The PLANCK Newsletter

Issue 7 | Information and news for the Planck community | April 2005

The HFI QM has been delivered !

J.-L. Puget et al.

The Cryogenic Qualification Model of the HFI has been built, assembled, tested, calibrated, and delivered to ESA. This represents a major milestone achieved in the development programme of HFI, which started some 12 years ago.

Before this delivery took place, the HFI Qualification Model of the Focal Plane Unit together with the whole electronic chain underwent tests and calibration during October and November 2004 in the Saturne chamber at IAS. Altogether the tests and calibration of these HFI elements all indicate that the design of the instrument was good and that we succeeded to reach the required performances for all the critical elements thanks to the very good work of all the different teams. More details are given below on the performances of the HFI, which are of course critically dependant on the bolometers performances, but just as much on the total optical efficiency, the noise performances of the read out electronics and the temperature stability of the cryogenic stages.

The optical efficiency was measured and found for the CMB channels to be between 20 and 45 % thus nearly all within the specification (25%), and some close to the goal of 50%.

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Heading towards the Flight Models

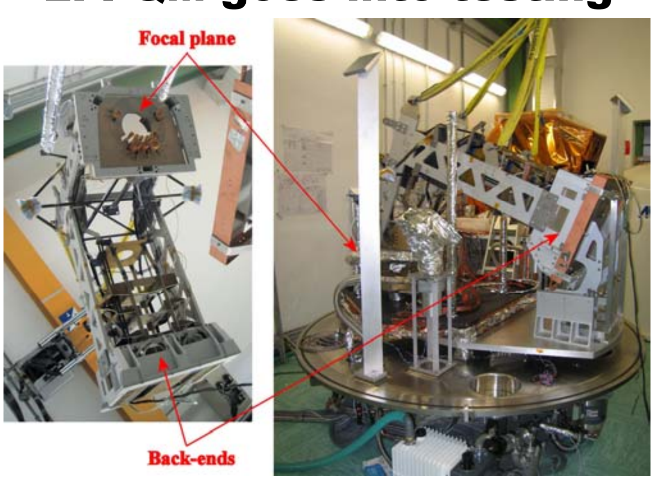
J. Tauber

This Newsletter is issued somewhat later than we would like. It is a reflection of the fact that the level of activity in all areas is increasing and the amount of time that can be dedicated to non-critical tasks is very low. This is true for all partners in the Planck project. The instrument teams in particular are now severely stretched: the LFI team from having to support the quasi-simultaneous development, integration and test of the Qualification and Flight Models; whereas the HFI team must support the integration of the Flight Model at the same time as the integration of the HFI QM onto the qualification satellite, and very soon the cryo-qualification test activities at satellite level. It is a good time for all members of the Planck collaboration to be proactive in offering all the support they can to the "core" instrument and DPC teams.

The current high level of activity is of course also a reflection of the fact that the Project is now in full gear and therefore that we are well on the way to the launch. As most of you know, the launch date has recently been delayed by about 6 months (from February to August of 2007) due to a number of circumstances affecting industry and institutes. Each such delay causes heavy financial shortfalls and management hardships to everybody involved, and ESA is now determined to keep to the current launch date.

>>> Heading towards the Flight Model continues on page 2

LFI QM goes into testing



The qualification model of LFI (at left) was integrated into its cryofacility (at right) in Laben, Milano. The tank was closed on 14 April and at the time of issue of this Newsletter the instrument is being cooled down in preparation for testing.

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Towards the Flight Models

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The HFI qualification model went through its calibration campaign and has been delivered to ESA. The data are still being analysed, but all indications are that the performance of the HFI will meet expectations. Many congratulations to the HFI teams for this outstanding success! This event signals the end of the era where only simulated data is available. From now on real data taken from real hardware can and must be the focus of attention.

One of the major highlights of the year will be the test campaign which will qualify the thermal behavior of the satellite and payload. This will take place at the Centre Spatial de Liège starting around April, where a representative model of Planck will be cooled down to operational temperatures (see article in this Newsletter). This complex test will give us much needed information on the passive and active cooling systems on board Planck. At the same time it will enable a first end-to-end test of HFI in flight-like conditions. The other most important events will be the scientific characterisation campaigns of the LFI and HFI flight models, and their subsequent delivery to ESA for integration into the satellite.

These major activities are going to yield a flood of data which will keep not only the instrument teams but also the DPC teams very busy. It is the first test of working in close-to-operational conditions, and we all have to keep in mind that we are learning lessons which will be very useful in preparing for post-launch operations.

CALENDAR OF (SOME) EVENTS

REVIEWS

LFI IQR: 30 MAY, 2005 (IASF, BOLOGNA)

PLANCK SCIENCE TEAM MEETINGS

ST24: 27-29 JUNE, 2005 (IAP, PARIS)

ST25: 2-4 NOVEMBER, 2005 (ROME)

ST26: 10-12 JANUARY, 2006 (ESTEC)

WORKING GROUP MEETINGS

WG7: 12-16 SEPTEMBER, 2005 (PARIS), TOGETHER WITH A WORKSHOP ON "SKY POLARISATION AT FAR-INFRARED TO CM WAVELENGTHS"

News from the Planck reflector programme

H.U. Norgaard-Nielsen

ASTRIUM (D) has now finished the production of the flight models of the primary and secondary reflectors. Both have been coated with Aluminium at the Calar Alto Observatory in Spain. Mechanical measurements showed that the reflectors satisfy (at room temperature) the requirements on the quality of the optical surfaces.

The reflectors have also gone successfully through a series of mechanical tests including vibration. Due to problems with the test setups at CSL, Belgium, only limited amount of knowledge of the behaviour of the reflectors at operational temperatures (~ 50 K) has been obtained so far. A special team has been appointed by ESA to review the whole verification scheme both on reflector and telescope level.

The Planck payload qualification model at Alcatel (Cannes), in the configuration used for acoustic testing. The qualification model of the primary reflector can be appreciated.

Post-doc Opportunity

Research Fellowships at ESTEC- post-doctoral positions in Submm/CMB astronomy will be open within the Planck group at ESA. Any Planck-related research topic will be considered, though Interstellar Medium is of particular interest to the group. Interested scientists please contact directly J. Tauber – jtauber@rssd.esa.int.

