

## APC - Astroparticule et cosmologie

Rapport Hcéres

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agence d'évaluation de la recherche  
et de l'enseignement supérieur

Department for the evaluation of  
research units

AERES report on unit:

AstroParticule et Cosmologie

APC

Under the supervision of  
the following institutions  
and research bodies:

Université Paris 7 - Denis Diderot

Centre National de la Recherche Scientifique

Commissariat à l'Énergie Atomique et aux Énergies

Alternatives

Observatoire de Paris



January 2013



agence d'évaluation de la recherche  
et de l'enseignement supérieur

Research Units Department

President of AERES

**Didier Houssin**

Research Units Department

*Department Head*

**Pierre Glaudes**



# Grading

Once the visits for the 2012-2013 evaluation campaign had been completed, the chairpersons of the expert committees, who met per disciplinary group, proceeded to attribute a score to the research units in their group (and, when necessary, for these units' in-house teams).

This score (A+, A, B, C) concerned each of the six criteria defined by the AERES and was given along with an overall assessment. NN (not-scored) attached to a criteria indicate that this one was not applicable to the particular case of this research unit or this team.

**Criterion 1 - C1** : Scientific outputs and quality ;

**Criterion 2 - C2** : Academic reputation and appeal ;

**Criterion 3 - C3** : Interactions with the social, economic and cultural environment ;

**Criterion 4 - C4** : Organisation and life of the institution (or of the team) ;

**Criterion 5 - C5** : Involvement in training through research ;

**Criterion 6 - C6** : Strategy and five-year plan.

With respect to this score, the research unit concerned by this report and its in-house teams received the overall assessment and the following grades:

- Grading table of the unit: **AstroParticule et Cosmologie - APC**

C1	C2	C3	C4	C5	C6
A+	A+	A	A+	A+	A+

- Grading table of the team: **E1 ADAMIS**

C1	C2	C3	C4	C5	C6
A	A	A	A+	A+	A

- Grading table of the team: **E2 High-Energy Astrophysics (AHE)**

C1	C2	C3	C4	C5	C6
A+	A+	A+	A	A+	A+

- Grading table of the team: **E3 Cosmology and Gravitation**

C1	C2	C3	C4	C5	C6
A+	A+	A	A+	A+	A+

- Grading table of the team: **E4 Neutrinos**

C1	C2	C3	C4	C5	C6
A+	A+	A+	A+	A+	A+



• Grading table of the team: **E5 Theory**

<b>C1</b>	<b>C2</b>	<b>C3</b>	<b>C4</b>	<b>C5</b>	<b>C6</b>
A	A+	A	A	A+	A



## Evaluation report

Unit name:	Astroparticule et Cosmologie
Unit acronym:	APC
Label requested:	UMR
Present no.:	UMR 7164
Name of Director (2012-2013):	Mr Pierre BINETRUY
Name of Project Leader (2014-2018):	Mr Pierre BINETRUY

## Expert committee members

Chair: Mr Steven KAHN, Stanford University, USA

Experts :

- Mr Jean-Jacques AUBERT, CPPM, Marseille
- Mr Richard BOND, CITA Toronto, Canada
- Mr Jules GASCON, IPNL Lyon, France (CoNRS representative)
- Mr Georges HELOU, Caltech, USA
- Mr Wim HERMSEN, SRON, Amsterdam, Pays-Bas
- Mr François MONTANET, LPSC Grenoble, France, (CNU representative)
- Mr Stefan SCHOENERT, TU Munich, Germany
- Mr Gabriele VENEZIANO, College de France, Paris

Scientific delegate representing the AERES:

Mr Cristinel DIACONU



## Representative(s) of the unit's supervising institutions and bodies:

Mr Claude CATALA, Observatoire de Paris

Mr Gabriel CHARDIN, CNRS/IN2P3

Mr Philippe CHOMAZ, CEA

Mr Richard LAGANIER, Paris 7

Mr Olivier LA MARLE, CNES

Mr Denis MOURARD, INSU



## 1 • Introduction

### History and geographical location of the unit

The Laboratoire Astro-Particule et Cosmologie (APC) was formally created in 2005 to provide a coherent focus for the emerging fields of particle astrophysics and cosmology within the Paris area. The scientific teams that comprised the laboratory began their association in the period 1999-2004 in three main areas: (i) High Energy Astrophysics, (ii) Cosmology and Gravitation, and (iii) Neutrinos. They moved to the new campus of Paris Rive Gauche (PRG) in 2006 along with the transfer of the University Paris 7 Diderot to that location. The laboratory is supported by a mixture of agencies and funding sources, including CNRS (both IN2P3 and INSU), CEA, Observatoire de Paris, and the Paris Diderot University. The University has devoted a strong hiring program to APC, averaging roughly 2 to 3 positions per year in the period 2001-2010.

### Management team

The director of the Laboratory is Mr Pierre BINETRUY. He is assisted by two Deputy directors: Mr Sotiris LOUCATOS and Ms Alessandra TONAZZO. Scientists associated with the laboratory belong to at least one of the following teams: (1) ADAMIS (data analysis and computing), headed by Mr Radek STOMPOR; (2) High Energy Astrophysics, headed by Mr Etienne PARIZOT; (3) Cosmology and Gravitation, headed by Mr Yannick GIRAUD-HÉRAUD; (4) Neutrinos, headed by Mr Antoine KOUCHNER; and (5) Theory, headed by Mr David LANGLOIS. Technical and administrative personnel are assigned to technical and administrative departments, respectively. The head of the technical department is Mr Christian OLIVETTO, and the head of the administrative department is Ms Emmanuelle ANCOURT-FOISSAC.

### AERES nomenclature

The scientific activities of the laboratory fall under ST2 (Physics) and ST3 (Earth and universe sciences).

