Observatory (VO), users support (helpdesk, user training), a Proposal handling platform for scientific observations and the centralized web Science Gateway, relying on the Authentication & Authorization (A & A) system. The main feature of the Science Gateway is to provide an access with a single identification to all CTA applications. In this context, the APC IT Department is committed to implement the Proposal Handling Platform for scientific observations to the CTA consortium. After developing our demonstrator to assess the feasibility and the usability of the Django framework solution, a functional prototype was successfully presented to the CTA Consortium in October 2016. The V1 version of this official CTA software is currently under development at the APC IT Department for a production scheduled in 2017. This software is also now under integration into the Data Global model, through databases connections, and with other CTA softwares, in particularly the A & A system. The integration into the Science Gateway is in progress. The V2 version of the PHP application is expected for delivery in 2018.

LISA: Data Processing Center (DPC). The space interferometer LISA concept was selected by the ESA in 2012 as one of the two next large space missions. In this project, France took the responsibility to provide the Data Processing Center to the consortium, a task led by the APC laboratory. Between 2012 and 2017, the APC IT Department led a first Phase 0 study in collaboration with the French space agency CNES and the Cap Gemini company to build a proto-DPC. This task was necessary to assess the cost and technical needs of such a facility and strengthen the position of the APC laboratory in relation to the consortium. Several members of IT Department staff joined this effort to build a collaborative development platform including: continuous integration, automatic tests and documentation, code analysis, control version system, and common virtual environment supplying. This proto-DPC was tested by hosting the main simulation code of the LISA scientific community (LISACode) in a strong collaboration with the scientists involved. The proposed technical solution and tests results were then presented to the consortium at several collaboration meetings. The LISA data-analysis working group then uses the proto-DPC to build the scientific proposal in response to the ESA's 2016 call of tender. In the meantime, the APC IT Department started to study the challenging task of providing a hybrid infrastructure, where analysis codes could possibly benefit from on-demand CPU resources to optimize the total cost of the hardware.

EUCLID: The CODEEN development platform. The CODEEN (COmmon DEvelopment ENvironment) platform for the EUCLID mission provides a production environment for developers to implement, upgrade and test algorithm prototypes using various libraries and tools. This platform offers rapid iterations between developers and optimizes code development efficiency.

It provides also a continuous integration and deployment of the EUCLID data analysis software in the development standards adopted by the EUCLID community. CODEEN covers all the activities of a software factory: source code management, binary generation, documentation, quality assurance, test, packaging and continuous deployment. Engineers from several research and space agencies (CNRS, CNES, ROE) are in charge of the CODEEN platform design to meet the needs of a high-quality working environment.

Thus, the different SDC (Science Data Center) and the software developments within OUs (Organizational Units) aim to integrate this platform. In this context, the APC IT Department is responsible for the design, evolution, consolidation and management of this software infrastructure. It also brings its expertise for developers support. Currently, the platform management requires more than 30 virtual machines based on the VMware Virtualization system. In view of the future needs of the EUCLID data analysis, a migration on the cloud infrastructure is under progress.

FACe. The Centre François Arago (FACe) is a platform of the APC laboratory project created in 2010 to support data analysis in space missions. It brings material resources (calculation clusters, storage servers, Current Design Facility) and services (technical support on algorithmic and coding, server and development platform administration). A detailed description of the FACe is appended in Appendix 2.

Software development for data analysis and simulation

Planck. The Planck satellite mission, launched in 2009, published two major data releases, with associated papers between 2012 and 2016. A third and last one is still under development and expected to be published at the end of 2017. The IT Department effort was focused on the component separation task with the SMICA method. The Department took the responsibility for the SMICA pipeline all along the data analysis process, starting from temperature first season observations where the SMICA CMB map was selected to be the leading pipeline, to the challenging polarization data still under improvement. The pipeline has been continuously improving for four years and has been used in diverse steps of the analysis. Part of the effort was on understanding and reducing the polarized systematics effects, which prevented the publication of the large scales in the second release.

EUCLID: SIM-EXT and EXT. The EUCLID data processing pipelines test and validation require a large amount of realistic simulated data, produced by combining a common Universe model and instruments parameters. The APC is involved in the production of these simulations within the OU-SIM working group. The related activities are the development of an external data simulation code and its integration in the general OU-SIM simulation pipeline. Therefore, the APC prepares the next Scientific Challenge (SC3) taking place in 2017 and participates to the SC3 dedicated meetings. This challenge will integrate EXT and MER pipelines for the first time. This work is done in close interaction with the DES and the KIDS external data surveys in order to match the needs for the challenge.

Concerning the EXT activity, the APC is the French leader for the "Euclidization" of external data from ground-based telescopes, such as the DES, the KiDS and of the Canada France Imaging Survey (CFIS). If an agreement is concluded, the APC will also have to manage the LSST data stored on the French SDC at the CC-IN2P3.

The APC contributes also to the software PA/QA management of the EUCLID project.

MHD simulation. The Simulation MHD (Magneto Hydro Dynamic...) modelizes accretion-ejection instability and is implemented on computing cluster because calculations of AEIJ (accretion-ejection instability jet) need large RAM and CPU resources. The codes are massively parallelized and highly optimized with new mathematical algorithms (Constrainted Transport for divergence free, Adaptive Mesh Refinement...). A new mathematical approach (Particle In Cell) is currently under implementation.

Academics and Others Activities of the IT Department

The IT Department is strongly involved in many IT expert networks of institutions, such as the IN2P3 and CEA/IRFU 'Réseaux des informaticiens' (RI3), the DevLOG 'Développement Logiciel' and 'Groupe Calcul'. Members of staff gave also talks or presented poster in many conferences and workshops. The list is given in Appendix 4.

SWOT analysis

Strengths	Weaknesses
• HPC cluster and VM cluster for prototyping at the APC laboratory. • The consolidation of the IT department office in the FACe makes exchanges easier and	• Lack of staff for administration system and network activities due to non-replaced departures of two engineers (one retirement, one internal mobility to the development pole).

strengthen group cohesion. • High-level skills in software infrastructure, computing, virtualization (cloud, Docker container) are assets for the involvement in space projects. • Involvement in long-term space projects gives a long-term stability to the IT Department activities.	• Lack of staff to maintain the laboratory web sites. • Insufficient ties between the IT Department and some members of scientific groups involved in LSST/EUCLID activities (Photo-Z projects, LSST atmospheric calibration, simulations of ground-based telescope data for coupling LSST and EUCLID data). • Activities for several permanent members of staff are spread between too many projects and do not comply IN2P3 management recommendations (80% FTP on a main project, and 20% on another). • A lot of project teams includes only one permanent member of the IT Department.
Opportunities	**Threats**
• Strong team around DPC LISA project. • Participation in the IN2P3 IT networks.	• High ratio of fixed-term contracts results in instability for the projects (risk of skill loss, high turnover) • Difficulties to find specific skills on the labor market due to wage competition with private companies. • Increase of non-technical time-consuming activities (management, funding applications, hiring processes, reports to funding agencies). • Funding difficulties to renew completely hardware material arriving at the end of 5-years guarantee. • Our very great involvement in different projects prevents us from seizing other opportunities of collaborations or participation in generic R&D programs. • Activities on MHD simulation and real-time software development on the IGOSAT are currently not visible on the IN2P3 NSIP management tool.

Strategy and the five-year plan

Involvement in the Planck project is expected to be completed with the publication of the third release at the end of 2017. CMB activities will mostly continue in the IT department through participation to dedicated research programs such as ANR.

The MUTIN and GATE system developed in the frame of the CTA project is now completed and installed at the Observatoire de Paris in Meudon. Its future use is mainly for teaching.

The CTA Proposal Handling Platform is still under implementation and expected to be operational in 2019.

The launch of the IGOSAT nano-satellite is scheduled between the end of 2019 and the beginning of 2020.

The EUCLID project will still mobilize the IT Department continue through external data simulations of and the CODEEN development platform which must be fully operational for the mission launch in 2021. The number of engineers hired on fixed-term contracts will be maintained during this period.

The LSST camera team continues the development of the Camera Control System and the Filter Change System for a first light detection in 2021. It is thus crucial to keep strategic skills, in particular by hiring the current non-permanent engineer on a permanent position.

Generic activities on algorithms such as the MHD simulations will still proceed.

The phase A for the LISA space project starts in the beginning of 2018. The APC laboratory will collaborate closely with the French space agency CNES. Consequently, activities on the Data Processing Center will significantly increase with the expected arrival of a fixed-term engineer and a large commitment of the IT Department permanent staff.

The data processing of the ECLAIRs instrument on SVOM satellite will really start in 2017 and a 5 years-term engineer will reinforce the IT Department.

Finally, among the emerging activities, the preparation of the LSST data processing will also begin at the end of 2017. Under the condition of an agreement between the EUCLID and LSST collaborations, the IT department gets involved the joint data treatment, more specifically on the EUCLID side.

Between 2017 and 2022, 2 to 3 more non-permanent members of staff will join the IT Department whereas the number of apprentices will be kept at 2. Since the non-permanent ratio of the total workforce of the development pole will increase up to 50% including apprentices, reinforcement by at least one permanent position is necessary. It is also crucial that the Administration System and Network team reaches a critical size to face the increasing support needs of the users in the laboratory. Hiring of one or two more permanent members of staff is thus needed to complete the team.

9. Instrumentation department

General presentation. The Instrumentation Department gathers simulation, engineering and technical skills, which are not specifically related to mechanics or electronics and are needed to setup an experiment, lead a R&D program or integrate an instrument. The members of staff integrate the general matrix organisation of the APC laboratory and contribute to the engineering tasks of projects. They are engineers with various expertises such as experimental physics, optics, silicon detectors, photodetection, spectrometry (alpha, beta, gamma) and integration/test.

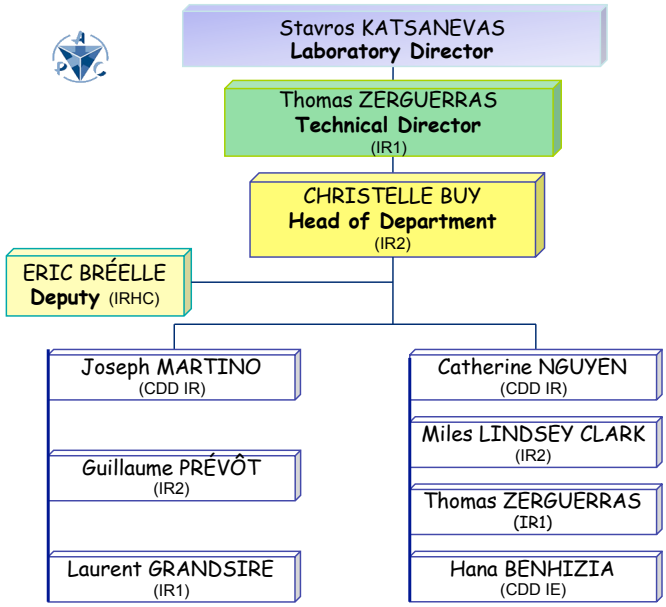
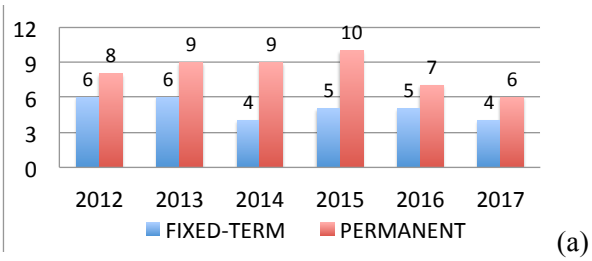


Figure 17. Organization chart of Instrumentation Department

Evolution between 2012 and 2017. Since 2012, the staff of the Instrumentation Department varied between 10 and 15 people. Most of them are on fixed-term contracts (CDD) to reinforce the task force of projects. However, the number of permanent staff has slightly exceeded the number of temporary staff for two years.

Between 2012 and 2015, hiring included two permanent CNRS engineers (an optician, an integration and test engineer) on external examination contest, three engineers (optics, data analysis of a spatial mission demonstrator and system engineering for the large mission, a project manager for nanosat project) on fixed-term contracts funded by projects, the French space agency (CNES) or tutelage organizations of the APC laboratory (Paris-Diderot University, CNRS). The current technical director of the APC laboratory is also member of the Department and joined the laboratory through the CNRS internal mobility program. However, the Department faced the departures of a project manager engineer for another public institution and of an optics engineer and an instrumentalist engineer (AIT/AIV, photodetection) who joined private companies.

Moreover, the two cryo-microelectronic engineers left the Instrumentation department (in 2016) to create a dedicated « MicroElectronics department »



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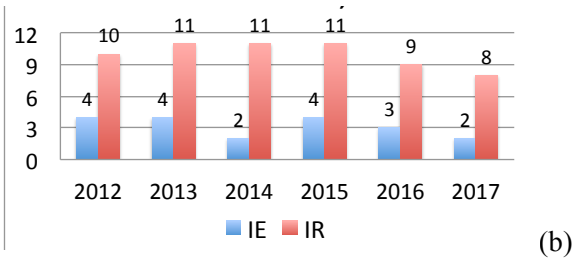

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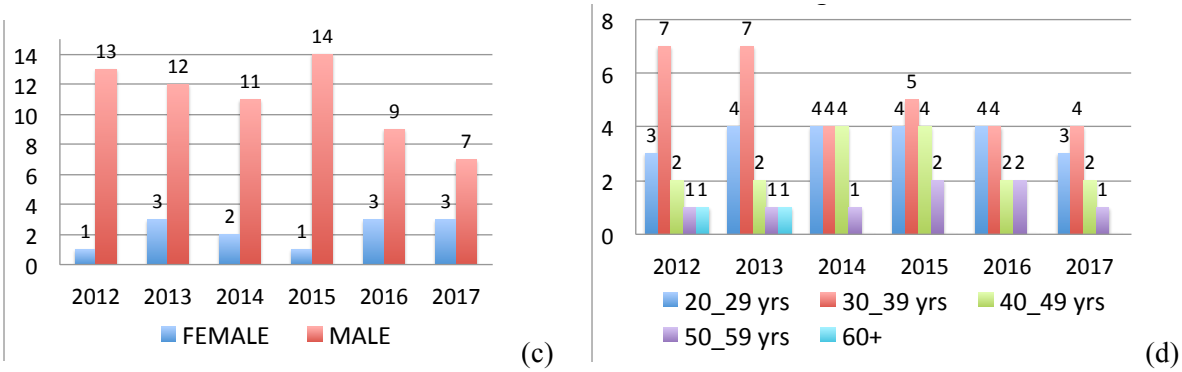


Figure 18. Instrumentation department staff evolution according to (a) contract term, (b) status, (c) gender and (d) age distribution

New skills acquired between 2012 and 2017. The competences were acquired and developed to meet the needs of the projects either through hiring or internal training programs.

- Cleanroom (class 100000) facility installation and management (LISA, Virgo, TARANIS)
- Reinforcement of the skills in cryo microelectronics. Design and tests of 3 new ASICs operating at 4K for the readout and multiplexing of superconducting bolometer array (BSD project, QUbic). As explained previously, the two dedicated engineers left in 2016 to create a new department in the APC laboratory.
- Creation of an optician team.
- Creation of optical benches (LISA on table, Laguerre-Gauss generation, telescope). Strong expertise in optical simulation tools (NGO/LISA, Virgo).
- Development of photomultiplier and scintillator characterization test-benches. Skills developed in the frame of projects such as TARANIS and PhenX.
- Start of an activity on silicon detectors, in particular on double side stripped detectors (DSSD), and development of a dedicated test bench for the electrical characterization of DSSD detectors.
- Development of new competences in AIT/AIV (Planck HFI optical setup, TARANIS) - Experimental competences in the field of Sub-Kelvin activities (BSD).
- Polar logistics. Setup of an experiment in Antarctica (Brain).
- Characterization of the atmosphere humidity at Dome C in Antarctica, for ground-based instruments for CMB studies.
- Radiation-hardness studies of the bolometers for the PLANCK mission under high-energy proton beams.
- Radioactive sources management and use.
- Risk analysis of projects.

Main skills and capabilities

Optical laboratory: cleanroom and simulation tools. The APC has an ISO8 clean room of 128m^2. This room is divided in three parts: two rooms host the optics experiments dedicated respectively to the LISA and VIRGO projects and include many optical components such as laser, mirrors, lenses, optomechanics, autocollimators and a wavefront analyzer. The third is dedicated to AIT/AIV activities.

The cleanroom is equipped with a comb of frequencies, manufactured by the MenloSystems company (see Appendix 2 on LISA cleanroom for more details).

At the APC, we used mainly four complementary optical softwares in order to develop optical systems for Virgo and LISA projects. The Zemax and FRED softwares allow implementing optical systems

such as telescopes, analyze their performances, tolerances, aberrations and straylight to further optimize the optical layout. Lightools is mainly dedicated to the straylight analysis. The Optocad software simulates the propagation of gaussian beams and defines the astigmatism of the systems. Its use is simpler but less complete than Zemax or FRED.

DSSD characterization tool. A probe station (Karl-Suss PM5), CLR-meter and picoamper meter is installed in the AIT/AIV cleanroom. The simulations to modelized and understand the silicon DSSD electrical behavior has been performed with Silvaco. This software was provided by the IN2P3 computing center, but the compétence left APC with the fixed-term contract people. A refrigerated characterization chamber (-40°C - +60°C) working at atmospheric pressure was developped to study the DSSD response as a function of temperature.

Spatial mission simulation tool and system engineering. The APC laboratory is involved in space missions, such as LISAPathfinder. The project team develops specific tools with a strong contribution of the Instrumentation Departments to characterize thrusters and control loops, define the daily process checking of operation and long-term temperature effects monitoring. The results of these studies form a crucial feedback for the simulations to define the future LISA mission, which aims to launch a gravitational-wave observatory in space.

Products and activities

QUBIC. QUBIC is a cosmological experiment to demonstrate the existence of the inflation period by measuring the B-modes of the CMB polarization, which are the consequence of the primordial gravitational waves created by inflation.

From a technical point of view, this measurement will be carried out using an innovative technology, the bolometric interferometry. It makes possible to combine the high sensitivity of the bolometer matrices with the control of the systematic effects of the interferometers.

Since 2012, the project has successfully completed several critical steps, including the validation of the detection chain (TES, SQUIDs, ASIC, superconducting cables, hot electronics, control software and reading) at the millimeter laboratory. In 2016, the design of the instrument was fixed and a Technical Design Report was published.

In 2016, decision was taken to move the location of the future complete instrument from the Dome C in Antarctica to Argentina. It was also decided to manufacture and test a Technological Demonstrator in 2017 before modifying it in 2018 (additional pixels, more powerful optics) to make the final instrument that will take scientific measurements on the Argentinian site starting 2019-2020.

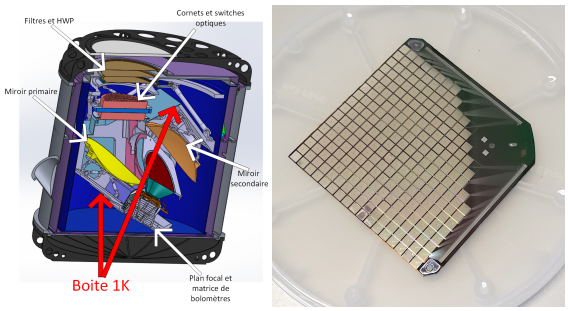


Figure 19. (Left) View of the Qubic cryostat (Right) Bolometer array

Compton Telescope. The project started in 2011 to develop a mini Compton telescope, with dedicated spectrometry and electrical test benches.

- Development a mini Compton telescope

The first step of this project is to study a DSSD from the MUSETT experiment, connect to an IDef-X ASIC (developed by CEA/AIM). Electronic is compound of four electronic boards.

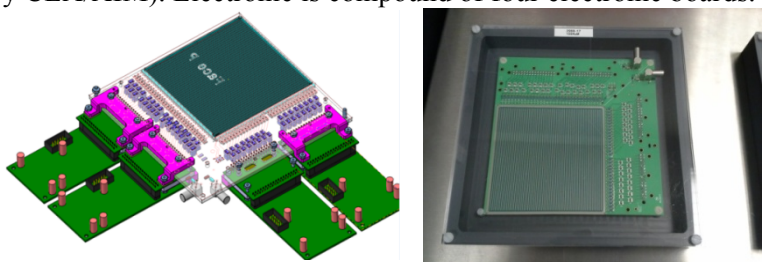


Figure 20. Scheme of the electronic of a DSSD designed at the APC and manufactured by the MICRON company. Reading electronics relies on the IDeF-X ASIC from the CEA/AIM.

Unfortunately, the DSSD MUSETT was not suitable for the reading electronics because the leakage current was too large. The post-doc on the project has thus recovered another silicon detector (Tristan) that has been connected to the electronic chain supplied by the CEA. Test with radioactive sources were successful and made possible to achieve an important milestone of the project. During summer 2016, two hybrids DSSDs designed at the APC were manufactured and delivered by the MICRON company.

- Electrical characterization test bench

An electrical characterization test bench was developed at the APC and installed in the cleanroom. This bench is made of a probe station enclosed into a black box and measures the dark current and the electrical capacitance thanks to a Pico ampere meter and a RLC-meter. Mechanical supports were designed and manufactured to hold the DSSD on the probe station.

- Spectroscopic characterization test bench

This test bench is made of a vacuum chamber to install the experimental set up to characterize DSSD, as shown on the figures.

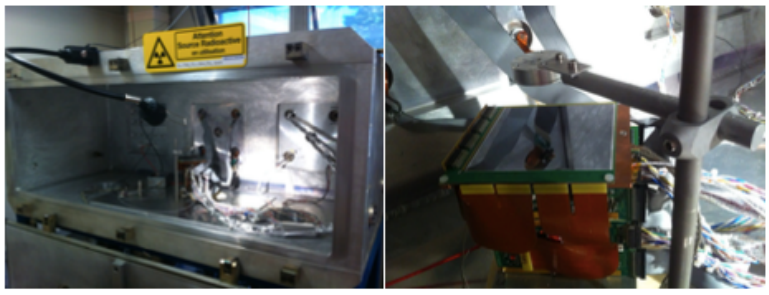


Figure 21. (Left) Vacuum chamber from CEA/DSM/IRFU/SEDI/LDEF (Right) DSSD MUSETT exposed to a radioactive source

Virgo. Virgo is a ground-based Michelson interferometer dedicated to the detection of gravitational waves, which are the radiative solutions to the equations, which govern space-time dynamics.

- R&D: Laguerre-Gauss mode generation and interferometry

Upgrades of this detector are planned in order to improve its performances and sensitivity. The main detection limit at a frequency around 100 Hz of this Advanced Virgo detector comes from the mirror thermal noise. One option to reduce this noise is to use higher-order Laguerre-Gauss modes, which have a multi-ringed power distribution wider than a Gaussian mode. Thus, such beams allow averaging the thermal noise fluctuations over a larger mirror surface and to reduce the thermal noise impact on the detector. Many techniques are available to generate higher-order Laguerre-Gauss beams.

At the APC, the chosen technique relies on diffractive optical elements (DOEs) mounted on a table-top experimental set-up to generate higher-order Laguerre-Gauss mode and produce interferometry with a method scalable to the requirements of GW detectors. The obtained coupling efficiency exceeded 96% and an interferometric pattern is clearly identified.

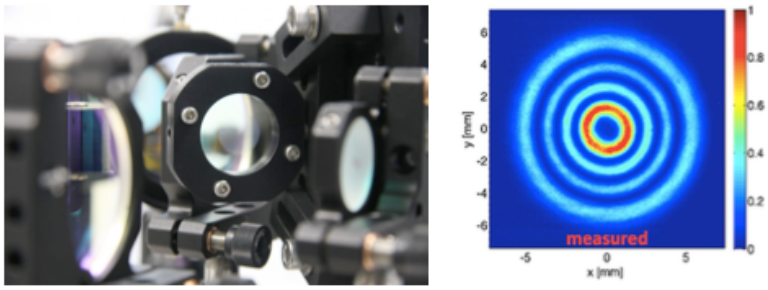


Figure 22. (Left) Diffractive Optical Element (DOE) used for the LG33 generation (Right) Transverse intensity generation of the LG33 beam after the DOE

- Advanced Virgo telescopes

The APC is responsible of the design, construction, tests, integration and pre-commissioning of the telescopes for the Advanced Virgo experiment. These telescopes are made of mirrors and lenses to reduce or increase the laser beam size (from 5cm to 1mm and vice-versa) at several positions inside the detector. Tests include measurements of the frequency resonances to quantify the vibration noise of the optical mounts, validate the optimum operation of the picomotors and the alignment procedure of the parabolic mirrors. The telescopes were successfully installed on the Virgo experimental site and the complete interferometer is currently under commissioning.

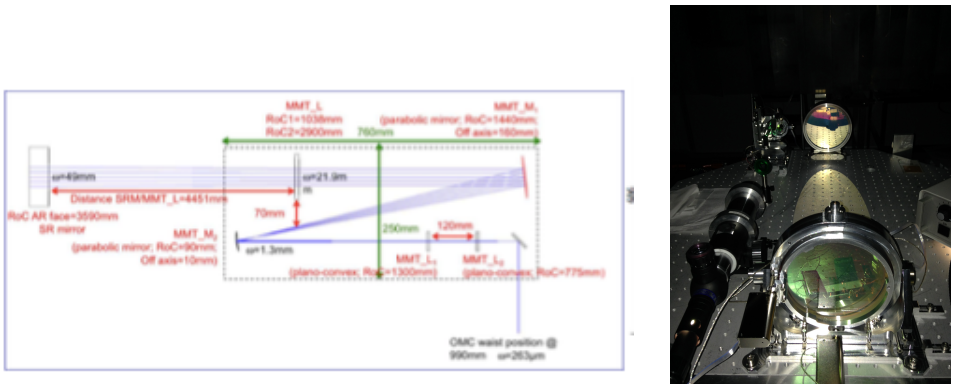


Figure 23. (Left) Optical layout of the Injection and Dark Fringe telescopes for Advanced Virgo designed with Zemax (Right) Integration of the telescope on the Injection bench

LISA. The LISA mission opens a whole new window into the heart of the most energetic processes in the Universe, with fundamental consequences for physics and astronomy. During its five-year duration, LISA is expected to detect gravitational waves from the inspiral and merger of massive black holes in the centers of galaxies or stellar clusters located at cosmological distances, and also from the inspiral of stellar mass compact objects into massive black holes.

- R&D and AIT French phases

The activities led at the APC in LISA prepare the future AIT taken in charge by France and instrumental R&Ds.

In the field of the AIT, the Instrumentation Department of the APC contributes to an ESA ITT dedicated to the straylight analysis of the LISA telescope. This project aims to assess how the

roughness of optical components affects light diffusion and detector sensitivity to define specifications for the telescope design.

Moreover, the Instrumentation Department is involved in the Phase 0, in collaboration with the French space agency CNES, to prepare the AIT, inventory the needed infrastructures and tools, determine experimental test conditions in terms of cleanness and magnetic purity, technical and scientific skills and the consequent funding.

Two instrumental R&D programs are related to the LISA mission at the APC laboratory. The first is dedicated to the laser frequency stabilization obtained by locking the laser light on a molecular transition such as iodine. This technique is improved by placing an iodine cell in a resonant optical cavity. This R&D program is now completed since 2013.

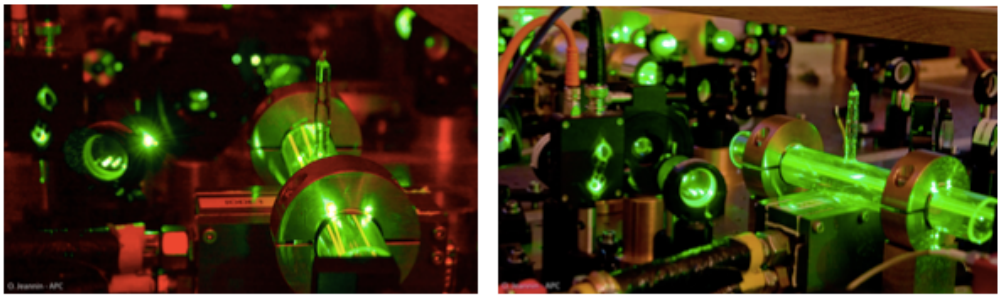


Figure 24. Experimental layout of the iodine laser stabilization. Fluorescence and reflections in the iodine cell and optics.

The second experiment, called LOT (LISA On Table), simulates the LISA interferometer under vacuum to study the contribution of different components (laser, photodiodes, phasemeters) to the noise.

