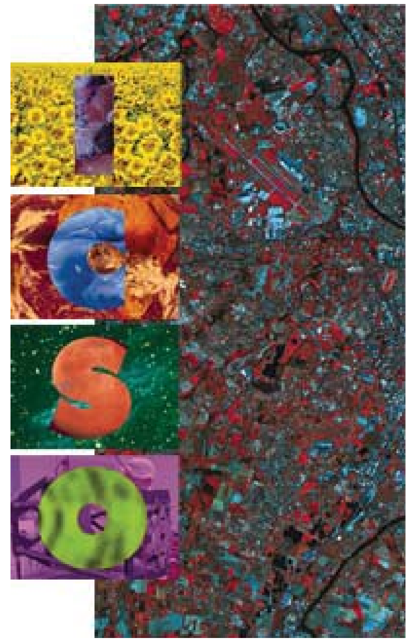
International Conference on Space Optics—ICSO 2000

Toulouse Labège, France

5–7 December 2000

Edited by George Otrio



Straylight analysis for the planck telescope

Denis Dubruel, Julien Brossard, Patrick Astruc,
Peter de Maagt, et al.

International Conference on Space Optics — ICSO 2000, edited by George Otrio, Proc. of SPIE Vol. 10569
105690E · © 2000 ESA and CNES · CCC code: 0277-786X/17/$18 · doi: 10.1117/12.2307942

STRAYLIGHT ANALYSIS FOR THE PLANCK TELESCOPE

Denis DUBRUEL [(1)], Julien BROSSARD [(1)], Patrick ASTRUC [(1)], Peter. DE MAAGT [(2)], Thomas. PASSVOGEL[(2)], Jan. TAUBER[(2)]

[(1)] ALCATEL SPACE INDUSTRIES
100, boulevard du midi - BP 99
06156 Cannes la Bocca Cedex - FRANCE.
denis.dubruel@space.alcatel.fr

[(2)] European Space Agency
Keplerlaan 1, Postbus 299
2200 AG Noordwijk, The Netherlands
tpassvogel@estec.esa.nl

ABSTRACT – PLANCK and FIRST will be launched from the European Space Port Kourou by an Ariane 5 in 2007 and spin-operated during 14 months at the L2 Lagrangian point. The aims of PLANCK are to obtain definitive images of the CMB fluctuations and to subtract the primordial signal to high accuracy from contaminating astrophysical source of emission. This can be achieved by a space telescope having a wide frequency coverage and excellent control of systematic errors (eg. stray light and thermal variations).

The telescope is an off-axis aplanatic design consisting of two concave ellipsoidal mirrors with a 1.5-meter pupil, derived from radio frequency antenna, but with a very wide spectral domain ranging from far infrared (350 µm) up to millimeter wavelengths (10 mm). The short wavelength detectors (bolometers operating at 0.1 K) are located at the centre of the focal plane while the high wavelength ones (based on HEMT amplifier technology operating at 20 K) are located at the periphery.

The Planck telescope operates at a temperature below 60 K. This level is achieved in a passive way, i.e. using a cryogenic radiator. Furthermore, this radiator must accommodate a set of coolers dedicated to the focal plane, cooling one of the experiments down to 0.1 K.

The main performance of the Planck spacecraft is the result of the electromagnetic performance of its telescope combined with its capacity to reject parasitic signals characterised by the Straylight Induced Noise (SIN). In this case , three sources are studied and modelled, the internal straylight coming from the spacecraft itself, the galactic straylight coming from the sky, and the straylight induced by planets.

This paper will describe the methods, tools and results obtained by Alcatel to *assess this performance.*

Keywords : Space, Telescope, Infrared, Antenna, Radio frequency, straylight.

1 – INTRODUCTION

Planck is an ESA scientific mission dedicated to produce map of the temperature fluctuations of the Cosmic Microwave Background, the fossil radiation carrying direct information from the early universe. The CMB was discovered in 1965 by Penzias&Wilson. In 1989, the NASA's Cosmic Background Explorer (COBE) was launched leading in 1992 to the detection of small temperature irregularities ($\Delta T/T \approx 1.10^{-5}$) on angular scale of about 7°.

Since then, ground and stratospheric flight balloon experiment have improved the spatial resolution. Hence NASA and ESA have planned two missions : MAP (2000) and PLANCK (2007) with improved resolution and sensitivity.

PLANCK will provide true all-sky maps of the background radiation at 9 frequencies bands (30 - 860 GHz) covering the major sources of microwave emission. To achieve the scientific goals of PLANCK, the primordial anisotropy signal has to be separated to high accuracy from contaminating extragalactic and galactic foregrounds. The PLANCK instrument design is composed of two detectors arrays; a low frequency instrument (LFI) based upon HEMT detector for frequencies range within 30 to 100 GHz and a high frequency instrument (HFI) composed of bolometers to cover 100 to 860 GHz.