### Unit workforce

Unit workforce	Number as at 30/06/2012	Number as at 01/01/2014	2014-2018 Number of project producers
<b>N1:</b> Permanent professors and similar positions	28	27	27
<b>N2:</b> Permanent researchers from Institutions and similar positions	41	44	44
<b>N3:</b> Other permanent staff (without research duties)	41	46	
<b>N4:</b> Other professors (Emeritus Professor, on-contract Professor, etc.)		2	2
<b>N5:</b> Other researchers from Institutions (Emeritus Research Director, Postdoctoral students, visitors, etc.)	29	21	21
<b>N6:</b> Other contractual staff (without research duties)	20	17	
<b>TOTAL N1 to N6</b>	<b>159</b>	<b>157</b>	<b>94</b>
Percentage of producers	<b>100 %</b>		





<b>Unit workforce</b>	<b>Number as at 30/06/2012</b>	<b>Number as at 01/01/2014</b>
Doctoral students	31	
Theses defended	47	
Postdoctoral students having spent at least 12 months in the unit*	25	
Number of Research Supervisor Qualifications (HDR) taken	12	
Qualified research supervisors (with an HDR) or similar positions	40	54



## 2 • Assessment of the unit

### Strengths and opportunities

APC has made very significant contributions to its chosen fields of research. These are detailed in the assessments that follow. In addition the laboratory has established significant ties to industry associated with its major hardware efforts, and a number of staff members have taken on important roles in French public outreach activities. The management of the laboratory is well appreciated by the staff, and morale is generally quite high. Communication both downward and upward is effective through direct channels and through the Laboratory Council.

APC is establishing itself as a major center for the support of space experiments among CNRS laboratories. It successfully teamed up with IPGP and AIM on a "labex" proposal called UnivEarthS. In addition, it has taken part in an "equipex" proposal called GRAVITER for the preparation of space missions in fundamental physics and earth and planetary sciences. This latter proposal only made it to the wait list, but it is being considered for the campus extension in Ivry. Finally, the establishment of the Francois Arago Centre (FACe) has provided a unique multi-mission data analysis facility for data storage and processing with direct connectivity to CC-IN2P3. All of these events present promising new opportunities for growth at a national level in space research.

### Weaknesses and threats

The Committee identified no major weaknesses in the laboratory. There is a modest threat associated with the fact that the Director will soon step down as Director. He has personally played an enormous role in the establishment of APC and in the guidance of its formative years. He will be very difficult to replace.

APC has developed a very ambitious strategic plan, involving many new projects. If all of these projects come to fruition, the laboratory will be strapped to fulfill all of its desired roles, and some difficult choices will have to be made.

### Recommendations

The laboratory should be continued at its present level with modest growth to support its diverse and exciting scientific program.



### 3 • Detailed assessments

#### Assessment of scientific quality and outputs

APC has made significant contributions to international particle astrophysics and cosmology research in a number of diverse areas. Particular highlights over the past five years include:

- The Double CHOOZ experiment provided the first measurement of  $\theta_{13}$ , a major result in particle physics. APC played a leading role in this experiment,
- APC scientists developed key new techniques for the estimation and removal of foregrounds in the Planck CMB dataset, which have attracted international attention at the highest level,
- They have also made a very strong contribution to Planck science output, with particular attention to systematics,
- APC has spearheaded the effort to maintain momentum behind LISAPathfinder and eLISA. FACE is playing a substantial role in helping to facilitate French and European activity in this area,
- APC scientists continue to lead the analysis of data from IBIS/ISGRI instruments on INTEGRAL,
- The laboratory hosts a vigorous theoretical effort, with good connection to its experimental program,
- APC has established strong participation in HESS, facilitating multi-wavelength studies of nonthermal astrophysical sources, and leading to a future significant role in CTA,
- The laboratory has played major hardware and interpretive roles in the Pierre Auger Observatory,
- The laboratory has made important contributions to the ANTARES project,
- APC scientists have established a strong publication record for the Laboratory as a whole.

#### Assessment of the unit's academic reputation and appeal

The laboratory's academic reputation is very strong. Elements that contributed to the establishment and maintenance of that reputation include:

- The APC-led Double CHOOZ design became the standard for the worldwide reactor neutrino facility,
- The establishment of FACE has positioned APC strongly at the center of French space mission support, especially within CNRS,
- Several individual scientists at APC have received high levels of recognition, eg award of IUF, Medaille de Bronze 2010 in CNRS, ERC,
- APC scientists have Principal Investigator roles on major facilities (INTEGRAL, SIMBOL-X, QUBIC, JEM/EUSO, Double CHOOZ),
- The APC theory group has established itself as a center for cosmology and modified gravity research, especially within the Paris area.

#### Assessment of the unit's interaction with the social, economic and cultural environment

APC has established significant ties to industry associated with its major hardware efforts. In particular the "amont/aval" strategy that the laboratory has developed leads to outsourcing to industry of major fabrications at higher technical readiness levels. This facilitates strong academic/industrial partnerships in some key technical areas.

Several laboratory staff members have taken very significant roles in French public outreach activities in the fields of cosmology and astroparticle physics.

The laboratory has participated in IAEA Vienna studies on neutrino detection for non-proliferation and safeguard activities.



### Assessment of the unit's organisation and life

The management of APC is highly appreciated by the staff, and the morale is high. Communication is effective between the various units and with the central administration. The leadership has done a very effective job at anticipating trends in European and French science funding, and taken appropriate steps to ensure that the laboratory is well-positioned as funding patterns evolve.

The APC Technical Division has emerged quickly into a strong service unit supporting the hardware programs of the laboratory. The leadership does a very good job managing the balance between the multiple demands on the engineering groups. Morale is high, although the ratio of technical to scientific staffing levels is lower than optimal. The division has taken steps to establish itself as a major center for space engineering, especially among IN2P3 labs. The TARANIS Project is an excellent testbed for developing relevant experience in this arena.

APC has made excellent progress at integrating the broad disciplines of particle astrophysics and cosmology in a cohesive way across experiment, observation, and theory.

### Assessment of the unit's involvement in training through research

The total student and postdoc numbers are appropriate for a laboratory of this size. The mentoring of graduate students is taken seriously, and is applied uniformly throughout the laboratory. The situation is somewhat less clear for postdocs, some of whom do not feel adequately mentored during their brief stays there.

### Assessment of the five-year plan and strategy

The laboratory has developed a strategic planning process engaging all staff to plan its future for the next two decades. Strong investments are being made in gravitational wave physics, wide-field survey cosmology, neutrino physics, and multi-messenger high energy astrophysics.