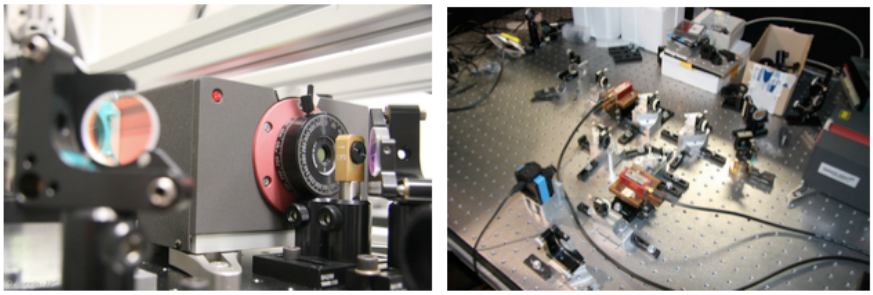
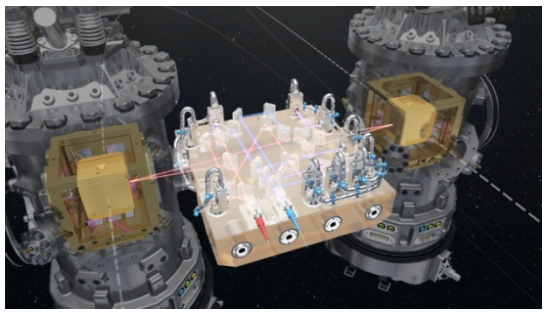


Figure 25. (Left) Infrared laser and optical elements of the experiment (Right) First optical tests

LISA Pathfinder. The ESA LISApathfinder mission launched on December 3rd, 2015 aims to demonstrate the technological feasibility of the future space based gravitational wave observatory LISA. The satellite embedded two test masses of 2 kg, separated by 38cm, free from any mechanical contacts in the satellite. Their relative acceleration is monitored on board to a level below fm $s^{-2}/\sqrt{Hz}$.



The mission is already a total success, reaching and then exceeding by a factor of 10 the requirements on noise level during the science operations between March 2016 and June 2016.

The extension of the mission started in December 2016 and will last until late June 2017. During this period, the main objectives will be to have a better understanding of the very low frequency noise (below 0.1 mHz) and the improvement of the noise level over the relevant LISA bandwidth.

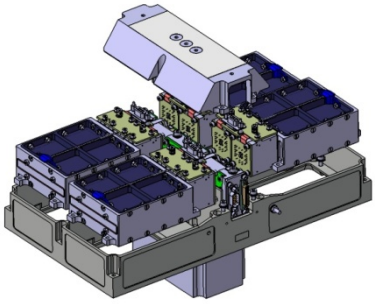
The Instrumentation Department is directly involved in the science operations by participating to the shifts and and the daily analysis. The motivations and contributions were on the following topics:

- The design and analysis of micro-propulsion thrusters dedicated experiments.
- The detection, modelling and fit of glitches in all the data. This led to the production of the cleaned time series as final products for the mission at FACE/APC.

The future of the LISA Pathfinder activities at the APC will be mainly focused on feedback for the future LISA mission.

TARANIS. The APC laboratory is responsible for the development and the delivery of the main detector of the Taranis microsatellite (CNES mission), the Gamma ray and relativistics electrons (XGRE) detector. Taranis will be launched in 2018 and will provide a study of the magnetosphere-ionosphere-atmosphere coupling via transient processes (TLEs).

The detector is composed of 12 scintillator detection units dispatched in 3 sensors. Each detection units are composed of three layers of detection (two Plastic scintillators and one LaBr3 crystal detector), optically linked to a set of two photomultipliers.



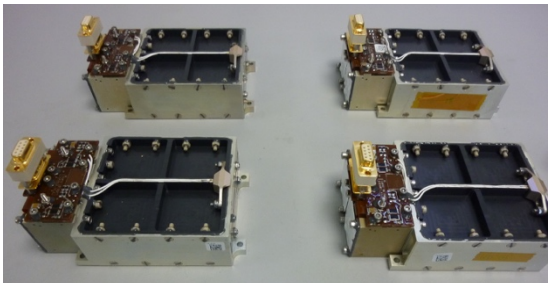
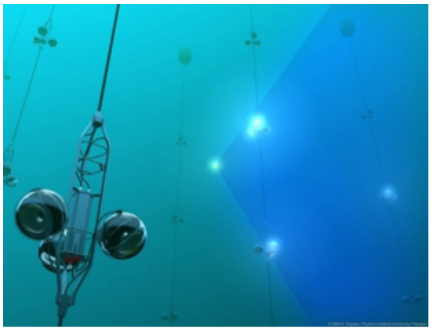


Figure 26. One of the three XGRE Sensors

The development of the instrument involves mechanical, vacuum, and thermal qualifications along with calibration phases of the complete acquisition chain.

Product assurance is mandatory for all the tasks. The related activities are research laboratory instrumentation and tests, material, process and components tracking, reliability analysis, configuration control, non-conformities, documentation and project monitoring (Gantt planning with extraction of priority actions).

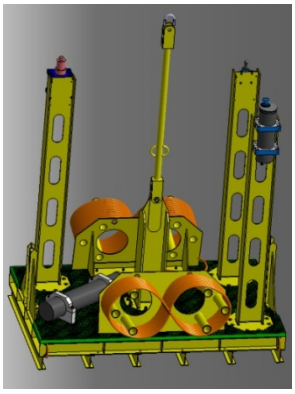
KM3NET.



The APC laboratory contributes to the development of the future kilometer-sized telescope KM3NET being deployed in the Mediterranean Sea. The group is involved in the development of the Oscillation

Research with Cosmics in the Abyss (ORCA) undersea Cherenkov neutrino detector, which is part of the distributed KM3NeT infrastructure. It will be devoted to the study of the fundamental properties of neutrinos, exploiting the abundant flux of neutrinos produced by the interactions of the cosmic rays with the atmosphere. Activities include:

- Characterization of photodetectors
  * Single Phaselectron Detection Efficiency Cards.
  * Quantification of afterpulses.
  * 8m^3 tank equipped with hodoscopes to characterize the KM3NeT optical modules.
- Detector studies
  * Influence of calibration in charge of reading electronics on detection efficiency and data-MonteCarlo agreement.
  * Angular resolution.
  * Using the pre-production model of the digital optical module KM3NeT (PPM-DOM) installed on the ANTARES instrumental line



Moreover, the APC is responsible for the design, development and deployment of the Calibration Unit of the detector. The Calibration Unit integrates all the instruments needed for the timing and positioning calibration of the optical modules. It also includes an autonomous Instrumentation Line dedicated to measuring the environmental parameters.

EUSO. The international JEM-EUSO Collaboration (extreme universe space observatory) aims at detecting ultra-high-energy cosmic-ray showers from space. A series of pathfinder missions have been conceived: EUSO-Balloon (CNES balloon mission), EUSO-SPB (NASA long duration balloon) and mini-EUSO (inside the ISS).

In 2012, the CNES asked the APC laboratory to take in charge the project management of the EUSO-Balloon mission, in addition to its numerous workpackages (detector integration, tests & calibration). This includes product assurance, documentation delivery, preparation of the conformity matrix, templates, risk analysis, interfaces documents, integration plans writing and updates, project monitoring, and coordination at the international level (9 countries over 4 continents with significant contributions).

EUSO-Balloon had a successful flight in Canada in August 2014, measuring Earth's nadir UV emission (background for cosmic rays), validating the acquisition of laser events and increasing the TRL of the instrument.

Following this success, the APC took the responsibility of the design, development, integration & calibration of two new detectors: EUSO-SPB (launched on a Super Pressure Balloon by NASA from New Zealand in April 2017) and mini-EUSO, onboard the ISS (launch by ASI and ROSCOSMOS scheduled in early 2018).

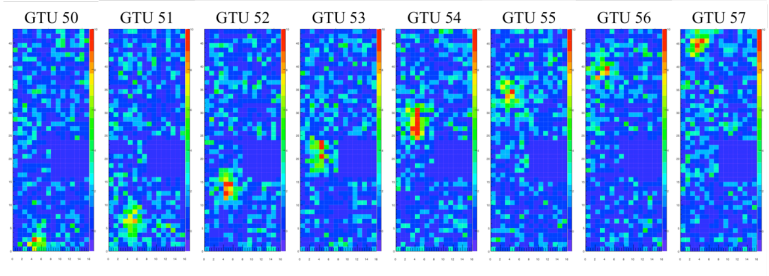
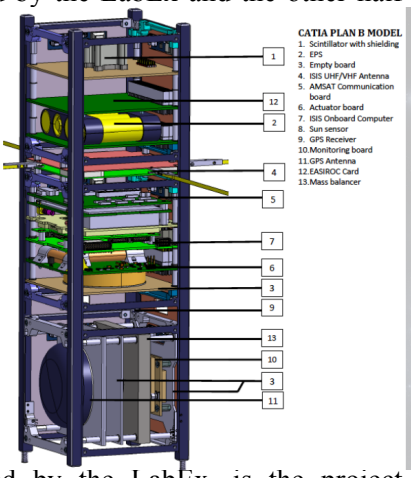
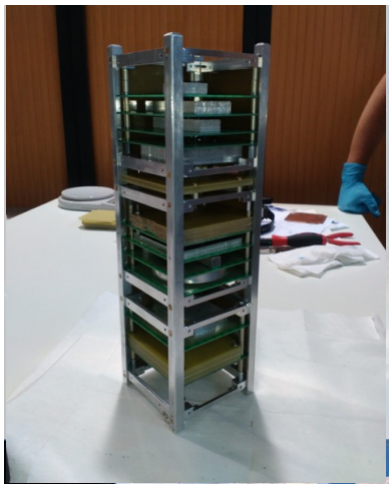


Figure 27. Trigger validation & first event detection

IGO SAT. IGOSat is the first educational 3U CubeSat (10x10x30 cm) developed at the Paris Diderot

University. It is supported by the LabEx UnivEarthS and the CNES (French Space Agency) through the JANUS program for educational CubeSats. The total cost of IGOSat is estimated to a 1 M€ over 7 years, from which half is funded by the LabEx and the other half by the CNES (through a funding agreement with the University).





The APC and the IPGP (Institut de Physique du Globe) are the main laboratories involved in the development and supervise the students working on IGOSat. The IGOSat project Scientist is Hubert Halloin (Associate Professor, APC) and Hana Benhizia (IR, APC), on a short-term contract funded by the LabEx, is the project manager.

The main objective of IGOSat is to give to the Paris Universities students (and beyond) hands-on experience of a real satellite project while doing technology demonstration, within a scientific mission project. With the help of about 10 scientists and engineers from the APC and the IPGP laboratories to supervise the project, more than 200 students have already been working on IGOSat.

Each year, about 15 interns (from bachelor to master level) are supervised by APC and IPGP researchers and engineers. The internships duration is typically from 3 to 6 months. The interns come from several Universities and engineering schools in France (Univ. Paris Diderot, UPMC, Univ. Paris 11, ISAE/SUPAERO, Univ. Toulouse III / Paul Sabatier, Ecole Centrale, etc) and abroad (mostly from India and Vietnam).

The students are involved in every step of the satellite development. It includes various engineering fields such as thermal and mechanical design, electronic engineering, attitude determination and control systems, embedded software programing, telecommunications, system engineering, etc.

IGOSat will orbit around the Earth on a circular, quasi-polar orbit at about 650 km, and will carry two scientific payloads:

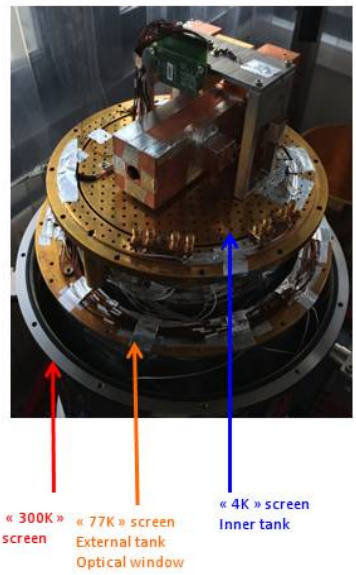
- A state-of-the-art high-energy particles scintillator (CeBr3 scintillator readout by a Silicon Photo-Multiplier) for detecting gamma rays and electrons above the poles and the South Atlantic Anomaly (SAA).

- A Dual-frequency GPS receiver to observe the Total Electron Content (TEC) of the Ionosphere through GPS occultation, by measuring the phase shifts of the L1 and L2 GPS carrier frequencies;

The IGOSat project started end of 2012 and entered the Phase C (detailed definition phase) in September 2016, following a successful Preliminary Design Review, presented by interns in front of CNES experts, in June 2016.

The IGOsat teams also participates to various conferences and outreach activities, such as the « Fete de la Science », the organization of a Student's Cubesat Workshop at University Paris Diderot every year, a dedicated website (www.igosat.fr), a twitter account (@IGOSAT_Diderot).

EUCLID. As part of the ESA's Euclid space mission, the APC was in charge of building an experimental bench for radiation-hardness studies on a NISP (Near Infrared Spectrometer & Photometer) detector with radioactive sources and ionizing particles beams produced by accelerators. The main milestones completed are the following:



- In January 2014, the instrumentation of a cryostat with liquid nitrogen was completed. Two mechanical designs, one for a commercial detector model and another for an engineering model were achieved and integrated the dedicated electronics reading and the cabling, manufactured by the AXON company.

- A successful measurement campaign was led at the LPSC Grenoble with cold radioactive sources (Fe55 and Am241) in January 2016. The data analysis is still in progress.

- In April 2016, a measurement campaign with a 23MeV proton beam was led at the TANDEM accelerator facility in Orsay. Unfortunately, the beam intensity, even at its minimum, remained too high compared to the expectations and do not allow representative measurements.

- Consequently, another test campaign was led in December 2016 with a 37MeV proton beam at the Louvain-la-Neuve University (UCL) in Belgium to reproduce the effects of irradiation equivalent to a solar flare and the total dose of the mission. The engineering detector performances and conditions of operations were checked with radioactive sources at the CPPM laboratory in Marseille before and after this campaign to give reference measurements.

The project team took great care in moving the set-up (cryostat and the acquisition system) to the different locations and solving the problems of electromagnetic compatibility, which were the main technical challenges. The data analysis of these campaigns is under progress and is a priority. The figure shows the setup with the cryostat, which was mounted in front of the beam at the UCL facility.

Academics and Others Activites of the Instrumentation Department

- Participation in the optics and radioactive safety networks.
- Trainees supervision (from High school to Master 2 and engineering schools)
- Writing of scientific papers/ participation to conferences

SWOT analysis

Strengths	**Weaknesses**
• Specific skills compared to other IN2P3 laboratories: optics, AITV (Lisa, Virgo, Taranis) • Project leader of space/ground-based/balloon (Taranis, Lisa, Euso, Qubic, Igosat) • National and international visibility (Taranis, Virgo, Lisa, Qubic, Euso, Igosat)	• Turn over, important fixed-terms contracts • Significant risk to loose skills -> expertise held by a single permanent/fixed-term contract -> limitation of the people for new R&D -> minimum logistical support • Operation of the cleanroom (Taranis, Igosat, Euso)
Opportunities	**Threats**
• Collaborations that come to us for specific realizations and give financial or human resources • New R&Ds (Gamma Cube, XLisa, Scintillators…) • Calls of tender from space agencies (ITT, R&D Lisa, Core, Athena…) • Major projects (Lisa, Euso, Virgo…)	• Budget cuts • Restriction of contracts with impossibility of converting fixed-term contracts in permanent positions • Administrative procedures (databases, career follow-up, recruitment procedures…)

Strategy and the five-year plan

- Reinforce the optical team which is currently composed by only a permanent engineer and another hired on a fixed-term contract.
- Reinforce the department with system engineer for new spatial projects as LISA.
- Reinforce the department with AIT/AIV engineer for TARANIS and LISA.
- Acquire competences on simulations of Silicon Detectors (Silvaco software)

Main objectives for the five next years on the projects are the following:

QUBIC: The manufacture of the Demonstrator is well advanced and the cryostat (manufactured by the Italian partners) is expected to arrive during summer 2017 at the APC. The integration of the detection chain will then take place in the APC assembly hall together with a validation test campaign during the second half of 2017.

The success of the aforementioned operations would hopefully open the path to build a complete instrument to be installed in Argentina.

Advanced Virgo: commissioning and first detection with the Virgo collaboration

LISA: first results on the diffused light, and definition of the Phase 0

Lisa Pathfinder: end of the science operation and feedback for LISA

TARANIS: The APC team is currently finishing the integration, the qualification and the calibration phase of the instrument, leading to a delivery expected for mid-2018.

The mission is meant to be sent by the end of 2018 and the team will be involved in all the satellite integration and commissioning phase before and after the launch of the satellite.

EUSO: launch of Mini-EUSO and EUSO-SPB2 during the next years

IGOSAT: The completion of the flight model is expected beginning 2018, with a launch scheduled for 2019.

10. Electronics and Microelectronics department

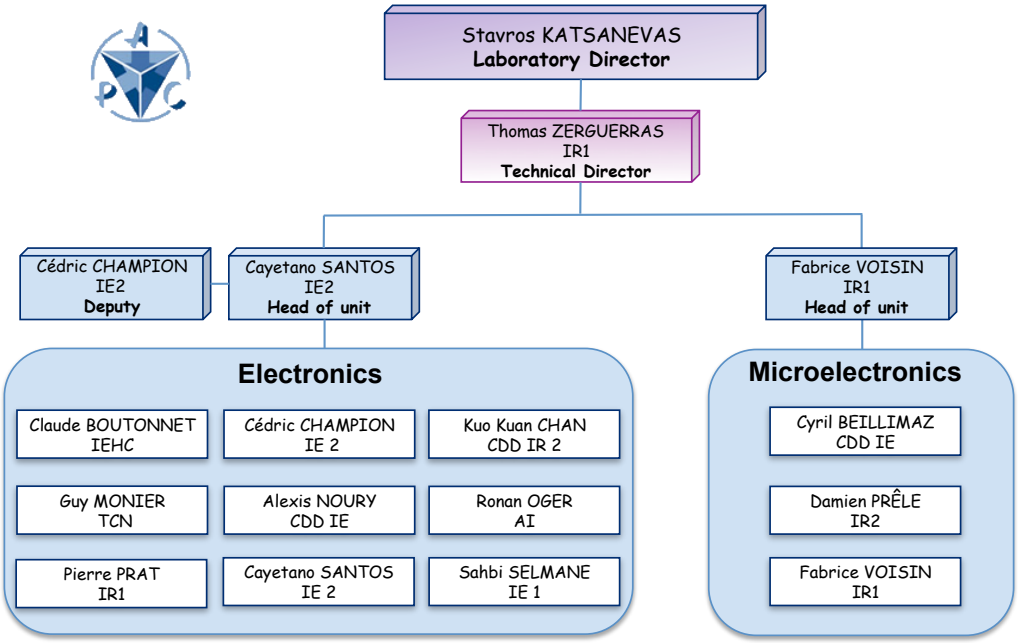


Figure 28. Organization of the electronics and microelectronics department within APC

10.1 Electronics department

General presentation.

The Electronics Department brings together various skills in the field of electronics. Those are computer-aided simulation of electronic assemblies, engineering of analog front-ends and conception of digital systems, including numerical processing.

Therefore, the department gathers highly skilled engineers in analog and digital electronics together with dedicated technical staff fulfilling all necessary needs in today's projects. The Electronics Department is integrated in the general matrix organization of the APC laboratory, and brings its specific knowledge on electronics to the projects in close interactions with members of scientific groups and other technical departments.

Evolution 2012-2017

Since its creation in 2006, the Electronics Department benefited from the arrival of new members who bring skills previously missing to the department and endorse responsibilities in projects. Departures have several causes such as retirement, end of contract for fixed-term staff, mobility to other CNRS laboratories or to other departments inside the APC laboratory. In particular, opening of new permanent positions did not cover retirement. The reinforcement in project teams relies most often on fixed-term engineers, which can induce a high turnover detrimental to the progress of projects.

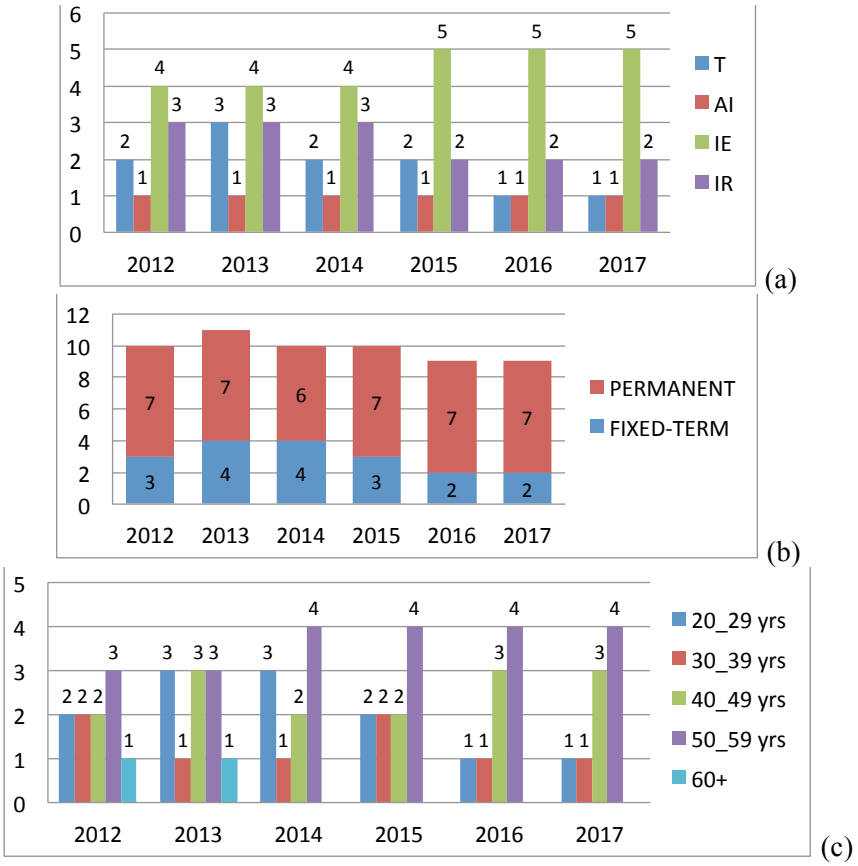


Figure 29. Electronics department staff evolution according to (a) status, (b) contract term and (c) age distribution

It is thus expected and necessary to maintain and develop the number of research engineers, in parallel to consolidate the technician support. The Electronics Department need to strengthen its conception and design task force by hiring at least one research engineer on a permanent position and consolidate technical support for cabling and PCB routing.

Products and activities

Double Chooz. A full acquisition system, largely designed at the APC, is installed on the two neutrino detectors at the Chooz Nuclear Power Plant. This acquisition is based on the VME64x 500MHz Flash-ADC board (VX1721) developed in collaboration with the Italian company CAEN. This joined effort led to a highly stable and broadly remote-controlled continuous data taking system now running on site for many years. A custom, largely optimized version of the firmware fitted the specific needs of the experiment by minimizing the dead time of the acquisition system, based on a VX1721 board, at trigger rates above 1 kHz.

Taranis. The Tool for the Analysis of RAdiations from lightNIngs and Sprites, TARANIS, is a micro satellite project. The APC is responsible for the XGRE instrument. The Electronics Department takes in charge the development, tests and delivering of the electronics readout fulfilling to the mission requirements, including dedicated front-end taking the different kind of sensors involved (LaBr3 and plastic scintillators glued to photomultipliers) into account. An Analog card shapes the PMTs output signals after prior amplification, provides fast reset and generates triggers. Additionally, a dedicated board sets a proper bias to the PMTs through a resistor bridge. Finally, a numerical board including a FPGA digitizes the signal for further processing and data analysis. This electronics system follows ECSS and Radhard standards for space missions.

KM3NET. The Electronics Department contributes on two topics related to the Calibration Base for the KM3NET project. The first is the integration of the various subsets composing the calibration base (CB container) as well as the global integration of the various subsystems constituting the Laser

Beacon Module. The second is the validation and characterization of the calibration base interfaced with all the external devices or their emulations. In parallel, a photomultiplier tube test bench is under construction to complete the existing infrastructure of the MEMPHYNO test bench, made of two hodoscopes (top and bottom), a water tank and an acquisition system. This electronics system, developed at the APC, provides cosmic muon trajectography. A MAROC3 ASIC developed at the IN2P3/Omega group is connected to a FPGA to perform the hodoscope data readout.

CTA. The APC is currently in charge of the overall CTA work-package dealing with the clock distribution and time-stamping system. The Electronics Department contributes to the development of a technical solution for the CTA array's software coincidence trigger system. Following a first custom-built system based on the MUTIN (Multi Use Telescope INterface) card, a new TiCks board based on the CERN open hardware White Rabbit clock distribution system and the SPEC standard has been designed. An upgrade adds new functionalities such as nanosecond time stamping, UDP stack for data transmission, remote configuration and external triggering of CTA cameras. The TiCkS board is expected to be used in the CTA's NectarCam-MST cameras and the large size telescope (LSTs).

LISA & LISA-Pathfinder. The Electronics Department contributes to R&D activities of the future Laser Interferometer Space Antenna (LISA) mission, such as the study and development of the electronics system for the LISA hardware Simulator LOTE (LISA On Table Equipment) and the characterization of its phase noise with a phasemeter. A complete set-up is installed in the low-noise room of the APC laboratory to test precision voltage references and RF components (mixers, amplifiers, dividers). An ultra low phase noise synthesizers based on a commercial DDS generator controlled by a phasemeter is also under development. Moreover, the Electronics Department is involved in the LISAPathfinder mission who aims to validate the main technologies necessary for the future gravitational waves space observatory LISA. The French space agency CNES commissioned the APC laboratory to supervise the study and realization of the Laser Modulator (LM), entrusted to the RUAG Company (Zurich, Switzerland) and made of an optical box unit (LMU) and an electronic box unit (LME). An engineer of the Electronics Department was also in charge of monitoring this equipment during commissioning and the satellite operation.

Juno. JUNO is an international collaboration aiming at the development of a liquid scintillator antineutrino detector. The APC takes the responsibility for the front-end electronics design of the sPMT instrument, based on the CatiROC ASIC designed by the IN2P3/Omega group. In a joined effort with the Omega group and the CENBG laboratory, the Electronics Department develops the software and firmware necessary to acquire and monitor the acquisition. In parallel, the APC is in charge of the conception of a compact, 8 ASIC, 128 channels front-end board to provide advanced features between the PMTs and the JUNO backend electronics.

ProtoDUNE-DP/WA105. The Electronics Department is involved in the future Deep Underground Neutrino Experiment (DUNE) and its prototype, the ProtoDUNE-Dual-Phase experiment WA105 at the CERN. The Electronics Department contributes to the integration of the CatiROC ASIC, designed by the IN2P3/Omega group, which provides custom functionalities specific for processing fast signals of PMTs detectors. The developed front-end electronics form factor is based on the FPGA mezzanine board (FMC) standard and is intended to be connected on top of an AMC COTS μTCA motherboard.

EUSO-Balloon / EUSO-SPB. EUSO-Balloon (CNES) and EUSO-SPB (NASA) are demonstrators of the future Extreme Universe Space Observatory (JEM-EUSO). The Electronics Department is engaged in the definition of the electrical architecture of the balloon in collaboration with the INSU/IRAP laboratory, as well as in the integration and tests activities of the Photo Detector Module (PDM). Finally, it takes part to the conception of the High Voltage Power Supplies (HVPS), in collaboration with the NCBJ laboratory in Poland.

Athena. The Advanced Telescope for High ENergy Astrophysics (ATHENA) is a space mission driven by the ESA and the French space agency CNES. The APC is in charge of the Warm Front End Electronics (WFEE) based on an ASIC designed by the Microelectronics Department. This ASIC amplifies the signals from the SQUID sensor with minimum noise and feeds them to the digital readout chain. In addition, it controls the SQUID bias and is part of the instrument global control loop. The Electronics Department designs the PCB dedicated for this ASIC and develops the surrounding

hardware for the WFEE for global integration in the space instrument. The Electronics and Microelectronics department collaborate closely to design, implement, test and validate the WFEE.

GATE. GATE is a scintillator array intended for academic purposes. It was previously designed to apply to the clock distribution, trigger time-stamp and software event coincidence for the CTA experiment. The heart of this system is the MUTIN (Multi Use Telescope INterface) card based on programmable logic (FPGA), designed to be mounted on the telescope. It receives the central clock at a frequency of 10 MHz from a MUTIN clock-distribution crate, which distributes this clock signal to the whole telescope array, via optical fibers, and continuously measures the round-trip signal time for calibration.

Compton R&T. The Compton R&T is a collaboration between several IN2P3 laboratories, with LABEX and CNES funding, to develop hybrid DSSD (Double-Sided Silicon Strip Detector) and its electronics readout with a balloon flight as important milestone. The Electronics Department is in charge of the realization of the hybrid PCB board (maintenance of the DSSD, HV, SSD ASICs link), interface cards including a FPGA and the VHDL coding to manage connection with the ASICs (IDeF-X manufactured by the CEA), event reading and ethernet PC connection

SWOT analysis

Strengths	Weaknesses
• High level experience in VDHL coding • Deep knowledge in specialized front end ASICS of the IN2P3/Omega group • Analog processing with front end adaptation and sensor integration • Possibility to acquire specialized education within the department • Experience in analog/digital pcb development	• In a context of rapidly changing technological environments, the existing challenges to keep the pace are strongly limited by the short time available to upgrade technical skills • Some key missing technical skills limit the complexity of the projects we are able to get involved in • Part of the Electronics Department is composed of non-permanent members of staff close to finish their hiring contracts. This is a major threat for the projects they are involved in • Some permanent members must need to involve in time-consuming non-technical activities • There is clearly insufficient staff with respect to the number of existing ongoing projects • The number of research engineers able to assume responsibilities is low • A too large dispersion in several kind of activities could jeopardize the Department coherence • Specific skills rely in most of the projects on one engineer
Opportunities	**Threats**
• Provision of a motivating scientific environment with continuous technical challenges	• Two engineers are close to retirement. If they are not replaced, the Department staff will fall under a critical size • Increasing difficulties to hire specifically skilled engineers or technicians on the labor market for the projects we are involved in, particularly due to the wage competition with private companies

	• Local investment in projects is reduced to a single apc engineer, making project management sensitive to any unexpected event

Strategy and the five-year plan

The following conclusions arise from the analysis of the activities during the last five years. Two permanent positions are going to leave to retirement; additionally, two non permanent positions are expected to leave in a close future It is necessary to share available skills between projects In order to optimize achievements it is advised for the members of the Department to:

recentre their activities;

to acquire new skills through projects and training

During the five coming years, the Electronics Department is expected to stay involved in the following on-going projects: LISA, Compton balloon, ATHENA (with non-permanent staff), CTA and KM3NET. The Department will review continuously its commitments according to the manpower at its disposal.

