Mem. S.A.It. Vol. 83, 72

Memorie della

The Planck mission

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Abstract. The European Space Agency's *Planck* satellite was launched on 14 May 2009, and has been surveying the sky stably and continuously since August 2009. Its performance is well in line with expectations, and it will continue to gather scientific data until the end of its cryogenic lifetime. We give an overview of the current status of *Planck* and describe the first data (the Early Release Compact Source Catalogue) and scientific papers which have been released to date by the *Planck* Collaboration.

Key words. Cosmology: observations – Cosmic background radiation – Surveys – Space vehicles: instruments – Instrumentation: detectors

1. Introduction

The *Planck* satellite[1] was launched on 14 May 2009, and has been surveying the sky routinely since 13 August 2009. *Planck* carries a scientific payload consisting of an array of 74 detectors sensitive to a range of frequencies between ~ 25 and $\sim$ 1000 GHz, which scan the sky simultaneously and continuously with an angular resolution varying between $\sim$30 arcminutes at the lowest frequencies and $\sim$5 arcminutes at the highest. The array is arranged into two instruments: the detectors of the Low Frequency Instrument (LFI; Bersanelli et al. 2010; Mennella et al. 2011) are pseudo-correlation radiometers, covering three bands centred at 30, 44, and 70 GHz; and the detectors of the High Frequency Instrument (HFI; Lamarre et al. 2010; Planck HFI Core Team 2011a) are bolometers, covering six bands centred at 100, 143, 217, 353, 545 and 857 GHz. The design of *Planck* allows it to image the whole sky approximately twice per year, with an unprecedented combination of sensitivity, angular resolution, and frequency coverage. The *Planck* satellite (see Fig. 1), its payload, and its performance as predicted at the time of launch, are described in 13 articles included in a special issue (Volume 520) of Astronomy & Astrophysics. The main objective of *Planck* is to measure the spatial anisotropies of the temperature of the Cosmic Microwave Background (CMB), with an accuracy set by fundamental astrophysical limits. Its level of performance will enable *Planck* to extract essentially all the information in the CMB temperature anisotropies. *Planck* will also measure to high accuracy the polarisation of the CMB anisotropies, which encodes not only a wealth of cosmological information, but also provides a unique probe of the ther-

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[1] *Planck* (`http://www.esa.int/Planck`) is a project of the European Space Agency – ESA – with instruments provided by two scientific Consortia funded by ESA member states (in particular the lead countries: France and Italy) with contributions from NASA (USA), and telescope reflectors provided in a collaboration between ESA and a scientific Consortium led and funded by Denmark.

mal history of the Universe during the time when the first stars and galaxies formed. In addition, the *Planck* sky surveys will produce a wealth of information on the properties of extragalactic sources and on the dust and gas in our own Galaxy. The scientific objectives of *Planck* are described in detail in Planck Collaboration (2005).

2. Status

At the time this paper is being submitted, *Planck* has completed four surveys of the whole sky. In January 2011, the first set of *Planck* data was released to the public by ESA. This data set is the Early Release Compact Source Catalogue (ERCSC), a list of unresolved and compact sources extracted from the first complete all-sky survey carried out by *Planck*. The ERCSC (Planck Collaboration 2011d) consists of:

- nine lists of sources, extracted independently from each of *Planck*'s nine frequency bands
- two lists of sources extracted using multiband criteria targetted at selecting specific types of source, i.e.,
  - "Cold Cores," cold and dense locations in the Insterstellar Medium of the Milky Way, selected mainly based on their estimated dust temperature
  - clusters of galaxies, selected using the spectral signature left on the Cosmic Microwave Background by the Sunyaev-Zeldovich (SZ) effect

The ERCSC is a high-reliability compilation of sources, released early to give the astronomical community a timely opportunity to follow up these sources using ground- or space-based observatories, most particularly ESA's *Herschel* observatory, which has a limited lifetime. The ERCSC is made available to the public through an online distribution system accessible via *http://www.rssd.esa.int/Planck*.