The overall program has many uncertainties, but is ambitious. If all of these projects come to fruition, the laboratory's technical division may find it difficult to fulfill all of the desired roles proposed by the scientific staff.

Through its partnership in UnivEarthS, and the establishment of FACe, APC has positioned itself well to play a strong role in space astrophysics efforts in France in future years. These efforts are strongly supported by CNRS, CNES, CEA, and the University.

A potential new major project that emerged from the strategic planning process is SKA. The laboratory will need to take proactive steps to establish a credible program in this new field.



## 4 • Team-by-team analysis

**Team 1 :** ADAMIS

**Name of team leader:** Mr Radek STOMPOR

**Workforce**

Team workforce	Number as at 30/06/2012	Number as at 01/01/2014	2014-2018 Number of project producers
<b>N1:</b> Permanent professors and similar positions	2	3	3
<b>N2:</b> Permanent EPST or EPIC researchers and similar positions	5	7	7
<b>N3:</b> Other permanent staff (without research duties)	1	1	
<b>N4:</b> Other professors (PREM, ECC, etc.)			
<b>N5:</b> Other EPST or EPIC researchers (DREM, Postdoctoral students, visitors, etc.)	1	2	2
<b>N6:</b> Other contractual staff (without research duties)			
<b>TOTAL N1 to N6</b>	<b>9</b>	<b>13</b>	<b>12</b>

Team workforce	Number as at 30/06/2012	Number as at 01/01/2014
Doctoral students	11	
Theses defended	5	
Postdoctoral students having spent at least 12 months in the unit	5	
Number of Research Supervisor Qualifications (HDR) taken	1	
Qualified research supervisors (with an HDR) or similar positions	2	6



## • Detailed assessments

### Assessment of scientific quality and outputs

ADAMIS is the smallest scientific group at APC, consisting of 8 permanent research staff, 5 students and 3 postdocs. However, the group has strong connections to Cosmology-Gravitation and High-Energy Astrophysics, as well as to 'Service Informatique' inside APC; in fact, all ADAMIS group members are also members in at least one other group. The "transverse" nature of ADAMIS emphasizes the use of computer science, numerical or statistical techniques to address physics data analysis or simulation topics.

The ADAMIS group has had special success with SMICA (a component separation software package for Planck data) and the Planck Sky Model, whose significance derives from the importance of component separation to the analysis of Planck data. As Planck data and results start going public in the Spring of 2013, the contributions of ADAMIS will become more evident and enhance the profile of APC.

### Assessment of the unit's academic reputation and appeal

In accordance with its transverse nature, ADAMIS members publish and are visible in the computer science literature, and maintain significant collaborations outside of the physics community, e.g, with INRIA. They also maintain a good network of collaborators within France, including several alumni of the group (now at LPCE or ECP). All this adds up to substantial academic influence and appeal, as demonstrated by their journal refereeing activities, and their participation on international cross-disciplinary collaborations.

### Assessment of the unit's interaction with the social, economic and cultural environment

While ADAMIS has not found opportunities for technical transfer to non-academia, they do have a strong presence in cultural outreach. For instance, a key member of the group has received the Haute-Maurienne Vanoise 2012 Award for best popular book in astronomy ("Les nouveaux messagers du cosmos"). The group is also active in a variety of public outreach events, and in high school teachers training.

### Assessment of the unit's organisation and life

The group is well organized and made a particularly energetic presentation, reflecting an enthusiastic leadership. They have served the APC as a whole well by carrying out effectively the transverse activities in collaboration with Cosmology-Gravitation and High-Energy astrophysics, and by engaging some members of the 'Service Informatique'.

### Assessment of the unit's involvement in training through research

The group has produced 5 doctorates in the last 5 years, with 5 more students currently enrolled. The group trained a total of 15 masters students. This is a good record for the modest number of permanent staff (8). ADAMIS staff is quite active in teaching at various levels.

### Assessment of the five-year plan and strategy

In terms of strategy and planning, the group's plan reflects the general trends and projects at APC rather than formulating their own scientific trajectory. The ADAMIS strategy seems to center on their ability to respond to scientific opportunities with novel ideas and quick implementation, especially in the data analysis domain, but also in simulations.



**Team 2 :** High-Energy Astrophysics (AHE)

**Name of team leader:** Mr Etienne PARIZOT

### Workforce

Team workforce	Number as at 30/06/2012	Number as at 01/01/2014	2014-2018 Number of project producers
<b>N1:</b> Permanent professors and similar positions	6	6	6
<b>N2:</b> Permanent EPST or EPIC researchers and similar positions	13	14	14
<b>N3:</b> Other permanent staff (without research duties)			
<b>N4:</b> Other professors (PREM, ECC, etc.)			
<b>N5:</b> Other EPST or EPIC researchers (DREM, Postdoctoral students, visitors, etc.)	12	6	6
<b>N6:</b> Other contractual staff (without research duties)			
<b>TOTAL N1 to N6</b>	<b>31</b>	<b>26</b>	<b>26</b>

Team workforce	Number as at 30/06/2012	Number as at 01/01/2014
Doctoral students	7	
Theses defended	6	
Postdoctoral students having spent at least 12 months in the unit	9	
Number of Research Supervisor Qualifications (HDR) taken	3	
Qualified research supervisors (with an HDR) or similar positions	9	12



## • Detailed assessments

### Assessment of scientific quality and outputs

The AHE group is a very ambitious and dynamic group, constituting the largest entity in APC with 24 permanent members and 36 PhD students and postdocs over the last five years. It is engaged in many international projects on astroparticle physics with telescopes or instruments detecting photons, cosmic rays or neutrinos. This can be in space with the successfully operating INTEGRAL observatory, and with future space missions such as ASTRO-H, SVOM/ECLAIRS, and JEM-EUSO, or on the ground with HESS, ANTARES, the Pierre Auger Observatory, the X-shooter detector and preparing for CTA and KM3NET.