Staff. The Electronics Department needs to renew its staff and keep a critical size for involvement in projects. At least, the Department must keep five engineers on permanent positions for design studies and two assistant engineers for technical assistance. The current key profiles identified are the following:

- 1 analog expert engineer (Pierre Prat)
- 2 digital engineers (Cédric Champion, Cayetano Santos)
- 1 pcb expert engineer (Ronan Oger)
- 1 pcb expert assistant (**new position**)
- 1 daq/acq expert (**new position**)
- 1 prototypist (Guy Monier)

Additionally, two engineers, Sahbi Selmane and Claude Boutonnet, currently involved respectively in JEM-EUSO and KM3NeT, are going to retire in the next five years. It is thus crucial they are replaced so that the Electronics Dpt keeps a critical size. Finally, non-permanent members of staff are appreciated reinforcement for the Department to support projects. However, they must be under the supervision of at least one permanent member of staff to avoid loss of skills, which can affect the projects. Moreover, the APC laboratory must seize any opportunity to shift the fixed-term contract to a permanent position to sustain expertise in the Electronics Department.

10.2 Microelectronics department

The microelectronics department. The microelectronics department develops ASICs (Application Specific Integrated Circuits) for the implementation of instruments dedicated to observational cosmology and astroparticle experiments. The microelectronics activity is present at the APC since its creation, initially regrouped within the electronic department and then within the experimental technics department. The growing needs for the use of integrated circuits in most of the emerging projects in the laboratory led to the creation, in the beginning of 2016, of a specific microelectronics department. The microelectronics staff consists of two permanent members: Fabrice Voisin, research engineer at APC since 2003, currently head of the microelectronics department, attached to the QUBIC and WFEE ATHENA projects; Damien Prêle, research engineer at APC since 2007, WFEE ATHENA project manager and attached to the QUBIC project.

In September 2015, a third engineer, Cyril Beillimaz, with a fixed-term contract funded by the French space agency CNES has joined the microelectronics department to carry out the Phase A of the WFEE

ATHENA project. Since September 2016, Si Chen, a PhD student supervised by Damien Prêle, is also involved in the development of integrated circuits within the framework of this same project.

The APC's microelectronics department has full-custom design skills of both analog and mixed ASICs using CMOS and BiCMOS technologies for applications operating at room or cryogenic temperatures.

In particular, a specific expertise has been developed within the IN2P3 for the design of ultra-low-noise (<< 1 nV / √Hz) ASICs, operating at cryogenic temperature (down to 4.2 K) for the front-end readout of superconducting sensors (TES, SQUID) and/or hardened to radiative environments for space applications.

Over the last five years, the department contributed also to the development of Single Photon Avalanche Diode (SPAD) arrays for the production of single photon sensitive imagers using CMOS ASIC technology (Gamma Cube project).

Products and activities

QUBIC (Q&U Bolometric Interferometer for Cosmology)

The microelectronics department has developed an expertise in the field of SQUID (Superconducting QUantum Interference Device) multiplexers for the readout of large Transition Edge Sensor (TES) arrays using low-noise integrated circuits operating at cryogenic temperature (4.2 K).

The department is in charge of the realization and the qualification of ASICs dedicated to the cryogenic detection chain of the ground based telescope QUBIC (2 focal planes of 1024 TES each), international experience of bolometric interferometry in the range of millimeter and submillimeter wavelengths (150 GHz and 220 GHz) for the study of Cosmic Microwave Background (CMB) B modes polarization.

Two versions of the ASIC were carried out, one in 2012 ("SQMUX128") for the integration and the validation of one quarter of the QUBIC detection chain in a dilution cryostat (2015) and the second one in 2016 ("SQMUX128_evo") for the demonstrator of the final instrument in its dedicated cryostat (2017).

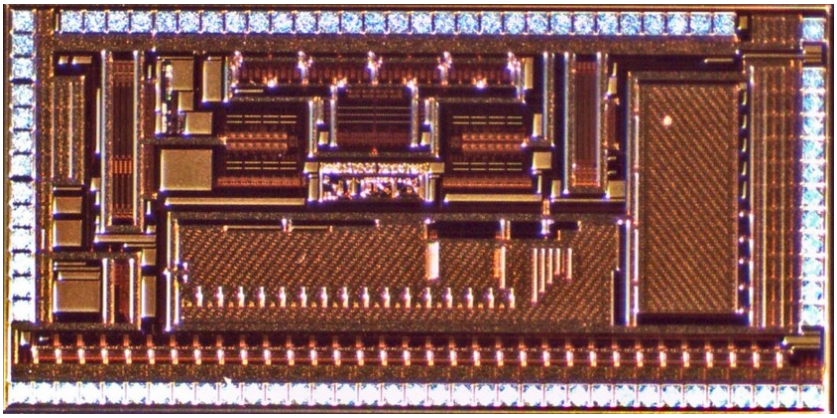


Figure 30. "SQMUX128_evo": ASIC in standard BiCMOS SiGe 0.35µm AMS technology for the readout and the multiplexing of the QUBIC instrument.

These ASICs achieve the multiplexing in time domain (TDM) of 4 columns of 32 SQUIDs for the readout of 128 TESs. They integrate an ultra-low noise amplifier (0.2 nV/√Hz) with 4 multiplexed inputs, 32 multiplexed current sources required for the biasing of SQUIDs, a digital circuit for the addressing sequencing and a serial link for parameterizing of the overall circuit.

The microelectronics department is also largely involved in the implementation of the entire detection chain and its integration into the instrument: definition and characterization of TESs (300 mK superconducting detectors); specification, outsourcing and testing of SQUIDs (superconducting preamplifier at 1 K); realization and integration of SQUIDs and ASICs modules (PCB); management of interconnections (bonding, cables assemblies and connectivity); specification and interfacing with the warm data acquisition electronics (300 K).

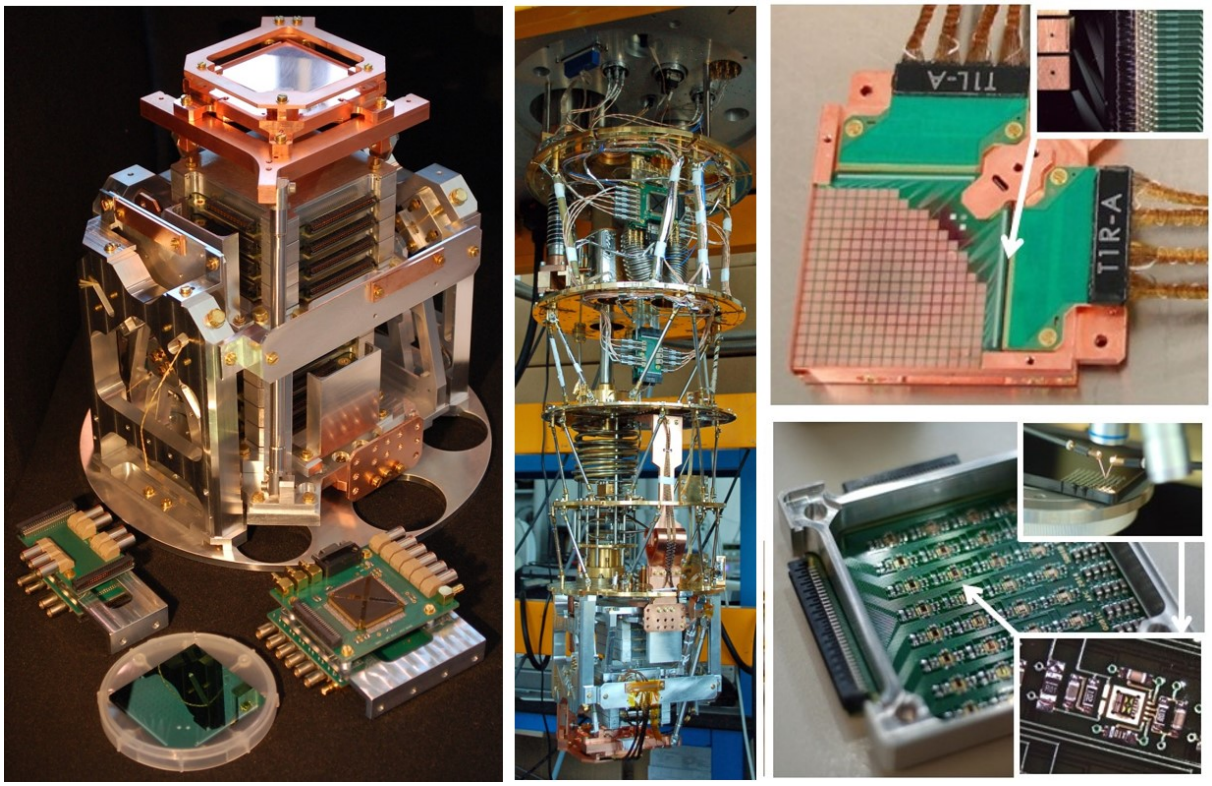


Figure 31. Left and middle - integration and the validation of one quarter of the QUBIC detection chain in a dilution cryostat; top and bottom right – interconnections and testing of TESs and SQUIDs respectively.

PMO collaboration

The use of ASICs operating at very low temperatures was proposed in the framework of an international collaboration with the PMO Institute (China) for the implementation of the focal plane of a telescope located at Dome A in Antarctica. In 2013, the microelectronics department realized, tested and provided to the collaboration a new ASIC ("SQMUX24") integrating the functionalities needed for the TDM readout of 24 TESs. A second ASIC is being prepared for 2017 to readout the 1024 TESs of the final instrument.

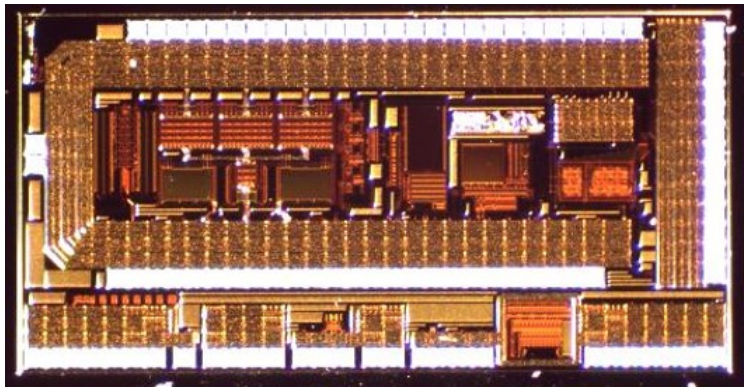


Figure 32. "SQMUX24": ASIC in standard BiCMOS SiGe 0.35µm AMS technology for the TDM readout of 24 TESs in the framework of the PMO collaboration.

ATHENA (Advanced Telescope for High Energy and Astrophysics)

The APC laboratory is in charge of the WFEE (Warm Front End Electronic) sub-assembly of the X-ray Integral Field Unit (X-IFU) proposed for the Athena X-ray Observatory, a large mission of the ESA science program, to be launched in 2028. The focal plane of the X-IFU instrument consists of

3840 TES multiplexed in frequency domain (FDM) with a rate of 40, the number of channels to amplify and then to process is reduced to 96. The main function of the WFEE, located at the interface of the cryostat and the DRE (Digital Readout Electronic), is to integrate, in ASICs operating at 300 K, the 96 amplification channels (ultra-stable gain 100 V/V, 1-6 MHz, 1 nV/√Hz) and the adjustable current sources (current DAC) required for the biasing of the SQUIDs present at the cryogenic stages as well as a serial link (I2C / RS485) for the parameterization of the overall circuits.

A first ASIC version ("awaXe_v1") was submitted to the foundry at the beginning of 2016, including test vehicles in order to identify the topologies that could be compatible with the WFEE requirements and to validate the radiation hardening techniques used for the design of digital cells.

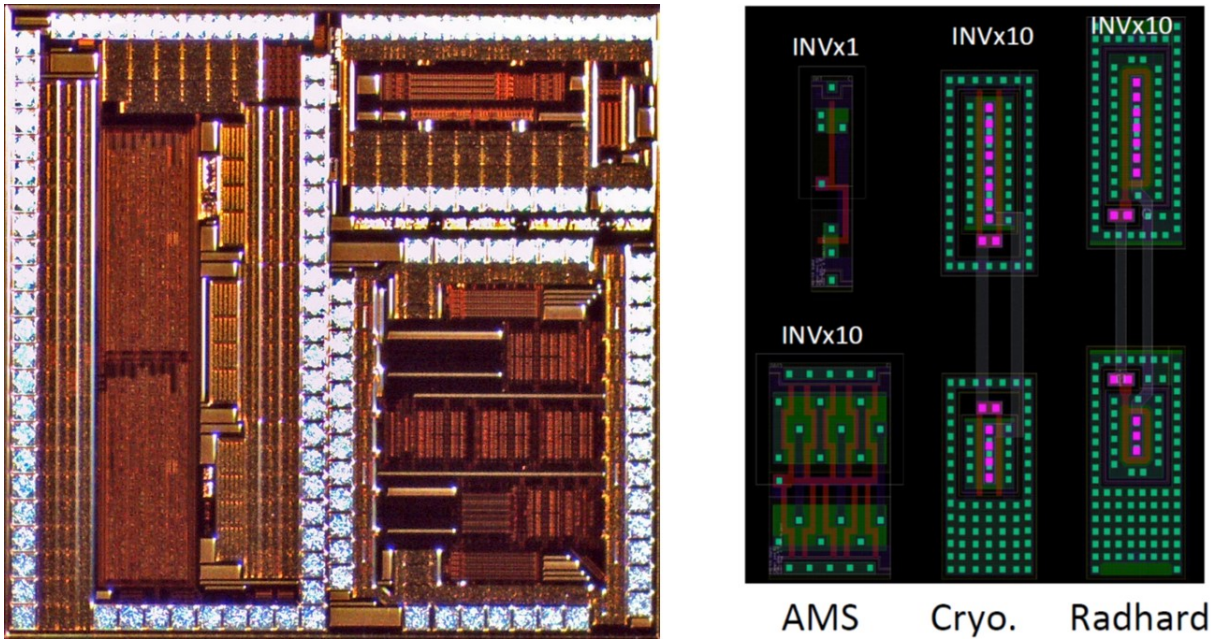


Figure 33. Left - first ASIC version "awaXe_v1" in standard BiCMOS SiGe 0.35µm AMS technology to identify topologies compatible with the WFEE requirements; right – inverter cells of the full custom rad-hard digital library developed at APC.

The microelectronics department is also in charge of the ASIC characterization phases, including a radiation tolerance qualification campaign (dose and beam), as well as the development of associated PCBs and test benches.

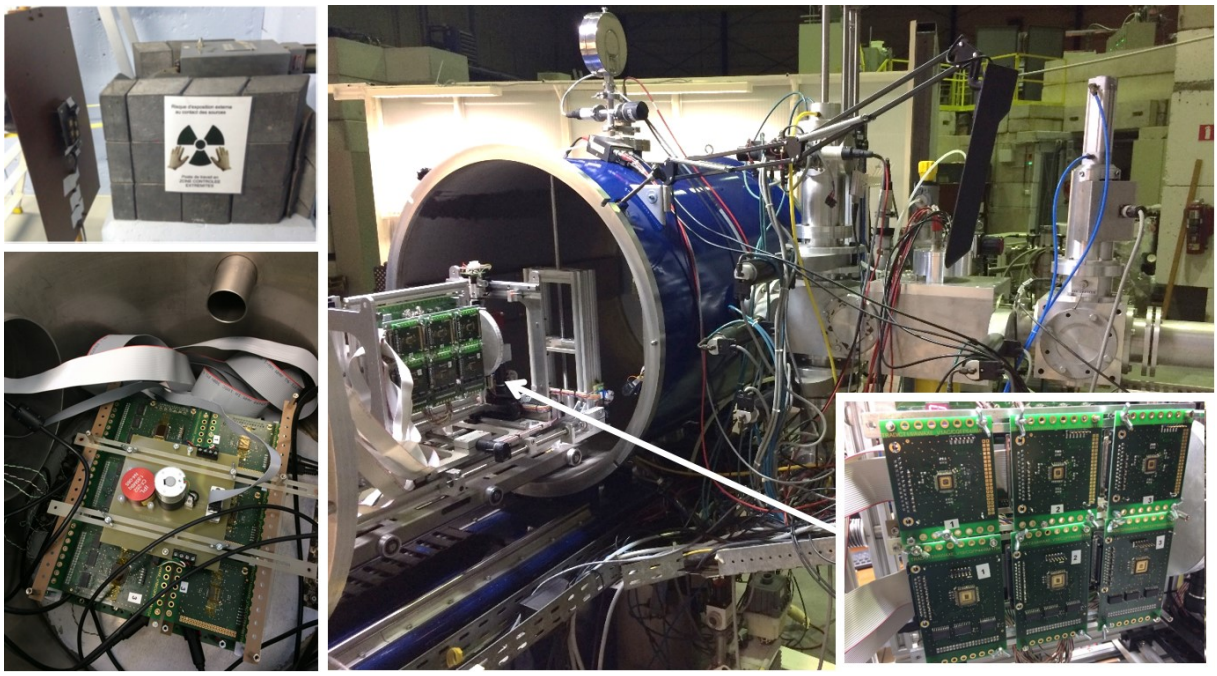


Figure 34. Top left – radiation dose tests on COCASE facilities (CEA Saclay) with a cobalt 60 source; bottom left – SEL tests on TRAD company facilities (Toulouse) with a californium 252 source; right - qualification SEL tests on UCL Louvain cyclotron (Belgium).

A second ASIC version ("awaXe_v2") is being developed for a submission expected before the end of 2017 to provide to the collaboration a "breadboard" integration for the implementation of a demonstrator scheduled at the end of phase A (January 2018).

Gamma Cube:

The microelectronics department participated in the development of Single Photon Avalanche Diode (SPAD) arrays in standard CMOS ASIC technology for the production of single photon sensitive imagers for the Gamma Cube, R&D for spatial gamma tracker project. The study of an integrated coding and multiplexing system leads to the realization, in 2014, of an ASIC ("IMACUP") in the framework of an academic collaboration with the LE2I (Electronic, Computer and Image Laboratory). The microelectronics department supported also the characterization of this multiplexed SPAD array as well as the implementation of the associated test bench.

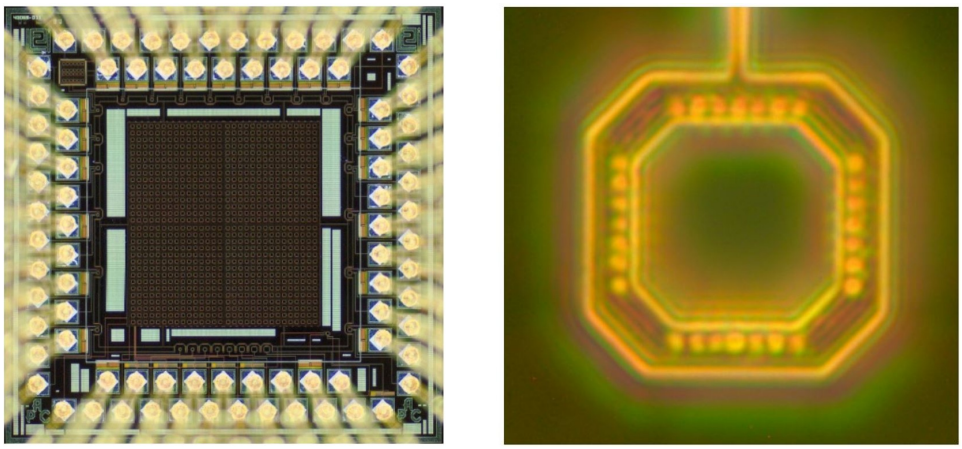


Figure 35. Left - ASIC "IMACUP": 30 x 30 SPADs array in standard CMOS 0.35µm AMS technology; right - 10µm Single Photon Avalanche Diode (SPAD).

This activity stopped due to lack of human resources available in the laboratory to carry out the microelectronics developments. However, this work led to an industrial valorization prospective (SATT, Wtech) of the concept of camera "gamma cube" for medical applications.

SWOT analysis

Strengths	Weaknesses
• Microelectronics skills: full custom design of analog and mixed ultra-low noise ASICs for cryogenic applications (down to 4.2 K) and/or Rad-Hard for space applications • Specific expertise (unique in IN2P3): understanding / implementation of SQUID cryogenic multiplexers for the TES arrays readout • Experimental skills: implementation of cryogenic equipment, integration of instruments, detectors characterizations (ASIC, SQUID, TES, KIDS, SPAD...), Rad-Hard qualification campaigns	• Human resources: actual microelectronics staff just meets the needs of ongoing projects, recruitment of a third permanent in microelectronics is required to get involved in new projects • Skills dispersion due to a lack of human resources available in the laboratory or even specific expertise: involvement in instrumental developments which are not microelectronics but needed for progress on projects • Skills dispersion resulting from the growing of management activities, non-technical but as much time-consuming
Opportunities	**Threats**
• Developments recognized by the entire national / international community and contributed to the involvement of the APC in the ATHENA project as well as in the prospects for participation in the LiteBIRD satellite project (JAXA / US col.), the fourth generation of American instrument for the CMB study S4 or its European equivalent E4	• Stopping projects due to budget cuts or lack of funding (QUBIC) • Non-recruitment of a third permanent in microelectronics will increase the difficulties currently encountered by the service.

Strategy and the five-year plan

Achievement of ongoing commitments. The microelectronics department will continue to carry out the long-term developments on the QUBIC project that should extend beyond the technological demonstrator. The service is also fully involved in the WFEE ATHENA project with commitments planned up to 2028.

Participation in future projects. The microelectronics department aims to meet the demands of emerging projects in the laboratory requiring its expertise. In particular, it could contribute to the LiteBIRD satellite project but also to the project of fourth generation of American instrument for the CMB study S4 or its European equivalent E4.

Strengthening of human resources. The participation to a new project is mainly determined by the human resources available in the microelectronics department, which are already overworked. One of the 5-year objectives is then to expand the service with the recruitment of a third microelectronics research engineer to reach the critical size needed not only to meet future demands but also to honor ongoing commitments.

11. Mechanics department

General presentation

Structure

The Mechanics Department is composed of 8 people, shared between the design office (7) and the workshop (1). It is in charge of the development of mechanical subsystems of instruments, usually in close connection with other subsystems (electronics, optics, sensors, cryogenics…). It contributes to the laboratory projects at all stages: preliminary studies and specifications, design and simulation, manufacturing, integration and assembly of components, followup of industrial subcontracting, tests and on-site installation. Inside the laboratory matrix organization (departments vs projets), the members of the team have also responsibilities in projects, as project managers or mechanical architects for instruments or sub-systems, both for on-board (satellites, balloons) and for ground-based experiments. The ecosystem in which the department evolves, includes close relations with the CNRS/IN2P3 institute for shared softwares CATIA V5 (CAD) and ANSYS (FEA), exchanges within the CNRS mechanics network and benefits of the support from the Paris Diderot University raw material store.

The department can rely on several equipment in the laboratory (3 axis numerically controlled machining centre; programmable 3D coordinate measuring machine; ABS additive manufacturing printer…). More details on the workshop are reported in Appendix 2: Equipment and Platforms.

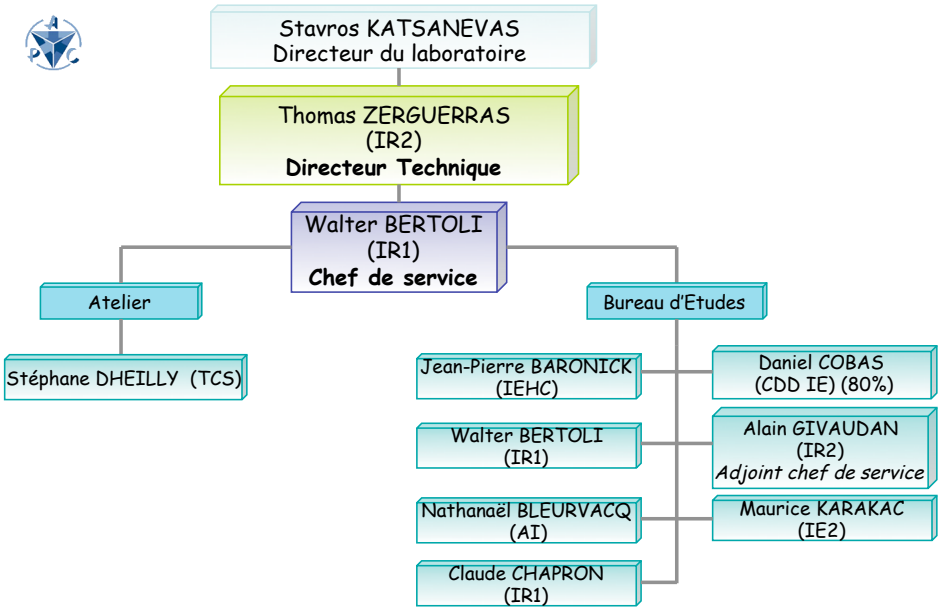


Figure 36. Organization chart of the Mechanics department

Evolution 2012-2017

Staff

After a period of high turnover with 11 arrivals and 8 departures (2007-2012), the staff tends to be more stable since 2015. There is today only one designer hired on fixed-term contract. In 2015, a new technician skilled in machining arrived at the department through the CNRS mobility program to replace the departure of the former. However an unbalanced ratio engineers/design drafters still remains.

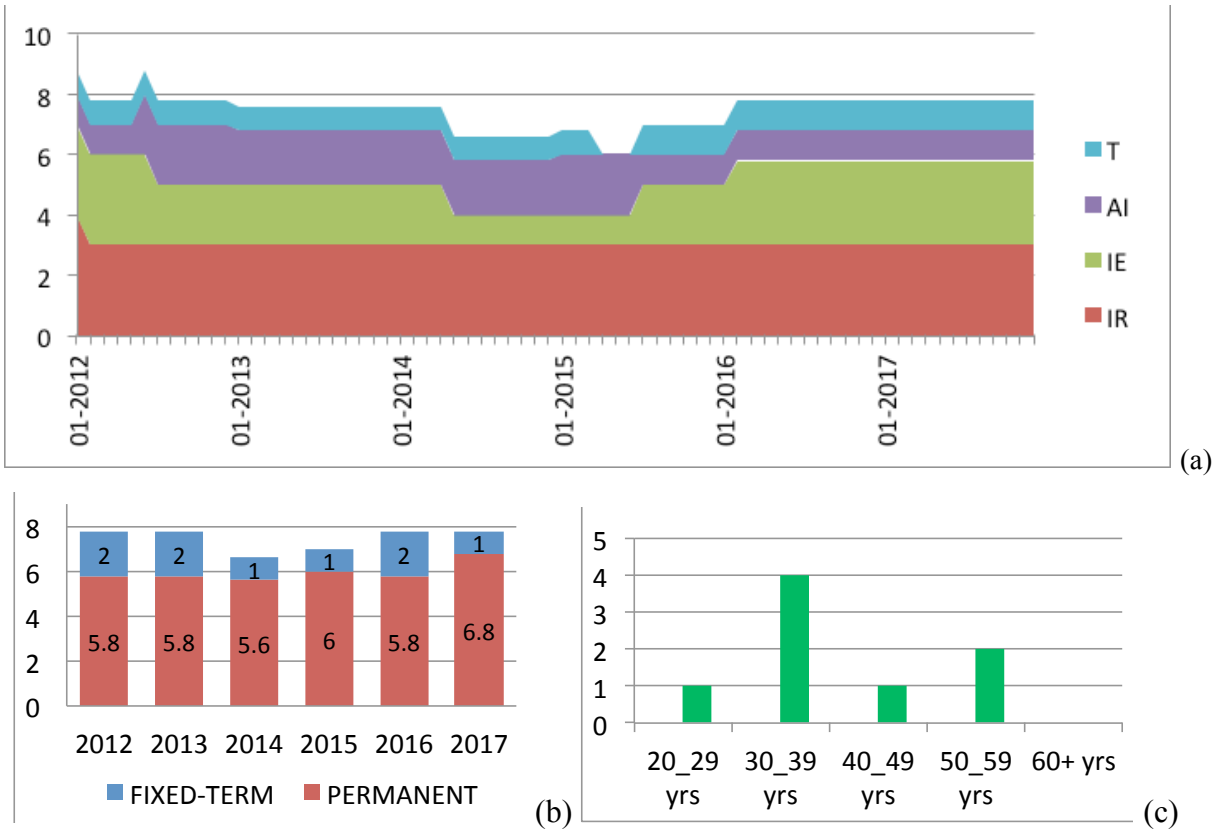


Figure 37. Mechanics department staff evolution according to (a) status, (b) contract term and (c) age distribution

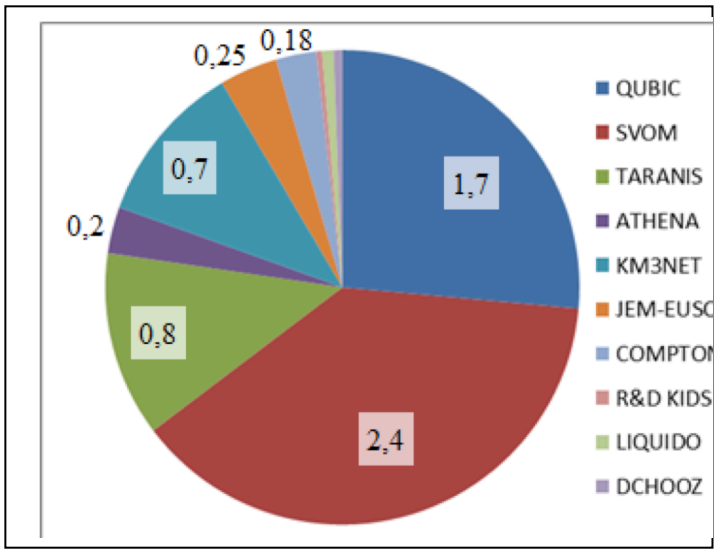


Figure 38. FTE 2016 for the design office of the Mechanics department

Competence evolution

The numerical machining centre has been equipped with a Heidenhain touch probe for workpiece measurement, which improves capabilities and reduces time preparation for milling parts. Moreover, capabilities of this milling centre are better used since DXF drawing files are imported from the design office directly into the iTNC530 control, which saves time in programming 2D contours.

