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Planck sheds new light on the Big Bang

After fifteen months of observation, the European Space Agency (ESA)'s spacecraft Planck, launched in 2009 to observe the cosmic microwave background (the relic radiation from the Big Bang), has delivered its first results. The wealth of information they provide about the history and composition of the universe includes in particular: the most accurate map of the cosmic microwave background ever obtained; evidence of an effect predicted by inflationary models; a lower value for the expansion rate of the universe; and a new estimate of its composition. Much of this data was collected by Planck's main instrument, HFI, which was designed and assembled under the supervision of the Institut d'Astrophysique Spatiale (CNRS/Université Paris-Sud) with funding from CNES and CNRS.

Ever since it was discovered in 1965, the cosmic microwave background has been an invaluable source of knowledge for cosmologists, a kind of Rosetta Stone enabling them to unravel the history of the universe since the Big Bang. This sea of photons, which can be detected over the whole sky at radio wavelengths, is evidence of the state of the very early universe and shows the first traces of the large-scale structures that subsequently developed. Produced 380 000 years after the Big Bang, at the time when the first atoms formed, this relic radiation reaches us almost unchanged, providing scientists with an image of what the universe looked like at its birth around 13.8 billion years ago. Comparing these measurements with theoretical models provides a wealth of information, not only about the evolution of the universe since the appearance of the cosmic microwave background, but also about the earlier events that led up to it and are little known to astrophysicists.

A new map of the cosmic microwave background

This is one of the windows opened up by the Planck mission into the primordial universe. Launched in 2009, the ESA spacecraft has been mapping the cosmic microwave background over the whole sky for the past year and a half. Planck has two instruments, one of which, the High Frequency Instrument (HFI), was designed and assembled under the supervision of the Institut d'Astrophysique Spatiale (CNRS/Université Paris-Sud) with funding from CNES and CNRS. The instruments made it possible to measure the variations in light intensity of the primordial universe with unprecedented sensitivity, further refining earlier observations by the COBE and WMAP space missions, launched in 1990 and 1998 respectively. These variations in light intensity (which appear in the form of patches of varying brightness) are in fact the imprint of the seeds of the large-scale structures in today's universe. They correspond to the regions where matter subsequently clumped together and then collapsed in on itself, giving birth to stars, galaxies and galaxy clusters.

According to some theories, the origin of these 'lumps' or fluctuations in the cosmic microwave background is to be found in 'inflation', an event that occurred earlier in the universe's history. During this extremely violent episode, which is thought to have taken place 10^{-35} seconds after the Big Bang, the universe underwent a sudden expansion phase, increasing in size by a huge factor of at least 10^{26}. Planck has demonstrated the validity of one of the key predictions of inflationary theories, namely that the light intensity of 'large-scale fluctuations' should be slightly greater than that of 'small-scale fluctuations'. However, at bigger scales, the observed intensity is 10% lower than that predicted by inflation, an enigma that no theory is yet able to explain. Planck's findings also confirm with a high degree of certainty the existence of other previously observed anomalies, such as an unexplained asymmetry in average temperatures observed on opposite hemispheres of the sky, and the existence of a cold spot.

The data from the Planck nominal mission has given rise to around 30 simultaneously published papers which are available from 21 March 2013 at http://sci.esa.int and from 22 March 2013 at www.arxiv.org.
Other findings include:

- Confirmation that the universe is flat.
- A lower value for the Hubble constant, and therefore for the expansion rate of the universe.
- A new estimate of the composition of the universe, on the sole basis of the cosmic microwave background: 69.4% dark energy (compared to the earlier estimate of 72.8%), 25.8% dark matter (previously 23%), and 4.8% ordinary matter (previously 4.3%).
- Invaluable new maps that refine the scenario of the history of the universe and improve understanding of the physics governing its evolution. These maps show how dark matter and ordinary matter are distributed across the sky. The diffuse infrared background radiation corresponds to the light emitted by the dust in all the galaxies over the past ten billion years, making it possible to identify the regions where objects made of ordinary matter are concentrated.
- An initial analysis of the cosmological signal polarization, which shows that Planck results are remarkably consistent with data about the intensity of the cosmological microwave background at scales corresponding to future galaxy clusters. A more detailed analysis will be provided in 2014, together with other findings from the Planck mission.

The contribution of French research to the Planck mission

France is responsible for the Planck-HFI High Frequency Instrument, which has played a key role in the cosmological findings. It cost €140 million to build, involving 80 researchers from ten CNRS, CEA and university laboratories, as well as a large number of engineers and technicians. France contributed more than 50% towards its construction and the processing of its data. Half this funding was provided by CNES, the other half by CNRS and the universities. France also participates in the funding of the mission itself through its financial contribution to ESA's scientific program, representing 15% of the cost of the mission.