WG5: Clusters and Secondary Anisotropies

N. Aghanim and M. Bartelmann

Planck Working Group 5, "Clusters and Secondary Anisotropies", has the goal of identifying potential sources of secondary anisotropies, estimating their impact, developing methods for subtracting them from the primary CMB data and estimating their parameters, and providing algorithms for doing so to the Data Processing Centres. Naturally, the primary source of secondary anisotropies are galaxy clusters, which leave their imprint on the Planck data through the Sunyaev-Zel'dovich effect(s).

The working group tasks were grouped into six major workpackages. The first deals with estimating the contamination of the galaxy-cluster signal due to insterstellar dust, or to radio- and infrared (IR) sources. Such sources, either outside of or embedded in galaxy clusters, could be high-redshift IR galaxies, or radio galaxies known to be hosted by clusters. Assessment of the contamination by such emitting sources has started recently, showing that the IR emission from interstellar dust has very little effect on the cluster parameter estimation. Radio sources and IR galaxies might in turn affect the Compton parameter determination; they need to be tackled with complementary observations. Also under this workpackage, data needs to be assembled which allows the contamination to be better assessed, follow-up observations with suitable telescopes such as ALMA or Herschel need to be planned, and simulations need to be carried out for determining how the Planck data can be cleaned of such contaminations.

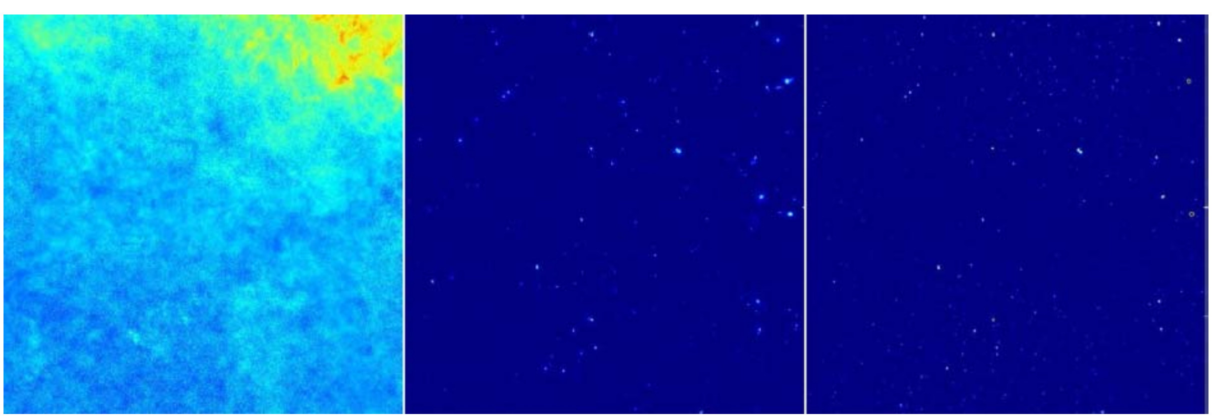
The second, third and fourth major workpackages aim at collecting optical, X-ray, and sub-millimetre data on galaxy clusters. The main goal here is to support the cluster detection by Planck, or the removal of the cluster signal from Planck's primary data, using all possible other data sources on known galaxy clusters. Besides identifying known clusters on the sky, these data-assembly workpackages should allow a better characterisation of the physical properties of clusters which merely appear as point sources in the data.

The fifth major workpackage encompasses the broad area of simulations. These are necessary for estimating the amplitude of secondary anisotropies, and for developing algorithms for cleaning the primary data, building reliable cluster catalogues, and possibly identifying additional secondary effects. Using hydrodynamical numerical simulations, it was recently shown that the polarised signal from galaxy clusters and filaments is far below the Planck detection limit and can thus be safely ignored in the reference sky model.

Finally, the sixth major workpackage has the goal of finding methods for characterising the physical properties of the galaxy clusters, for which Planck itself will provide not much more than the Compton parameter of the intra-cluster gas, integrated across the solid angle covered by the clusters.

The workpackage addressing simulations is currently the most advanced. Many aspects have to be covered. The cluster distributions in space, mass, and velocity based on analytic techniques or dark-matter simulations have been investigated. Also, the detailed hydrodynamical structure of a large number of individual clusters and the resulting Sunyaev-Zel'dovich and X-ray signal have been simulated. These studies have led to the construction of full-sky maps of the thermal and kinetic SZ effects, the development of filtering techniques for extracting cluster catalogues, and the realistic assessment of cluster selection functions. Simulations of the closely related integrated Sachs-Wolfe and gravitational-lensing effects are ongoing and approaching completion, and detailed modeling of the imprint of reionisation on the microwave sky is under way.

Given this progress, the priorities of WG 5 must now be shifted to collecting ancillary data in the optical, X-ray and sub-mm regimes. This will facilitate the Planck data analysis, improvement of the simulations, further development of cluster-detection algorithms, and a realistic assessment of contaminating effects. Algorithms exist already which are close to being usable by the Data Processing Centres. Critical comparison, realistic test, and delivery of the algorithms will be another important task for WG 5. The realistic full-sky maps of the SZ signals produced as part of the WG 5 activities have been provided to the Planck community and can be obtained as part of the simulation package.



Left panel: *30°×30° map of the microwave sky near the Galactic plane at 353 GHz**; centre panel**: thermal Sunyaev-Zel'dovich cluster signal contained in that map;* ***right panel***: *detected cluster signal after filtering the left map (from Schäfer et al. 2004).*

LFI QM Instrument Testing and Calibration

M. Bersanelli, N. Mandolesi, A. Mennella, F. Pasian, A. Zacchei

The LFI Qualification Model includes four of the eleven radiometer chain assemblies (RCAs) foreseen for the flight instrument. Two of them (at 30 and 44 GHz) are integrated and tested at Laben Alenia Spazio, Milano, and two at 70 GHz in Ylinen/Millilab, Finland.

The 30 GHz QM Radiometer Chain Assembly (RCA) in the Laben Alenia Spazio RCA cryo-facility.

