PLANCK UPDATE

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1 The PLANCK mission concept

The PLANCK experiment is an ESA medium class mission which aims at performing an unprecedented survey of the Cosmic Microwave Background (CMB). With an angular resolution of about 8 arc-minutes, a sensitivity reaching 6 micro-Kelvin rms per beam, and allowing polarization measurements, it will allow to derive the cosmological parameters with a precision of the order of a few %.

The PLANCK instrument consists in a 1.5 meter diameter off-axis telescope placed at point L2, 1.5 million kilometers from the Earth in the anti-solar direction. A total of 104 detectors working in full power mode are placed at the focus. They sample the spectrum over 9 frequency bands from 30 GHz to 900 GHz. The telescope is spinning at 1 rpm around its axis so that the beams are scanning the sky in a direction 80 degrees apart from this axis. The spin axis being kept toward the anti-solar direction, a full survey is obtained in about 6 months. The total mission duration is 24 months, which provides redundancy. Figure 1 presents a summary of the detectors in each wavelength band and their sensitivities. There are two detector assemblies in the PLANCK focal plane. Those are under the responsibility of two different scientific consortia: HFI (PI J.L. Puget, IAS Orsay Fr.) and LFI (PI R. Mandolesi, Bologna It.). The telescope and the service module will be built and assembled under the responsibility of an industrial contractor. The High Frequency Instrument (HFI) uses spider-web bolometers cooled

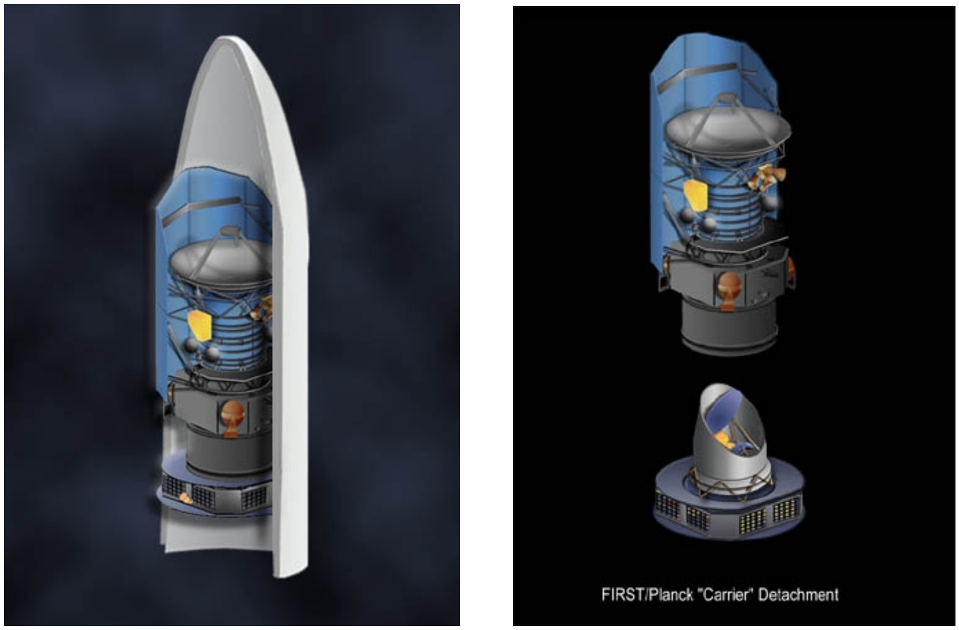


Figure 1: Common assembly of FIRST and PLANCK in the Ariane 5 launcher.

at 0.1 Kelvin , and the Low Frequency Instrument (LFI) uses HEMTs cooled at 18 Kelvin. The details of the focal plane assembly of the 104 horns from the 2 instruments are shown in Fig. 2.

The telescope is passively cooled at about 50 Kelvin. A set of hydrogen-sorption coolers provide a stage at about 18 Kelvin. An intermediate 4 Kelvin stage is obtained with a mechanical Joule / Thompson cryocooler. Finally, an open-cycle ^{3}He / ^{4}He dilution refrigerator provides the 0.1 Kelvin stage for the bolometers. PLANCK will be launched together with FIRST in 2007, in the same Ariane 5 rocket. Fig. 1 shows the FIRST / PLANCK assembly in their common launcher.