The group has a leading role in imaging the hard X-ray/soft gamma-ray sky with the delivery of, and analysis of data from the imager IBIS/ISGRI aboard ESA's INTEGRAL. Extremely accurate characterization of the imager response allowed the generation of important results, e.g.: the 3rd and 4th IBIS source catalogues (>700 sources), opening up the non-thermal hard X-ray sky; deep multi-messenger studies of source-crowded regions of the Galactic Plane, most notably the GC region studying the past activity of the central BH; in the IBIS Compton mode the first detection of polarization in gamma-rays from the BH binary Cyg X-1 and a GRB, rendering the most stringent limit on violation of Lorentz invariance. Furthermore, the group was successful in multi-wavelengths and multi-instrument studies of unidentified sources, such as AGN, PWNe and compact binaries. The latter also included observations at TeV energies with HESS. Preparatory studies are made to harvest with HESS II, and the group is involved in scientific and design studies for CTA.

The responsibility for the TARANIS/XGRE flight hardware is recognition of the acquired technical expertise in AHE over the evaluation period and offers an excellent opportunity to manage a complete space system in the APC laboratory.

In neutrino astronomy, the period under evaluation marked the transition from the construction phase to the data exploitation phase of the ANTARES telescope. The group has a strong role with important responsibilities in ANTARES. Scientific harvesting started in 2008, with e.g. best limits on neutrinos from point sources. An interesting initiative has been taken by the AHE group for joint multi-messenger research between the ANTARES and VIRGO/LIGO collaborations. Finally, the group is actively involved in R&D for the European KM3NET, exploiting its expertise in photo-detection.

In the field of ultra-high-energy cosmic rays (UHECRs) the AHE group realised major contributions to the hardware and science of the Pierre Auger Observatory, gaining global recognition for data analysis and interpretation in this field. The modelling and interpretation addressed e.g. the acceleration and propagation of Galactic cosmic rays as well as UHECRs. A major result is the shown degeneracy of the measured UHECR energy spectrum, whether one is dealing with just protons or mixed nuclei, leading to different conclusions on the observed 'ankle' in the spectrum and the phenomenology of the transition from a galactic to an extragalactic origin. The suggestion from Auger measurements of a transition towards heavier nuclei at the highest energies is now shared by a large part of the international community.

The group is now focussing on the development of the international JEM-EUSO mission, to be flown aboard ISS, with a preliminary balloon campaign EUSO Balloon approved by CNES with flights in 2014.

### Assessment of the unit's academic reputation and appeal

The AHE group has significant responsibility in many national and international projects, studies, and proposals, such as: Co-PI INTEGRAL/IBIS; Leading M3 mission proposals to ESA (CAPSiTT, COSPIX); Simbol-X studies (PI, Project Scientist); TARANIS Co-PI XGRE, project manager; contribution to ASTRO-H, Co-PI; scientific contributions to HESS, HESS2, CTA, ANTARES working groups, AUGER; EUSO-balloon, project manager; JEM-EUSO National PI.





### Assessment of the unit's interaction with the social, economic and cultural environment

In its R&D and instrumental activities the group has direct links with industry. An example is an international collaboration with industrial partners, in particular THALES, for the development of the new generation of semi-conducting sensors. The AHE group is also coordinating the European Network ITN 'INFIERI' (Intelligent FAST Interconnected and Efficient devices for Frontier Exploitation in Research and Industry) for the development of high-tech solutions for signal processing on detectors (front-end) or final processing (far-end), including again THALES. Involvement in the production of 3D Compton imaging software offers the possibility for multiple applications in society.

The AHE group has been very active in organizing outreach activities such as many outreach conferences, bars des sciences, many outreach articles and seven books, exhibitions, creation of the "House of Astroparticles" in the 3D virtual environment "Second Life". Furthermore, a series of conferences and lectures at the "Open University" (DAPAEUS) were given.

### Assessment of the unit's organisation and life

The group is involved in a diversity of activities, projects and techniques organized in sub-groups operating in a large number of separate national and international collaborations. The interactions in the sub-groups are intense, and the organisation within space projects is of an international standard. There is significant overlap in the scientific themes addressed by the different projects. However, due to the various commitments of the sub-groups in the many international (closed) collaborations, the AHE group meetings, seminars, and further interactions between the sub-groups are irregular. The interdisciplinary nature of AHE can be better exploited, also in the education of students.

### Assessment of the unit's involvement in training through research

The AHE staff has been strongly involved in research education activities, through the supervision of many Licence, Master (25) and PhD students (17, of which 7 defended their theses), the participation in various academic programs and networks, the development of innovative education tools and programs, the writing of books and lecture notes, e.g.:

- Founding member of the IDPASC international doctorate network; European Initial Training Network, INFIERI; ANR "EVEIL",
- Academic responsibilities for Université Paris Diderot: Chargé de mission TICE; member of Presidential team, Teaching council, Physics Department council,
- Curricula: Creation of the Astroparticle branch of the NPAC Master; responsible of the NPAC Master for Paris Diderot; member of the Doctorate School council; coordination of the new License programme L1, L2, L3,
- Production of multimedia educative material,
- Weekly journal club for PhD's and postdocs.



## Assessment of the five-year plan and strategy

The combination of studying energetic particles (electrons, protons, nuclei), non-thermal astronomy (X-rays, gamma rays, TeV photons) and neutrino astronomy in AHE, collaborating in APC with teams of the ADAMIS, Theory and Neutrinos groups, makes APC a strong site for Astroparticle Physics. The AHE group has been involved in major international projects in this field, and, building on the acquired expertise, has a very ambitious five-year plan. The aim is to maintain a balance between an effective participation in the next-generation experiments, data analyses and astrophysical interpretation. Seeking to play a leading role in the definition and preparation of future experiments, the group has recently strengthened its instrumental component in the field of photo-detection and innovative signal processing solutions. In Europe, it is leading the development of a next-generation Compton telescope for a major step in studies in the low-energy gamma-ray domain. However, there are significant uncertainties. Several of these plans involve large international programmes (JEM-EUSO, CTA, KM3NET, international X-ray observatory, SVOM, Compton Space telescope) for which funding, international selection and/or time lines are uncertain. All of these projects will come to fruition at the end of this decade or even later. But, there is a sufficiently high probability that a number of these international projects will be selected, and the AHE group is in an excellent position to provide significant or leading contributions.