An essential French contribution to the Planck project was the supply of the cooling system keeping the HFI instrument at a temperature of 0.1 degrees above absolute zero. Patented by CNES, the system was invented by Alain Benoît (CNRS) from the Institut Néel (earning him the 2012 CNRS Medal of Innovation) and developed by Air Liquide. Thanks to this innovation, the HFI camera holds the record as the coldest-ever space instrument, with a cryostat that was cooled to -273,05°C for around a thousand days.
(http://www2.cnrs.fr/presse/communique/2679.htm).

The scientific results are mostly processed by CNRS, and in particular Jean-Loup Puget (at IAS), HFI Principal Investigator, and François Bouchet (IAP), Co-Principal Investigator.

French laboratories taking part:

- APC, AstroParticule et Cosmologie (Université Paris Diderot-Paris 7, CNRS, CEA, Observatoire de Paris), Paris: development of testing facilities.

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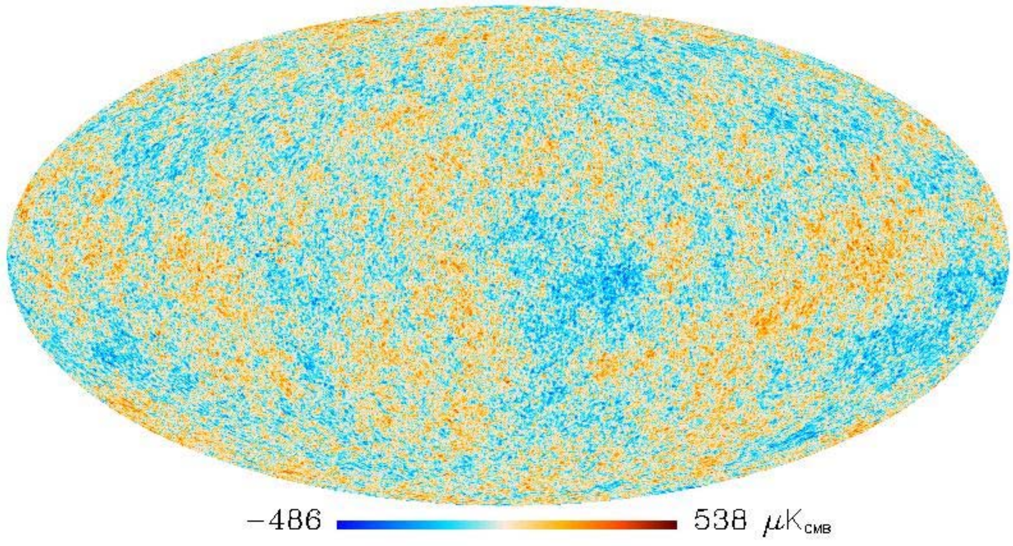
- IAP, Institut d'Astrophysique de Paris (CNRS, UPMC), Paris: development of scientific objectives and data processing design.
- IAS, Institut d'Astrophysique Spatiale (Université Paris-Sud, CNRS), Orsay: initial design and scientific and technical responsibility for the instrument.
- Institut Néel (CNRS), Grenoble: development of cryogenics at 0.1 K.
- IPAG, Institut de Planétologie et d'Astrophysique de l'Observatoire des Sciences de l'Univers de Grenoble (CNRS, Université Joseph Fourier Grenoble 1), Grenoble : instrument modeling.
- IRAP, Institut de Recherche en Astrophysique et Planétologie de l'Observatoire Midi-Pyrénées (Université Paul Sabatier Toulouse III, CNRS), Toulouse: development of the detectors' electronics.
- CEA-IRFU, Institut de Recherche sur les Lois Fondamentales de l'Univers du CEA, Saclay: electromagnetic compatibility studies.
- LAL, Laboratoire de l'Accélérateur Linéaire (CNRS, Université Paris-Sud,), Orsay: development of the on-board computer.
- LERMA, Laboratoire d'Etude du Rayonnement et de la Matière en Astrophysique (Observatoire de Paris, CNRS, ENS Paris, Université Cergy Pontoise, UPMC), Paris: instrument modeling.
- LPSC, Laboratoire de Physique Subatomique et de Cosmologie (Université Joseph-Fourier Grenoble 1, CNRS, Grenoble INP), Grenoble: development of cryogenics at 20 K.
- CNRS's National Institute of Nuclear and Particle Physics Computing Center (CC-IN2P3): takes part in data storage and processing.

To find out more: www. planck.fr.



Map of the cosmic microwave background temperature over the whole sky, drawn up by the Planck collaboration on the basis of data collected by the HFI and LFI instruments on the spacecraft. The color scale is in millionths of a degree, corresponding to the difference in temperature compared with the average -270.425 °C measured by the COBE spacecraft in 1992.
Credit:: ESA – Planck Collaboration

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Special event:
"The Big Bang: will Planck reveal the origin of the Universe?"
"*Parlons-en*": the CNRS public debates
Thursday 28 March 2013 at 7 pm
Free admission - Musée du quai Branly (37 Quai Branly - 75007 Paris)
Take part in the online debate from 7 pm, by clicking on www.20minutes.fr and www.cnrs.fr/lesgrands

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