Table 1: PLANCK frequency bands, number of detectors (p = polarized), beam widths and sensitivities.

	LFI (56 HEMTs at 18K)				HFI (48 bolometers at 0.1K)					
ν (GHz)	30	44	70	100	100	143	217	353	545	857
Nb of detectors	4	6	12	34	4	12	12	6	8	6
Polarized det.	p	p	p	p	/	p(9)	p(8)	/	p	/
Beam (´)	33	23	14	10	10	7.1	5.0	5.0	5.0	5.0
Spillover	-21 dB				-29 dB					
1σ (mJy)	13	19	25	27	9	11	11	19	38	43
1σ ($10^6\Delta$T / T)	1.6	2.4	3.6	4.3	1.7	2.0	4.3	14	147	6700

2 Critical issues

A number of critical issues (thermal architecture, temperature stability, stray-light) have been cleared during the phase A studies conducted with ESA, the laboratories, and an industrial subcontractor (Alcatel Space).

The new payload architecture proposed by Alcatel is shown in Fig. 3. The telescope is passively cooled down to 50 K owing to three intermediate shields. The service module is at ambient temperature. The cold parts of the payload are protected against the radiation from the warm service module by an O-ring screen. This ring is essential to protect both optically and thermally the telescope against unwanted radiations.

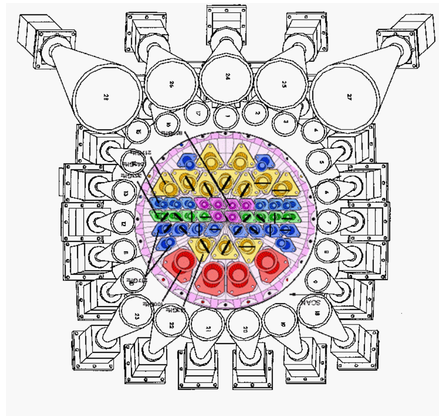


Figure 2: Face-on view of the PLANCK focal plane, HFI (inner) and LFI (outer).

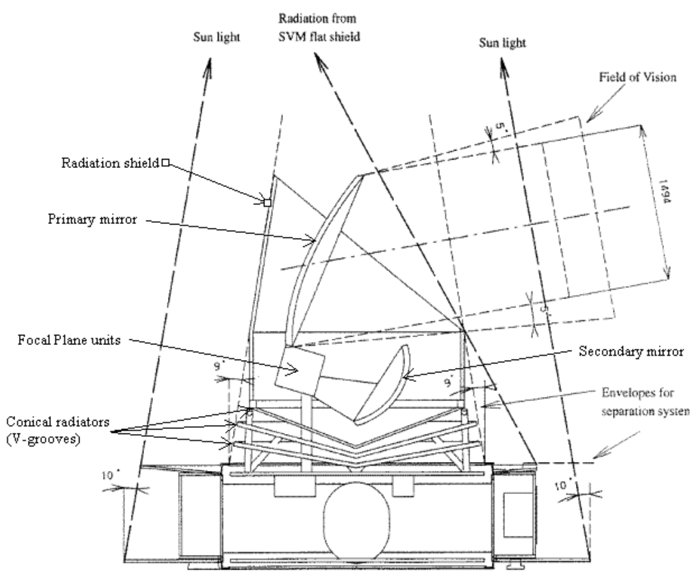


Figure 3: The new architecture of the PLANCK payload.