**Team 3 :** Cosmology and Gravitation

**Name of team leader:** Mr Yannick GIRAUD-HÉRAUD

**Workforce**

Team workforce	Number as at 30/06/2012	Number as at 01/01/2014	2014-2018 Number of project producers
<b>N1:</b> Permanent professors and similar positions	8	7	7
<b>N2:</b> Permanent EPST or EPIC researchers and similar positions	10	11	11
<b>N3:</b> Other permanent staff (without research duties)	3	2	
<b>N4:</b> Other professors (PREM, ECC, etc.)			
<b>N5:</b> Other EPST or EPIC researchers (DREM, Postdoctoral students, visitors, etc.)	3	3	3
<b>N6:</b> Other contractual staff (without research duties)	1	1	
<b>TOTAL N1 to N6</b>	<b>25</b>	<b>24</b>	<b>21</b>

Team workforce	Number as at 30/06/2012	Number as at 01/01/2014
Doctoral students	8	
Theses defended	12	
Postdoctoral students having spent at least 12 months in the unit	4	
Number of Research Supervisor Qualifications (HDR) taken	4	
Qualified research supervisors (with an HDR) or similar positions	12	16



## • Detailed assessments

### Assessment of scientific quality and outputs

The Cosmology and Gravitation group has strong and active teams working in three main areas of research: (1) Experimental investigations of the cosmic microwave background, with particular emphasis on the detection of B-modes that could provide the signature of inflation; (2) Cosmological analysis of large spectroscopic and imaging surveys for the determination of constraints on the nature of dark energy; and (3) The detection of gravitational waves using both ground- and space-based detectors.

In the first area, the group has played a leading role on the Planck HFI experiment, having taken charge of the polarization characterization of that instrument, the removal of cosmic ray impacts, the correction for non-linearities in the instrumental response, the estimation of noise parameters, and the characterization of the beams at different scales. They have also worked with the ADAMIS group on the identification and removal of foregrounds. On the analysis side, they have participated in investigations of polarization in general, the search for non-Gaussianities, and the study of Galaxy clusters through the Sunyaev-Zeldovitch effect. This group also includes an active hardware development component through the "Laboratoire millimétrique", which has pioneered the development of transition edge sensors and kinetic induction detectors.

The group working on the cosmological analysis of large galaxy surveys is heavily involved in BOSS, EUCLID, and LSST. On BOSS, they played a key role in the first detection of the baryon acoustic oscillations signal in the Lyman-alpha forest toward distant quasars. On EUCLID, they are leading the planning for the merging of ground-based visible-band data with the EUCLID infrared data for the determination of photometric redshifts. On LSST, they are leading the software development for the camera control systems, and are key members of the photometric calibration working group.

The gravitational wave group is one of the major players of the eLISA project, and its precursor LISAPathFinder mission. APC contributed significantly to the writing of the "Yellow Book" that was submitted to ESA in support of this project, and played a key role in the simulation of detector performance and parameter estimation. For LISAPathFinder, the FAcE was chosen to host the "Complementary Data Centre", which will support ESA's main data center. On Virgo, this group has been involved in all aspects of the data taking and data analysis of the existing experiment, and the design and construction of the Advanced Virgo upgrade. In particular for Advanced Virgo, they have led the optical design, and taken responsibility for the construction of the mode-matching telescopes. Through their "Laboratoire optique", they have also been researching new techniques to reduce thermal noise in the mirrors of future gravitational wave detectors.

### Assessment of the unit's academic reputation and appeal

This group is very well known in Europe through the key roles they have played in the Planck mission and in the European gravitational wave community. In particular, a member of this group is one of three "main investigators" for the eLISA consortium, and other members have won significant awards of distinction both inside and outside France. The group has attracted excellent postdocs and students for all of its activities.

### Assessment of the unit's interaction with the social, economic and cultural environment

Through its two laboratories and through its hardware development programs, the Cosmology and Gravitation group has strong connections to industry. In addition, members of this group have been very active in education and public outreach programs through exhibitions, activities with high schools, public conferences and continuing education. In particular, through the "Université Ouverte", members of this team have taught cosmology-related courses to the public over a wide range in age and background.

### Assessment of the unit's organisation and life

The group appears to be functioning well, and morale is very high. Coherence among the diverse programs is achieved via bimonthly meetings and through a journal club. The present leadership is strongly supported by the staff.



### Assessment of the unit's involvement in training through research

The Cosmology and Gravitation group has been active in the training of students. There have been 12 doctoral theses completed during the past 5 years, and 8 are on-going. In addition, members of this group have supervised 15 M1 students and 14 M2 students. These are impressive numbers for a group of this size. In addition, group members have been active in Summer Schools in their respective fields.

### Assessment of the five-year plan and strategy

The long-term strategy involves a continuation of vigorous activity in all three areas, with a gradual transition of some members of the group from CMB research over to the analysis of large galaxy surveys, as EUCLID and LSST come on line. While this plan is well-motivated, it will take care and monitoring to ensure that that transition is effective, given the differences in culture between these two fields. The future of the space-based gravitational wave effort remains uncertain, and will depend critically on the success of LISAPathFinder. However, APC is well-positioned to capitalize on that success as this program moves forward.



**Team 4 :** Neutrinos

**Name of team leader:** Mr Antoine KOUCHNER since Oct. 2012 (Ms Alessandra TONAZZO before)

**Workforce**

Team workforce	Number as at 30/06/2012	Number as at 01/01/2014	2014-2018 Number of project producers
<b>N1:</b> Permanent professors and similar positions (persons/FTE)	4	4	4
<b>N2:</b> Permanent EPST or EPIC researchers and similar positions (persons/FTE)	6	5	5
<b>N3:</b> Other permanent staff (without research duties) (persons/FTE)			
<b>N4:</b> Other professors (PREM, ECC, etc.) (persons/FTE)		1	1
<b>N5:</b> Other EPST or EPIC researchers (DREM, Postdoctoral students, visitors, etc.) (persons/FTE)	5	7	7
<b>N6:</b> Other contractual staff (without research duties) (persons/FTE)			
<b>TOTAL N1 to N6</b> (persons/FTE)	15	17	17

Team workforce	Number as at 30/06/2012	Number as at 01/01/2014
Doctoral students	2	
Theses defended	5	
Postdoctoral students having spent at least 12 months in the unit		
Number of Research Supervisor Qualifications (HDR) taken	2	
Qualified research supervisors (with an HDR) or similar positions	5	7



## • Detailed assessments

### Assessment of scientific quality and outputs

The neutrino group at APC and its experimental projects are internationally highly visible. The group consists currently of 13 staff scientists, 5 Postdocs, 5 PhD Students and visitors, and pursues a well tailored science program with a focus on the reactor neutrino experiment Double Chooz, the solar neutrino experiment Borexino, and on future projects addressing the measurement of the neutrino mass hierarchy with atmospheric neutrino with the deep-sea water Cherenkov telescope Orca and with long-baseline neutrino oscillation project Laguna-LBNO. The latter also aims to address CP violation studies in the Lepton sector.