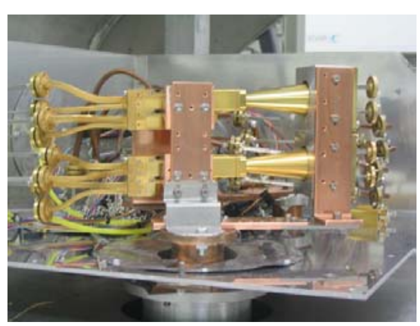
The 4-20 K LFI-RCA cryo-facilities, dedicated to RCA testing, were designed to provide thermal interfaces representative of the flight conditions, both in terms of absolute temperature and stability. The first RCA to be tested and calibrated at Laben was the 30GHz QM. As typical for first-time integration and testing, numerous unexpected problems and complications appeared, including an electrical malfunction in one of the front-end cryo circuits (now understood and fixed), which hampered the test procedure in two of the four channels. In spite of this, several tests and characterisation measurements were successfully performed. The balancing of the cryogenic phase switches, which are used to chop the signal at 4 kHz at each detector diode between the sky and the 4K reference load, was carried out following the planned iterative procedure. The system noise temperature was measured using a blackbody calibrator cooled at a set of cryogenic temperatures, typically in the range 7-20 K.

The measured system temperature (about 24K) and effective bandwidth (5GHz) are in good agreement with the values expected from unit level measurement and radiometer model. It should be noted that the QM low noise amplifiers (LNAs) used in the QM models are less performing (typically a factor of 2) than those now being tested and implemented at Jodrell Bank and Millilab for the flight instrument. Even so, the 30GHz LFI QM is outstanding compared to typical performances in this frequency range: this is due to the combination of high quality active and passive components running at cryogenic (~20K) temperatures. In addition, the tests showed that the radiometer arms exhibit good isolation and excellent linearity up to 30K input load temperature. Long (10-hours or more) integration tests were carried out to characterize the stability of the system, resulting in knee frequencies below 50 mHz, i.e., compliant with the LFI scientific requirements. Another important test was the characterisation of the radiometer susceptibility to fluctuations in the physical temperature of its front-end components (mainly LNAs, feed horn and orthomode transducer). The tests indicated good agreement between measured and model-estimated susceptibility of the front-end module (FEM), thus validating our strategy of deriving thermal stability requirements at the critical interfaces with the rest of the payload.

After completion of the 30GHz testing, the Laben RCA chamber has been prepared for the 44 GHz QM radiometer chain. All the 44 GHz QM parts (after testing at unit level at Jodrell Bank, Univ. of Cantabria, and IFP-CNR Milano) have been delivered, integrated, and mounted in the Laben set-up for testing and calibration. In parallel, the two QM radiometers at 70 GHz have been assembled and tested at Millilab, and have been delivered to Laben for integration in the QM model with flight-like waveguides.

Also in parallel, the LFI Instrument-Level Cryo-facility, manufactured at CSL, has been received and validated by Laben. It comprises single-stage coolers at 25 K and 12 K maintaining a 40 K radiative environment, 20 K front-end units and reference loads, three stages simulating the three PPLM V-grooves (at about 50, 96K, and 146K), and the 300 K back-end and warm electronics. Stabilisation is achieved with PID controllers on all thermal stages. Preliminary tests were performed on the LFI focal plane unit, populated with thermo-mechanically representative dummies, yielding results in line with the LFI thermal model predictions. The FPU was also tested mechanically, and successfully passed sine and random vibration at qualification levels. The QM data acquisition electronics manufacturing at Laben is completed, the qualification tests have been performed successfully and it is now ready to be integrated in the LFI QM. Similarly, the radiometer electronics box assembly (REBA) has completed qualification at CRISA and it is now back at the Instituto de Astrofísica de Canarias (IAC), Tenerife, for installation of application software.

The LFI ground calibration activity is fully supported by the LFI DPC. The ground data acquisition, visualization and analysis software (Rachel, RANA) are performing well at RCA level and will be extended for Instrument level testing. Dedicated software was built to ingest and store RCA data as FITS files. The files are organised by means of an SQL database and can be searched through a web interface by specifying constraints on the values of the keywords contained in the FITS header. Calibration data are routinely archived at the DPC and made available to LFI Calibration Team (groups in Italy, Finland, UK, Spain, USA) under controlled access.



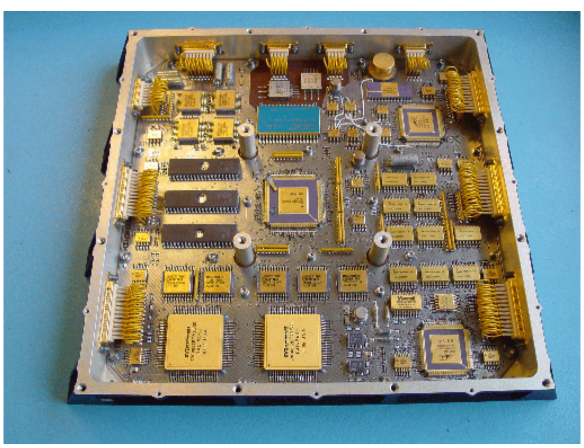
The 70 GHz RCA front-end in the cryo facillity. Two feed horns are visible on the right, connected to OMTs and FEMs and waveguides on the left. The copper-backed unit on the right is a sky simulator cooled by the 4K stage.

Planck activity at LAL

F. Couchot, J. Haïssinski, S. Henrot-Versillé, O. Perdereau and S. Plaszczynski

The Laboratoire de l'Accélérateur Linéaire (Orsay) belongs to the French Institute for Nuclear and Particle Physics, which for the past 15 years has been involved in observational Cosmology in the framework of its Astroparticle Physics programme. In 1990 we started working in this field at LAL within the EROS collaboration by performing a search for microlensing events and for SNIa explosions. Planck is the first LAL participation in a space project and is also our first participation in a CMB observation programme. However, having joined the HFI team since 1997, we aim at contributing to a variety of tasks, namely the construction of the instrument, the ground calibration, the DPC Level 2 developments and some Level 3 related matters. CMB as a tool for cosmology is our main physics interest, with a special attention given to its relation to neutrino masses. We are also involved in the Archeops balloon programme.

A ten-person technical team has the full hardware and software responsibility of the design, building and delivery of the HFI on-board processor (DPU) which controls the Readout electronic Unit, the 4K and the 0.1 K coolers, and which also produces the HouseKeeping and Science compressed data flows. This also includes the expertise in the HFI ground monitoring (RTA) and commanding. This 7-year effort is approaching its completion: the first DPU Model was successfully used during the CQM calibration of HFI at IAS last November and the Flight Spare and Flight DPU Models will be delivered this year.