The new technician, arrived in 2015, is also able to use another older numerical milling machine (iTNC155 control) and has experience in flow waterjet cutting.

The purchase of a sturdy 3D printer has allowed learning tips for designing and using additive manufacturing of plastic parts.

Of course, the evolution of competences follows the needs of the different experiments the department is involved in. Thus, more people are able to use 3D CMM for manual metrology and checking parts before integration.

Through its involvement in the DoubleChooz projet, the Mechanics Department gained a better knowledge in stainless boilermaking of big tanks, subcontractors' follow-up and integration of large steel structures.

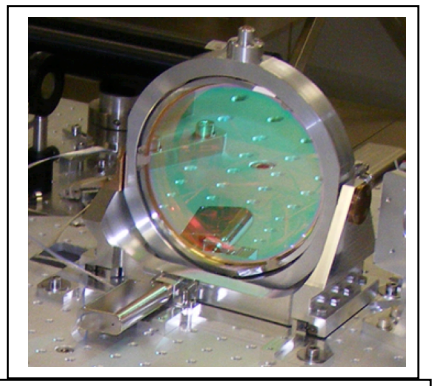
With the study of 2 subsystem / instrument for satellite, the Department has learnt a lot in the space field:

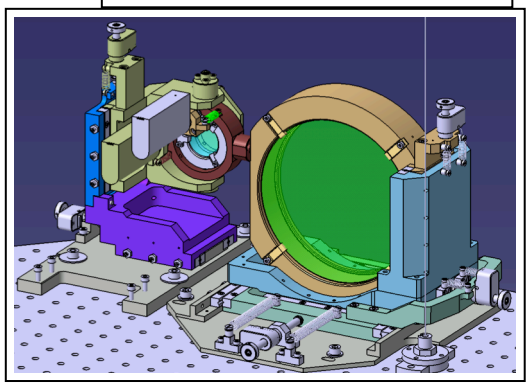
- design of highly integrated mass-optimized system including sensors and electronics readout
- dynamic specifications, and related design & simulation
- qualification of models (vibration and shock)
- integration in cleanroom environment

But working for space applications remains a long term learning. The engineer hired for the KM3NeT project brings his expertise in offshore deployment of instruments and mechanics in deep-sea environment. Since the CNRS/IN2P3 institute has changed of FEA software, the engineers and members of the design office have been trained and still learn gradually to use the new software (ANSYS).

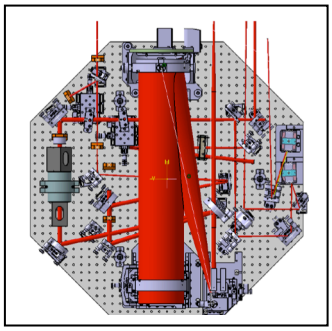
Products and activities

Advanced Virgo. The APC laboratory designed the 5 new telescopes for laser injection and signal detection. They consist of a set of lenses and mirrors to increase or decrease the laser beam diameter. The geometry of the optics requires having elements with diameter up to 150mm. The tuning of the optics along several degrees of freedom (translation and rotation) with few mrad precision, together with the size, the weight allowance and the integration space constraints on suspended optical tables, require the design of specific mounts. Motions are controlled by pico-motors integrated in the mounts, whose design meets the contamination and vacuum environment specifications, and gives strong stability, repeatability and low noise dynamic behavior.

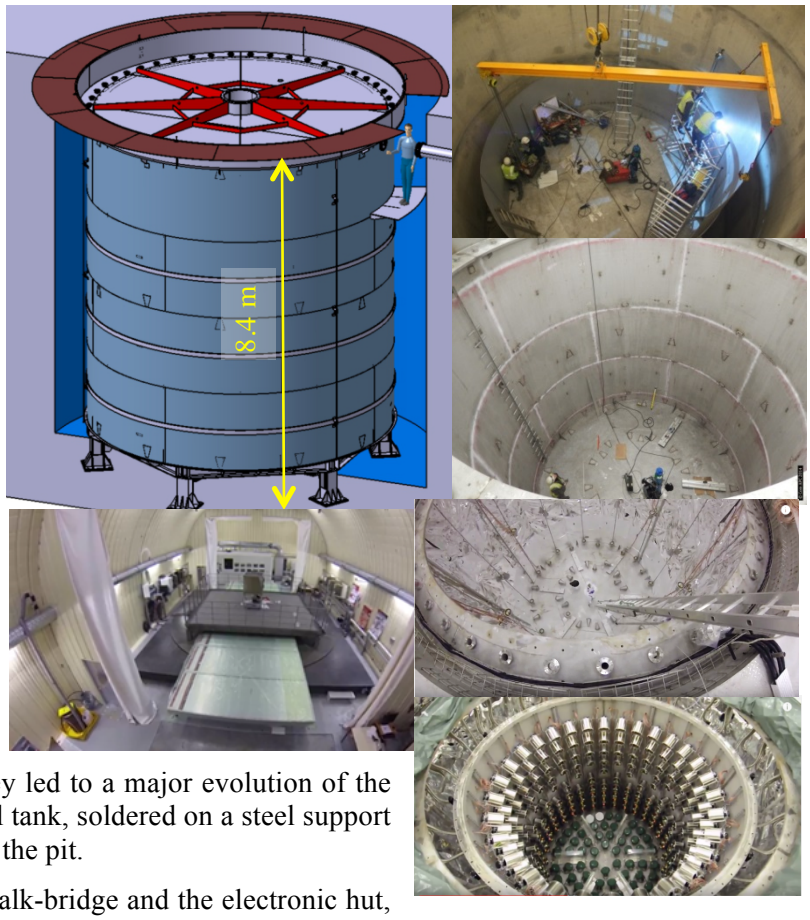




The new mechanical design started in 2012 (after specifications changes), followed by the manufacturing of most of the parts at the APC workshop up to 2014. The optics was then assembled on mounts in cleanroom in Italy in 2015. The alignment commissioning proved to be successful.

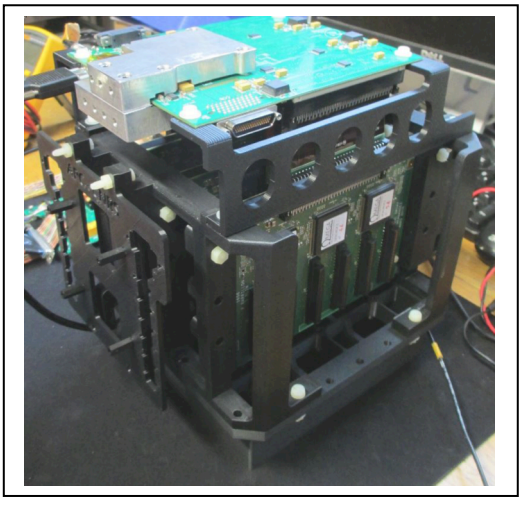


Double Chooz. On the near detector, the APC had the responsibility of the outer tank (Veto), the shielding around it, the walk-bridge surmounting the detector, plus the electronic hut. For this second detector, cost reduction led to replace the steel shielding by immersing the vessels into water with its full height. Getting a required thickness of 1m of water on each side (but the top) was made possible by the excavation of a new larger underground lab. On the other hand, this new configuration implies new constraints: a resulting upward buoyant thrust of 45T, a compression force due to the difference of water and liquid scintillator densities, corrosion. They led to a major evolution of the design consisting on a stainless steel tank, soldered on a steel support structure, anchored to the bottom of the pit.



Including the steel top shield, the walk-bridge and the electronic hut, the studies, calls for tender, industrial follow-ups and on site assemblies & tests have spanned from 2012 to 2015. Compliance of interfaces allowed the installation of the others sub-systems to go flawlessly (PMTs, inner vessels, the feedthroughs, the outer Veto, the calibration box) within collaboration schedule. The successful outcome was the start of data collection in 2015.

EUSO-SPB. After the success of the first balloon flight in 2014, the Mechanics Department was asked to adapt the mechanical structure of the PDM (focal plane of 9 PMT with their electronics) after improvements on the electronics boards and the HV supply. The new design gives a more compact architecture easier to assemble, with boards and cabling better integrated and an improved HV insulation. Most of the mechanical parts including the PMT housing structure were designed to be manufactured with ABS plastic on our 3D printer, to achieve a faster, more versatile and mass optimized design.

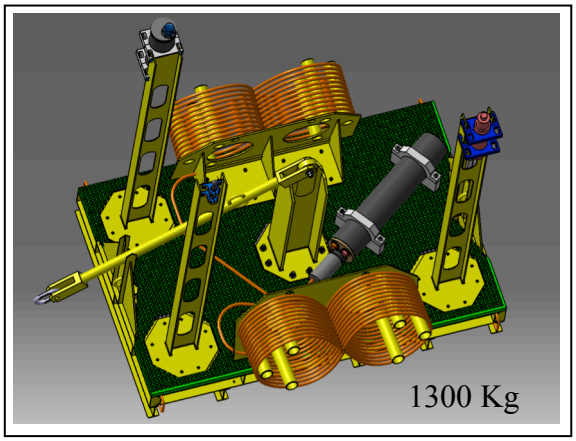


This assembly has been successfully tested and shipped to New Zealand for the second flight under NASA responsibility. The next step forward is mini-EUSO, to be embedded on the ISS.

EUCLID. The APC has the responsibility for testing a Teledyne H-2RG infrared sensor (2048x2048 pixels array) and its readout ASIC for radiation. Working temperature of 90K for the sensor and 140K for the electronics readout are required. The Mechanics Department designed the mechanics setup to

hold the devices on the cooling plate of an existing cryostat. The sensor was fixed on a bulky copper part whose heat capacity and mass allowed a safe cooling rate, slower than the critical one. The design met the sensor package interface and handling procedure with dedicated tool (according Quality Assurance Policy). The setup inside cryostat is positioned so that sensor is aligned with aperture for test beam. The setup included a support for a radioactive source close to the sensor.

KM3Net. The APC laboratory is in charge of the design, building and qualification of the Calibration Base (CB) and its instruments (Laser Beacon, Hydrophone and LBL Emitter). Both the Hydrophone and LBL emitter are off the shelf instruments, whereas the Laser Beacon is completely developed by the APC. The whole base will be connected to an Instrument Unit designed by the CPPM to constitute the Calibration Unit.



The 50 meters jumpers, subsea connectors and a base container will also be part of the CB.

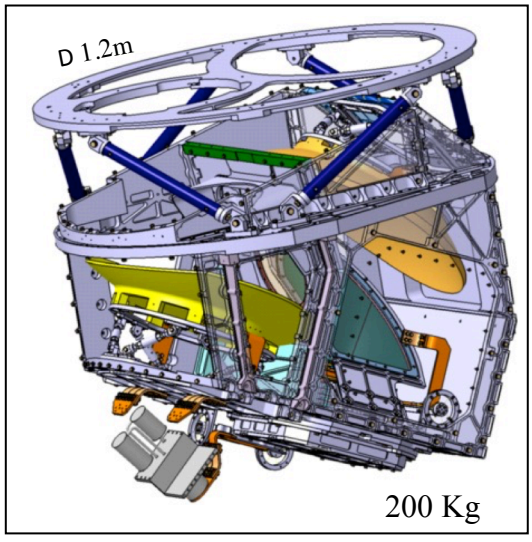
The Laser Beacon design implies (aside optical calculation for proper laser beam diffusion within the subsea installation) mechanical studies to ensure tightness, structural resistance and moisture-free internal atmosphere, to resist a long-term immersion below 3500m water depth.

The main structure is designed to meet life time specification (20 years+) on the seabed, taking into account:

- Corrosion protection via sacrificial anodes (detailed calculation made by a third part)
- Considering corrosion during the lifetime to implement a security thickness on the steel structure.
- A proper fabrication follow-up, especially for the welding, cleaning and coating of the structure.

The specific shape of the CB is driven by the concern of putting away the different instruments from seabed sediments to make proper measurement. Most of the mechanical design is done, but still waiting for the confirmation of some internal components (PCBs). The ongoing work is now mainly related to the feedback of suppliers (workshops, corrosion specialists) in order to enter in the detail design phase prior to fabrication.

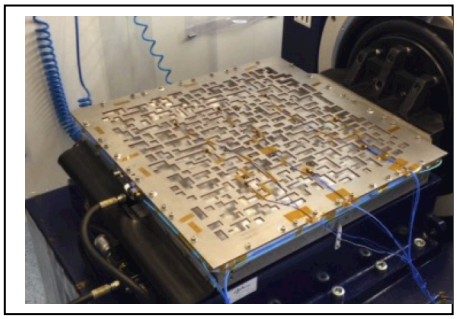
QUBIC. The involvement of the Mechanics Department in the QUBIC project has started with the design of the mechanics to support the focal planes, with highly integrated electronic read-out boards. A prototype of ¼ of the instrument focal plane was manufactured to validate the assembly of bolometer matrix and the thermal behavior (focal plane cooled down to 100mK).



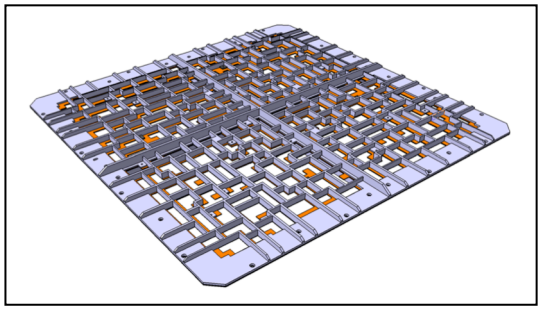
In parallel, a R&D on the manufacturing process of horns subsystem has been developed (“strata-design”) to reduce the cost (800 horns needed). After the 1st prototype, due to lack of manpower this development was transferred to an Italian laboratory, member of the QUBIC collaboration. But the Mechanics Department has stayed involved in the mechanics of the switches, located in the center of the horns to close or open every horn for calibration purpose.

In 2014, the Department started the study of the mechanical and thermal architecture of the instrument inside the vessel. The whole structure has to be cooled down to 1K and have the optics aligned despite shrinking. Technical challenges are very high as many components have to fit inside a tight space for logistics concern and in the same time keep the optical path clear. These main components are: 2 focal planes fully equipped, 2 wide off-axis ellipsoidal and paraboloidal mirrors, horns matrix, dichroic, electronics and cabling, thermal conductive paths. The assembly process is also part of the design. Moreover the architecture has to be mass-optimized for thermal concern (heat capacity vs cooling power) but on the other hand be stiff enough. This is the main challenge to keep optics alignment in different orientations when the instrument, once installed on a telescop frame, will survey the sky. The design is now completed and manufacturing is on-going. Some assembly tools are still to be designed.

SVOM / ECLAIRs. The Mechanical Department has the responsibility of the design of the coded mask of the ECLAIRs instrument for the SVOM mission. The technical challenge comes from the size (540x540 mm²) of the self-supporting mask, combined with vignetting, thermoelastic stress over a range of temperature (-80°C/+40°C), and mass/stiffness ratio for dynamic behavior.



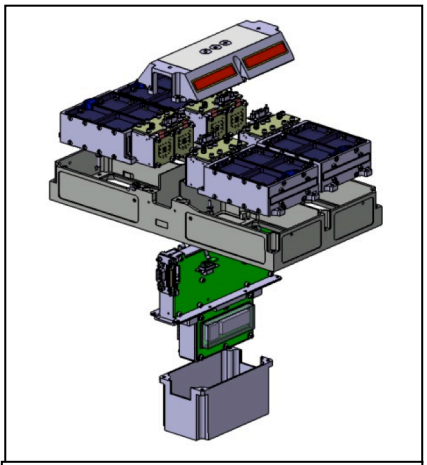
A first design relied on a 0.6mm thick Tantalum sheet (allied 2.5% of Tungsten) which is tensed to keep it flat. However the coupling with the support shielding structure led to overstress the mask in vibration simulation, and the French space agency (CNES) recommended at the 2nd phase B review (2012) to study a new design with USA-free components.

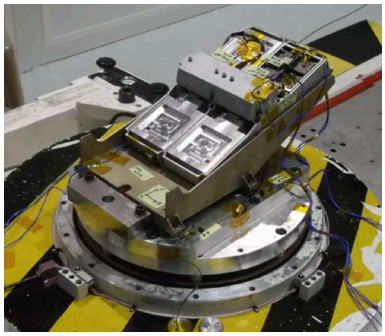


A new pattern proposed by scientists, in agreement with science requirements, gives a new ratio between hole size and focal plane pixel size, leading to a hundred larger holes mask instead of an initial configuration ith 4000 holes. This made possible a new design based on a layer of pure Tantalum glued in sandwich between 2 layers of Titanum with a special elastomer to accommodate thermoelastic strain.

The space mission was put on hold at the end of 2012 during 2 years. In 2014, the mission resumed with major evolutions: new satellite platform and launcher under Chinese responsibility, whereas the CNES took over the shielding structure supporting the mask from the CEA. In 2016, a test of a first satellite structural model in this new configuration showed new levels of vibration with an increase up to 390%. A full scale prototype of the mask was built to verify the manufacturing feasibility then tested on a shaker to check its dynamic behavior and strength. Unfortunately, the results obtained with the new loadings did not meet the specifications. Consequently, a third design introduced ribbed Titanium plate to increase 1st natural frequency and thus avoid critical frequency range (ribs position are different for each hole of the pattern which allows higher ribs without vignetting). A reinforcement cross has been recently added and simulations are on-going to validate this pattern configuration.

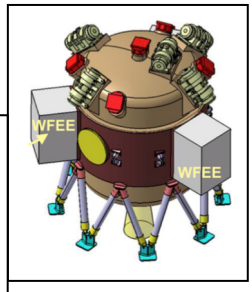
Taranis / XGRE. The Mechanics Department is responsible for the mechanical architecture of the XGRE instrument for the TARANIS space mission, consisting of 3 scintillator-based detection units (plastic scintillators and LaBr3 crystals) readout by PMTs. This instrument is a very compact system with a high level of integration between the detectors, the PMTs, the different electronics boards, the connections & cabling and the mechanical structure. The mechanical design had to meet the CNES standards, a mass budget of 5.5 kg per module, and to face the constraints on size, interfaces and vibration level for the support of the different detection elements. From the preliminary studies in 2009, the project has gone through the different phases, delivering prototypes, STM, QM and up to three flight models. The Mechanics Department made the design and drawings, sub-contracted simulations and the manufacturing of most of the parts but a few, machined at the APC workshop. It defined also the integration procedures, MGSE tooling, performed metrology and assembly in cleanroom and wrote AQ reports. Finally, it led the different campaigns of vibration and shock tests to qualify the models and check their dynamic behavior, including flight models.

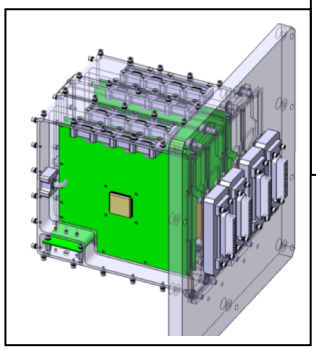




A tightness weakness in LaBr3 housing appeared following qualification test of flight models, requiring a modification submitted to the crystals supplier, the Saint-Gobain company. This leads to the production of 12 new crystals for the 3 flight models and 4 others for qualification models whose delivery is scheduled during summer 2017.

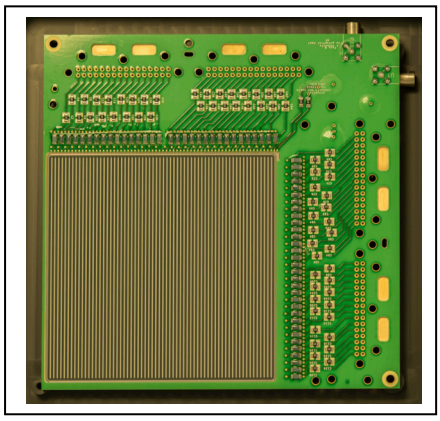
ATHENA/W-XIFU. The APC has the responsibility of the warm front-end electronic of the X-IFU instrument for the ATHENA space mission. The Mechanics Department studies the structure enclosing the ASICs PCBs, fixed on the cryostat outer vessel within the allocated volume, taking the mass budget requirements into account. This box needs the crossing of 300 wires coming from 2K stage and 200 wires going to the warm digital read-out.





In this phase A, different configurations are studied according to the specifications hypothesis concerning connectors (shielded or not; vacuum-tight or glued cables without connector). The design of the PCBs must comply with the vibration levels required. the choice of pass-through structure and the

R&T Compton telescope. This R&D consists of the development of thick (1.5mm) double-sided silicon detector and its electronic read-out chain, then of the superimposition of 3 detectors to build a camera for gamma photon detection.



The Mechanical Department assumes the project management of this R&D funded by LabEx Univearth and CNES. It has also contributed to the specifications and to the design of the PCB on which DSSDs are integrated (allowing a wire bonding on each side).

R&D KIDs. The mechanical department provides support for this R&D (few parts).

R&D LiquidO. The Mechanics Department has done preliminary study of a prototype to hold a "lattice" of wavelength shifting fibers.

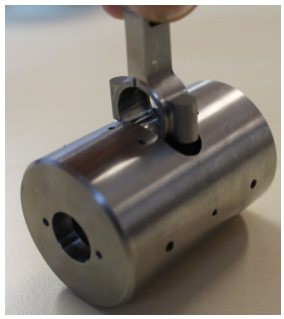
Academic activities

- IGOSat (student nanosat)

Support for the mechanical architecture and manufacturing of the nanosat

- Planet seismometer

Mechanical study of an invar resonant cavity (joint PhD with APC and IPGP)



Invar resonant cavity

SWOT analysis

Strengths	**Weaknesses**
• Good skills in mechanics design (CAD, FEA) • Experience in related fields (vacuum, cryogeny, clean room, QA) • Capabilities to manufacture parts and perform their metrology (CMM) • Better staff retention after a period of turnover	• Understaffed team: - undersized manpower with respect to projects requirements and equipment use - difficulties to keep / develop tech. skills up-to-date - out-of-balance Eng. / Draft ratio for design office • Lack of expertise in FEA in specific cases (space, …) • Weak department (design office) organisation (vs projects – Matrix structure) • Few capitalisation of experience within department • ECSS standard knowledge
Opportunities	**Threats**
• Space projects and LabEx UnivEarths (funding, technical challenges, R&D) • Business networks (CNRS mechanics network + equipments pooling; IN2P3) • Fab lab Ivry/Seine (Techshop L-M) [waterjet cutting…] • Platform of Integration & Tests (PIT) @ USQV [vibrating pot,…)	• Backgrounds (projects; lab; university infrastructures) • Ineffective use of skills; dispersion and delution of skills (CAD, FEA, management) • Too many space projects for present manpower ("worn-out"; lack of experience in assessment of risks and manpower) • Only one technician at the workshop • User support manpower (for computers administration)

Strategy and the five-year plan

Projects. Several projects are still on going (short- and mid-term) as Taranis/XGRE (2018), QUBIC (2018), SVOM/ECLAIRs (2019/2020), KM3NeT (2018 -1st phase), R&T Compton telescope (2018/2019), Athena/WFEE-XIFU (2025/2026).

Then, future potential experiences could bring new activities for the mechanics department: eLISA, EUSO-like, next CMB experiment (CORe-like), eAstrogam, Liquido.

Staff. Within the next five years, the department will loose 2 people (1 retirement and 1 end of contract), which will impact Athena and to a less extend KM3NeT. As each of these 2 persons are the only mechanical engineer on each of these projects, and as they will quit APC before these projects end, it is likely to become a manpower issue for the lab.

For the balance of the department, it is very important to replace at least the person who will retire.

Competences to acquire and develop. It is very likely that the CNRS/IN2P3 will upgrade the CAD system used in the Institute from CATIA V5 to V6. The Mechanics Department will need to keep up with the new version and associated new files management system.

The revolution of metal additive manufacturing is on going and may be useful on some project in special cases. Several skills are associated with this new technology:

- Knowledge of the different processes (advantages, drawbacks, post-treatment needed, …)
- Topology optimization software
- CAD surface modeling (to adapt to protean shape design of parts coming from topology optimization)

The Department needs to improve its knowledge of the ANSYS Workbench (new modeler SpaceClaim, vibrations, parametric studies and surface response, topology optimization).

For milling, the workshop will try to keep up with up-to-date technology (CAM, trochoidal machining).

12. Quality team and project support

General presentation.

The CQAP unit is directly linked to the technical direction of the APC Laboratory. The quality team activities are transversal with the APC activities, projects and services. Quality is the intrinsic characteristics of a system, component or process that allow conforming to customer requirements. The quality team is responsible of the APC product assurance activities in order to deliver high quality products or services. The goal is to develop a specific Quality Team, giving consistency in the organization of the APC laboratory and uniformity to projects control and support activities.

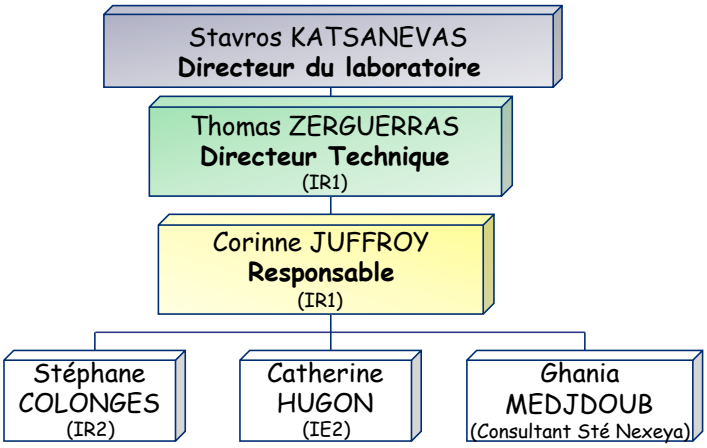


Figure 39. CQAP unit organization chart

Evolution between 2012 and 2017

The CQAP unit staff was of 4 engineers until mid of 2012 and then reduced to 3 due to the departure of one member of staff not replaced yet.

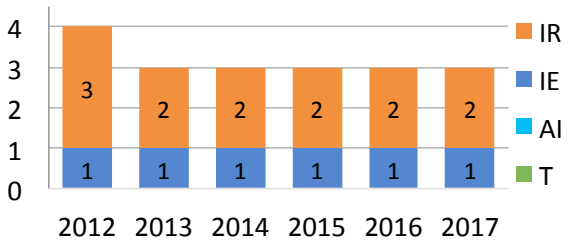


Figure 40. CQAP Members Evolution

Development of Skills and Evolution. The CQAP unit has reinforced its skills since its creation in 2007 to meet the needs of the projects led at the APC and developed a strong expertise in Product Assurance for space missions, especially in AIT/AIV (Assembly, Integration, Tests and Verification).

Main skills and capabilities

Project Assurance Quality. The quality activities are transversal and applicable inside all the laboratory services and projects with the goal of continuously improving the scientific instruments produced by the laboratory. Quality assurance tasks consist in implementing steps in order to control the critical parameters of a system or a project. It includes the redaction and the implementation of the Quality Manual, procedures, product traceability and non-conformances system, and project processes management. For both space projects and ground observatories, Product Assurance is mandatory to obtain high quality products compliant with their specifications. For the products to fulfill the required functions in a safe, available and reliable way, the CQAP unit runs the quality assurance, together with dependability and safety activities. Moreover, the unit selects and validates material, processes, electrical and mechanical components of products.

A specific review organization of the projects (Cellule Suivi des Projets) is set up at the APC laboratory to follow project status, give recommendations and decisions in terms of hardware facilities, human resources and skills availability. The choice of submitted projects depends on their imperatives and their progress status.

Electronic Product Quality Assurance. The CQAP unit has developed expertise in qualification and electronic product assurance which are of high interest when purchasing space application components and preparing qualification test plan documents for subcontractors. In this context, the CQAP members of staff have established ties with other radiation and reliability experts inside professional networks and by attending conferences. Another application of these skills is to assist and advise internal and external microelectronic designer teams to harden their design or mitigate radiations effects.