At the same time, the *Planck* Collaboration has published a package of scientific papers consisting of:

- a paper (Planck Collaboration 2011a), which describes the history and main performance elements of the *Planck* satellite in its first year of life
- two papers describing the performance of each of *Planck*'s two instruments (LFI and HFI) within the same period (Mennella et al. 2011; Planck HFI Core Team 2011a)
- a paper describing the thermal performance of *Planck* in orbit (Planck Collaboration 2011b)
- two papers describing the data processing, which has been applied to the data acquired by LFI and HFI, to produce the maps used for the ERCSC and the scientific papers in this package (Zacchei et al. 2011; Planck HFI Core Team 2011b)
- an Explanatory Supplement to the ERCSC (Planck Collaboration 2011w), describing in detail the production and characteristics of the ERCSC
- a paper summarising the production of the ERCSC, and the main characteristics of the sources that it contains (Planck Collaboration 2011d)
- twelve papers describing in more detail: (a) specific aspects of different source populations contained in the ERCSC (radio sources, infrared galaxies, galaxy clusters, cold cores etc.); and (b) cross-correlation analysis and follow-up observations which form part of the scientific validation and analysis of the ERCSC data. These papers are:
  1. Planck Collaboration (2011e) describes the physical properties of the sample of clusters included in the ERCSC
  2. Planck Collaboration (2011c) describes the validation of a subset of the cluster sample by follow-up observations with the *XMM-Newton* X-ray observatory
  3. Planck Collaboration (2011f) analyses the statistical relationship between SZ flux and X-ray luminosity of the ERCSC cluster sample
  4. Planck Collaboration (2011g) uses a high signal-to-noise subset of the ERCSC cluster sample to investigate the relationship between X-ray-derived masses and SZ fluxes

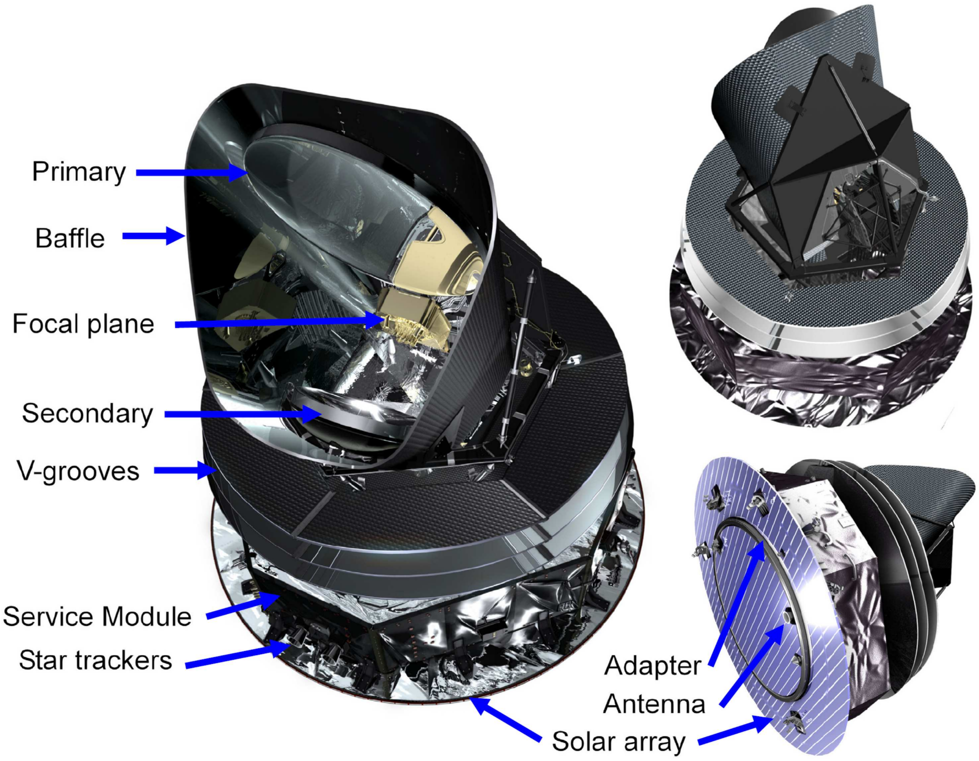

Fig. 1. An artist's impression of the main elements of the *Planck* satellite.