The DPU CQM processor board.

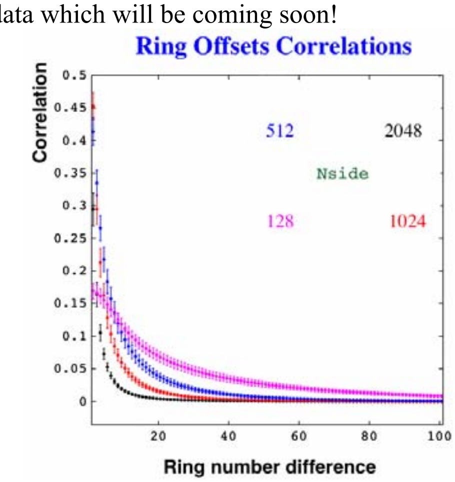
For the HFI calibration, we contributed to the upgrade of the IAS Saturn cryostat for Planck and we have the responsibility for checking the level of optical cross-talk between horns. For this check, we developed specific pulsed sources using carbon fibres. These sources are also used to characterise the time response and the linearity of the bolometers.

Cross-talk horns (left) in front of HFI horns, on the IAS Saturn calibration set-up

As far as the preparation for the data processing is concerned, we are heavily involved in the setting up of the general L2 software framework and we are responsible for the non-polarised map making (GPH424). For instance we developed the Mokapix software that calculates the ring offsets and the related covariance matrix.

Destriping was also one of our successes with the Archeops data. This was achieved by developing a specific algorithm called "cross-scan destriping". Archeops gave us the opportunity to work on real data. We were responsible for the attitude reconstruction, for the optical cross-talk measurements (which allowed us to validate the carbon fibre sources used for HFI), and for part of the beam mapping and the systematic effects detection and removal.

Another field of interest on which we worked first with the Archeops data was the direct extraction of CMB power spectra from the time line. In particular, we investigated the scaling properties of the Fourier coefficients with respect to the colatitude angle of the scanned rings. We are still working on this subject and we anticipate that, when applied to HFI data, this method will provide a thorough check on the presence of residual systematic errors.
Concerning the interpretation of the CMB spectrum, we gained experience by analysing the Archeops data, and we published a model-independent filtering scheme which we applied to the first results of WMAP. We also ran COSMOMC on Planck-like simulated spectra to estimate our future sensitivity to the neutrino mass (cf. Alexandre Bourrachot's Ph. D. thesis). Our small group is very busy and happy to work on CMB, and actively preparing for the "real" data which will be coming soon!



Mean offset correlation output by MOKAPIX L2 destriper on a 1 year simulated mission, as a function of ring number difference, for four Healpix pixel size values.

News from ESA's Herschel-Planck Project Team

G. Crone, and T. Passvogel

Industrial activities for both Herschel and Planck have progressed significantly, and the Critical Design Review (CDR) cycle has now been completed with the sequential successful completion of the Planck and Herschel Payload modules in June/July 2004 and the Space Segment CDR (also including Service Modules (SVM)) in October 2004.

This review cycle together with the Instrument Level Qualification reviews, Planck Reflectors and Herschel Telescope development status, Launcher and Ground segment Reviews have been fed into the Mission CDR bringing all elements together. This review, chaired by ESA's Director of Science (Prof. D. Southwood) was successfully completed in April 2005 with a number of specific recommendations and actions being given to the Project Team. As far as the spacecraft development was concerned, the solar array development, the Reaction Control System tanks (i.e. the qualification of a suitable technology for the inner liquid control membrane), and the on board software remain areas of concern that are late compared with the overall spacecraft development. Specific plans of action compatible with the launch date have been agreed by the Board.

The Instrument delivery dates are not currently compatible with the industry schedule and the Board has endorsed the approach proposed by the Project to help in the recovery of the instrument schedules. In general two or three sub-systems per instrument are late, and the Project has changed its management approach to actively follow these issues in detail with each PI team. All efforts must be made to maintain the launch date of 3rd August 2005. The ESA Herschel/Planck Project was recently granted the financial envelope to accommodate the unavoidable delay from February to August, however no funds have been allocated beyond this date, and indeed some instruments are in the same situation vis-à-vis their funding agencies. As part of the M-CDR recommendations a mechanism to manage potential instrument de-scope was introduced, in the event that recovery of instrument schedule and flexibility of integration activities in industry could not accommodate late instrument delivery.

The verification of the Planck Reflectors and Telescope was a major issue at the review and a modified verification approach was presented to the Board. The main problem areas with respect to the baseline was that the chosen method, infrared interferometry, to measure the detailed surfaces of the primary and secondary reflectors at the operational temperature has shortcomings for the primary reflector and some extrapolations between secondary surface data to primary and/or extrapolations of primary data to lower temperatures are needed. Videogrammetry is to be used to augment the reflector's global shape knowledge and is now the sole method to be used at telescope level. The Board has set up an internal expert group to both work on the full technical development of the approach with a management team to regularly review the progress and endorse the approach step by step. The manufacturing and mechanical testing of the FM reflectors and telescope structure is complete and the preparation for the RFQM test campaign preparation is well underway at Alcatel.

HFI has completed its qualification review and in common with all Herschel instruments, delta qualification of some warm units on the SVM is needed. The 20K Sorption cooler has also completed its Qualification Review, and the first flight unit (FM1) has been delivered to Alcatel for integration on the flight panels and into the first flight cryogenic test. The second (FM2) cooler is currently in final testing at JPL with the QM electronics and will be shipped to Alcatel for integration in early June.

The preparation for the test of the CQM Spacecraft is well advanced, with an early build up of the complete model last Autumn for a successful acoustic test which also included the Planck QM reflectors and telescope structure (see picture on page 2). Since then, all elements of the HFI CQM instrument have been integrated with the LFI "dummy" into the second build up of the CQM spacecraft (see pictures on page 13) for the upcoming cryogenic test campaign, including test of the quasi-entire cooling chain and HFI performance testing at CSL in Liège in Belgium (see article on page 8). The CQM will leave Alcatel beginning of May for integration into the CSL chamber which has already been commissioned for Planck use with the first "cool down" in the so called blank test in March of this year.

