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# Planck: final data from the mission lends strong support to the standard cosmological model

**In 2013, ESA's Planck mission unveiled a new image of the cosmos: an all-sky survey of the microwave radiation produced at the beginning of the Universe. This first light emitted by the Universe provides a wealth of information about its content, its rate of expansion, and the primordial fluctuations in density that were the precursors of the galaxies. The Planck consortium publishes the full and final version of these data and associated articles on the ESA website on 17 July 2018. The corresponding articles have been submitted to the journal *Astronomy & Astrophysics*. With its increased reliability and its data on the polarisation of relic radiation[1], the Planck mission corroborates the standard cosmological model with unrivalled precision for these parameters, even if some anomalies still remain. For this work the Planck consortium called upon some three hundred researchers, in particular from CNRS, CNES (the French national space agency), CEA (the French Alternative Energies and Atomic Energy Commission) and several universities in France.**

Launched in 2009, ESA's Planck satellite mapped the cosmic microwave background, microwave radiation emitted 380,000 years after the Big Bang, when the Universe was still a hot, almost completely homogeneous gas. Tiny variations in its temperature provide information about its content, its rate of expansion and the properties of the primordial fluctuations that gave rise to the galaxies. An initial analysis of the data set was published in 2015, in the form of eight all-sky maps that included the polarisation of the cosmic microwave background, which determines how the waves that make up light vibrate on tiny scales. This key information bears the imprint of the last interaction between light and matter in the primordial Universe. However, only a preliminary analysis had been carried out on it.

The polarisation of relic radiation produces a signal 50 to 100 times weaker than that of its temperature and 10 to 20 times weaker than that emitted by the polarized emission of Galactic dust. Thanks to its HFI (High Frequency Instrument), the Planck satellite nonetheless obtained an extremely precise map of primordial polarisation across the entire sky. This was a world first and provides us with a wealth of information.

Comprehensive, definitive and more reliable, the data published on 17 July 2018 confirms the preliminary findings, supporting a model which provides an excellent description of the content of the Universe in terms of ordinary matter, cold dark matter and dark energy (whose nature is unknown), with an inflation[2] phase at

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[1] Polarisation is a property of light in the same way as colour (or frequency) or direction of propagation. Although this property is invisible to the human eye, it is familiar to us (e.g. sunglasses with polarised lenses or 3D glasses for the cinema). It generally provides us with information about the physical processes that gave rise to it.

[2] An extremely rapid expansion of the Universe in its very first moments, giving rise to primordial density fluctuations.

its very beginning. This cosmological model can now be derived using temperature or polarisation data independently, with comparable accuracy. This considerably reinforces the standard model of cosmology, however surprising this may be[3]. The results are described in a set of a dozen scientific papers, involving around three hundred researchers (see list of French laboratories involved below).

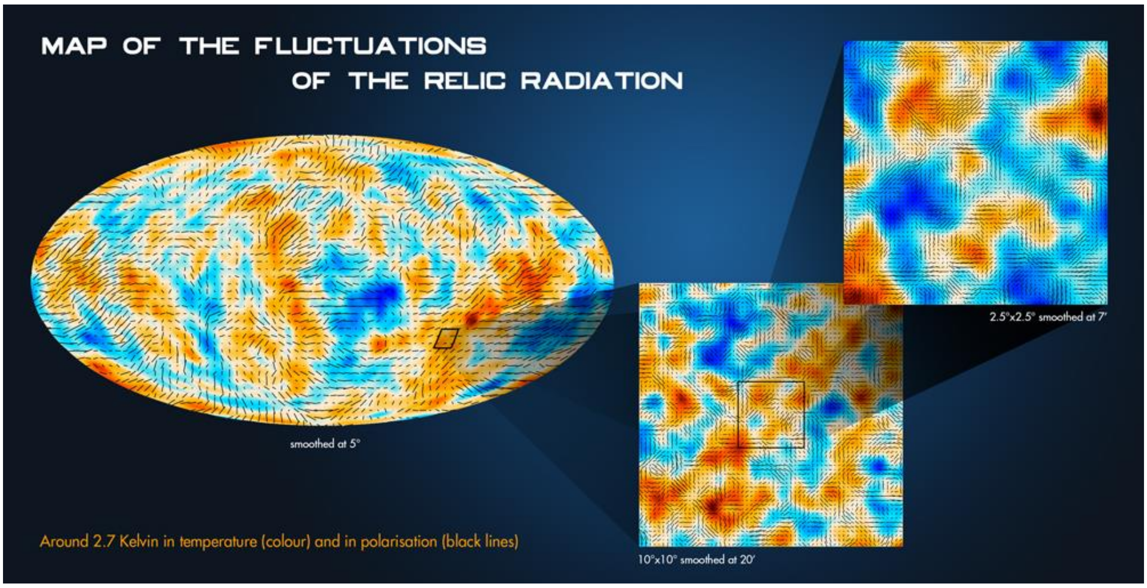
However, some anomalies and limitations remain. In particular, the rate of expansion of the Universe differs by a few percent depending on whether the data from the Hubble Space Telescope or from the Planck mission are used. This question is still an open one, and a host of telescopes will be marshalled in an attempt to resolve the issue.