5. Planck Collaboration (2011h) studies the relation between SZ flux and optical properties of galaxy clusters by stacking *Planck* fluxes at the locations of the MaxBCG optical cluster catalogue
6. Planck Collaboration (2011v) studies an exceptionally X-ray luminous and massive galaxy cluster detected by *Planck* at z∼1
7. Planck Collaboration (2011i) analyses the statistical properties of a complete sub-sample of radio sources drawn from the ERCSC
8. Planck Collaboration (2011j) describes the spectral energy distributions and other properties of some extreme radio sources, using *Planck* ERCSC data and ground-based observations
9. Planck Collaboration (2011l) presents the spectral energy distributions of a sample of extragalactic radio sources, based on the *Planck* ERCSC and simultaneous multi-frequency data from a range of other observatories
10. Planck Collaboration (2011m) studies the dust properties of nearby galaxies ($z < 0.25$) present in the ERCSC
11. Planck Collaboration (2011s) presents the statistical properties of Cold Cores as observed by *Planck*, in terms of spatial distribution, temperature, distance, mass, and morphology
12. Planck Collaboration (2011r) presents the physical properties and discusses the nature of a selection of interesting Cold Cores observed by *Planck*.

– seven papers describing in more detail selected science results, based on the maps which were used as input for the production of the ERCSC. The results addressed in these papers are characterised by their robustness, a critical element required for publication at a rather early stage in the reduction of the *Planck* data. These seven are:

1. Planck Collaboration (2011n) presents estimates based on *Planck* and *IRAS* data for the apparent temperature and optical depth of interstellar dust in the Small and Large Magellanic Clouds, and investigates the nature of the millimetre-wavelength excess emission observed in these galaxies
2. Planck Collaboration (2011o) presents estimates of the angular power spectrum of the Cosmic Infrared Background as observed by *Planck* in selected regions of the sky
3. Planck Collaboration (2011k) estimates over the whole sky the apparent temperature and optical depth of interstellar dust based on *Planck* and *IRAS* data, and investigates the presence of "dark" gas, i.e., gas which is not spatially correlated with known tracers of neutral and molecular gas
4. Planck Collaboration (2011p) constructs the spectral energy distributions of selected regions in the Milky Way, using *Planck* maps combined with ancillary multi-frequency data, and investigates the presence of anomalous excess emission which can be interpreted as arising from small spinning grains
5. Planck Collaboration (2011q) estimates the radial distribution of molecular, neutral, and ionised gas in the Milky Way, using as spatial templates a wide variety of tracers of the different phases and components of the interstellar medium
6. Planck Collaboration (2011t) presents a joint analysis of *Planck*, *IRAS*, and 21-cm observations of selected high-Galactic-latitude fields, and discusses the properties of dust in the diffuse interstellar medium close to the Sun and in the Galactic halo
7. Planck Collaboration (2011u) presents *Planck* maps of a selection of nearby molecular clouds, and discusses the evolution of the emitting properties of the dust particles embedded in them.

The next release of *Planck* products will take place in January 2013, and will cover data acquired in the period up to 27 November 2010. It will include:

– cleaned and calibrated data timelines for each detector
– all-sky maps for each frequency band between 30 and 857 GHz
– catalogues of compact sources extracted from the frequency maps
– maps of the main diffuse components separated from the maps, including the CMB
– scientific results based on the data released.

A third release of products is foreseen after January 2014, to cover the data acquired beyond November 2010 and the end of *Planck* operations.

Acknowledgements. This paper is written on behalf of the Planck Collaboration. A description of the Planck Collaboration and a list of its members, indicating which technical or scientific activities they have been involved in, can be found at (http://www.rssd.esa.int/index.php?project=PLANCK&page=Planck_Collaboration). The Planck Collaboration acknowledges the support of: ESA; CNES and CNRS/INSU-IN2P3-INP (France); ASI, CNR, and INAF (Italy); NASA and DoE (USA); STFC and UKSA (UK); CSIC, MICINN and JA (Spain); Tekes, AoF and CSC (Finland); DLR and MPG (Germany); CSA (Canada); DTU Space (Denmark); SER/SSO (Switzerland); RCN (Norway); SFI (Ireland); FCT/MCTES (Portugal); and DEISA (EU).

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