The Flight Model spacecraft integration sequence will start at Alcatel immediately after CQM shipment. There will be two cryogenic tests conducted: the first essentially being to test the performance of the sorption cooler at system level (not needing the fully equipped spacecraft), whilst the second campaign is at full assembly level with the flight LFI and HFI and complete cooling chain.

The proto-flight SVM - structure and panels have already been delivered from CASA in Spain to Alenia, the SVM responsible, for integration activities. The first round of avionics tests have also been performed at Alenia with the avionics model in the Planck configuration.

In conclusion good progress has been made but hard work is ahead to achieve successful instrument-level testing and Spacecraft level tests within the programmatic constraints.

Herschel Key Projects: the roadmap for the Planck community

L. Valenziano, G. Lagache, K. Ganga, and

B. Guiderdoni

The Planck and Herschel missions, to be launched together in 2007, will offer an exceptional opportunity to the scientific community. The two payloads are complementary: Planck will provide full-sky maps in nine frequency bands (from 30 to 857 GHz) at moderate angular resolution; Herschel will offer spectroscopic, photometric and imaging capabilities (from 545 to 5000 GHz) with high sensitivity and good angular resolution. Part of the Herschel observing time will be devoted to large programs called 'Key Projects'. These projects will by definition use large amounts of observing time, provide observations of exceptional archiving quality, and have a compelling science case. The Herschel Science Team will issue the announcement for opportunity for Key Projects (KP) in late 2005.

On the Planck side, the Science Team (ST) has committed the working groups 6 and 7 to exploit the possible synergy between the two missions. This is required since any activity that will use Planck's data within the proprietary period must be approved by the ST. The coordinators of the WG 6.4 and 7.5 (for the extragalactic and galactic science respectively) have collected and presented to the ST 15 abstracts, prepared by scientists involved in Planck, which will eventually evolve in Herschel KP proposals. Using Livelink Explorer (http://astro.estec.esa.nl/livelink), you can find the abstracts in "Planck/Common Items-/Working Groups, WG 6.4 and WG 7.5" .

The proposals generally fall into two broad categories:

- Point sources follow-up:
  - Galaxy clusters (detected by Planck through the Sunyaev Zel'dovich effect)
  - Galactic targets (cold cores, anomalous clouds)
  - Infrared galaxies, Active Galactic nuclei, Flares
- ~100 deg^2 wide surveys:
  - Extragalactic: probe statistically the spectral energy distribution of the galaxies contributing to the Cosmic Infrared Background and their clustering properties.
  - High latitude galactic: investigate changes in dust abundance and emission properties.

These surveys will also serve to define the best strategy for modelling the dust and Cosmic Infrared Background foregrounds for CMB studies. It should be noted that there is also a Herschel team called 'Hi-Gal – a map of the Galactic plane', preparing a KP proposal that is interesting to Planck people: some of us are already involved.

The Planck ST recommends to the people involved in these abstracts to make all efforts to combine proposals with similar science cases. This will lead to stronger proposals and will avoid unproductive competition.

The plans regarding Planck/Herschel proposal were presented to the Planck community at the Consortia Meeting in Garching, (January 2005) to extend the information and the participation to a wider community. As a next step, the coordinators of the WGs 6.4 and 7.5 will prepare a template for the Planck-side Herschel proposals and make it available on LiveLink. Preliminary proposals be requested by June, 2005. WG coordinators will examine them and make recommendations to the involved teams. Final proposals will be submitted to the Planck ST in December 2005. After ST approval, teams will work to respond to the AO for Herschel (open-time) KP, the deadline of which is currently expected to be in the second half of 2006.

Note*: *the authors of this piece have been asked by the Planck Science Team to coordinate this activity and should be the first point of contact on this topic.

More news from the HFI

– *continued from page 1*

The temperature stabilities for the horns at 4K and the filters at 1.6K were also checked to be within the very strict requirements especially in the critical frequency range (10^{-2} to 100 Hz) when the PID regulations are activated. This gives also very good temperature stability for the 70 GHz reference horns of the LFI. The situation is not as good for the 30 and 40 GHz where the large fluctuations at low frequencies from the Sorption Cooler induces out of specifications fluctuations for the LFI reference horns. Nevertheless, measurement of the temperature in flight should provide sufficient information to remove most of these fluctuations in the data processing although the level of accuracy with which this can be done remains to be established.

The 100 mK bolometer plate requires, not surprisingly, a very strict temperature stability: 30 nK/Hz$^{1/2}$ in the 10^{-2} to 100 Hz range. Such a stability is not only difficult to achieve but also difficult to measure! A non optimal set-up of the parameters of high sensitivity 100 mK thermometers prevented measurements of temperatures as low as expected, but we still obtained an upper limit of temperature fluctuations very close to the specs. The readout electronics are also within specs with an absence of 1/f noise down to 10^{-2} Hz.

The 4K and 20 K coolers will be tested separately in the system tests to be held in Liège. Significant uncertainties still exist on the performances of the overall cooling chain including these two elements but these should be mostly answered in the coming months.

The flight model detectors have all been delivered by JPL/Caltech to Cardiff and all show excellent performances including the 100 GHz PSBs, which were introduced late to compensate the loss of the 100 GHz LFI channels.

Cryo-qualification testing of the Planck satellite

B. Guillaume

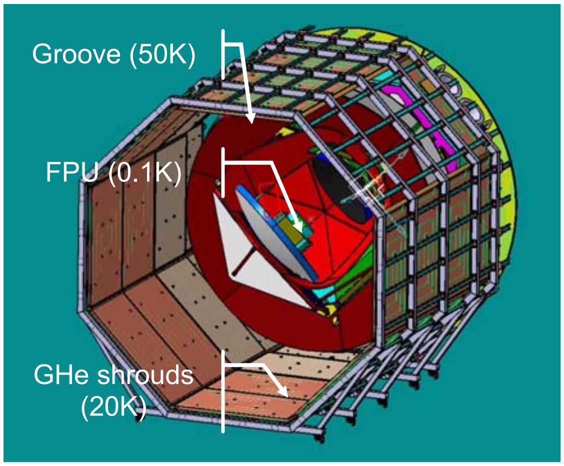
Planck is about to undergo satellite-level thermal qualification at the Centre Spatial de Liège, an ESA Coordinated Test Facility (http://www.ulg.ac.be/cslulg/home.html). A thermally-representative model of the satellite and payload module will be shipped from Alcatel to CSL in mid May. Once at CSL, it will be cooled to operational temperatures and tested in realistic flight conditions. Using the existing vacuum facility (FOCAL-5), a thermal adaptation has been designed especially for this purpose (see diagram), and is outfitted with helium-cooled shrouds that will allow the satellite payload module to passively cool to its operational temperature of between 50 K and 60 K. A special cold load (black-body at ~5 K, see picture) will be placed in front of the focal plane to simulate the cold sky.