**The Planck collaboration was awarded the 2018 Gruber Prize in Cosmology, and involves the following laboratories in France:**

- APC, AstroParticule et Cosmologie (Université Paris Diderot/CNRS/CEA/Observatoire de Paris), Paris.
- IAP, Institut d'Astrophysique de Paris (CNRS/Sorbonne Université), Paris.
- IAS, Institut d'Astrophysique Spatiale (Université Paris-Sud/CNRS), Orsay.
- Institut Néel (CNRS), Grenoble.
- IPAG, Institut de Planétologie et d'Astrophysique de Grenoble, (CNRS/Université Grenoble Alpes)[4], Grenoble.
- IRAP, Institut de Recherche en Astrophysique et Planétologie (Université Toulouse III - Paul Sabatier/ CNRS/CNES)[4], Toulouse.
- CEA-IRFU, Institut de Recherche sur les Lois Fondamentales de l'Univers du CEA, Saclay.
- LAL, Laboratoire de l'Accélérateur Linéaire (CNRS/Université Paris-Sud), Orsay.
- LERMA, Laboratoire d'Etudes du Rayonnement et de la Matière en Astrophysique et Atmosphères (Observatoire de Paris/CNRS/ENS/ Université Cergy-Pontoise/Sorbonne Université), Paris.
- LPSC, Laboratoire de Physique Subatomique et de Cosmologie (Université Grenoble Alpes/CNRS/ Grenoble INP), Grenoble.
- CC-IN2P3, CNRS's National Institute of Nuclear and Particle Physics (IN2P3) Computing Center.

[3] 95% of the Universe is made up of dark matter and dark energy, whose nature is not known. Researchers can only detect it through its gravitational effect. The independent and vital contribution of polarisation is thus key to better understanding how the Universe works.

[4] IPAG is part of the Observatoire des Sciences de l'Univers de Grenoble, while IRAP belongs to the Observatoire Midi-Pyrénées.




*Maps of the direction of polarisation of primordial light represented by rods whose length is proportional to the intensity of the polarisation. Temperature anisotropies are shown in the background in colour. The all-sky map only shows large scales. The two square maps are successive enlargements of the regions bounded by a black contour (around the south ecliptic pole), which shows that Planck measured cosmological signals at scales much smaller than those that can be shown on an all-sky map. © ESA - Planck Collaboration - HFI-France*

## To find out more

Two press releases about previous results from the Planck mission:
- Planck reveals the dynamic side of the Universe, February 2015
- Planck: new revelations on dark matter and relic neutrinos, December 2014

- Information about Planck on the CNES website: https://planck.cnes.fr/en/PLANCK/index.htm

## References

Planck 2018 results. I. & Overview and the cosmological legacy of Planck.
Planck 2018 results. II. & LFI data processing.
Planck 2018 results. III. & HFI data processing.
Planck 2018 results. IV. & CMB and foreground extraction.
Planck 2018 results. V. & Power spectra and likelihood.
Planck 2018 results. VI. & Cosmological parameters.

Planck 2018 results. VII. & Isotropy and statistics.
Planck 2018 results. VIII.& Lensing.
Planck 2018 results. IX. & Constraints on primordial non-Gaussianity.
Planck 2018 results. X. & Inflation.
Planck 2018 results. XI. & Polarized dust foregrounds.
Planck 2018 results. XII. & Galactic astrophysics from polarization.

Available on the ESA website : https://www.cosmos.esa.int/web/planck/publications

**Contacts**

**CNRS researcher** I François Bouchet I bouchet@iap.fr / skype: francois.bouchet ( in Los Angeles)
**CNRS researcher** I Jean-Loup Puget I I jean-loup.puget@ias.u-psud.fr
**CNRS Press Office** I Alexiane Agullo I **T +33 1 44 96 51 51** I alexiane.agullo@cnrs-dir.fr