The launch is forecast in 2007 from the european space port in Kourou by an Ariane 5, the PLANCK mission will be merged with another ESA mission FIRST (see fig. 1). Those two missions going to Lissajous orbit around the libration point (L2) in the Earth-Sun system.

ORBITS & MISSION

The separation from the launcher is performed in two steps :
FIRST is separated first from Planck upon Ariane 5 commands, then Planck is separated from Ariane 5 in a standard way. At the end of the launch phase a 3 axis stabilisation is required to separate FIRST. Then a re-orientation followed by a spin up to 1 rpm will be initiated to allow the PLANCK separation.
From that moment, both spacecraft will independently travel in direction to the L2 Lagrangian point of the Sun / Earth system (see fig. 2). FIRST will be directly injected in a "large Lissajous" orbit around L2, while Planck will orbit around L2 on a "small Lissajous" (+/-400 000 km) orbit after an injection manoeuvre taking place around 3 months after the launch. A detailled system presentation of FIRST and PLANCK is given by JJ Juillet et al [1]. These orbits provide very stable thermal environment (Sun Earth and Moon directions remain permanently in a limited cone) and provide also a low radiation environment. The operation and observation strategies will maintain the sun inside allowable directions compatible with the design of PLANCK (see fig. 3,fig. 4).

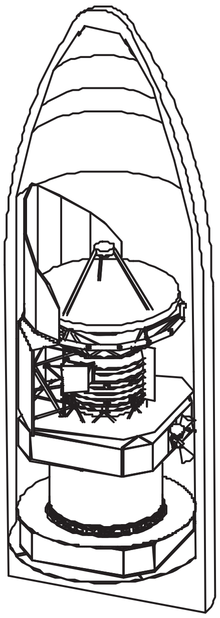


Figure 1: FIRST and PLANCK merged under Ariane 5 fairing.

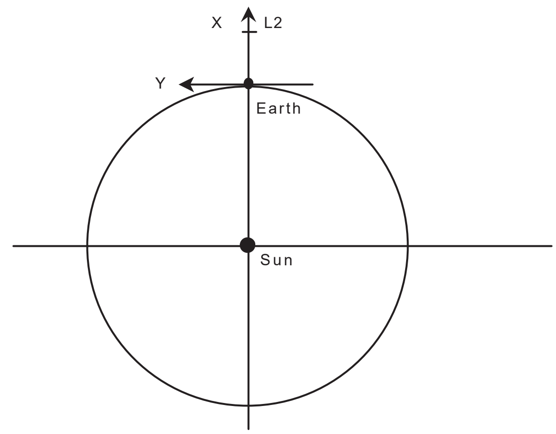


Fig 2 : Sun / Earth L2 point

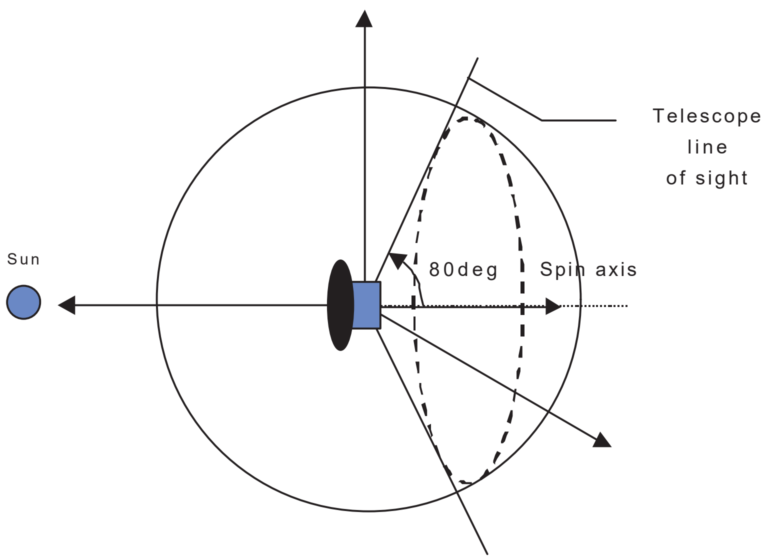


Figure 3 : Planck observation strategy

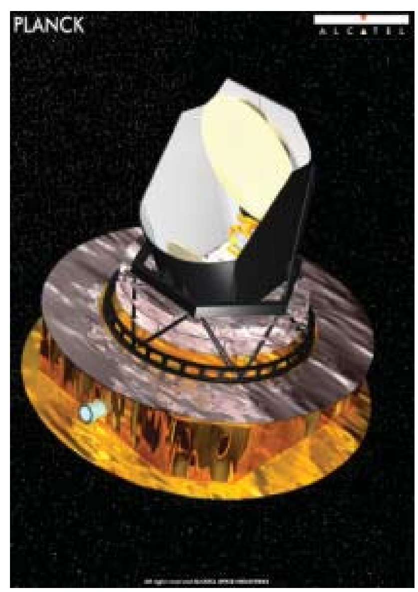


Fig 4 : PLANCK Spacecraft.