The satellite model used for this test is very close to being fully flight representative; however, some important differences with respect to the flight model are present:

- Of the two instruments, only HFI's Cryo-Qualification Model is present. LFI is replaced by a mechanically and thermally representative structure.
- The cooling of HFI will be accelerated by a dedicated cooling loop.
- Of the sorption cooler, only the cold-end and associated piping is present. The compressors will be replaced with ground equipment which supplies hydrogen from bottles to the cold-end.
- Thermal representative models will replace the telescope reflectors (which are needed for other tests).
- The (room temperature) Service Module contains only the units needed to operate the test.

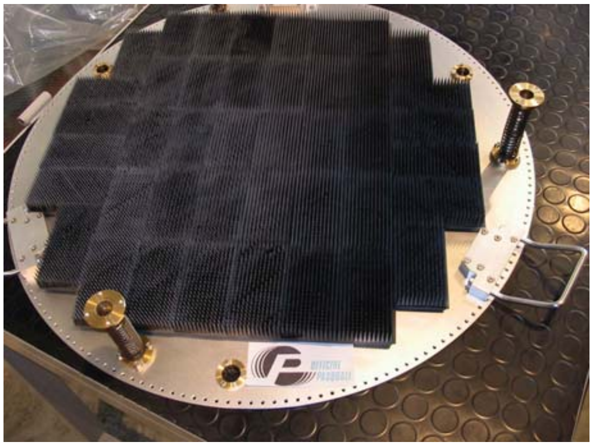
A first test with a mechanical mock-up of the Planck satellite was performed at room temperature in order to verify that the spacecraft fits into the thermal shrouds inside the vacuum vessel (see figure). A second test, called "blank test", was performed without the mock-up but with the thermal shrouds and the special cold load. Lamps inside the thermal shrouds simulated the thermal load of the Planck satellite and its payload in order to verify that the test facility will provide the right thermal and vacuum environment for the real Planck spacecraft.

It is expected that the cooling down will start in June and testing will take place in the June-July period. This is the first major test for Planck at satellite, which will answer a number of tricky questions regarding its thermal behavior. It will also be the first opportunity for HFI to be subjected to a complete end-to-end test, including the full cooling chain; and will complete its qualification. The same facility will be used later to carry out similar tests on the FM satellite, in that case with the full payload complement and the flight Service Module.



A schematic diagram showing the main elements of the facility used to cool Planck to operational temperatures. The different temperatures of components are indicated. "FPU" stands for focal plane unit.

The actual facility at CSL, showing the vacuum tank, the mechanical mock-up used for the first test on the stand that will hold the satellite, and the helium-cooled shroud. The latter are on rails for insertion into the tank.

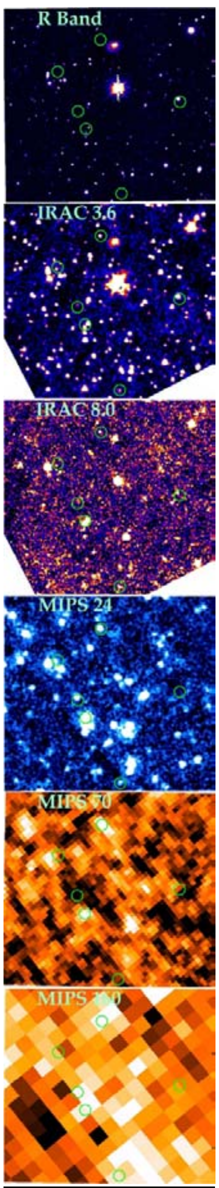


The cold load that will be placed in front of the focal plane. It is made of pyramidal-shaped absorber (Eccosorb) which will be cooled from the back to ~5 K by liquid Helium. The LFI instrument test facility will use a cold load of very similar design.

Highlights of *Spitzer* Extragalactic and Cosmological Observations

Hervé Dole

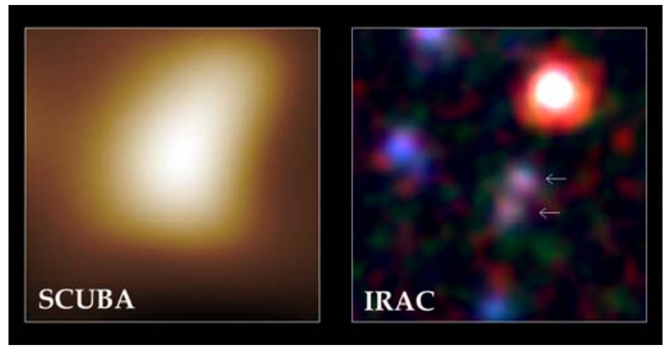
NASA's Space Telescope *Spitzer* was launched almost two years ago, and is presently providing a continuous stream of high quality multi-wavelength infrared data. With more than 5 years of expected lifetime, this cryogenically cooled 85-cm telescope has 3 focal plane instruments. It has two imaging instruments, IRAC (Fazio et al., 2004) and MIPS (Rieke et al., 2004), operating at wavelengths of 3.6, 4.5, 5.8, 8.0, and 24, 70 and 160 µm, and a spectrograph, IRS (Houck et al., 2004), operating between 5 and 38 µm with two spectral resolution modes. Spitzer benefited from the ISO experience and from several technology improvements. Important innovations are 1) large detector arrays, capable of simultaneous observations at 3 or 4 wavelengths, with a field of view of more than 5′x5′; 2) the warm launch concept allowing to carry less liquid helium for a longer lifetime; 3) an Earth-trailing orbit, ensuring a stable thermal background. These capabilities facilitate the measurement of 3.6 to 160 µm spectral energy distributions (SED) of galaxies in a few minutes of integration time. A wealth of results in extragalactic astrophysics is emerging, and most of the data are in usable form and already available for download.