Product Quality Assurance in Space Projects. Since 2012, CQAP has consolidated and completed its product assurance expertise for space projects in the following related fields: risk, reliability analysis, technology readiness level review, electronic (EEE components qualification and selection), Firmware (VHDL…), and mechanic. Assembly Integration Tests and instrumentation Quality Assurance skills developed with the Taranis project.

Document and Information Management / Reporting. This skill has been developed inside the CQAP unit to manage effectively the information needed in scientific, technical and administrative processes inside the laboratory. This task covers the needs of Electronics Document Management, scientific bibliography, development of database studies and various types of indicators. This activity provides crucial information for the APC laboratory and funding agencies together with an efficient support for decision-making at global laboratory management level (Directors Boards, Scientific Advisory Board, Working Groups on prospects, etc.).

Products and activities

In 2015, a new electronic data management (EDM) system called ATRIUM replaced the former system EDMS. ATRIUM provides a more user-friendly interface and an efficient document tracking of the APC projects. The migration of the 4000 APC documents from EDMS to ATRIUM was a success. ATRIUM is operated by the CNRS/IN2P3 institute (National Institute of Nuclear Physics and Particle Physics) with a CQAP member of staff as local administrator at the APC to assist and advise APC Project Managers, create their restricted area inside the system and manage all access rights.

The Document and Information Manager of the APC laboratory contributes to the automation of publication repositories from the INSPIRE-HEP database to the HAL- IN2P3 system for the CNRS/IN2P3 projects. INSPIRE-HEP is an open access digital library dedicated to High Energy Physics (HEP). Once completed, the publications integrate automatically themselves in the HAL-IN2P3 database.

The Document and Information Manager uses the Limbra application, which lists the scientific production of collaborations and extracts bibliometric lists to meet the requirements of the HCERES evaluation board. In the future, this application available for all researchers in the laboratory provides several bibliometric indicators.

The Document and Information Manager promotes the creation of an Open Researcher and Contributor ID (ORCID) for the scientists of the laboratoty. An ORCID ID simplifies research workflows, resolves name ambiguity and ensures the proper authorship attribution.

The Document & Information Manager creates, develops and maintains a reporting system to generate a set of key indicators monitoring the activities at the APC. First designed to produce indicators on human resources, this database has been producing Projects indicators since 2014 to provide visibility on the workforce involved in projects. The laboratory staff contributed actively to the design of this Database to make it fully operational.

Activities on projects

TARANIS. The APC laboratory is in charge of the Gamma ray and relativistic electrons (XGRE) detector delivery to the CNES for the Taranis project. Product assurance is mandatory for all the tasks. Related activities are materials, processes and components tracking, reliability analysis; configuration control; non-conformities, documentation and project monitoring. The CQAP unit is involved in:

- Product Assurance for electronic components and radiations
- Risk analysis
- Vibration and shock tests
- Integration and tests process
- Incoming inspection
- Traceability
- Schedule reporting
- Financial reporting
- All documents required for space experiment workflow and project review of space agency.

SVOM. The CQAP unit takes in charge the Product Assurance of the coded mask of the ÉCLAIRs instrument for the SVOM mission. The activities include material and processes purchasing, quality control of the AIT/AIV operations, documentation writing and update related on the following topics:

- Conformity matrix
- Risk analysis
- Non-conformities procedure
- Templates

EUCLID. Euclid is an ESA mission to map the geometry of the Dark Universe. The CQAP unit is involved in the qualification process of the detector NISP (Near IR Spectrometer Photometer) that aims to measure galaxies redshifts. This involves the reliability analysis for electronic components and detector radiation hardness.

ATHENA. ATHENA is a new European led mission in the field of the "Hot and Energetic Universe". The CQAP unit is involved in the qualification process of the X-IFU (X-ray Integral Field Unit) instrument that is a X-ray micro-calorimeter spectrometer for high-spectral resolution imaging. This involves documentation management and reliability analysis for electronic components.

CTA. A CQAP member is the local quality correspondent of the electronic development activities for the CTA project at the APC laboratory. Another CQAP unit engineer manages the RAMS (Reliability, Availability, Maintenability and Safety) for NECTARCAM, which is one of the camera (2 OOO kilograms – 2 meters * 3 meters – 1855 detection unit / camera) designed for the MST Telescopes (20 are planned to be installed in Canaria and Chile).

This involves analysing all the camera components reliability (Failure rate calculation, failure modes and effects analysis, specification, design and manufacturing review). Reliability engineering is a specific skill developed in APC laboratory and is unique for the NECTARCAM project. The RAMS Analyses are performed for all the equipment developed and manufactured by the institutes and laboratories. The CQAP unit takes thus fully part to the CTA collaboration.

KM3Net. KM3NeT (Cubic Kilometer Neutrino Telescope) is a future European research infrastructure that will be located at the bottom of the Mediterranean Sea. The CQAP unit is involved in the reliability analysis on electronic cards of the Digital Optic Module (DOM).

Academics and others activities of the CQAP. The CQAP members of staff contribute to various professional networks:

- A CQAP engineer is member of the QeR (Quality in Research) network Steering Committee.
- CNRS electronic network, GDR ERRATA,
- IMDR…
- Democrite network (IN2P3 documentation and libraries network), ATRIUM Users Committee (IN2P3 ATRIUM Users network), GED-IN2P3 Project (IN2P3 group in charge of the choice, test

and implementation of the new EDM system, based on the Nuxeo freeware), ADBS network (French information workers network).

- A CQAP engineer is the laboratory correspondent for technology transfer. Moreover, he gives Electricity and electronic training courses in the Energy Physics professional license and master at the Paris-Diderot University.

SWOT analysis

Strengths	Weaknesses
• A dedicated Quality unit in the laboratory while it doesn't exist in the others CNRS/IN2P3 laboratories. • Specific skill in Product Assurance in Electronic at the APC laboratory • The specific skill in Quality and Product Assurance for the activities of AIT/AIV is a real asset for the futur spatial projects of the laboratory.	• Lack of human ressources to meet the needs of projects • Risk due to strong splitting of activities in the projects
Opportunities	**Threats**
• The existence of the Quality unit is an advantage to take part in space projects.	• Human ressources policy of supervision institutions. • Increase of time-consuming non technical activities like management and institutional consultancy

Strategy and the five-year plan

Competences to acquire or develop. In the different projects scenarios identified by the scientific groups and the projects, it appears that Quality Assurance support is an absolute requirement. Furthermore, the existence of a unit dedicated to QA/PA at the APC laboratory is an asset from government and space agencies point of view. The different prospective scientific scenarios and technical domain evolutions show that current skills have to be reinforced in coming years through internal or external training and hiring of new collaborators:

Product Assurance with an expertise in electronic, risk, reliability analysis, and EEE components qualification and selection. This expertise is necessary to manage electronics components qualification for space missions. This skill is crucial for the TARANIS, ATHENA and EUCLID projects and also needed for on-ground (CTA) or undersea (KM3NET) large detector assemblies, which include millions of embedded electronics channels.

Assembly Integration Tests and instrumentation Quality Assurance for all flight model instruments. Projects like the TARANIS satellite or the EUSO stratospheric balloon show how Quality Assurance in Integration and Validation process for embedded science instruments is crucial to obtain sufficient reliability and traceability during the development of the instruments. Consequently, studying, organizing and following all the quality process during the AIT/AIV phases is mandatory to complete and deliver successfully flight model detectors.

Quality Assurance for software development in all aspects of science data processing.

As a conclusion, these needs and skills are obviously crucial in the short term for adequate management of projects to bring the mandatory Quality Assurance support to space, on-ground and undersea projects. Therefore, hiring of 1 to 2 additional engineers are needed between 2017-2022 to fulfil these tasks.

13. Administration

General presentation

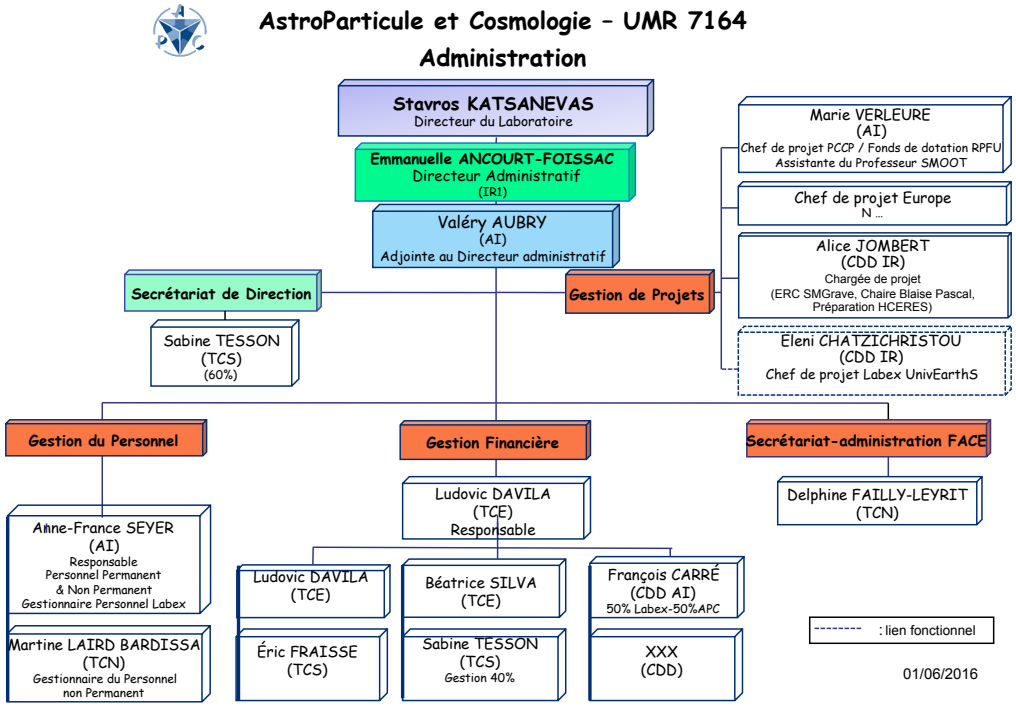


Figure 41. Administration organization chart

The administrative service of the lab gathers 13 officers, under the responsibility of the administrative director, in charge of managing and assisting the research activities. This service manages the funding allocated to the lab by its governing bodies, the CNRS, Paris-Diderot University, CEA and Paris Observatory, as well as the human resources. They also manage associated research structures activities, sometimes hiring project managers to work on projects such as the Labex Univearths, the European innovative training network INFIERI and the Paris Centre for Cosmlogical Physices. Following the creation of the François Arago Centre (FACe) in 2010, part time of a financial officer and an administrator were appointed and dedicated to the centre.

Evolution between 2012-2017. The evolution of the administration service is mainly characterised by its involvement in the project structure adopted since the re-organisation of the lab. The project structure is present in all fields of activity of the lab, for instance: the financial management revolves around a referent physicist, a project manager and a designated administrator. From this year, this organisation has been reinforced with the reallocation of all the spending categories of the lab according to the thematic groups. Henceforth, the person in charge of a thematic group (High Energy Astrophysics, Cosmology, Gravitation, Neutrinos, Theory) has only one designated intermediary for the financial management who is also his contact officer for all projects or contracts stemming from the group theme.

It is worth noting the establishment of a project platform "Labex Univearths" gathering the Labex project manager, recruited by Paris-Diderot University, the HR officer in charge of APC permanent employees, who also manages all recruitment requests on the Labex appropriation before their implementation by the university, and the administrator in charge of the labex appropriations.

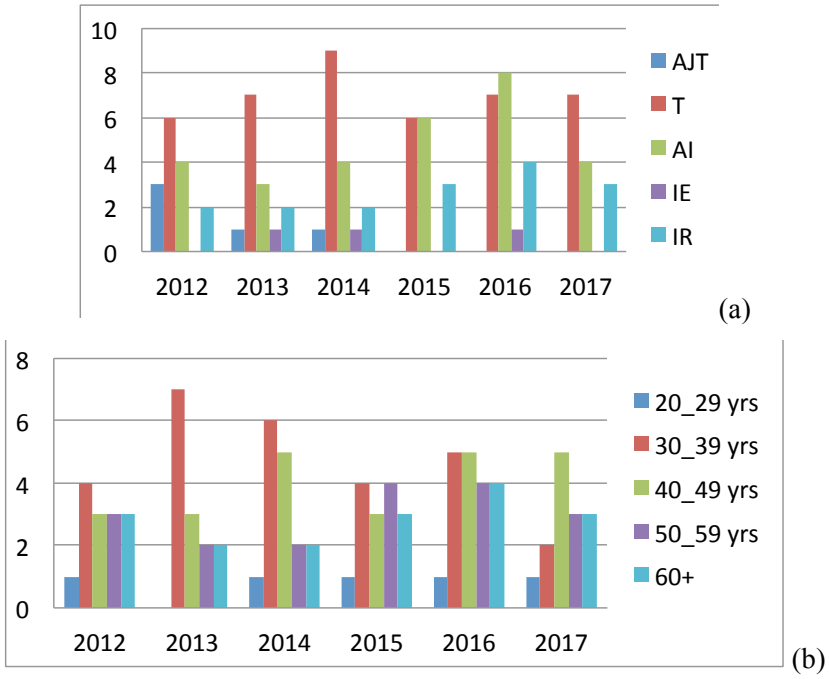


Figure 42. Administration staff evolution by (a) status and (b) age distribution

Financial management. The financial management of APC is carried out by 6 officers whom are not all appointed to this activity on a full-time basis.

Therefore, the "hard core" part of the management is done by 4 officers (ETPT) who are sharing the work for 105 entities. These entities display the matrix organization in thematic groups, services and scientific projects. The APC budget grew from 5,282 € in 2012 to 7,176 M € in 2016. A large part of this increase is due to the increase of external grants (ANR, Europe) and national instances (CNES, Region…). Since the 1st January 2012, the APC lab has been under global delegation of CNRS administration (DGG). Most of its appropriations have been managed using the CNRS management tool (GESLAB). However the PCCP, LabeX management and IdeX USPC activities, funded in part or totally by a Paris Diderot University dotation remains on the university management tool (SIFAC). This double accounting has been a source of many difficulties.

In particular, and for the last two years, through IDEX USPC, funding have been added to the appropriations managed according to the rules and with the tools of the university (IDEX chair of excellence, IDEX appropriations for the foreshadowing of the science hub, USPC funding for the long term hosting of a foreign professor, etc.). The activities resulting from these Paris Diderot University appropriations are carried out by one single officer, from the financial management service, who is on a fixed-term contract.

Thanks to an analysis of these DGGs tentatively implemented by the CNRS and Paris Diderot University, it was decided in 2016 and announced in March 2017 that a framework agreement would be finalised between our two governing bodies in order to redefine the scope of the actions managed by each one of them. If the majority of our appropriations keep falling under the CNRS, exceptions are now to be taken into account, and in particular, the management of the ERC grants, for which the affiliation of the depositary determines the administrative supervision of the management. The effects of these new agreements will have to be assessed alongside their implementation.

Moreover, between 2015 and 2016, the regional division on which the APC administrative services depends on changed from CNRS Paris B to CNRS Paris Villejuif (2015), causing many changes in our financial management tools, and the setting up of the Public Budget and Accounting Management (GBCP) at the CNRS (on the 1st January, 2016). Both works were achieved with a reduced workforce. Lastly, since this year, the CNRS has dematerialised its invoicing. For the time being, this new procedure leads to an important workload for the workflow management

The challenges for the financial management at APC are to maintain a high reactivity and creativity regarding the diversity of the funding sources.

As an exemple of the diversity of sources of funding, we show below the percentage of resources obtained in 2012 and 2016 (excluding permanent and non-permanent CNRS, University and CEA salaries). The "proper ressources" (that is ressources not obtained through the "tutelles") have increased from 72% in 2012 to 91% in 2016 (although this presentation is biased from the fact that in the GBCP the multiannual budget is notified in the first year, so the budget is "forward loaded"). If one includes the salaries of the permanent and non-permanent salaries CNRS agents (Those of CEA and University are not precisely known) these percentages become 30% (of a total of 12 M€) in 2012 to 47% (of a total of 13,7 M€). In the same period, the invoices have increased by 50% and the agent missions by 33%.

Financial management activities

Years	Number of orders	Number of invoices	Number of missions
2012	2627	2884	864
2016	2519	4198	1154

Table 5. Financial management activities in 2012 and 2016

HR management. APC gathers at the 02/06/2017, 194 employees, permanents or non-permanents with various terms.

- 61 permanent researchers and academics
- 49 permanent ITA and BIATSS
- 20 non-permanent researchers
- 19 non-permanent ITA and BIATSS
- 33 PhD candidates
- 2 contracts of apprenticeship (CNRS)
- 10 professors emeritus

Moreover, the lab welcomes each year about 50 funded interns. This has become an activity similar to the recruitment regarding the numerous documents and signatures (educational institution, tutelage university host, rewarding tutelage…) to be collected to allow the internship. Two officers are dedicated to the HR management for the permanent and long-term contracts, and for the non-permanent contracts. Their work consist of following the recruitment procedures, welcoming the new collaborators, helping and advising the staff in their career, competitive exam, time off, leave of absence. These two officers advise and assist in all aspects of HR regulation. The implementation of new tools also concerned the human resources section of the lab.

The CNRS wanting the dematerialisation of the acts, monitoring and analysis of its HR has gradually designed management tools with this in mind. Thus, since 2016, LABINTEL has been replaced by RESEDA. It's a database that allows a true monitoring of its staff. This led to a substantial work for our HR colleagues for rebuilding the census database of the lab staff regardless of their affiliations. The necessary follow-up of the absences and holidays of the whole CNRS staff, especially regarding the European Union's audits, led to set up an absence management tool: AGATE. This monitoring tool is administered and managed by the head of the permanent staff but it is done for all the lab members.

The ITA staff career progression is now carried out on SIRHUS. Career records are fully made online and are validated by all the stakeholders by electronic signature. The follow-up of the whole campaign and the advices to the direction board as well as to the staff are carried out by the administrator in charge of the permanent staff. To comply with university requirements, the lab must maintain a presence database of its staff (DBPRG), with their status record, location and phone contact. This is carried out by the HR part of the APC lab.

The analysis that can be made is that the multiplication of the non-interconnected databases, coming from our governing bodies, causes a repetitive data entry work, with significant risks of forgetting to update one of them, and therefore lead to the loss or distortion of information.

Each year, the lab experiences an average of 100 entries and departures of non-permanent staff. This figure demonstrates, if still needed, the necessary proactive and reactive management carried out by the RH staff of the unit.

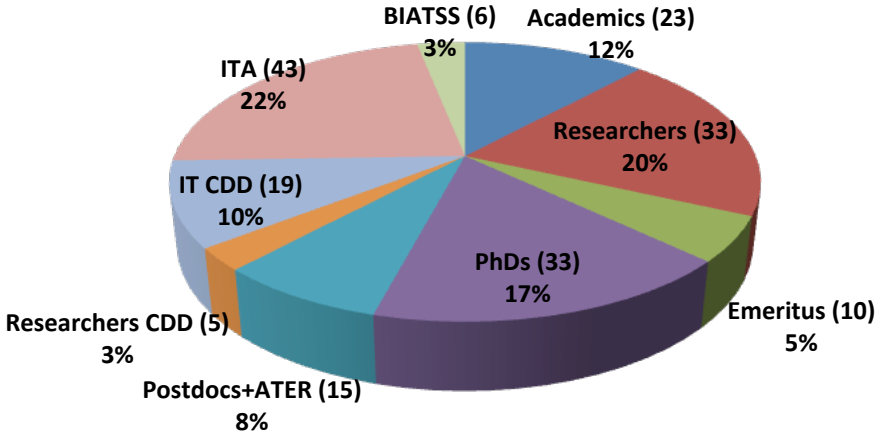


Figure 43. APC laboratory composition (192 persons) – 02/06/2017

In 2017, the administrator in charge of the non-permanent staff will go into retirement. her replacement will be dealt with using non permanent staff with a one-year contract allocated by the CNRS. Our hope is to have a permanent staff in 2018. 2018 could be the year of retirement for the administrator in charge of the permanent staff of the lab.

SWOT analysis

Strengths	Weaknesses
• Organisation of the unit on the basis of the project structure • Professionalisation of the administrative professions. Greater expertise to assist researchers (European project managers, PCCP project manager, designated financial officer…) • Adaptability of the staff to the many changes required by our governing bodies (tools, procedures, organisation)	• Undersized unit, leading to a structural fragility at the departure of one of its member • Increase of the financial mangement activities, and in particular concerning the university (SIFAC tool), with a team of officers trained for the CNRS financial management tool (GESLAB tool) • The overall drop in the number of staff across the civil service forces the units to recruit non permanent employees, which again creates instability within the organisation
Opportunities	**Threats**
• The laboratory is very dynamic. The diversity of its members, the variety of the partnerships, and therefore funding, is an opportunity for staff from the administrative unit, who are constantly called upon to renew their skills and increase their expertise.	• The departures from the administrative unit, an average of one per year, due to staff's mobility or retirement, place a serious risk of loss of skills and expertise when a long time is needed to get them back.

APPENDICES

Appendix 1: Contractual mission statement (not relevant)

Appendix 2: Platforms and Equipments

1) The platform François Arago Center (FACe)

The *François Arago Centre* (FACe)[9] is a project at the APC laboratory and is supported by the IPGP within the Space Campus of the Paris Diderot University. The center was founded in 2010 with the goal to support space-based experiments facing the challenge of data treatment of steadily increasing and complex data sets. The center provides services, such as computing facilities (HPC cluster and storage), data analysis, archiving, and distribution support, access to the heavy-duty computing facilities at CC-IN2P3, and office space to both, ground and space-based projects with strong French involvement. As a competence center, it also provides training and expertise on new technologies (cloud, Big Data). The computing power and data storage volume available at the FACe amounts to 652 cores and 42Tb for the pallelel-computing cluster and close to 80 virtual servers dedicated to space missions and on-ground observatories. All these services rely on a storage capacity of 180Tb.

In the spirit of François Arago, who combined many fields of natural science in his work, enabled science by focusing attention on new technologies and supporting scientific development through communication between many disciplines, we want to serve the scientific community. The aim is to bring together scientists from different fields, data and software engineers, the scientific community and the public in order to best exploit the data provided by today's state-of-the-art experiments.

The FACe is a combined effort of its partners, i.e. the APC laboratory, the French research agency CNRS/IN2P3, the French space agency CNES, the Paris-Diderot University, the IPGP, the CEA/Saclay, the Observatoire de Paris and the Space Campus (http://www.campusspatial-paris.fr/). The center is installed in the Biopark complex on the third floor of the building 13 rue Watt in the 13th arrondissement of Paris, across the street of the APC laboratory and within the open campus of the Paris Diderot University.

As an APC project, the FACe is headed by a project scientist (Cécile Cavet) and a project manager (Michèle Detournay). The scientific projects at the FACe are under the guidance of the project scientist, while the technical and infrastructure aspects are managed by the project manager. The FACe is fully integrated in the organisational structure of the laboratory, i.e. the director of APC is the director of the FACe and the administrative head is the same as at the APC (Emmanuelle Foissac).

The main projects at the FACe in 2017 are Euclid, LISA-Pathfinder, LISA, INTEGRAL, CTA, SVOM, and LabEx UnivEarthS related activities. As an example of support, for the Euclid project, the continuous integration platform is hosted at the FACe and for the LISA project, the future Data Processing Center (DPC) will be designed and hosted by the center.

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[9] More information can be found on the website: http://www.apc.univ-paris7.fr/FACe

2) Millimetric Laboratory

The Millimetric Laboratory, located on the fourth floor of the Condorcet B-Building, is dedicated to the development of cryogenic detectors and detection architectures for the accurate measurement of the Cosmologic Microwave Background (CMB) polarization. Research focuses more specifically on two developments:

- Superconducting detectors arrays (bolometers, KIDs) cooled at very low temperatures (T<300mK)
- Planar superconducting micro-wave components for building advanced detection architectures

These activities are part of the BSD (B-mode Superconducting Detectors) French collaboration, initiated by the APC laboratory, and include also the development of the associated readout electronics. These instruments are tested and validated in the laboratory and are the master pieces of future experiments such as QUBIC.

Skills related with the Millimetric Laboratory include:

- Characterization of mechanical and electronic components (semi-conductors, superconductors) at cryogenic temperatures (from 77K down to 10mK)
- Characterization of low frequency (< 1MHz) and Radio Frequency (RF) (> 10GHz) electronics components at ambient and cryogenic temperatures
- Ultra low noise electronics measurements
- Simulations of RF components
- Photometric characterization of cryogenic detectors

The following equipment provides the tools for all the aforementioned studies:

- A dilution free cryostat with pulse-tube cooler (Oxford Instrument, cooling power of 160µW at 100mK)
- A 300mK ^{4}He/^{3}He cryostat with pulse-tube cooler (Oxford Instrument)
- A 4K cryostat with pulsed-tube cooler (Oxford Instrument)
- A 4K photometer covering a wavelength range from 300µm to 3mm (Infrared Lab)
- A B1500A Semiconductor Device Analyzer (Agilent Technology)
- A 89411A-DC Vector Signal Analyzer (Hewlett Packard)
- Several low-noise amplifiers (Stanford Research System)
- A low-noise Spectrum Analyzer (Stanford Research System)
- A10GHz-350GHz Vector Network Analyzer (ABmm)
- Softwares: CST MWS, Sonnet, Zemax

Contact: Michel Piat, piat@apc.univ-paris7.fr

3) Photodetection Laboratory

The Photodetection Laboratory gather activities on development test and production of photodetection systems for Particle Physics and Astroparticles at the APC laboratory, principally for detectors set-up installed undersea (ANTARES, KM3NeT-ORCA), underground (DOUBLE-CHOOZ, DUNE/WA105) and on-ground (JUNO) or embedded on balloons or satellites (JEM-EUSO). Another possible application is medical imagery. Associated skills are tests and calibrations of photodetectors (PMT, SiPM, APD…), using a patented method to measure the single-electron response, and developments on the associated reading electronics. The Photodetection Laboratory hosts also dedicated instrumentation training sessions for License L3, Master M1 and M2 students.

The equipment of the Photodetection Laboratory includes:

- CAEN NIM (model NIM8301600) and VME (6021/631) crates
- CAEN VME-USB 2.0 Bridge, model V1718
- Hundreds of electronic modules at NIM and VME standard (multi-channels Discriminator, multi-channels TDC and ADC, Translators, Scalers, Logic and Linear Fan-In Fan-Out…)
- CAEN Multi-channels fast amplifiers, models N978 and N979.
- CAEN preamplifiers model A424F

- CAEN Universal Multi-channel Power Supply System 750W, model SY1527LC
- CAEN A1535N cards for SY1527 slots
- CAEN N470 4 channels High Voltage Power Supply
- A TEKTRONIX TDS5104B 4-channels Oscilloscope
- A FESTO 3-axis table
- A NEWPORT Motorized rotation plate, model URS75CC
- A NEWPORT SMC100CC 1-axis controller for CC motor with mounting bracket, USB interface and 80W power supply
- A NEWPORT optical table (200x100 cm^2)
- Optical components including laser and UV diodes, filters, lenses and adapted supports.
- A HORIBA Jobin Yvon technology IHR320 imaging spectrometer and a CCD BI UV, cooled with liquid nitrogen.
- A HORIBA Jobin Yvon technology achromatic adapter for optical fiber.
- 3 black boxes for photodetectors characterization
- A KEITLEY 2010/E low-noise multimeter
- A KEITLEY 6514/E electrometer

Contact: Thomas Patzak, patzak@apc.univ-paris7.fr

4) Optics Laboratory

a. VIRGO cleanroom. The VIRGO cleanroom is dedicated to optical measurements and tests for gravitational wave detectors (Advanced VIRGO experiment), R&D activities for new generation instruments (Laguerre-Gauss modes) and possible applications for geosciences (early earthquakes detection). The technics rely on laser interferometry and metrology. The cleanroom is equipped with:

- Two INNOLAG YAG lasers, model Mephisto 500mW
- A He-Ne laser
- Two optical tables
- A Fullvac 300x500mm^2 cylindrical vacuum vessel
- A ISOWAVE accordable Faraday insulator
- A DSO1024A oscilloscope
- Two new Focus 4004 Electro Optic Modulator
- A PHASICS front-wave analyzer
- A GENTEC XLP12-1S-H2 power detector
- A Beamage Focus II beam profiler
- Six DMK41AUC02 cameras
- Opto-mechanics and optical components
- Software: Zemax

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b. LISA cleanroom. The LISA cleanroom hosts experimental test-benches dedicated for TDI measurements on optical signals, studies on active compensation of optical path-length in the framework of the LISAPathfinder and LISA projects. Another test-bench is mounted for R&D on a seismometer, based on gravitational wave detection technique. The 1GHz REFIMEVE+ signal for high precision time measurement is also available in this room. Furthermore, the room is equipped with:

- A MENLOSYSTEMS comb frequency generator: a laser emits at frequency values separated by a 250MHz interval on a large spectral band (from 1 to 2µm). Each mode or frequency is phase-locked, producing a pulsed emission with a repetition of 250MHz and duration of a few femtoseconds. When stabilized with an external reference, such a device is a high-performance frequency reference for wavelengths between 1 and 2µm. The frequency comb links radiofrequencies with optical frequencies: for instance, when stabilized at 1.5µm, the output signal is converted at 1GHz or 10MHz to be used as reference for other electronic devices.