The Double Chooz experiment provided the first measurement of the neutrino mixing angle  $\theta_{13}$  using anti-neutrinos from the nuclear power reactor with a novel type of detector. The experimental result of Double Chooz is a ground breaking discovery in the field, which is recognized worldwide and which is of a transformational nature with wide ranging implications. International competitors are the Chinese-US Daya Bay and the South-Korean Reno experiments. The APC team, together with the group from CEA Saclay, are the initiators and the core teams of the experiment. APC scientists have leading roles in the Double Chooz experiment, including the spokesperson and physics analysis coordinator, and have important instrumental responsibilities. The first presentations to the science community at international conferences were made by APC members.

Despite limited funding, the APC neutrino group also made important contributions to the solar neutrino experiment Borexino. This includes the precision measurements of solar  $^7\text{Be}$  neutrinos, low-threshold  $^8\text{B}$  neutrino spectral analysis, first measurements of solar pep-neutrinos and the energy dependent mapping of the matter induced neutrino conversion transition in the sun (MSW effect). Further initiatives which generated worldwide visibility and interest, are the reactor anomaly which could be reconciled with eV sterile neutrinos. One APC scientist obtained an ERC grant to realize an artificial neutrino source to be deployed in a large liquid scintillator detector at KamLAND, and a Borexino to search for very short baseline oscillations, which would be driven by sterile neutrinos at the eV scale.

### Assessment of the unit's academic reputation and appeal

Based on its reputation, the neutrino group succeeded to attract first class scientists from abroad which is reflected in the hiring of staff from the UK, Germany and Italy, as well as excellent PhD students and postdocs. The reputation of the group is also manifested by a CNRS Médaille, an European ERC grant, an ANR grant, as well as the European funded Laguna-LBNO design study within FP7. Members of the neutrino group have been organizers of several international conferences, hosting the European doctorate school ISAPP, and are members of international scientific committees (e.g. CERN SPSC). As a core team of the Double Chooz experiment, the neutrino group serves also as a hub for the international collaborators from Europe, Russia, USA, Brazil and Japan. The academic reputation resulted also in the recent hiring of two staff and the attraction of a neutrino theorist to the theory group.

### Assessment of the unit's interaction with the social, economic and cultural environment

The neutrino group obtained strong regional support from the Champagne Ardenne region for the Double Chooz experiment. In return, the group organized a conference in the region and regular public lectures within the Double Chooz outreach program. One group member is a delegate in the Vienna IAEA as neutrino expert, in the IAEA project 'neutrinos for safeguard and non-proliferation'. The neutrino group gave public outreach talks in the Palais de la Découverte, a member of the group wrote a book on neutrinos for the general public and the Double Chooz experiment inspired a cartoon widely read in France. The digital signal converter (FADC) used in the Double Chooz experiment has been developed together with an Italian company and the device is now commercially available to other experiments and to industry.

### Assessment of the unit's organisation and life

The members of the neutrino group show an extremely enthusiastic spirit and have close links between projects. Moreover, there is strong transverse communications with other units. For example, the neutrino group leader was previously a member of the high-energy group working on Antares. A member of the neutrino group is the current deputy APC director.



### Assessment of the unit's involvement in training through research

Members of the neutrino group are co-founders of the international doctorate school IDAPP and had several international co-supervisions of PhD students. In total 8 PhD students joined during the recent period and they are fully integrated in the scientific activities of the group. All PhD students who finished during the period under review found postdoc positions. From the recent four postdocs (three of them on-going), one won the CNRS competition and obtained a permanent position at APC. The group has also been very active in training master students, in total amounting to 13.

### Assessment of the five-year plan and strategy

The present focus of the neutrino group is the completion of the Double Chooz experiment, and on a precision measurement using both rate and shape of the energy spectrum to reduce the uncertainties of the mixing angle  $\theta_{13}$ . With less resources, but not with less relevance, the group continues to contribute to Borexino with near term goals to measure or limit the solar CNO flux, as well as a measurement of neutrinos from the Earth with increased statistics. At intermediate time scales, the neutrino group pursues the Ce-LAND (ERC grant) and SOX neutrino source projects for sterile neutrino search. It should be mentioned that the neutrino group at APC is the only group which has the potential to pursue both projects synergistically, opening a unique possibility at APC, exploring the possibility to deploy a Ce neutrino source both in Borexino and KamLAND.

Given the large value of the mixing angle  $\theta_{13}$ , a feasibility study for determining neutrino mass hierarchy using atmospheric neutrinos in a deep-see Cherenkov detector (ORCA) has commenced recently at APC. The APC neutrino group was successful in obtaining an ASPERA grant in cooperation with the south-pole-based IceCUBE/Pingu project. Further strategic developments concern possible participation in the liquid argon direct Dark Matter search experiment Dark Side which is considered synergistic with the low-background expertise of the group and the Laguna-LBNO design study, also employing liquid argon as detector medium. The latter is an international long-term project, which likely will only be realized in a US/European collaboration.

The strategy of the neutrino group guarantees that transformational physics results can be expected in the future, comparable to their current achievements.