Astonishing panchromatic images of local galaxies, like M81, NGC55, NGC300, or NGC7331 enable to determine physical quantities (dust temperature, star formation rate, and PAH content) and their spatial variation. This has e.g. led to the discovery of a new 17 µm PAH feature in normal galaxies (Smith et al., 2004).

Cosmological surveys with Spitzer aim at characterizing high redshift galaxies such as their physical properties, their evolution with redshift and environment, and their role in the stellar mass content of the Universe. Mid- and far-infrared galaxy counts (Chary et al., 2004; Dole et al., 2004; Fazio et al., 2004; Marleau et al., 2004; Papovich et al., 2004) and the analysis of the spectral properties of galaxies (Lagache et al., 2004; Le Floc'h et al., 2004; Huang et al., 2004; Lonsdale et al., 2004, Yan et al., 2004) show that luminous infrared galaxies (LIRG) start dominating the infrared energy density above $z \approx 0.5$, and that a significant fraction of ultra-LIRG is present at $z \geq 1$. IR spectroscopy led Houck et al. (2005) to report the presence of Silicate absorption features on $1.7 \leq z \leq 2.8$ hyper-LIRG optically extremely faint galaxies. So far, ~75%, ~23% and ~7% of the cosmic infrared background is resolved at 24, 70 and 160 µm, respectively. It is anticipated that deep FIR surveys will eventually resolve a larger fraction.

← Example of data on a 5′ x 5′ field. From top to bottom: R-band (CFHT), and by Spitzer: IRAC 3.6 µm and 8.0 µm , MIPS 24, 70, and 160 µm.The green circles show the positions of some submillimeter sources. (H. Dole / IAS/ Arizona / MIPS/ IRAC).



A SCUBA 850 µm source (left panel) resolved in about 600 s with IRAC (right panel, indicated by arrows). (Univ. Kent)

The quick detection (after 750 s of integration time) of high redshift submm galaxies (SMG) and radio sources (Egami et al., 2004;, Ivison et al., 2004) allows to characterize for the first time their SEDs, and also give estimates of the cosmic star formation rate density evolution with redshift. Serjeant et al (2004) show that *Spitzer* IRAC sources contribute to ~20% of the 850 µm background and more than half of the 450 µm background. Frayer et al. (2004) and Charmandaris et al. (2004) also report detection of submm and radio sources. Even shallow *Spitzer* images of large fields with IRAC, and MIPS at 24 µm, help in a crucial way to identify the high redshift population of SMG. Furthermore, the analysis of the submm maps of Planck all-sky and Herschel surveys can benefit from the very efficient, less confusion-limited deep Spitzer 24 µm imaging of large sky areas to identify and quantify (individually or statistically) the spectral shape of such high redshift sources.

Finally, Spitzer is able to detect very remote systems. Quasars at $4 \leq z \leq 6.5$ are quickly detected at 24 µm at the mJy level (F. Fan & D. Hines et al., priv. comm.). Egami et al. (2005) report an IRAC detection of a $z \approx 7$ lensed galaxy behind the cluster A2218.

Note: more information on Spitzer can be found at http://www.spitzer.caltech.edu. Most of the data are in usable form and already available for download at http://archive.spitzer.caltech.edu.

SPITZER SPACE TELESCOPE

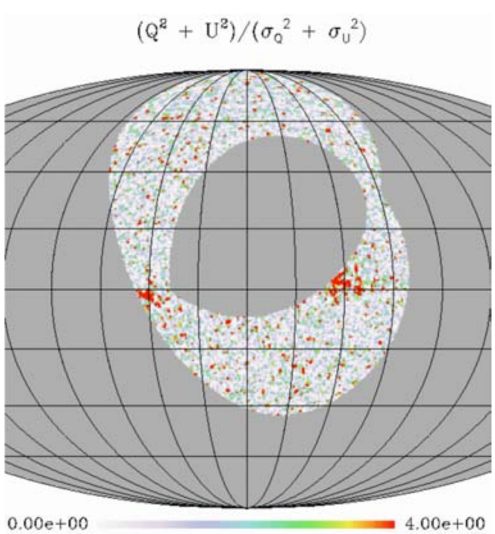
Dust polarized thermal radiation after Archeops

Nicolas Ponthieu

In October 2002, Archeops provided the first estimation of the CMB temperature anisotropy power spectrum ranging from the COBE angular scales up to the end tail of the first acoustic peak (Benoît et al, 2003) was also equipped with three ortho-mode transducers at 353 GHz to measure the polarization of Galactic dust thermal radiation. Indeed, dust emission is expected to dominate the CMB at frequencies above 100 GHz, and optical data have shown for many years that this radiation should be polarized. This polarization is an important foreground for CMB polarization studies, in particular Planck, and must therefore be carefully accounted for in the data analysis. However, little is known about dust polarization since no measurement on scales larger than a few arcminutes in the Galactic plane were available and theoretical predictions are still much debated.

First polarization detection of diffuse dust emission

The analysis of Archeops data at 353 GHz (Benoît et al., 2004) lead to the first detection of regions coherently polarized over several square degrees (see figure below), with a degree of polarization sometimes as high as 10%. These regions were neither systematically the brightest nor the faintest parts of their local environment and the orientation of their polarization was rather distributed over 180°. These results show that dust polarization is not *a priori* correlated to the total intensity.



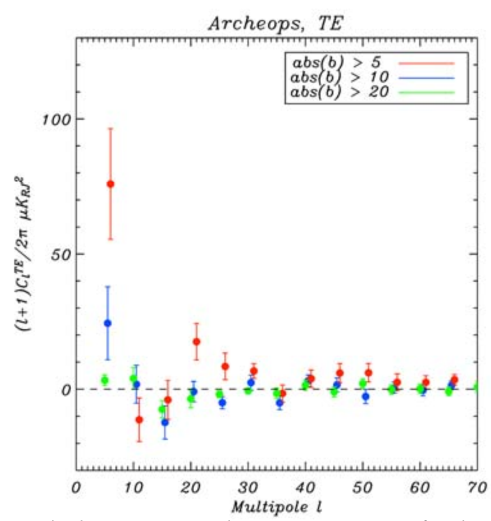
Map of the normalized squared polarized intensity $(Q^2+U^2)/(\sigma_Q^2 + \sigma_U^2)$. Significantly polarized regions over several square degrees appear in the Galactic plane.