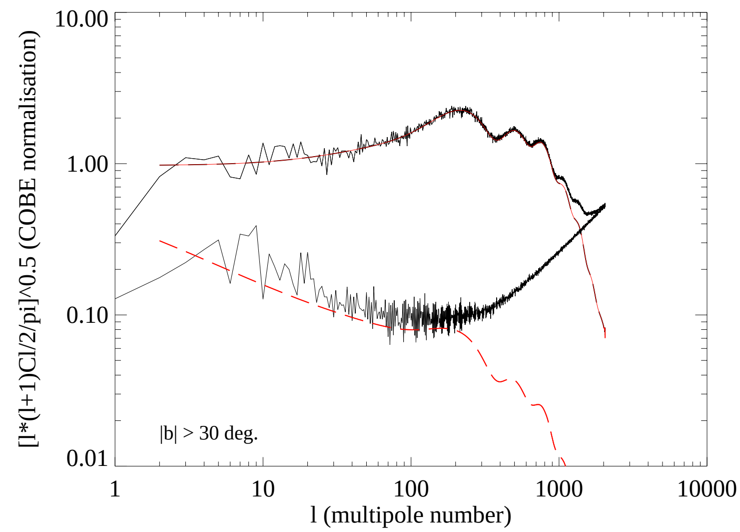
The temperature stability of the telescope and its baffle down to a level of about one micro-Kelvin is essential for the success of the mission. Temperature fluctuations of the warm parts of the payload will induce temperature fluctuations of the cold parts. The two main sources of temperature variations for the PLANCK payload are: 1) the radiator of the hydrogen sorption cooler, and 2) the rotation of the satellite when the spin axis is tilted from the sun axis. Both sources are expected to generate temperature variations of the order of several Kelvin in the warm service module. With the new architecture, the rejection of those fluctuations for the cold stages (telescope and baffle) is of the order of 1 ppm. This is enough to guaranty the requirement.

Regarding the stray-light issue, detailed simulations have shown that the far-sidelobe pickup on the Galaxy and other strong sources is lower than the survey noise level at all spatial frequencies except in the 2 high frequency bands, 545 and 857 GHz. In those two bands the level of the far-sidelobe pickup exceeds the rms noise level by a factor 3 to 4 at spatial frequencies corresponding to multi-pole modes smaller than $l = 10$.

3 Full mission simulation at 143 GHz

Fig. 4 shows a simulation of the sky map which will be obtained from the 143 GHz bolometer channel (all detectors co-added) and its spherical harmonics power spectrum (Cl's). This simulation uses a simple scanning strategy where the spin axis is periodically tilted 10 degrees from the ecliptic plane to cover the polar caps. We use the nominal bolometer noise performance with a 1/f component characterized by a critical frequency, $f_{knee} = 0.06 Hz$. Each sky circle is calibrated on the CMB dipole, assuming the COBE/DMR direction and amplitude. The de-stripping is optimized globally by subtraction of a constant on each data circle, using a maximum gradient iterative technique. In Cl space the noise (lower black curve) is dominated at low multi-pole numbers by the calibration procedure and at high multi-pole numbers by the detector noise. However the noise induced by the calibration uncertainty is close to the cosmic variance (red dashed curve).

For detailed informations on the PLANCK mission see the WEB pages at http://sci.esa.int/planck/



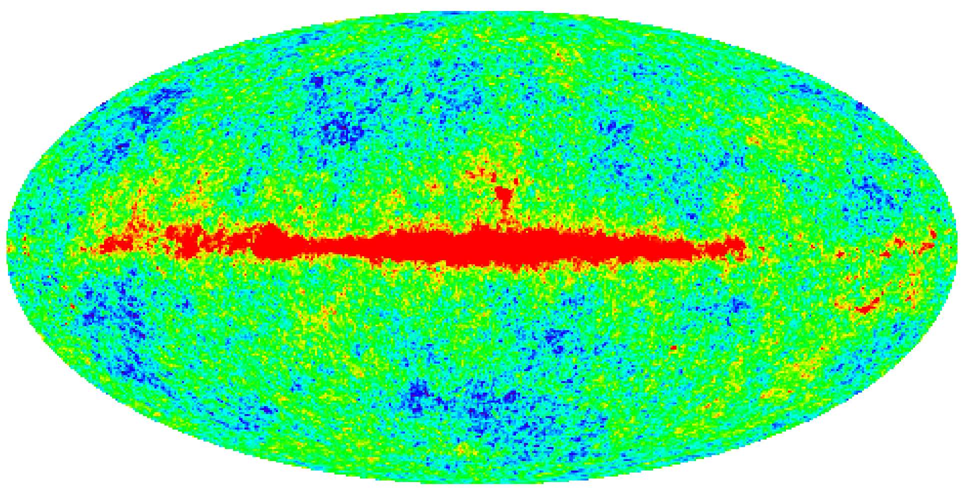


Figure 4: Map (lower) and Cl transform (upper) of a full sky simulation of the 143 GHz PLANCK / HFI channels: noisy lines = recovered sky (upper) and noise (lower), smoothed lines = input model (upper) and cosmic variance (lower).