**Team 5 :** Theory

**Name of team leader:** Mr David LANGLOIS

**Workforce**

Team workforce	Number as at 30/06/2012	Number as at 01/01/2014	2014-2018 Number of project producers
<b>N1:</b> Permanent professors and similar positions	8	7	7
<b>N2:</b> Permanent EPST or EPIC researchers and similar positions	6	7	7
<b>N3:</b> Other permanent staff (without research duties)			
<b>N4:</b> Other professors (PREM, ECC, etc.)		1	1
<b>N5:</b> Other EPST or EPIC researchers (DREM, Postdoctoral students, visitors, etc.)	8	3	3
<b>N6:</b> Other contractual staff (without research duties)			
<b>TOTAL N1 to N6</b>	<b>22</b>	<b>18</b>	<b>18</b>

Team workforce	Number as at 30/06/2012	Number as at 01/01/2014
Doctoral students	3	
Theses defended	19	
Postdoctoral students having spent at least 12 months in the unit	7	
Number of Research Supervisor Qualifications (HDR) taken	2	
Qualified research supervisors (with an HDR) or similar positions	12	13



## • Detailed assessments

### Assessment of scientific quality and outputs

The Theory group of APC covers, from a theoretical viewpoint, the research topics of the lab as well as some more formal lines of research. It consists of about 15 permanent members, evenly shared between University and CNRS, and about the same number of non-permanent members in the form of post-docs and Ph. D. students. It also benefits from the presence of three associate members (spending regularly a share of their time at APC) and of the proximity of the new PCCP Center directed by Nobel Laureate Mr George SMOOT.

The following topics have considerable overlap with the experimental activities of the lab:

- Theoretical cosmology and models of inflation to be tested through their observable predictions about non-gaussianities and polarization in the CMB anisotropies,
- Models of modified gravity, particularly those inspired by the possible existence, suggested by string theory, of extra dimensions of space. This is an area in which the group have given pioneering contributions,
- The theory of neutrino masses and oscillations of direct evidence to the Double Chooz experiment has been adequately reinforced with a new recent recruitment,
- The theory of cosmic ray acceleration with interesting implications for the experimental program on UHECR of the lab (AUGER),

In all these areas the APC group is at the highest level of international standards.

One regret is the lack of a theoretical component to support the experimental activity of APC in gravitational wave research (Advanced VIRGO, LISA pathfinder) after the departure of a leading theorist in 2005.

More formal lines of research include some of today's "hot topics":

- Holography with application to Heavy Ion collisions and Condensed Matter Physics,
- Higher-spin theories in curved backgrounds (like Anti de Sitter spacetime),
- Quantum Field Theory in curved space-time (with some possible application to cosmology),
- Coherent state quantization.

### Assessment of the unit's academic reputation and appeal

On the whole: a very good level of research with a good and balanced spectrum of topics for an experiment-driven lab.

The group is clearly very attractive to postdocs to Ph. D. students (a large share of APC postdocs and Ph. Ds for the group's size), and to visitors, and has excellent connections with other groups worldwide (DAMTP, Cambridge UK and Yukawa Institute, Kyoto, for instance). It has been co-organizing international conferences with the Perimeter Institute (Canada) and the Solvay Institute (Brussels). It was also able to attract both European and French funding through 1 ERC and 3 ANR grants, respectively.

### Assessment of the unit's interaction with the social, economic and cultural environment

The group has also high visibility and cultural impact with respect to the public through the organization of public conferences and exhibitions, popular science books and journals.



### Assessment of the unit's organisation and life

The group appears to function smoothly and without any visible problem. It organizes regular seminars as well as topical workshops that are well attended by members of the group as well as by theorists from the greater Paris area. Integration of the group in the FRIF (Federation de Recherche pour les Interactions Fondamentales), which regroups several theory groups in Paris (ENS, Paris 6, Collège de France, IAP), has been launched some 8 years ago, so far with partial success, but a higher involvement is being planned.

### Assessment of the unit's involvement in training through research

The theory group is strongly involved in teaching (even by some of the CNRS staff) at all levels (undergraduate, master and Ph. D.). Some teaching is also given outside of Paris 7 (e.g. at the Ecole Polytechnique).

### Assessment of the five-year plan and strategy

The future plans of the group are sound: they will continue the traditionally strong lines of theoretical research with very good interactions with the various experimental groups at APC and an increased interaction with other theory groups in Paris (via their membership in the FRIF). Hopefully their search for a GW theorist will also succeed.



## 5 • Conduct of the visit

### Visit dates:

Start: Wednesday 30 January 2013 at 11.00 am

End: Friday 1 February 2013 at 12.30 pm

Visit site: APC, Bâtiment Condorcet

Institution: Université Paris Diderot

Address: 10, rue Alice Domon et Léonie Duquet, Paris (13th)

Specific premises visited: laboratories, data centre Francois Arago, photodetection lab, clean rooms, millimetric lab, spectro-imager lab

### Conduct or programme of visit:

#### 1st day Wednesday January 30, 2013

11h00	Closed session of the committee
11h30	Plenary session (open) Director : APC Report and Project
12h30	Lunch and discussion
13h30	Plenary session (open) : <ul style="list-style-type: none"> <li>• Highlights of the Planck space mission (15'+5')</li> <li>• High energy phenomena in the Galactic centre (15'+5')</li> <li>• World theta_13 with Double Chooz (15'+5')</li> <li>• From k-essence to generalized Galileons (15'+5')</li> <li>• FAcE: first achievements (15'+5')</li> </ul>
16h00	Visit of the laboratory
17h30	Meet Non-permanent personnel (PhD Students) Closed
18h00	Meet Non-permanent personnel (Postdocs) Closed
18h30	Closed session, prepare next day
19h00	Adjourn



**2nd day, January 31, 2013 (all sessions closed)**

08h45	Meet Cosmology and Gravitation group
09h45	Meet Theory Group
10h45	break
11h00	Meet technical and administrative personnel
12h00	Meet ADAMIS group
13h00	Lunch
14h00	Meet High Energy Astrophysics group
15h00	Meet Neutrino group
16h00	Meet Laboratory Council
16h30	Break
16h45	Meet funding agencies : IN2P3, OP, CEA, Paris 7 (invited : INSU, CNES)
18h15	Meet Director