- A NKT Photonics fiber laser, model Koheras Basik E15 (l = 1.5µm), with active wavelength control and wide-range thermal wavelength tuning.
- A INNOLIGHT Mephisto 500 Nd-YAG laser (l = 1064nm, P=500mW)
- A INNOLIGHT Mephisto 1000 Nd-YAG laser (l = 1064nm, P= 1000mW)
- 3 optical tables: 2 of size 1.5x1.8m^2, 1 of size 1.5x1.5m^2
- A parallepipedic 120x120x40cm^3 vacuum vessel including an optical plate for tests down to a pressure of 0.1mbar. Vacuum is produced by a primary pump and a root pump.
- Optical components: a frequency doubling crystal, lenses, mirrors, Acousto-Optic Modulators (AOM), Electro-Optic Modulators (EOM), motors for optical tuning…
- A AGILENT TECHNOLOGIES 34980A multi-function switch/measure unit
- A AGILENT TECHNOLOGIES 34970A data acquisition switch unit
- Two STANFORD RESEARCH SYSTEMS SR830 DSP lock-in amplifiers
- A TEKTRONIX AFG3102 oscilloscope
- A AGILENT TECHNOLOGIES DSO1024A oscilloscope

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5) Integration and test laboratory

a. Integration and test cleanroom. The integration and test cleanroom is a working space of 50m^2 whose dust rate, temperature and hygrometry are controlled following the ISO 14644 norm. The air cleanness is of ISO 8 level (for 0.5 µm particles) corresponding to a class of 100 000. A badge system manages the access clearance and users must first put adapted protection clothes (gloves, bouffant hats, lab coats, over shoes) before entering the room which includes the following equipment:

- A Kelvintech space simulator of 1m^3 for vacuum and thermal qualifications of devices or instruments for temperatures between -60°C and +120°C for pressure down to 10^{-7}mbar.
- A Labview central acquisition system for temperature, voltage and mechanical stress measurement with 27 channels shared in 10 temperature measurement channels through thermocouples, 4 resistance measurement channels, 10 voltage measurement channels, 3 voltage supply channels: 0 to +20V, -20V to 0V and 0 to +6V.
- A Millipore Ultra-Pure Water distribution system
- A fume hood for components cleaning
- A 3D mechanical measuring machine
- A probe station for electronic components and detectors tests

This cleanroom hosts for instance the assembly and integration of the XGRE detector for TARANIS, tests of silicium detectors for COCOTTE and preparation of SQUIDs for QUBIC.

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b. Low electromagnetic noise room. The low electromagnetic noise room is air-conditioned, equipped with a Faraday cage and thermalization systems providing an environment minimizing the effects of electromagnetic fields and thermal variations, for testing electronic components. The thermal drifts are suppressed by placing components in a thermal air chamber or a thermal bath. The room is installed in the Condorcet building basement to minimize the effects of building vibrations and its dimensions are of 8.3x4.5m^2. This facility allows noise characterization of electronics components especially at low frequency in the frequency range from 0.1mHz to 1Hz.

The room temperature is regulated at a value between 20 and 25°C with accuracy better than 1°C and with a calorific power of 20kW. The floor is made antistatic with copper wires embedded in the coating.

Detailed characteristics of the room equipment are the following:

- A stainless steel Faraday cage (dimensions 3x2.5x2.5 m^3) with a PVC antistatic floor, 4 SMA connectors and a wave guide (144x 25mm) for crossings, airing with a cut at 20GHz, 5 EMC

filters on power supplies (4x32 A and 2x10 A in 220V), 2 grounding points, 2 wave guides (50mm diameter) with a 20GHz cut for passing liquids or gas.
- A 3GHz spectral analyzer
- A 1GHz 4 channels digital oscilloscope
- A data recorder (temperatures…)
- High accuracy power supplies
- A thermal air chamber (560x480x400 mm^3) for adjusting temperature at a value between +5 and +70°C with a stability better than +/-0.1°C and an uniformity in the room better than +/- 0.4°C.
- A thermal bath (150x150x200 mm^3) for adjusting temperature at a value between -45 and +200°C, with a stability of +/-0.01°C, a heating capacity of 3.5kW and a cooling capacity of 0.8kW at 20°C.
- Acquisition systems on PC and measurement devices (multimeters…)

Current use is for the characterization of electronics components of the Warm Front-End Electronics of the X-IFU instrument for ATHENA and tests of a phasemeter for LISA.

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6) Mechanics workshop

The mechanics workshop, located in the Condorcet B-building ground floor, is dedicated to the production and assembling of mechanical components to build mechanical structures for instruments or produce specific test and integration tools. The affected technician is skilled in programming and machining different kind of materials (plastics, metals…) for tight-tolerance parts (held on vise or even vacuum clamping). Examples of achievements are the PEEK components of the XGRE detector for TARANIS, the optical mounts for some of the VIRGO mirrors/lens or mechanical pieces for the mechanical structure of the QUBIC instrument. The equipment of the workshop includes:
- A recent numerical command 3-axis machining center (DMG DMU-70), connected to the University Paris-Diderot computer network to import digital files (drawings) from the design office
- An old numerical command 3-axis milling machine (Hermlé)
- Two conventional milling machines
- A conventional lathe
- A PC with CATIA V CAD software

To supplement the manufacturing capabilities, there is also a 3D-printing machine (FDM with ABS plastic) bought in 2015 (Stratasys Fortus 250mc) connected to a CAD computer (on the second floor).

In some cases, the workshop could also extend its abilities by using other machines (flow waterjet cutting machine) located in a nearby fablab (15min walking)

In addition to these equipements and the handtools for metrological control usually found in a workshop, parts and assembled sub-systems could have their dimensions/positions checked on a programmable high-precision 3D CMM (coordinate measuring machine) in a dedicated room.

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7) Assembly hall

The Assembly hall, located in the Condorcet-B building ground floor hosts AIT (Assembly, Integration, Tests) activities at APC. Build on a 300 m^2 surface, the hall is divided into several areas, separated by grids or removable walls, dedicated to different experiments. A badge system manages the access clearance.

Activities in the hall include test and validation of subsystems (such as photodetectors), high dimension 3D measurement machine (MMT), or complete assembly and test of instrument such as QUBIC.

The hall is equipped with a 4000 kg crane, with a height under hook of 3,4 meters. The access to the internal yard (where deliveries of instruments are made) is made with a 4m-width sliding door. The ceiling height is at least of 2,75 meters.

Other equipment available are a black box for optical studies, a 10 m^3 water tank for testing photodetectors to be operated undersea (*neutrino zone*), and various handling systems.

Two 25 kW heat exchangers are currently being installed in order to cool down the pulse tubes compressors used in cryogenic systems of experiences such as QUBIC.

A small zone ("*atelier de proximité*") is dedicated to small electrical or mechanical works, such as welding of electrical components or drilling.

A schematic plan of the assembly hall is shown on the figure below:

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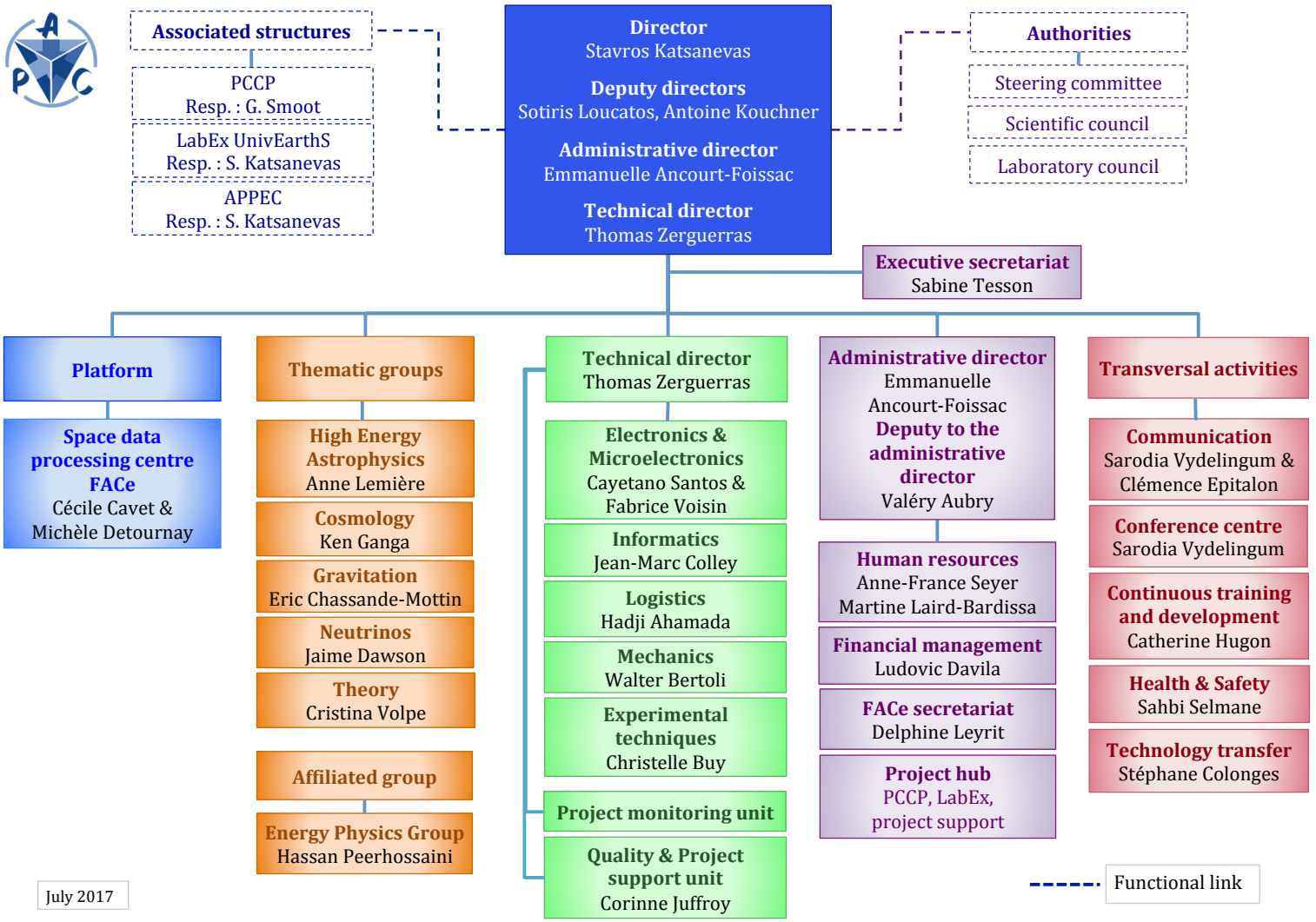
Appendix 3: Organizational chart



AstroParticule et Cosmologoe (UMR 7164) – Organisational chart

Appendix 4: Selected scientific production and activities

A4.1 Products of research

1. Journaux / revues

COSMOLOGY

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9. Bigot-Sazy, M.-A., R. Charlassier, J.-Ch Hamilton, J. Kaplan, et G. Zahariade. 2013. « Self-Calibration: An Efficient Method to Control Systematic Effects in Bolometric Interferometry ». *Astronomy & Astrophysics* 550 (février): A59. doi:10.1051/0004-6361/201220429.
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Autres produits présentés dans des colloques / congrès et des séminaires de recherche

COSMOLOGY

1. M. Bucher: July 2015, "The Planck Mission and Inflation," Marcel Grossman Meeting, Rome Italy
2. K. Ganga: July, 2015; European Physical Society Conference on High Energy Physics 2015; University of Vienna, Austria.
3. M. Piat: International School On AstroParticle Physics 2015, School on Cosmology, 15-25 juin 2015: CMB detectors.
4. R. Stompor: Invited speaker : Workshop and a summer school 'New Light in Cosmology from the CMB', ICTP, Trieste, Italy, July 22 - Aug 2, 2013.

GRAVITATION

1. E. Chassande-Mottin: European Week of Astronomy and Space Science, EWASS 2015, Ténérife.
2. H. Halloin: Conference « Gravitational Wave: New Frontier » on « Interferometry for eLISA », Séoul, Jan. 2013
3. E. Porter: « The detection of binary black holes in Advanced LIGO's first scientific run », TeV Particle Astrophysics, CERN, Switzerland, 2016
4. E. Porter « Exploring the mHz gravitational wave universe with eLISA », Rencontres de Moriond, La Thuile, Italy, 2015

HEA

1. D. Allard: European Cosmic-ray symposium 2014
2. S. Gabici: Acceleration of particles up tp PeV energies at the galactic centre, IAU Symposium 324: New frontiers in black hole astrophysics, September 12th-16th 2016, Ljubljana, Slovenia
3. S. Gabici : Gamma rays and the sources of galactic cosmic rays, TeVPA 2016, September 12th-16th 2016, Geneve, Switzerland
4. S. Gabici: The origin of cosmic rays, 28th Rencontres de Blois, Particle Physics and Cosmology, May 29th-June 3rd 2016, Blois, France
5. A. Goldwurm: Present & Past Activity of the Supermassive Black Hole at the Galactic Centre: recent results, 39th COSPAR Scientific Assembly: Spectral and Timing Properties of Black Holes and Neutron Stars (E1.2), Mysore (India), 13-21 July 2012.
6. P. Laurent: Guest talk at EWASS Meeting, Rome, 2012
7. M. Punch: « Svenska fysikersamfundets fysikdagar 2014 (Swedish Fundamental Physics Days) » : « The future global Cherenkov Telescope Array an observatory for Very High Energy Gamma−Ray Astrophysics »
8. R. Terrier: Talk sollicité au COSPAR 2014 (Moscou), à TeVPa 2014 (Amsterdam), à un colloque sur le centre Galactique (Heidelberg 2012).

NEUTRINO

1. A. Cabrera: 2013 EPS-HEP (Neutrino). Stockholm (Sweden)
2. J. Houque Dawson: 2014 Advances in Neutrino Technology (Los Angeles), invited speaker, Organic Liquid TPCs
3. H. De Kerret: Guest speaker at the Neutrino 2014 conference, Boston (2014)

4. D. Franco: Talk at 28th Rencontres de Blois on Particle Physics and Cosmology (Blois): "Overview of liquid noble dark matter experiments", June 2016.
5. D. Franco: Talk at Rencontres de Moriond (EW Interactions and Unified Theories): "First results from DarkSide-50", Mar 2015.
6. D. Franco: Talk at NOW 2012 (Otranto): "Results from Borexino", September 2012.
7. T. Lasserre: Invited talk on sterile neutrinos and Dark Matter at NOW 2016 workshop, Otranto, September 2016
8. A. Tonazzo: "WA105: a large-scale demonstrator of the Liquid Argon double phase TPC", Topics in Astrophysics and Underground Physics TAUP2015, Torino (Italy), 7-11 septembre 2015 [invitation par la Collaboration]
9. A. Tonazzo : "Statistical issues in future neutrino oscillation experiments", European Physical Society Conference EPS2015, Vienna, 22-29 juillet 2015 [invitation personnelle]
10. V. Van Elewyck [for the ANTARES & KM3NeT Collaborations], ANTARES, KM3NeT/ORCA: Astronomy and Fundamental Physics in the Abysses, NNN2014 : 15th Next Generation Nucleon decay and Neutrino detectors, Paris (France), 4 – 6/11/2014
11. V. Van Elewyck [for the KM3NeT Collaboration], KM3NeT: neutrino astronomy and oscillation research in the Mediterranean Sea, TeV Particle Astrophysics (TeVPA 2015), Kashiwa (Japan), 26 – 30/10/2015

THEORY

1. E. Kiritsis: "Scaling laws for the AC conductivity, from holography", 11th International Conference on Materials and Mechanisms of Superconductivity Geneva, Switzerland, August 2015.
2. N. Deruelle: “Models of gravity”, Bremen University, March 2012.
3. J. Serreau: “Nonperturbative infrared dynamics of interacting scalar fields in de Sitter space”, 7th International Conference on the Exact Renormalization Group (ERG) 2014, Lefkada, Greece, Sep. 22 - 26, 2014.
   D. Langlois: "A unifying description of dark energy", TEXAS Symposium on Relativistic Astrophysics, Geneva, 13-18 Dec. 2015 (Invited plenary talk)
4. C. Volpe, "Neutrino flavour transformation and supernovae", CIPANP2012, 29 May-3 June, Floride (Invited plenary talk)
5. C. Caprini: "Probing the expansion of the universe using GW standard sirens at LISA”, TeV Particle Astrophysics, CERN, Switzerland, 2016

ENERGY PHYSICS

1. R. Santiago Kern, J.P. Thermeau, K.J. Gajewski, L. Hermansson, J. Eriksson, P. Bujard, T. Junquera, F. Dieudegard, R. Ruber “The GERSEMI Vertical Cryostat at FRIEA”. IIR Cryogenics 2017 (Dresden, Allemagne), 2017

TECHNICAL SERVICES

1. D. Prêle, Détecteurs millimétrique, 10 ième journées de Cryogénie et de Supraconductivité, June 5 - 8 2012, Aussois, France.
2. D. Prêle, Les détecteurs TES: principes et technologie, Cours, 7ième école Détection de Rayonnement à Très Basse Température – DRTBT 2012, May. 21 - 25 2012, La Londe Les Maures, France.
3. D. Prêle, Semiconductor devices for cryogenic amplification, (Invited talk), 10th InternationalWorkshop on Low Temperature Electronics – WOLTE10, 2013, Oct. 14 - 17 2013, Paris, France.

4. Développements instrumentaux et méthodologiques

Prototypes et démonstrateurs

R&D

HEA

1. P. Laurent: Development of an X / gamma camera prototype based on Silicon track detectors (DSSD), read by low noise ASICs
2. R. Terrier, D. Prêle : Prototype of an SPAD imager in CMOS 350 technology (collaboration D. Pellion du LE2I)
3. M. Punch : Prototype "TiCkS" clock distribution & dating (avec C. Champion, R. Oger, S. Colonges)
4. M. Punch : Prototype « MUTIN » clock distribution & dating (avec B. Courty, C. Boutonnet, C. Champion, S. Colonges)

NEUTRINO

1. A. Cabrera : Conception & Realisation of LiquidO New Neutrino Detection Conception

Plateformes et observatoires

Methodology-Systems

COSMOLOGY

1. J.C. Hamilton: Technologic demonstrator of QUBIC being built at APC in 2017

GRAVITATION

1. H. Halloin: Development of an interferometric démonstrator for LISA : LISA On Table (funded by R&T CNES actions)
2. H. Halloin: Development of an interferometric reading system for planetary seismometers (financing on LabEx UniEarthS funds)

HEA

1. M. Punch: "GATE" scintillator network (with B. Courty, C. Boutonnet, C. Champion, S. Colonges, J-M. Colley)

NEUTRINO

1. Cabrera: Conception & Realisation of the Double Calorimetry Detector Design (JUNO)
2. D. Franco: Development of the ARIS setup for the measurement of the liquid argon (LAr) scintillation and ionization responses to nuclear recoils.
3. T. Lasserre: CeSOX: Responsible for the realization of the antineutrino generator of the CeSOX experiment
4. A. Creusot, V. Van Elewyck: responsibility of the conception and construction of the first Calibration Unit for KM3NeT/ORCA (with M. Lindsey Clark, C. Boutonnet, C. Champion, D. Cobas)
5. J. Dawson, D. Kryn: preparation of the Data Acquisition system for the Double Chooz Near Detector and upgrades for the Far detector.
6. J. Dawson, D.Kryn: responsibility for installation of electronics of Near detector on-site.
7. J. Dawson, co-responsable for the Commissioning of the Double Chooz Near detector and re-commissioning of the Far detector.

TECHNICAL SERVICES

1. P. Prat: Development of a low noise room installed in the buildings of the physics department of the University of Paris 7 (10 rue Alice Domon et Léonie Duquet).

5. Produits et outils informatiques

Logiciels

Simulation codes

GRAVITATION

1. A. Petiteau: LISACode, LISA mission simulator (principal developer)

HEA

1. F. Casse, P. Varnière: General relativity version of the MPI-AMRVAC code (1st French GRMHD code)
2. F. Casse, P. Varnière: Development of the first PIC-MHD code with adaptive grid in the world
3. J.N. Capdevielle: Monte Carlo CORSIKA Monte Carlo generator of proton-proton collisions, proton nucleus and other hadrons, adaptation LHC
4. S. Gabici: The crime code (describes the interactions between cosmic rays and molecular environments, namely molecular clouds) available as a webrun at the address: crime.in2p3.fr
5. E. Parizot: Participation in the development of numerical codes (by Denis Allard, APC) for the acceleration of ultra-high-energy particles in transrelativistic internal shocks of gamma-ray bursts
6. E. Parizot: Participation in the development of numerical codes (by Denis Allard, APC) for the propagation of ultrahigh energy cosmic rays (RCUHE) in the universe (energy losses, nuclear interactions / transmutations, magnetic deflections)
7. R. Terrier: Xspec model obtained by a code MC and an analytical calculation of the transfer of X radiation in a cloud: https://zenodo.org/record/60229#.WJCT6jZj7OQ

NEUTRINO

1. D. Franco: Monte Carlo chain for the DarkSide experiment
2. J. Coelho: OscProb simulator of neutrino propagation and oscillation in matter (used in various neutrino experiments) www.apc.univ-paris7.fr/Downloads/antares/Joao/OscProb_v2.0.1.tar.gz
3. S. Bourret, : Swim, a package for neutrino oscillation analyses with KM3NeT/ORCA

Analysis codes

COSMOLOGY

1. C. Rosset: Healpy (https://github.com/healpy/healpy)
2. N. Busca: public package for Lyman-alpha cosmology analysis (github.com/igmhub/pyLyA)

GRAVITATION

1. E. Chassande-Mottin: Time-frequency toobox, http://tftb.nongnu.org
2. J. Errard: CMB4cast (Errard et al 2016)
3. J. Errard: xForecast (Stompor et al 2016)

HEA

1. R. Terrier: Participation in the development of gammapy : https://github.com/gammapy
2. P. Varnière:
   - Creation of an XSPEC model which model disks with non-axisymmetric and non-monotonic structure
   - Creation of module for discs with non-axisymmetric and non-monotonic structure in GYOTO code of Ray-tracing of the observatory of Paris

NEUTRINO

1. D. Franco: Bayesian statistical analysis based on toy Monte Carlo and an extended unbinned likelihood to evaluate the neutrino mass hierarchy discrimination power of large neutrino detectors

Pipelines

HEA

1. B. Khélifi: CTA: Proposal Handling Plateform – Demonstrator built, realization ofcomplete prototype in progress
2. M. Punch, A. Djannati-Ataï: Participation in the development of CTApipe : https://github.com/cta-observatory/ctapipe
3. A. Djannati-Ataï, B. Khélifi, S. Pita, A. Lemière, R. Terrier: Developement of Hap-Fr pipeline for H.E.S.S.

Outils d'aide à la décision

TECHNICAL SERVICES

1. C. Juffroy: Participation to the development of the indicators base of the laboratory, which allows a better visibility of human resources working in projects.

6. Brevets, licences et déclarations d'invention

HEA

1. Détecteur de traces de particules ionisantes FR1352626 - 2013-03-25 de F. Lebrun, R. Terrier, C. Olivetto, P. Laurent and E. Bréelle http://bases-brevets.inpi.fr/fr/document/WO2014154556.html

7. Rapports d'expertises techniques, produits des instances de normalisation

1. Y. Giraud-Héraud: Participation in the writing of the report of the inter-agency working group CNES, CEA, INSU, IN2P3, Labex FOCUS. Millimeter-submillimeter detection roadmap (May 26, 2015)
2. A. Petiteau: Contribution to the report of the Gravitational Observatory Advisory Team (ESA)

8. Produits des activités didactiques

Ouvrages

E-learning, moocs, cours multimedia, etc.

MOOCs

GRAVITATION

1. MOOC *Gravity !* of P. Binétruy and G. Smoot with the participation of M. Barsuglia, J. Errard, K. Ganga, H. Halloin, P. Laurent, G. Patanchon, A. Petiteau, M. Piat, E. Porter
2. Passeport des deux infinis of J.L. Robert with the participation of E. Chassande-Mottin
3. MOOC Peser l'Univers of Observatoire de Paris with the participation of E. Chassande-Mottin

NEUTRINO

1. MOOC associated to Ecole Polytechnique and Université Paris-Saclay with the participation of T. Lasserre

THEORY

1. MOOC Histoire des sciences : une introduction de l'université de Montpellier with the participation of M. Lachièze-Rey

E-learning/Cours multimedia

COSMOLOGY

1. Virtual Institute of Astroparticle physics (VIA) de M. Khlopov avec la participation de D. Semikoz

HEA

1. Two video « Youtube » channels of E. Parizot since 2015:
   - A channel for students with videos from my courses: http://tinyurl.com/playlists-ep
   - A channel of popularization of Physics for a wider audience: http://tinyurl.com/etdorion

THEORY

1. Philosophie et Science: 2012 - 2015 les mardis de la philo, M. Lachièze-Rey (https://lesmardisdelaphilo.com/)

Demonstrators

COSMOLOGY

1. PW @ APC demonstration project, which aims to reconstruct the historical experience of Penzias and Wilson who first detected the cosmic diffuse background in 1964, with the participation of J. Errard

Other

GRAVITATION

1. H. Halloin: Gravitational Wave Detection Course at ISAE SUPAERO (2013) and Ecole de Mines de Nantes (2017)
2. E. Porter: Lecture on « Building and detecting black holes » - Cosmo in the Med, Malta 2014. Conference for secondary school students

NEUTRINO

1. Neutrino tomography: Experiments 17/07/2016 – Cours invité à la International School of AstroParticle Physics (ISAPP) Summer institute "Using particle physics to understand and image the Earth", L'Aquila (Italy)
2. Les télescopes à neutrinos ANTARES et KM3NeT 24/10/2016 – Conférence invitée à l'Ecole d'Automne du LabEx UnivEarthS, Aci Trezza (Italie)

THEORY

1. N. Deruelle: "Relativité Générale", Notes de Cours de DEA de Physique théorique, ENS, 1996- 2014

TECHNICAL SERVICES

1. C. Juffroy: Organizer of 3 National actions of training in Product Assurance.

2. S. Colonges: Electricity and electronic training courses in University Denis Diderot for Energy Physics professional license and master.
3. D. Prêle:
   - Lecture “Advanced Electronic Systems” and coordinator of the «electronic module» of the master SPACE & AERONAUTICS in the University of Science and Technology of Hanoi – USTH (https://cel.archives-ouvertes.fr/cel-00843641v5)
   - Lecture “Noise in electronic” – EIDD Paris Diderot University

9. Produits destinés au grand public

Émissions radio, TV, presse écrite

1. « La tête au carré » radio program of France Inter with the participation of D. Franco, E. Chassande-Mottin, D. Vignaud

COSMOLOGY

1. N. Busca: Scientific advisor for the short animation “Teorías/Theories” by Lilian Vazquez (supported by “Animation Artists in Residence”, Tokyo 2016)

GRAVITATION

1. A. Petiteau:
   - Interview with France Inter on the first results of LISAPathfinder
   - First results of LISAPathfinder: Le Monde, AFP, Le Figaro, les Echos, le Parisien
2. M. Barsuglia:
   - Podcast on the first detection of gravitational waves, Ciel & Espace, 2016
   - Conference at the Science Festival, Genoa Italy – Oct 2014
   - One-off courses in astronomy and introduction to science in elementary school (2015 and 2016)
3. E. Chassande-Mottin:
   - Press conference "Announcement of the first detection of gravitational waves" held at the CNRS headquarters in the presence of the Secretary of State for Higher Education and Research and the President of the CNRS. 11 February 2016
   - Interviews for 20 minutes, Le Monde, La Croix, Ciel et Espace

HEA

1. Radio program around the on RFI : «pourquoi le neutrino ?» (coupled with a mainstream seminar at the Musée des arts et métiers) with the participation of D. Allard
2. E. Parizot: examples of interventions in the media:
   - Weekly magazine « Le Point »: http://www.lepoint.fr/astronomie/le-soleil-a-rendez-vous-avec-mercure-08-05-2016-2037746_1925.php
   - L’Obs (Le Plus): http://leplus.nouvelobs.com/contribution/1227347-super-tempete-solaire-de-2012-nous-avons-echappe-de-peu-a-un-bouleversement-majeur.html
   - France TV info : http://www.francetvinfo.fr/meteo/climat/video-a-quoi-ressemblerait-paris-en-cas-de-mini-episode-d-ere-glaciaire_2034143.html
   - Le Point : http://www.lepoint.fr/science/la-chasse-aux-rayons-cosmiques-27-10-2014-1876012_25.php#xtmc=etienne-parizot&xtnp=1&xtcr=6

NEUTRINO

1. Interview France Culture with the participation of F. Vannucci

THEORY

1. N. Deruelle: End of 2015 beginning of 2016, participation in radio programs (RFI, France Culture twice, France Inter) on the 100 years of the RG and around my book “De Pythagore à Einstein”.
2. M. Lachièze-Rey:
   - Radio programs: http://marclrey.free.fr/Media/MediaMLR.html#RADIO
   - TV, newspaper: http://marclrey.free.fr/pub/pubVULG.html

Produits de vulgarisation : articles, interviews, éditions, vidéos, etc.

COSMOLOGY

1. M. Bucher:
   - In search of primordial gravitational waves from the Big Bang: the aftermath of BICEP2, M. Bucher,

Physics Comment: A South African Physics Magazine Vol. 6 Issue 3 & 4, November 2015, page 2
- M. Bucher, "Is the universe a sponge?," Physics World, 21 (November 2016) 50

2. M. Piat:
   - Live from the Big Bang on the roof of the Palais, interview and PW experience on the roof of the Palais de la Découverte for the magazine of the Palais de la découverte n ° 379, March-April 2012.
   - In pursuit of the "cosmic wave", interview for an article of the special issue Le Monde, The Einstein revolution, July 2015
   - Products of popularisation: articles, interviews, editions, videos, etc.