PLANCK ARCHITECTURAL DESCRIPTION

The spacecraft is spin operated at 1 rpm, the spin axis remains (+/- 15 deg) aligned with the Earth-Sun axis. The telescope light of sight is tilted by 80 degrees from the spin axis. In this frame, the whole sky will be covered. The telescope is mounted inside a baffle, thermally isolated from the Service Vehicle Module (SVM) via a groove thermal shield system. The general architecture is depicted in figure 5.

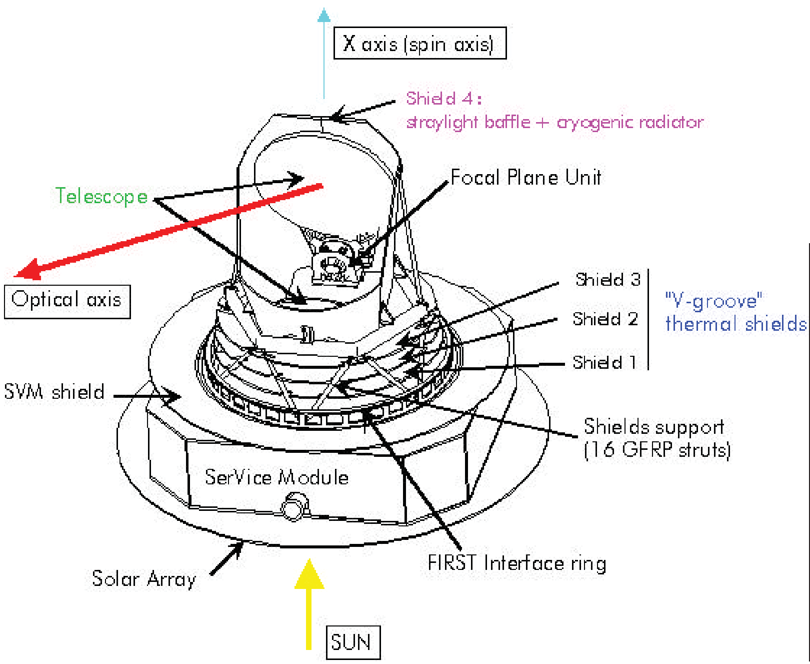


fig 5 : general architecture description

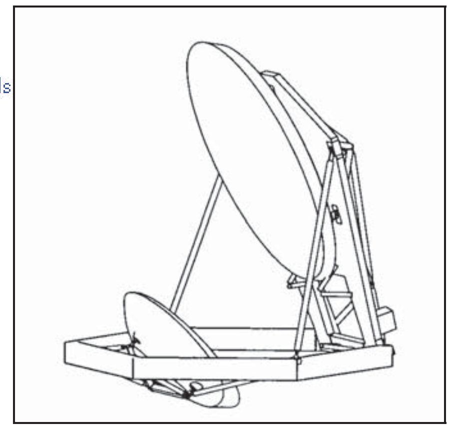


fig 6 : Optical configuration.

The optical telescope configuration (see. fig 6) optimisation has been described in a previous publication (Guy. Fargant et al [2]). The detector technology requires an efficient cool down system. This induces stringent thermal requirement (0.1 K for the HFI instrument, 20 K for the LFI) with low temperature fluctuations. The thermal design of the PLANCK payload has been published by Myriam Cornut et al [3].

The focal plane unit is composed by the HFI instrument (see fig 7) surrounded by the LFI one (see fig 8), all the horns/detectors are receiving the incoming signal passing through the optical system (secondary and primary mirror). The baffle surrounds the telescope for shadowing purposes : it is preferable to reject all the energy in the forward direction. This assembly is mounted over a V groove system designed to perform a passive thermal isolation. All this configuration is constrained by the FIRST interface tube for the launch configuration.

ABSTRACT – PLANCK and FIRST will be launched from the European Space Port Kourou by an Ariane 5 in 2007 and spin-operated during 14 months at the L2 Lagrangian point. The aims of PLANCK are to obtain definitive images of the CMB fluctuations and to subtract the primordial signal to high accuracy from contaminating astrophysical source of emission. This can be achieved by a space telescope having a wide frequency coverage and excellent control of systematic errors (eg. stray light and thermal variations).

The telescope is an off-axis aplanatic design consisting of two concave ellipsoidal mirrors with a 1.5-meter pupil, derived from radio frequency antenna, but with a very wide spectral domain ranging from far infrared (350 µm) up to millimeter wavelengths (10 mm). The short wavelength detectors