**3rd day, February 1, 2013 closed**

08h30	Closed session of the committee
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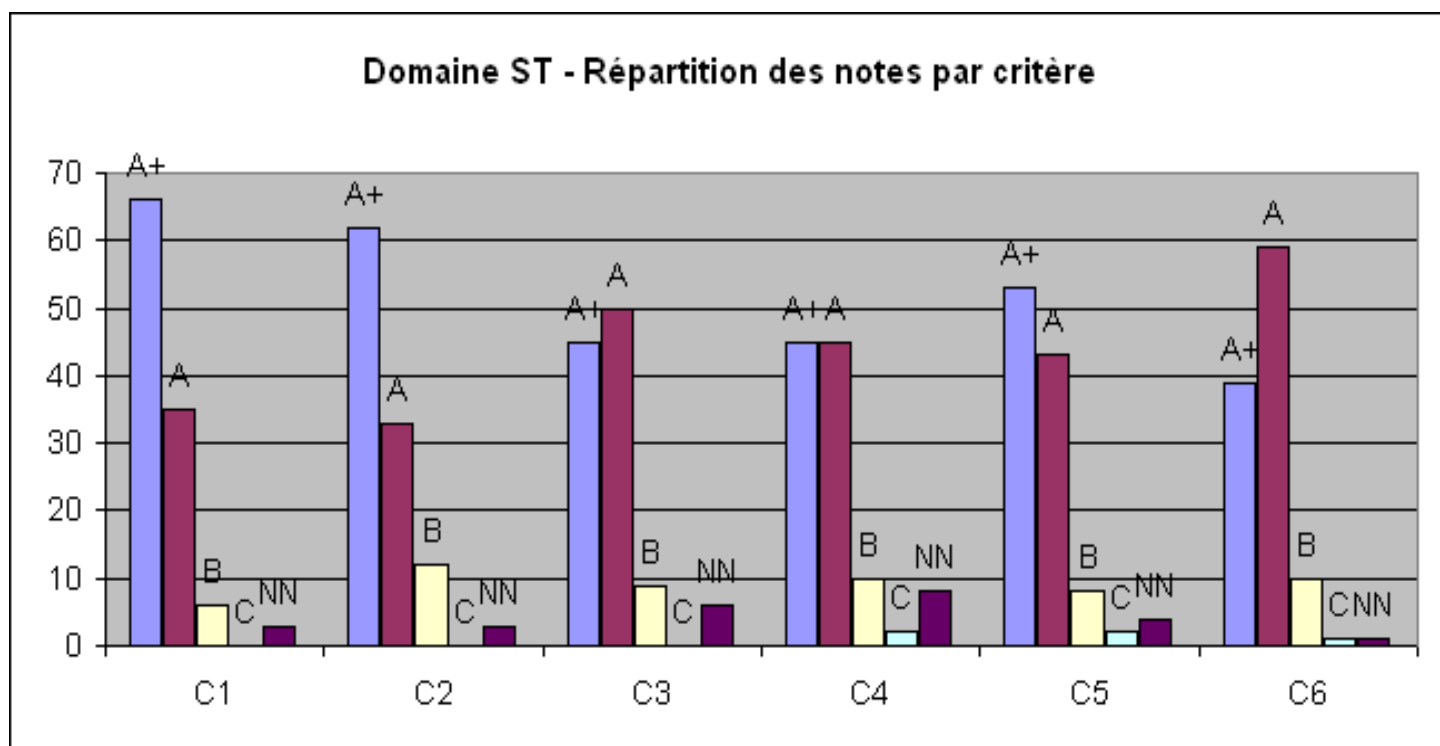
## 6 • Statistics

Grading tables and percentage per field

Critères	C1 Qualité scientifique et production	C2 Rayonnement et attractivité académiques	C3 Relations avec l'environnement social, culturel et culturel	C4 Organisation et vie de l'entité	C5 Implication dans la formation par la recherche	C6 Stratégie et projet à cinq ans
A+	66	62	45	45	53	39
A	35	33	50	45	43	59
B	6	12	9	10	8	10
C	0	0	0	2	2	1
Non Noté	3	3	6	8	4	1

Critères	C1 Qualité scientifique et production	C2 Rayonnement et attractivité académiques	C3 Relations avec l'environnement social, économique et culturel	C4 Organisation et vie de l'entité	C5 Implication dans la formation par la recherche	C6 Stratégie et projet à cinq ans
A+	60%	56%	41%	41%	48%	35%
A	32%	30%	45%	41%	39%	54%
B	5%	11%	8%	9%	7%	9%
C	0%	0%	0%	2%	2%	1%
Non Noté	3%	3%	5%	7%	4%	1%

Histogram





## 7 • Supervising bodies' general comments

Le Président

P/VB/LB/NC/YM – 2013 - 127  
Paris, le 06 mai 2013

M. Pierre Glaudes  
Directeur de la section des unités de l'AERES  
20 rue Vivienne  
75002 PARIS

**S2PURI40006408 - AstroParticule et Cosmologie - APC - 0751723R**

Monsieur le Directeur,

Je vous remercie, ainsi que les membres du comité de visite, pour l'envoi du rapport d'évaluation concernant l'unité Astroparticule et Cosmologie (APC), rapport qui souligne l'excellence de la qualité de la recherche qui est produite, attestée par le haut niveau qualitatif et quantitatif des publications tant au niveau national, qu'international.

Je me réjouis des commentaires très élogieux qui sont portés sur le laboratoire. Vous soulignez en particulier sa capacité à obtenir des financements sur des appels à projets (labex Univearths) et sur des appels d'offres nationaux ou internationaux comme l'"Equipex" GRAVITER. Je m'associe au comité quand vous citez la création du Centre Arago François (FACE) qui fournit une facilité d'analyse de données multi-mission unique et permet le stockage et le traitement des données avec une connectivité directe au CC-IN2P3 comme une des nombreuses réussites du laboratoire.

Ces succès témoignent du rayonnement et de la qualité de l'unité et laissent entrevoir de nouvelles opportunités pour la recherche spatiale au niveau national, ce dont notre université et ses partenaires ne peuvent que se féliciter.

Je vous prie d'agréer, Monsieur le Directeur, l'expression de toute ma considération.

Vincent Berger