GRAVITATION

1. H. Halloin: Contribution article in Sciences et Avenir on LISA Pathfinder, January 2016
2. A. Petiteau: Article on LISA and LISAPathfinder in the magazine « La Recherche »
3. E. Plagnol :
   - Lisa Pathfinder : Article in the journal CNRS/Liberation (june 10th, 2016)
   - The gravitational waves seen from space in "La Recherche"
4. E. Porter: Ciel et Espace (2016)

HEA

1. P. Laurent: participation in an Internet video simulating the fall of a space capsule into the supergiant black hole in the center of the Milky Way: "Bons baisers de Sagittarius A*": https://www.youtube.com/watch?v=wE8HGFg8ClA
2. S. Loucatos: Popularisation article in the German magazine Helmholtz Alliance for Astroparticle Physics (HAP)

NEUTRINO

1. A. Cabrera:
   - L'épopée des neutrinos. CNRS divulgation article in honor to the Neutrino Oscillation Discovery Nobel Prize 2015 With Hervé de Kerret. Paris (France) - 15th October 2015
   - JUNO ou la physique de neutrino : l'IN2P3 aux avant-postes. Article Issue 20, pp 30-32 @ the Embassy of France in Beijing (China)
3. S. Katsanevas:
   - Chapter au « Moment Grec », Editions du Regard, about art and science in Greece
   - "Une procession cosmique", opening essay in the book describing "Transhumances" a flagship project of Marseille Capitale Culturelle Européenne 2013. Published in Actes Sud.
   - "Fluctuat nec mergitur" essay on Linguistics and Cosmology, Mélanges for the linguist C. Clairis, Harmattan, 2014
4. A. Kouchner:
   - Scientific book reader on neutrinos (Author: Juan Antonio Caballero - published February 8, 2016) in the collection Cosmology of the Le Monde newspaper
   - Article published in "Pour La Science", February 2016. A neutrino telescope in the Mediterranean Sea
   - Interview for « Sciences et Avenir » (A. Khalatbari). 25 nov. 201. Cosmic neutrinos trapped for the first time
   - Interview for « La Recherche» (J. Bourdet). N° 484, February 2014
5. T. Patzak:
   - Movie about LAGUNA-LBNO online, Paris Diderot: http://www.univ-paris diderot.fr/sc/site.php?bc=recherche&np=pageActu&ref=4417
   - « La saga des neutrinos », published in Astronomie, N° 56, December 2012.

THEORY

1. M. Lachièze-Rey: 10 articles
2. J. Serreau: 1 article to Elementaire

Produits de médiation scientifique

1. Fête de la science with the participation of M. Barsuglia, J. Errard, H. Halloin, A. Lemière, E. Porter, M. Punch, A. Tonazzo

COSMOLOGY

1. K. Ganga: Participation to the CERN « Origins 2013 » media outreach program. See http://cds.cern.ch/record/1604427
2. M. Piat:

- The planets and the solar system, talk in a class of CM1, Ecole Boulard Paris, 22 April 2013.
- The Universe: structure and evolution, talk in a class of CM1, Ecole Boulard Paris, 4 July 2013.
- Evolution of the instrumentation for the observation of the CMB: from Penzias and Wilson to the measurement of polarized anisotropies, SAF, Paris, 15 mars 2014.

GRAVITATION

1. E. Chassande-Mottin:
   - Conference at the Science Festival, Genoa Italy – Oct 2014
   - Participation in the organization of the Night of the gravitational waves – March 2017
2. H. Halloin: Mainstream presentations for « Un chercheur, une manip » at Palais de la Découverte on the theme « La Relativité Générale en Action », February-March 2016
3. A. Petiteau:
   - Animations at the « Palais de la découverte » in the stand « un chercheur, une manip » on the subject « la relativité générale en action »
   - Lecture on gravitational waves at the open doors of the radio astronomical observatory of Nançay in 2015
   - Conference as part of my small academy campaign in Nonards (Corrèze), 2013

HEA

1. A. Lemière:
   - Project "Ballons Cosmiques": 2012-2013. Université P7 / APC/CNRS/CNES
     Coaching of seven high school students during one year: building a detector, launching a ballon, analysing data and presenting results.
   - How to teach high energy astrophysics in high school: Palais de la découvert (Mai 2013) Université Paris 7
2. E. Parizot:
   - Intervention at the TEDx conference (Paris 2011): http://tinyurl.com/tedx-ep
   - Invited to give the annual popularisation conference at the Dublin Institute for Advanced Studies en 2014 (au Trinity College, Dublin) (https://www.tcd.ie/provost/addresses/2014-11-13_DIAS.php https://www.dias.ie/2014/11/05/dias-scpspl2014/)
3. Bar des Sciences with the participation of M. Punch
4. A. Djannati-Ataï: Organization and hosting the « Neuit des Etoiles » (2012-), Perreuse, Treigny town, Yonne

NEUTRINO

1. S. Katsanevas:
   - Particiation to LabOrigins presentation “Du Mythe à la Science”, organised for SFP, July 2017-07-24
   - Lecture at the Beaux Arts for art and science (2017)
   - Member of the jury for the call for projects at the interface between art and science of the Foundation Daniel and Nina Carasso “Composer les savoirs pour mieux comprendre les enjeux du monde contemporain » (October 2015)
   - “Commanditaire”, together with Pierre Binétruy, of the work of art “Squaring the Circle” by Attila Csorgo to celebrate the 100 years of Cosmic Rays, financed by the Fondation de France in the framework of the program “Nouveaux commanditaires”. The work was first exposed in the Museum of Modern Art “Palais de Tokyo”, Paris and permanently exposed since June 2014 in the premises of the APC Laboratory.
   - Member (2012-2014) of the Scientific Council of HUMA-NUM large infrastructure of CNRS funding the digitalisation of documents of the humanities
   - “Scales of Time” presentation at the festival of Science and Philosophy, Foligno, 2014
2. A. Kouchner: Mainstream conference at Lions Club Paris Concorde, Paris, 26 March 2015. The new messengers of the Universe
3. T. Patzak: Conference « Le neutrino, au delà des frontières de nos connaissances », Treize Minutes de Paris Diderot : www.treizeminutes.fr
4. A. Tonazzo: Setting up a project with the Lycée de Givet, for the national scientific competition "C.Génial". Theme: measuring cosmic muons with Double Chooz detectors
5. F. Vannucci: Conferences on radioactivity at Insa and the IUT of Blois, June 2017
6. D. Vignaud: 02.05.2015 - Corse (Festival des Origines - Parc Galéa) - Journey to the heart of the Sun, the origin of life on Earth

THEORY

1. N. Deruelle:
   - Conference "La Gravitacion", Valparaiso, Adolfo Ibanez University, March 2013
   - Conferences "Cent ans de Relativité" in Saclay, at the LPTHE Paris 6, University of Nancy, end 2015, early 2016
2. C. Volpe: Interactive 2-hour Interventions in Elementary Schools:

- "How do "die" supernovae?" in two classes of CM2 (2017);
- "How do the stars live?" in two classes of CM1 (2016);
- "The small enigma of solar neutrinos" in two classes of CE2 (2015).

Débats science et société

GRAVITATION

1. E. Chassande-Mottin: Conference debate « Ondes gravitationnelles et coalescence de trous noirs » at Académie de sciences, Apr 2016

HEA

1. A. Lemière: Science and History: Seminar/debate on physics in the century of lights May 2014 and 2015 Université Paris 7

NEUTRINO

1. S. Katsanevas: "Il sentimento del Bosone, come le passioni attraversano la ricerca scientifica", public discussion with INFN president F. Ferroni, at the International festival of Philosophy, 2013 Modena.
2. A. Tonazzo: Public Lecture on "Neutrinos" in the lecture series "Physics meets the city", Rome, 12 May 2013.

THEORY

1. M. Lachièze-Rey: Conferences, debates and seminars: http://marclrey.free.fr/Media/ConfSeminairesMLR.html

10. Autres produits propres à une discipline

Responsabilités dans des projets internationaux

COSMOLOGY

1. **BOSS/eBOSS/DESI**
   - Lead Scientist of the French Participation Group to SDSS (E. Aubourg)
   - Member of the collaboration council of SDSS and of the Advisory Council (E. Aubourg)
   - Member of the steering committee of the "After Sloan 3" project (E. Aubourg)
2. **COrE**
   - Science working group coordinator (J. Delabrouille)
3. **Euclid**
   - Responsibility for the scientific coordination of the French Science Data Centre at CC-IN2P3 (Ken Ganga)
   - Co-chair of the SDC/OU-ext Organisation Unit (Eric Aubourg)
   - Co-chair of the Cluster Science Working Group (J. Bartlett)
   - One of the Legacy coordinators (J. Bartlett)
   - Co-chair of the SDC/OU-ext Organisation Unit (Eric Aubourg)
4. **LSST**
   - Software Architect for the Camera Control System (E. Aubourg)
   - Founding member of the French LSST board (J. Bartlett)
5. **Planck**
   - Coordinator of the IN2P3 Planck team (Y. Giraud-Héraud)
   - PRAC coordinator: Pipeline Running and Checking (K. Ganga)
   - HFI lead of Working Group 2 « component separation working group » (J. Delabrouille, J.F. Cardoso)
   - Explanatory Supplement co-oordinator (K. Ganga)
   - Lead of the « Planck Sky Model » project, one of the Planck delivery to ESA (J. Delabrouille)
   - Deputy coordinator of the HFI Core Team map-making group (R. Stompor)
   - Project HFI coordinator « Constraints on B-mode polarisation anisotropies » (C. Rosset)
   - Project HFI coordinator « Constraints on Inflationnary models from Planck Combined with astrophysical data sets » (Martin Bucher)
   - Coordinator « Optical/NIR follow-up and validation of Planck clusters » (J. Bartlett)
   - Follow-up program at NOAO (Gemini) for Planck clusters (J. Bartlett)

6. **POLARBEAR:**
   - Coordinator of the French involvement in POLARBEAR and principal coordinator on grants supporting POLARBEAR work in France (R. Stompor)
   - Member of scientific decision-making body of the experiment and a co-investigator on the NSF grants, which fund the project (R. Stompor)

7. **QUBIC**
   - Project scientist (J.-C. Hamilton)
   - Members of the Steering Committee (Y. Giraud-Héraud, J.-C. Hamilton, M. Piat)
   - Members of the Operational Panel :
     - Project Manager (L. Grandsire)
     - System Instrument Scientist (M. Piat)
   - Subtasks Architects:
     - Global Mechanical Architect (C. Chapron)
     - Detection Chain Architect (M. Piat)
     - Simulations and Data Analysis Architect (J.-C. Hamilton)

GRAVITATION

1. **LISA/LISAPathFinder**
   - Co-lead of eLISA European consortium, member of the LISA then eLISA science team, member of the ESA GW-TASAT (Gravitational Wave Technological Advisory Science Advisory Team), coordinator of the consortium LISA France (P. Binétruy)
   - PI of LisaPathfinder France (2005-2014: E. Plagnol, 2014-present: A. Petiteau)
   - Member of the LisaPathFinder science working team (E. Plagnol, A. Petiteau)
   - Co-coordinator of « LISA France » (G. Auger)
   - Lead of the CNES R&T « LISA on table » (H. Halloin)
   - Coordinators of the task force appointed by the ESA Science Team for the formulation of the eLISA mission (A. Petiteau and E. Porter)

2. **Virgo**
   - Member of the Virgo Steering Committee (since 2008, M. Barsuglia)
   - Membre du LIGO Program Advisory Committee (PAC), (2012-2014, M. Barsuglia)
   - Co-chair of the EM follow-up program committee (2013-2014, Eric Chassande-Mottin)
   - Co-chair of the Burst group (2014-2016, Eric Chassande-Mottin)
   - Co-chair of the Compact Binary Coalescence (CBC) group for the Advanced LIGO/Virgo collaboration (2016-present, E. Porter)
   - Member of the Data Analysis Council (DAC) for the Advanced LIGO/Virgo collaboration (2016-present, E. Porter)
   - Member of the EGO/Virgo Science and Technology Advisory Committee (STAC), (2010-2015, E. Porter)
   - Member of the EGO/Virgo External Computing Committee (ECC), (2012-2014, E. Porter)
   - Responsible for the exploratory project E3 of the Labex UnivEarthS on "Géophysique et détecteurs d'ondes gravitationnelles" (APC−IPGP collaboration), (since 2011, M. Barsuglia)

3. **LISA**
   - Co-lead of eLISA European consortium, member of the LISA then eLISA science team, member of the ESA GW-TASAT (Gravitational Wave Technological Advisory Science Advisory Team), member of the GOAT (Gravitational Observatory Advisory Team), member of the GWWG (P. Binétruy)
   - Co-PI of LISA, final version accepted by ESA (2016-2017: P. Binétruy; 2017-present: A. Petiteau)
   - Coordinator of « LISA France » (2005-2017: P. Binétruy, G. Auger; 2017-present: C. Caprini, H. Halloin)
   - Lead of the CNES R&T « LISA on table » (H. Halloin)
   - Lead of the LISA-AIVT France (H. Halloin)
   - Lead of the LISA-DPC France (A. Petiteau, M. Le Jeune)
   - Author of the the LISA mission configuration proposal for ESA's Cosmic Vision L3 program (2016-2017, E. Porter)
   - Co-chair of the LISA Cosmology working group (2012-present, C. Caprini)
   - Co-chair of the LISA Data Analysis working group (2012-present, E. Porter)
   - Co-chair of the LISA Science of measurement group (2012-present, H. Halloin)
   - Member of the EGO/Virgo Science and Technology Advisory Committee (STAC), (2010-2015, E. Porter)
   - Member of the EGO/Virgo External Computing Committee (ECC), (2012-2014, E. Porter)

- Author of LISA mission proposal for ESA's Cosmic Vision L2/L3 selection program (2012-2013, E. Porter)
- Authors of the "Gravitational Universe" proposal for ESA's Cosmic Vision L2/L3 selection program (2012-2013, P. Binétruy, C. Caprini, H. Halloin, A. Petiteau, E. Plagnol, E. Porter)
- Authors of the the LISA mission configuration proposal for ESA's Cosmic Vision L3 program (2016-2017, P. Binétruy, C. Caprini, H. Halloin, P. Binétruy, C. Caprini, H. Halloin, J. Martino, A. Petiteau, E. Plagnol, E. Porter)

4. **LAGUERRE**
   - Responsable scientifique du projet ANR « LAGUERRE » (interférométrie avec modes de Laguerre-Gauss pour la détection des ondes gravitationnelles. (2010-2014, M. Barsuglia)

5. **E−GRAAL**
   - Coordinateur scientifique du projet ANR E−GRAAL (Earthquake Gravity Alerts) (depuis 2015, M. Barsuglia)

HEA

1. **HESS, HESS-2, CTA**
   - Deputy-spokesman of the HESS collaboration (M. Punch)
   - Coordination of the HESS AGN working group (M. Punch)
   - Responsibility of the Quality workpackage of CTA (HEA team, M. Punch)
   - Participation to the CTA Science workpackage:
     - Responsibility of the SNR and Molecular Clouds working group (S. Gabici)
     - Responsibility of the reconstruction in the Data working group (A. Djannati-Ataï)
     - Co-responsibility of the advanced analysis methods working group (A. Djannati-Ataï)

2. **INTEGRAL**
   - Co-PI of the IBIS instrument and permanent member of the INTEGRAL User Group (F. Lebrun)
   - Participation to the INTEGRAL User Group (→ 2009) (A. Goldwurm)
   - Member of the Time Allocation Committee (2009-2010, R. Terrier), (2017-2018, A. Goldwurm)

3. **JEM-EUSO and EUSO-Balloon**
   - Initiator of the French participation to the mission and National PI of JEM-EUSO (E. Parizot)
   - Member of the Executive Committee of JEM-EUSO (E. Parizot)
   - Deputy European Coordinator of JEM-EUSO (E. Parizot)
   - International Project manager of the EUSO-Balloon mission (funded by CNES) (G. Prévôt, physicien référent: E. Parizot)
   - Responsible of the calibration workpackage for JEM-EUSO and EUSO-Ballon (P. Gorodetzky)

4. **SVOM/ECLAIRs**
   - Responsible of the coded mask of the main instrument (ECLAIRs) (C. Lachaud)
   - Responsible of the General Program data analysis pipelines of the ECLAIRs instrument for the SVOM French Science Center (A. Goldwurm)

5. **TARANIS/XGRE**
   - Co-PI of the XGRE instrument (F. Lebrun, P. Laurent)
   - Project manager (C. Olivetto, M. Lindsey-Clark)

6. **ATHENA – X-IFU**
   - Responsible for the WFEE sub-system of the X-IFU instrument of the ESA L3 Athena mission (scientific responsible: A. Goldwurm; project manager: D. Prêle)
   - Co-Investigator science – consortium X-IFU (A. Goldwurm)
   - Co-Investigator instrument - consortium X-IFU (D. Prêle)
   - Member of X-IFU science team (A. Goldwurm)
   - Member of the X-IFU instrument engineering team (D. Prêle)
   - One co-chair (P. Laurent) and several members in the Athena Working Groups

7. **ANTARES, KM3Net**
   - Spokesperson (A. Kouchner) ANTARES
   - Responsible of the Astronomy working group (~60 people, largest of the collaboration, divided into 4

subgroups): since 2008 (A. Kouchner)
- Responsible of the data quality (V. van Elewyck)
- Responsible of the working groups “Charge and Energy Calibration” and “Point-like sources” (up to 2008) (A. Kouchner)
- Coordination of the DAQ Front End Electronics Calibration group (since 2006) (A. Kouchner, then B. Baret)
- Member of the Steering Committee of the collaboration (since 2008) (A. Kouchner, B. Barret)
- Member of the collaboration’s Publication Committee (since 2011) (A. Kouchner, B. Barret)
- Working group leader of ORCA in KM3NeT (A. Kouchner)
- Members of the collaboration’s Publication Committees (since 2012) (B. Baret, V. Van Elewyck)
- Members of the collaboration Conference Committees (since 2012) (V. Van Elewyck: chair since Nov 2016)

NEUTRINO

1. **Double Chooz**
   - Spokesperson (H. De Kerret),
   - Three members of the Executive Committee (H. De Kerret, T. Lasserre, A. Cabrera)
   - Co-coordinator of the electronics (J. Dawson),
   - Coordinator of the detector, online and data acquisition (A. Cabrera)
   - Co-coordinator of the European analysis group (A. Cabrera)
   - Head analysis coordinator (T. Lasserre)

2. **DUNE**
   - Collaboration board (T. Patzak)

3. **LAGUNA-LBNO**
   - Head of the Science Board (T.Pazak)
   - Member of the Science Board (A.Tonazzo)

A4.2 Research activities and indices of recognition

1. Activités éditoriales

Participation à des comités éditoriaux (revues, collections)

COSMOLOGY

1. M. Bucher: Guest editor of special thematic issue of Modern Physics Letters A on «Beyond the concordance cosmology» (with Yeinzon Rodríguez) Volume 31, Number 21 (10 July 2016)
2. M. Khlopov:
   - Member of Editorial Boards of International Journal of Modern Physics D, Gravitation and Cosmology, Journal of Astrophysics and Aerospace Technology, Journal of Pure & Applied Physics, Scientific Voyage Journal
   - Lead Guest Editor of special issues “Composite dark matter“ of International Journal of Modern Physics D; “Dark Atoms and Dark Radiation” of Advances in High Energy Physics and "Indirect dark matter searches" and “Particle Dark Matter Candidates” of Modern Physics Letters A

HEA

1. S. Gabici: Member of the editorial board of the International Journal Of Modern Physics D
2. S. Loucatos: Co-editor of the proceedings of the Moriond Electrofaible conference in 2013
3. S. Pita: One of the editors of the IN2P3 conjuncture report carried out in 2014 by Section 01 of the National Committee. Participation in editorial committees within the HESS collaboration

NEUTRINO

1. D. Franco: Guest Editor on Advances in High Energy Physics Special Issue on the Direct Dark Matter Search.
2. T. Patzak: Proceedings editor, 7th Symposium on large TPCs for low-energy rare event detection : Paris, France, December 15-17, 2014, P. Colas (ed.), I. Giomataris (ed.), I. Irastorza (ed.), Th. Patzak (ed.). 2015. Published in J.Phys.Conf.Ser. 650 (2015) no.1.
3. F. Vannucci: Editor for Advances in High Energy Physics, 2016

THEORY

1. N. Deruelle: Editor of JCAP since 2006, of EPL in 2016
3. J.P. Gazeau: Member of the Advisory Panel of the Journal of Physics A: Math. and Theoretical
4. D. Langlois: Participation in editorial committees (magazines, collections):
   - Editorial Board of Classical and Quantum Gravity (since 2011)
   - Editorial Board of the International Journal of Modern Physics (since 2010)
   - Editorial Board of the European Physical Journal C (since 2014)
5. C. Volpe: Editorial board of "Journal of Physics G: Nuclear and Particle Physics" (2008-2017).

ENERGY PHYSICS

1. H. Peerhossaini: Associate Editor of the Journal of Applied Fluid Mechanics

Direction de collections et de séries

COSMOLOGY

1. E. Aubourg: co-manager, co-director of collection at Soleb edition

2. Activités d'évaluation

Responsabilités au sein d'instances d'évaluation

Cf. Évaluation de projets de recherche

Évaluation d'articles et d'ouvrages scientifiques

COSMOLOGY

1. E. Aubourg: évaluations d'articles pour A&A, ApJ
2. J. Bartlett: Referee for A&A, MNRAS, ApJ
3. M. Bucher: referee for Classical & Quantum Gravity, JCAP, Phys Rev Lett, MNRAS, Astrophysical Journal, Physics Letters B, Reviews in Mathematical Physics, General Relativity and Gravitation, International Journal of Modern Physics; also temporary appointment as Deputy Editor of PRL (ad hoc appointment for final judgment in appeal because of recusal of regular subject area editor)
4. N. Busca: Referee for JCAP and Physics Letters B
5. M. Khlopov: Reviewer in Physics Letters B, International Journal of Modern Physics A, International Journal of Modern Physics D, Modern Physics Letters A, Monthly Notes RAS, the Universe
6. M. Piat: Referee for Infrared Physics Technology, Journal of Low Temperature Physics, IEEE Transactions on Terahertz Science and Technology, Astronomy & Astrophysics, Experimental Astronomy

GRAVITATION

1. E. Chassande-Mottin: Rapporteur for Applied and Computational Harmonic Analysis, IEEE Trans. On Signal Processing, Pour la science, Journal of Physics, Signal processing
2. A. Petiteau: Rapporteur for Living Review in Relativity and Classical and Quantum Gravity
3. E. Porter: Referee for Physical Review D, Physical Review Letters, Classical and Quantum Gravity, Journal of Cosmology and Astroparticle Physics, and Pre-referee for Classical and Quantum Gravity
4. M. Barsuglia: Rapporteur for PRD, PRL, Optics Express

HEA

1. F. Casse: referee for ApJ, A&A, Science, European Journal of Physics D
2. S. Gabici: referee for journals (A&A (main journal and letters), American J. of Phys., ApJ (main journal and letters), Astropart. Phys., JCAP, MNRAS (main journal and letters), PASJ, Phys. Rev. D, Phys. Rev. Lett., Plasma Physics and Controlled Fusion, Science, Proc. of Science.)
3. P. Goldoni: Referee for « Monthly Notices of the Royal Astronomical Society »
4. A. Goldwurm: Referee for ApJ, A&A, MNRAS

5. P. Laurent: rapporteur for numereous journals (ApJ, A&A, NIM, Nature Astronomy)
6. E. Parizot: referee for Astroparticle Physics, JCAP (Journal of Cosmology and Astroparticle Physics), Phys. Rev. D, A&A, ApJ, Int. Journ. Modern Physics D, JHEP, New Astronomy, Phys. Rev. Lett.
7. R. Terrier: referee for ApJ and PASJ.
8. P. Varnière: referee for A&A, MNRAS and ApJ
9. A. Djannati-Ataï: referee for A&A, referee : evaluation panel for NRF-South Africa. (2014).
10. F. Lebrun : referee for A&A and ApJ.

NEUTRINO

1. J. Houque Dawson: Rapporteur for Nuclear Instrumentation and Methods
2. D. Franco: Referee for Physical Review Letter, Physical Review Special Topics: Accelerators and Beams, Physical Review D, Physical Review C, Nuclear Instruments and Methods A.
3. A. Kouchner: Rapporteur for Astrophysics and Space Sciences Transactions and the Astrophysical Journal.
4. T. Patzak: Peer Reviewer for NIMA and Journal of Physics G.
5. V. Van Elewyck: Reviewer for Journal of Cosmology and Astroparticle Physics (JCAP)
6. F. Vannucci: Jury of the festival of the two infinites: my thesis in 5 minutes, 2016

THEORY

1. C. Caprini: Referee for Physical Review D, Physical Review Letters, JCAP, MNRAS, Physics Letters B, GRG, IJMP
2. N. Deruelle: Regular referee for JCAP, JHEP, CQG, Phys. Rev D, Phys. Rev. Letters, Living Reviews, GRG, and occasionally for A&A, du Journal de Physique, des Annales de l'IHP, Phys Let B, EPL, Nuovo Cimento, European J.
3. J.P. Gazeau: referee for Journal of Mathematical Physics, Physical Review Letters, Physical Review (A,B,D,E), Annales de l'Institut Henri Poincaré, Annales Henri Poincaré, Journal of Physics A, Applied and Computational Harmonic Analysis, Letters in Mathematical Physics, Physics Letters A, Physics Letters B, Journal of Optics, Canadian Journal of Physics,Reports in Mathematical Physics, Review in Mathematical Physics, European Journal of Physics, European Physics Letters, Proceedings of the Royal Society of London: Mathematical, Physical and Engineering Sciences, Journal of Fourier Analysis and Applications, Journal of Geometry and Physics, International Journal of Theoretical Physics, Journal of Computational Physics, Mathematical Reviews, Physica A, Mathematical Physics, Analysis and Geometry, Annals of Physics (NY), Journal of Cosmology and Astroparticle Physics, Journal of Statistical Physics, Chaos and Fractal, Acta Cristallographica A, Journal of the Optical Society of America B, Signal Image and Video Processing, Foundations of Physics, Symmetry, Axioms, SIGMA, Applied and Computational Harmonic Analysis, Transactions of the American Mathematical Society
4. E. Kiritsis: Refereeing in all the journals of the domain
5. D. Langlois: Referee for Phys. Rev. Lett, Phys Rev D, Phys Lett B, JCAP, JHEP, CQG
6. J. Mourad: Referee for Phys. Lett. B, JHEP, Phys. Rev. D, Found. Phys.
7. D. Semikoz: Refereed articles for the following scientific journals : Science, Physical Revie Letters, Physical Review D, JCAP, JETP, Astroparticle Physics, Astrophysical Journal
8. J. Serreau: referee for Physical Review Letters, Physical Review D, Physics Letters B, Physica A, European Journal of Physics C
9. D. Steer: Referee for physical Review D, Physical Review Letters, Classical and Quantum Gravity, Nuclear physics B, Journal of High Energy Physics, Journal of Cosmology Astroparticle Physics, General Relativity and Gravitation, Mathematical Reviews.
10. C. Volpe: referee for Physical Review Letters, Physical Review C et D, Journal of Physics G, Physics Letters B, JCAP, Acta Physica Polonica, Europhysics Journal C, Astroparticle, Nuclear Physics A.

ENERGY PHYSICS

1. H. Peerhosssaini: referee for the following journals: Journal of Fluid Mechanics, International Journal of Heat and Mass Transfer, International Journal of Heat and Fluid Flow, Experimental Thermal and Fluid Sciences, Experiments in Fluids, Journal de Physique III, ASME Journal of Fluids Engineering, Compte-Rendu de l'Académie des Sciences, International Journal of Thermal Sciences, Applied Thermal Engineering, International Journal of Refrigeration, AIAA Journal, Chemical Engineering and Processing-process intensification, Chemical Engineering Science, European Journal of Mechanics-B, Physics of Fluids

TECHNICAL SERVICES

1. D. Prêle: Reviewer for journals such as: Nuclear Instruments and Methods in Physics Research, IEEE Transactions on Applied Superconductivity, IEEE Transactions On Circuits & Systems, Journal of Low Temperature Physics, Journal of Instrumentation ou encore Cryogenics.

2. T. Zerguerras: Reviewer for Nuclear Instruments and Methods for Physics Research A journal (Science Direct, Elsevier): one manuscript review in 2015, Certificate of Reviewing (June 2015), Certificate of Outstanding Contribution in Reviewing (September 2015)

Évaluation de laboratoires (type HCERES)

COSMOLOGY

1. Y. Giraud-Héraud : Since 2014, expert for the AERES for the assessment of doctoral schools

HEA

1. E. Parizot: Member of the committee of expertise of the AERES for the LUTH laboratory (Dec. 2012)
2. A. Goldwurm: Member of the HCERES team for the evaluation of IRAP (Oct.-Dec. 2014)

NEUTRINO

1. A. Kouchner:
   - Member of conseil scientifique de l'Institut de Physique Nucléaire d'Orsay (2011-2014)
   - Member of comité de pilotage du LabEX UnivEarthS
   - Member of the Scientific Council of the Physics Deparment of University Paris Diderot (since 2012).
2. T. Patzak: Expert for l'AERES. Member of the evaluation committee for the AERES of the LLR, Ecole Polytechnique
3. A. Tonazzo: Member of the evaluation committee HCERES of the laboratory CENBG Bordeaux-Gradignan, Feb. 2015
4. V. Van Elewyck: Member of the scientific Council of UFR de Physique Paris 7 since March 2016

ENERGY PHYSICS

1. Hassan Peerhossaini:
   - Délégué Scientific pour sciences pour l'ingénieur de l'AERES et puis du HCERES
   - Member of « Comité d'Orientation Stratégique » of Aix-Marseille University, France.
   - Member of the Scientific Council of The Wind Engineering, Energy and Environment Research Institute (WindEEE RI), Western University, Canada.

Évaluation de projets de recherche

COSMOLOGY

1. E. Aubourg:
   - Member of the content committee of the Cap Digital pole of excellence
   - Project evaluations for the FNRS, the ANR, the Spanish agency, the European Commission and Vice chair of the physical panel for Marie Curie fellowships (European Commission)
2. J. Bartlett:
   - Member of the groupe ad'hoc « Astrophysique et physique solaire » du CNES, advisory council (1997-2001)
   - Time Allocation Committee XMM-Newton
   - Member of the Groupement d'Experts Thématiques (GET) Physique des deux Infinis (Advisory council in astrophysics and particle physics) de l'UFR de l'Université Physique de Paris Diderot (2008-2012)
   - President of the GET Physique des deux Infinis (2012-2015)
3. M. Bucher: refereeing of research proposals : ANR, France; NSF, United States; Georgian Science Foundation, Georgia; NSERC, Canada; NRF, South Africa; STFC (United Kingdom)
4. K. Ganga: Member of the Collège des personnes qualifiées du conseil d'administration of the CFM Foundation (http://www.fondation-cfm.fr/)
5. Y. Giraud-Héraud:
   - Member of the inter-agency working group CNES, CEA, INSU, IN2P3, Labex FOCUS
   - External expert with the DGRI (Direction Générale de la Recherche et de l'Innovation)
6. J.C. Hamilton:
   - Expert for the Fond National Suisse (2013)
   - Expert for the ANR (2012)
7. M. Khlopov:
   - Member of Presidium of Russian Gravitation Society, Member of Astronomical Council of Russian Academy of Sciences, President of Center for Cosmoparticle physics "Cosmion"
   - 2013 evaluation process as Panel Member for the Exact Sciences and Engineering panel for Portuguese Foundation for Science and Technology (FCT), 2013, 2015 and 2016 evaluation of Portuguese FCT

projects and 2014, 2015, 2016 F.R.S.−FNRS proposals evaluation for Fund for Scientific Research (F.R.S.−FNRS), Belgium

8. M. Piat:
   - Since 2010: Member of the CNES Astrophysics Astronomy group whose objective is to guide the CNES choices for space missions and balloons
   - 2011-2014: Member of the scientific committee R&D of the Labex P2IO.
   - Since 2012: external rapporteur for the research evaluation agency in Italy (ANVUR, Agenzia Nazionale di Valutazione del Sistema Universitario e della Ricerca)
   - Since 2013: Members of the Scientific Committee of the National Cosmology and Galaxies Program (PNCG).
   - Since 2016: Member of the inter-agency group monitoring millimeter and submillimetric detection chains (CNES, IN2P3, INSU, CEA, INSIS, INP)
   - Participation in project review committees: Edelweiss, PILOT, CIDRE
9. R. Stompor: member of the project selection committee of Agence National de la Recherche, CES 31, 2016. External reviewer for: Paris-Saclay Center for Data Science grants (2014); interdisciplinary academic post profiles at Universite Paris-Sud: 'BQR Emploi 2015' (2014); an external expert for Royal Society, UK (2013).

GRAVITATION

1. Halloin:
   - Member of the Council of the CIAS (Centre International d'Ateliers Scientifiques) of the Observatoire de Paris since 2011
   - Member of the Scientific Council of the PN GRAM (Programme National Gravitation, Références, Astronomie et Métrologie) since 2015
2. A. Petiteau: Member of the Scientific Committee of the GPhys specific action of the Observatoire de Paris

HEA

1. D. Allard: Member of the Scientific Council of the National High Energy Program (PNHE)
2. J.N. Capdevielle: Expertise of the PhD thesis for universities of INDIA in 2015-16
3. F. Casse: Referee for the ANR and the FWO
4. S. Gabici: Referee for several funding agencies (Irish research Council, VENI VIDI VICI SCHEME of NWO, CEFIPRA: Indo-French Centre for the Promotion of Advanced Research, DFG Deutsche Forschungsgemeinschaft)
5. A. Goldwurm: Member in the SOC of 8 international conferences or workshops, including: 9th INTEGRAL Workshop, *The first 10 years of INTEGRAL*, 15-19/10/2012, BNF, Paris, France (Chairman du LOC et membre du comité scientifique) and Event 1.2 of the 40th COSPAR Scientific Assembly: *New Broadband perspectives in Galatic Center*, Moscow, Russia, 3-4 August 2014 (organisateur scientifique principale).
6. B. Khélifi: Within the Action Fédératrice « CTA » of the Observatoire de Paris, member of the evaluation committee since 2014 of the research projects submitted during the request for proposals
7. P. Laurent: Expert for the programme H2020-MSCA-IF
8. A. Lemière:
   - Member of the scientific Council of UFR de Physique Paris 7 since March 2016.
   - Member of proposal review process for the CHANDRA satellite : June 2013. Group: SNRs, SN, Pulsars and PWNe
9. S. Loucatos:
   - Since 2012, member of the Scientific Council of the National Laboratory of Gran Sasso, Italy.
   - Chair of the jury for post-doctoral scholarships from the GSSI institute, L'Aquila, Italy,
   - Expert evaluator for the FNRS (Belgium),
   - Expert evaluator for the labex Enigmass
10. E. Parizot, expert for: the ANR: solicitations for 7 files (including 4 that I agreed to appraise), the European Research Council (ERC) : Sollicitation for 3 files : Consolidator Grante (2014) ; ERC Starting Grant (2014), ERC Advanced Grant (2016), the SNSF (Swiss National Science Foundation), the DESR of the Région Pays de la Loire (projet EXTASIS), of European tenders (FP6 and Marie Curie grant)
11. S. Pita, evaluation of research projects: 8 years of experience (2008-2016) in the evaluation of the activity of the permanent researchers of the IN2P3 and of the candidature files for the CNRS entrance examinations, as a member of the section 03 and 01 of the National Committee.
12. M. Punch:
   - External member of the R&D committee of the LabEx P2IO (Physics of the Two Infinities & Origins) 2011 - 2013
   - Project review ANR (request for high level researcher) August 2015.
13. R. Terrier: Chairman of the Scientific Council of the National High Energy Program
14. P. Varnière: Evaluation of research projects: reviewer for NASA and NSF

NEUTRINO

1. A. Cabrera:
   - 2012-2014: ANGRA Project. CBPF, Rio de Janeiro, Brasil.
   - 2015 (International Reviewer SNO+) NSERC International Review Committee (Canada)
2. D. Franco: Scientific expert for ANEP (Agencia Nacional de Evaluación y Prospectiva), Spain, for the dark matter panel
3. S. Katsanevas:
   - ESEK Greek National Council for Research and Innovation (2016-2018)
   - INC International Neutrino Committee, the Long-Baseline Neutrino Facility (LBNF) infrastructure
   - ESFRI landscape subgroup on astronomy and astrophysics
   - ECFA European Committee for Future Accelerators
   - CERN council for the strategy sessions and strategy group
   - Fisica de Particulas et Aceleradores (FPA/MINECO), Spain (2015)
   - FLARE Swiss National Science Foundation (2015)
   - Canada Foundation for Innovation SNOLAB mid-term review (2014)
   - Roadmap for Large Infrastructures (Greek General Secretariat) (2013)
   - National Science Foundation (NSF) ICECUBE review (2013,2015)
   - Evaluation for European Research Council (ERC), Netherlands Organisation for Scientific research (NWO), Royal Swedish Academy of Sciences (KV), Suisse National Foundation (SNF), Belgian national research agencies (FNS and FWO), Italian Ministry for University and Research (MIUR, PRIN), Spanish Ministry of Science (MINECO), Instituto Nationale di Fisica Nucleare (INFN), Chinese Academy of Science (CAS), Ministry of Education, Youth and Sports of the Czech Republic.
4. A. Kouchner:
   - Member of the Scientific Council of DIM ACAV + (region IdF)
   - Scientific expert for the FNRS (Belgium)
   - 2011-2015 : Elected deputy member to the National Council of Universities, section 29.
   - Member of the Scientific Council of the Programme Nationale Hautes Energies (PNHE).
5. T. Lasserre: Expertise for large Czech infrastructures (neutrino physics at CERN and Fermilab)
6. T. Patzak: Expert for the Czech Academy of Sciences, Science and Technology Council (STFC), UK, Deutsche Forschungsgemeinschaft (DFG), Germany
7. A. Tonazzo: Project evaluator for the Czech Science Foundation (2015)
8. V. Van Elewyck: External scientific expert for FWO (Belgium)
9. F. Vannucci:
   - Board of Directors of the Société Philomathique (founded in 1788)
   - Jury of the festival of the two infinites: my thesis in 5 minutes, 2016

THEORY

1. P. Binétruy:
   - member of the DOE Review of the Cosmic Frontier Program (Washington, USA) in 2013
   - member of the review board of the DFG Collaborative Research Centre TRR33 (Bonn, Germany) in 2013
   - 2010-2017: Member of the Physical Sciences Working Group (PSWG) of ESA
   - 2011-2014 : Member of the Science Program Committee of the SLAC National Laboratory (Stanford, USA)
   - 2012-2015 : Member of the European Space Sciences Committee of the European Science Foundation
   - 2012-2015 : Member of the International Evaluation Committee (CVI) of INFN (Italy)
   - 2012-2013 : Member of the Technology Activities Science Advisory Team for a Gravitational Waves mission (GW- TASAT) of ESA
   - 2012-2017: Member of the eLISA Consortium Board
   - 2013-2017: Member of the Scientific Advisory Committee of ApPEC (Astrparticle Physics European Consortium)
   - 2014-2017 : scientific secretary of the AstroParticle Physics International Committee of IUPAP
   - 2014-2016 : member of the Gravitational Observatory Advisory Team of ESA
2. C. Caprini:
   - Evaluation of projects for the Labex P2IO postdoc tender
   - Member of the Scientific Council of the GRAM National Program
3. N. Deruelle:
   - Fondecyt (Chili), (external reviewer for proposals submitted to the Regular Research Funding Competition) regularly since 2009
   - MIUR (Italian Ministry for Education University and Research); evaluation procedure as a referee for

assignment of funds for university research programs, June 2012, 2013, 2014
- Romanian Ministry of Research, July 2012
- FNRS (Fonds de la Recherche Scientifique, Belgique) Apr. 2012, Sept. 2013, 2014, Mar. 2015, Mar. 2016
- 2012 - 2015: COFUND Marie Curie Fellowships
- 2016: ITN, COFUND, Marie Curie, ERC consolidating grants

4. J.P. Gazeau: Member of the European Science Foundation College of Expert Reviewers, Reviewer for Natural Sciences and Engineering Research Council of Canada (NSERC), Reviewer for Austrian Science Fund, Reviewer for Czech Science Foundation
5. E. Kiritsis:
   - 2015-2016: Marie Curie Grants
   - 2016: Royal Society (UK)
   - 2016: American Israeli binational foundation
   - 2015-2016: ERC
   - 2015: FWO (Flemish Research Council)
   - 2015-2016: FNRS (Fond national de Recherche, Belgique)
   - 2015: DOE (USA)
   - 2015: Leverhume Trust (UK)
   - 2015-2016: NFS
   - 2016: NWO (Pays-Bas)
   - 2016: STFC (UK)
6. D. Langlois:
   - Member of the 'Science of the Universe' panel in the ERC committee selecting the ERC Consolidator Grants (2012, 2014, 2016)
   - Assessments for the ERC, NSERC (Natural Sciences and Engineering Research Council of Canada), Chilean FONDECYT (Fondo Nacional de Desarrollo Científico y Tecnológico)
7. F. Nitti: FWO
8. D. Semikoz: Evaluated 7 projects for Russian Science Foundation , 10 projects for Russian Foundation for Research and 1 project for Netherlands Organisation for Scientific Research
9. J. Serreau: The Research Foundation – Flanders (FWO), Research Council of KU Leuven (University of Leuven, Belgium), Foundation for the Advancement of Theoretical Physics “BASIS”
10. D. Steer: Referee for ANR
11. C. Volpe:
    - Since 2014: Member of the Federation of Research on Fundamental Interactions (FRIF).
    - Evaluation of research projects for the Scientific Research Fund (F.R.S.-FNRS), National Science Foundation (NSF), Department of Energy (DOE).

ENERGY PHYSICS

1. J.-P. Thermeau: Expert member ANR: evaluation of APR generic projects ANR 2017

TECHNICAL SERVICES

1. C. Juffroy: Steering Committee member of the Quality in Research Network.
2. D. Prêle: Expert ANR for design superconducting detectors, evaluation committee CE24 micro and nanotechnologies; Electronic expert at competitive exams I.T.R.F./I.G.R. BAP C; Expert at competitive exam IGR BAP C, Ministry of Social Affairs and Health Paris; Expert ITRF BAP C, University of Evry, nano-satellite prospective with the Montpelier LUPM - INTENS; Electronic expert invited to the Critical Design Review - CDR Mission NASA: InSight / Seis ("Martian" seismometer)
3. T. Zerguerras: Member of the board for the entrance examination of an instrumentation engineer at the Paris-Diderot University (September 2015), Expert for ITRF entrance examination board in 2016 and 2017

3. Activités d’expertise scientifique

Activités de consultant

Personnel selection committees

COSMOLOGY

1. J. Bartlett:
   - Member of the jury of admission CNRS 2007
   - Member of the Groupement d’Experts Thématiques (GET) Physique des deux Infinis (Advisory council in

astrophysics and particle physics) de l'UFR de l'Université Physique de Paris Diderot (2008-2012)
- Président of the GET Physique des deux Infinis (2012-2015)
- Member of the Council National des Universités (CNU) (2004-2007)

2. K. Ganga: member of the CNRS/INSU Section 17.
3. M. Piat, 2011-2013: Member of the Board of the Doctoral School « Astronomie et Astrophysique d'Ile de France » (ED 127)

HEA

1. F. Casse: Vice-presidency of the CNU (college B) section 34
2. S. Pita, responsibilities within evaluation bodies: Scientific secretary of Section 01 of the National Committee from 2012 to 2016
3. A. Lemière: member of the selection committee for a position of MCF at University Orsay P11(2014)

NEUTRINO

1. J. Houque Dawson: Member of the National Committee for Scientific Research (Section 01) since September 2016.
2. S. Katsanevas:
   - Oskar Kein Centre Director selection committee (2015)
   - NOW/NIKHEF Director evaluation committee (2014)
   - IUF selection committee (2010-2013)
3. A. Kouchner:
   - 2013-2016 : Member of the Conseil d'UFR
   - 2014- 2016 : Member of the Doctoral School Council ED 560 and ED 127.
   - 2011-2015 : Membre suppléant élu au Conseil National de Universités, section 29.
4. A. Tonazzo:
   - Member of the selection committee (3 members in total) for a position of "Professore Ordinario" at the University of Naples, Italy, 2016.
   - Member of the selection committee for a post of Professor in Physics at the University Paris-Sud, 2016.
   - Member of the selection committee for a post of Professor in Physics at Paris-Diderot University, 2015.
   - Member of the selection committee for a position of Professor in Particle Physics at the Paris-Diderot University, 2015.
   - Member of the selection committee for an MCF position in Particle Physics at Paris-Diderot University, 2014
5. V. Van Elewyck:
   - Member of selection committee for University permanent positions (Maitre de Conférences):
     - 2012: (Université Paris Diderot (Section 29) – UFR Physique, Laboratoire IMNC),
     - 2013: (Université Paris Sud (Sections 29-30), UFR de médecine - UMR Inserm 1030),
     - 2015: (Université Paris Sud (Section 29), Département de Physique - Laboratoire IPN),
     - 2016: (Université Paris Diderot (Sections 29-34) UFR Physique - Laboratoire AIM)
   - Member of the Conseil d'UFR of Université Paris Diderot (since 2016)

THEORY

1. C. Volpe: Responsibilities within evaluation bodies: Section 02 of the National Committee in 2011-2012 (member appointed to the office); INFN Theory Committee (CSN4), "Astroparticle" activity: evaluation of the scientific activity of 13 nodes in 2013.
2. P. Binétruy; Member of the Scientific Committee of CNRS (2014-2017)

ENERGY PHYSICS

1. J.-P. Thermeau: Thermoacoustic consultant for the Hekyom company: Research collaboration contract Hekyom-Université Paris Diderot - 2014-2019

Participation à des instances d'expertises (type Anses) ou de normalisation

ENERGY PHYSICS

1. J.-P. Thermeau : Membre du comité scientifique « Thermique-Optique » du Laboratoire National de Métrologie et d'Essais (LNE) : 2012/2017

Expertise juridique

« Sans objet »

4. Organisation de colloques / congrès

Organisation de conference

- **APC conference organisation: 50 conferences organised by the APC lab including 20 with more than 100 participants**

Year	Number of conferences/Meetings	50-100 participants	More than 100 participants
2013	11	9	2
2014	18	10	8
2015	8	5	3
2016	14	9	5
2017	11	8	3

Table 1. Conferences and meetings per participant number organized at APC since 2012

COSMOLOGY

1. J. Bartlett:
   - Chair, Scientific Organizing Committee, Cosmology Summer School, ISAPP 2015, Paris, France, 15-26 June 2015.
   - Many participations to Scientific Organizing Committees
2. R. Stompor, Scientific Committee member:
   - International Conference on Parallel Processing and Applied Mathematics (PPAM 2013), Warsaw, Poland, Sep 8-12, 2013;
   - Polarized Foreground Workshop, Munich, Nov 26-28, 2012;
   - Parallel Matrix Algorithms and Applications Conference, Birckbeck University of London, London, June 28-30, 2012.

HEA

1. A. Djannati-Ataï: Organizer of a Workshop on Shower Detection at High Altitude, May 2014, Paris/APC
2. F. Lebrun, A. Goldwurm, S. Vydelingum, V. Beckmann, F. Mattana, J. Zurita Herass: 9th INTEGRAL workshop "An INTEGRAL view of the high-energy sky (the first 10 years)", (250 participants)
3. F. Lebrun, R. Terrier, P. Laurent : AstroMeV-1 (52 participants), AstroMeV-2 (64 paticipants)
4. S. Loucatos:
   - Member of the organizing committee (scientific) of the Blois conference, responsible for the neutrino session, co-organizer of the black and astrophysical session.
   - Member of the Organizing Committee (Scientific) of the Moriond Annual Conference on Electro-fault Interactions, responsible for neutrino, dark matter and astroparticle sessions.

NEUTRINO

1. S. Katsanevas:
   - APPEC Town meeting 6-7 April 2016, Paris
   - European and global Coordination on CMB, September 2015 and 2016 Florence
   - International Conference for Large Neutrino Infrastructures: 1st conference : APC, Paris June 2014, 2nd conference : Fermilab April 2015, 3rd conference Tokyo May 2016
   - Member of International Advisory Committees of international workshops and conferences: European Physics Society High Energy Physics Conference (2012-), International High Energy Physics (ICHEP) Conference (2013-), International Conference on Neutrino Physics and Astrophysics, Neutrino (2008-), Identification of Dark Matter (IDM), Neutrino Oscillation Workshop (NOW), Cosmology COSMO, Neutrino Factory NUFACT, NNN…
2. T. Patzak: Since 2013, Chairman of the organizing committee of the school of GiF.
3. T. Patzak, Chairman of internationale conferences:
   - NNN08 (Next Nucleon decay and Neutrino detectors), APC – Université Paris Diderot, September 11-13, 2008, Paris, France.
   - NNN14 (Next Nucleon decay and Neutrino detectors), APC – Université Paris Diderot, November 4-6, 2014, Paris, France.

4. A. Kouchner, V. Van Elewyck:
   - ORCA Workshop & perspectives in neutrino mass hierarchy measurements, APC (Paris), 17 - 18/04/2013 (~30 participants) (https://indico.in2p3.fr/event/8261/)
   - KM3NeT and associated science workshop, Institut de Physique du Globe de Paris, 6/12/2016 (~30 participants) (https://indico.cern.ch/event/587484/)

THEORY

1. N. Deruelle:
   - Member of the International Committee of Marcel Grossmann meetings
   - Member of the nominating committee of the Scie GRG
2. J.P. Gazeau: Chairman (2008-2014) and Honorary member (2015-) of the Standing Committee of the International Colloquium on Group Theoretical Methods in Physics (ICGTMP)
3. D. Steer: 2016, organizer of the international conference in Brazil "Cosmic Strings @ Brazil"
4. C. Volpe:
   - "Large TPCs for low energy rare event detection" and "Supernova Meeting", 5-7 décembre 2016, Paris
   - "Aspen winter conference on neutrino physics", 2-6 février 2012, Aspen.

5. Post-doctorants et chercheurs accueillis

42 post-doctoral researchers since 2012

6. Contrats de recherche financés par des institutions publiques ou caritatives

Contrats européens (ERC, H2020, etc.) et internationaux (NSF, JSPS, NIH, Banque mondiale, FAO , etc.)

European contracts

Name	Name of lab coordinator	Beginning Date	End Date	Funding
CE ASPERA II	APC	01/07/2012	31/12/2012	57 533,00 €
COSMOLOGY				
CE INFIERI	APC	01/02/2013	31/01/2017	797 307,00 €
CE CLOTHILDE	APC	01/01/2016	31/08/2017	173 076,00 €
GRAVITATION				
CE ASTERICS		01/05/2015	30/04/2019	499 859,00 €
HEA				
CE AHEAD		01/09/2015	28/02/2019	5 000,00 €
NEUTRINO				
CE LAGUNA LBNO	ETH Zürich	01/09/2011	31/08/2014	179 000,00 €
CE REACTNU	APC	01/01/2012	31/08/2014	193 594,00 €
CE TAUKITFORNE	APC	01/07/2012	30/06/2013	40 872,00 €
CE AÏDA		01/05/2015	30/04/2019	9 000,00 €
CE GENERA	APC	01/09/2015	31/08/2018	138 690,00 €
THEORY				
ERC NIRG	APC	01/07/2013	30/09/2013	1 471 296,00€
CE HOLOLAND	APC	01/03/2014	28/02/2017	279 780,00 €
ERC SM-GRAV	APC	01/01/2016	21/12/2020	941 398,00 €

Table 2. European projects at APC since 2012

Contrats nationaux (ANR, PHRC, FUI, INCA, etc.)

ANR projects

Intitulé	Date de début	Date de fin	Financement obtenu
COSMOLOGY			
ANR COSMOS	01/04/2012	31/03/2015	187 192,00 €
ANR QUBIC	01/01/2012	31/12/2014	425 558,00 €
GRAVITATION			
ANR E-GRAAL	01/10/2014	30/09/2018	309 280,00 €
ANR WAVEGRAPH	01/10/2015	30/09/2019	139 320,00 €
HEA			
ANR MACH	01/10/2014	30/09/2018	154 627,00 €
NEUTRINO			
ANR NUTOPS	15/12/2011	14/12/2014	170 000,00 €
ANR DAEMONS	01/04/2016	31/03/2020	214 292,00 €

Table 3. ANR projects at APC since 2012

Contrats avec les collectivités territoriales

Intitulé	Date de début	Date de fin	Financement obtenu
NEUTRINO			
Blaise Pascal International Research Chair	01/04/2017	18/11/2018	184 000,00 €

Table 4. Projects funded by local authorities at APC since 2012

Contrats financés dans le cadre du PIA

PIA projects

Name	Beginning Date	End Date	Funding
Labex Univearths	01/04/2011	31/03/2019	3 000 000,00 €
Chaire d'Excellence IDEX/USPC	01/01/2015	31/12/2017	120 000,00 €
Préfiguration de pôle SET IDEX/USPC	01/01/2016	31/12/2017	129 600,00 €
Accueil longue durée Professeur IDEX/USPC	01/01/2016	3/12/2016	88 000,00 €
Financement projet ONSET IDEX/USPC	01/01/2016	31/12/2017	130 000,00 €

Table 5. PIA projects at APC since 2012

Contrats financés par des associations caritatives et des fondations (ARC, FMR, FRM, etc.)

« Sans objet »

7. Indices de reconnaissance

Prix

COSMOLOGY

1. N. Busca: Prix du Magasin La Recherche Lauréat Astrophysique 2013

GRAVITATION

1. Virgo team (except E. Porter):
   - 2016 Gruber Prize in Cosmology
   - Special breakthrough prize in Fundamental Physics
2. M. Barsuglia: Professeur invité à National Astronomical Observatory of Japan (May-June 2014)
3. E. Chassande-Mottin: Prix Monpetit 2016, Académie des sciences

HEA

1. M. Punch: Prix Descartes for H.E.S.S. (2013)

Distinctions

i. PES

COSMOLOGY

1. K. Ganga: PES 2012-2014.
2. J.C. Hamilton: PES 2012-2014

GRAVITATION

1. E. Porter: PES 2012

NEUTRINO

1. A. Cabrera: PES 2012

THEORY

1. E. Kiritsis: PES (2015 and 2016)
2. D. Steer: PES (until 2012 and from 2014)
3. C. Volpe: PES (2014-2018)

ii. PEDR

COSMOLOGY

1. J.C. Hamilton: PEDR Prime d'Encadrement Doctoral et de Recherche 2016-2020

THEORY

1. J. Serreau: PEDR (2012-2016)

iii. IUF

COSMOLOGY

1. Senior J. Bartlett

NEUTRINO

1. Senior T. Patzak (starting 2013)
2. Junior A. Kouchner (starting 2016)
3. Junior V. Van Elewyck (starting 2016)

THEORY

1. Senior P. Binétruy (starting 2015)

iv. ERC

NEUTRINO

1. T. Lasserre: ERC Starting Grant (2012-2018)

THEORY

1. C. Deffayet: ERC Starting Grant (01/07/2013-30/09/2013)
2. E. Kiritsis: Distinctions: ERC Advanced Grant 2015.

v. Autres

COSMOLOGY

1. M. Barsuglia: Invited Professor at the National Astronomical Observatory of Japan (May-June 2014)

HEA

1. A. Djannati-Ataï, F. Lebrun, E. Parizot, D. Vignaud, S. Vydelingum: European doctorate school ISAPP 2012 "multi-messengers approach in high-energy astrophysics", Paris
2. F. Lebrun :
   - Member of the Scientific Committee of the CEA/IRFU Service d'Astrophysique (2005-2014)
   - Member of the Scientific Committee of the CEA/IRFU Service de Physique des Particules (2011-2013)
   - Member of the Scientific Committee of the CNRS/IN2P3 laboratory CSNSM (IN2P3) (2013)
   - Member of the Scientific Committee of the CNRS/IN2P3 laboratory LUPM (IN2P3) (2013-2014)

NEUTRINO

1. S. Katsanevas:
   - Chevalier de l'Ordre National du Mérite
   - Co-director (2014-2019) of the Laboratory of Excellence (LabEx) UnivEarths
   - Chairman (2011-2014) of Astroparticle Physics European Coordination (APPEC)
   - Acting director of the cluster of Exact Sciences and Engineering of the Community of Universities Sorbonne-Paris-Cité,
2. T. Lasserre:
   - Hans Fischer Fellow à « The Institute For Advanced Studies » de l'université de Munich dans le domaine des neutrinos et de la matière noire

THEORY

1. P. Binétruy:
   - Co-director (2007-2013) of the Laboratoire International Associé (LIA) KIPAC-APC
   - Co-director of the « laboratoire d'excellence » UnivEarthS « Earth, Planets, Universe » (2011-2013)
   - Director of the endowment fund « For Research and Training in the field of Physics of the Universe » since 2010
   - Member of the Scientific Committee of Observatoire de la Côte d'Azur (2014-2017)
2. N. Deruelle: Nominated affiliate professor at the Yukawa Institute, Kyoto University in 2015
3. J. Serreau: APS Outstanding Referee Award 2015

Responsabilités dans des sociétés savantes

HEA

1. J.N. Capdevielle: Member with tenure of the Académie des Sciences d'Outre-Mer (2011)
2. S. Loucatos: Société Française de Physique:
   - Member of prize committees: Yves Rocard Award for Technology Transfer, Joliot Curie Prize, Young Investigator Award.
   - Auditor for the Board of Directors.

THEORY

1. N. Deruelle: Appointed member of the GRG Society in 2013 with the mention "For her contributions to the two-body problem in general relativity and relativistic cosmology."
2. E. Kiritsis: Deputy Chair of the High Energy Physics board of the European Physical Society.

ENERGY PHYSICS

1. J.-P. Thermeau:
   - Member of the office of the French Association of Refrigeration - Commission Cryogénie Supraconductivité (AFF-CCS)
   - Member of the teaching committee of the Société Française du Vide (SFV)

Invitations à des colloques / congrès à l'étranger, séjours dans des laboratoires étrangers

Numerous invitations for conferences and short-term visits abroad