This analysis also showed that the diffuse Galactic radiation in the vicinity of the Galactic plane was polarized at the 3-5% level. The orientation of this diffuse polarization is coherent on large angular scale and mostly orthogonal to the Galactic plane, which confirms the general picture that optical and submillimeter polarizations should be orthogonal. We also observed that the polarization disappeared when the line of sight approached the Cygnus arm, which is compatible with the expectation that the Galactic magnetic field should follow the spiral arms on large scales.

First estimation of the polarized angular power spectrum of diffuse dust emission

In order to estimate the contamination of dust to future CMB polarization anisotropy studies, an improved treatment of the data has been applied which allowed the estimation of the angular power spectra on large angular scales (Ponthieu et al, 2005).

We find a 4σ detection of temperature/polarization correlation on angular scales $3 \leq l \leq 8$ when the Galactic plane is subtracted up to $b = 5°$ $[(l+1)C_l^{TE}(\text{dust})/2\pi = 76 \pm 21\ \mu K_{RJ}^2]$, which remains a 2σ detection when the latitude cut is moved to b=10° $[(l+1)C_l^{TE}(\text{dust})/2\pi = 24 \pm 13\ \mu K_{RJ}^2]$. This decrease of power with increasing latitude of observation is by the way expected from the variation of the depth of the line of sight. Concerning the pure polarization modes, we place a common upper limit at $(l+1)C_l^{EE/BB}(\text{dust})/2\pi \leq 11\ \mu K_{RJ}^2$ (2σ).



Temperature/polarization angular power spectrum for three different Galactic latitude cuts as measured by Archeops at 353~GHz.

In order to compare these results obtained at 353 GHz directly to CMB working frequencies, we extrapolated our results down to 100 GHz using the most recent estimations of dust spectral index (Lagache 2003). The amplitude of the *TE* correlation becomes $((l+1)C_l^{TE}(\text{dust})/2\pi = 1.7 \pm 0.5$ and $0.5 \pm 0.3\ \mu K_{CMB}^2$ on $3 \leq l \leq 8$ for $|b| \geq 5°$ and 10° respectively. Despite the uncertainty on the generalization of Archeops results on 20% of the sky to the whole sky, they indicate that dust will definitely be a major foreground for CMB polarization studies at high frequencies, and call for a its careful subtraction of the CMB anisotropy maps.

References:

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Benoît et al., 2004, A&A 424, 571
Lagache, 2003, A&A 405, 813L
Ponthieu et al, astro-ph/0501427

Review of the Planck Science Ground Segment

René Laureijs and Mike McKinnell

An important element of the Planck mission is the Science Ground Segment. It takes care of the survey operations (such as maintaining the scanning law), instrument operations (instrument tuning and calibrations), telemetry data handling, data processing, and product release. These tasks are of crucial importance for the scientific success of Planck. The Planck science ground segment consists of four centres: the Mission Operations Centre (MOC), the LFI and HFI data processing centres (DPCs) and Instrument Operations Teams (IOTs), and the Planck Science Office (PSO). The centres are located at different institutes in Europe, and, in addition, the HFI DPC itself consists of more than one institute. The highly distributed configuration of the science ground segment requires that the interfaces between the centres are carefully defined to ensure that the right information is correctly exchanged between the parties.

The Planck science ground segment was subject to a high level "design review", as part of the ESA Critical Design Review (CDR) cycle. The convening authority for this review was the Research and Scientific Support Department of ESA in conjunction with the Herschel/Planck Project. Formally, a CDR marks the end of the detailed design phase.

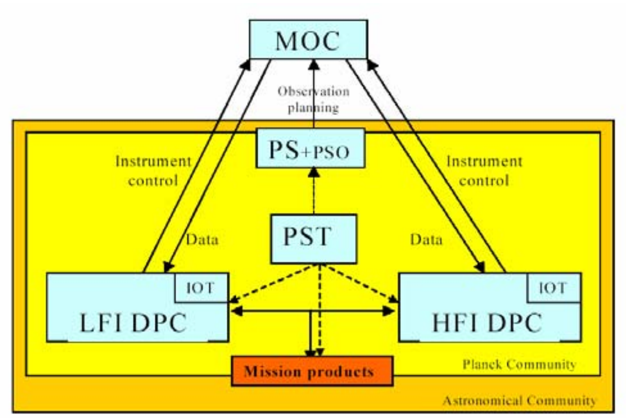
The science ground segment Design Review plenary meeting was held at the premises of the CNR in Bologna on 2-3 November 2004. At this meeting, the different parties presented the design and development approach and status of their systems; which were described in detail in a document package (available on Livelink). The review was chaired by M. Kessler, and was advised by two expert panels: a scientific one headed by M. Longair, and a technical one headed by J. Clavel, to ensure that both scientific and technical elements of the systems were properly considered. The board report was issued in February this year, and can be seen on Livelink. Besides important observations about the general state of the science ground segment, the report contains many detailed recommendations on issues that should be considered in order to improve the present development.

One major conclusion of the review is that the Board and scientific panel have been convinced of the superb scientific quality of the mission. The scientific panel believes that the mission will provide a long lasting legacy for future generations. It also re-emphasises the scientific advantages to having two instruments providing a large frequency range and that both LFI and HFI will contribute significantly to the common products to be derived from the Planck data. The general conclusion of the technical panel is that the parties in the science ground segment are progressing satisfactorily and that the science ground segment as a whole is in a shape appropriate at this time before launch.

The review board realized that the development work based at scientific institutes cannot be fully measured against the industrial standard from which the objectives of the review were obtained. To overcome this problem, the board recommends to divide the science ground segment into two different components which have different development time scales and different levels of criticality (and consequently need not adhere to the same type of control). The first component, SGS1 (for "Science Ground Segment 1"), is launch and operations critical and consists of all infrastructure necessary to acquire the Planck data and ensure that they are of sufficient quality for the Planck mission to achieve its scientific goals. The second component, SGS2, consists of the infrastructure required to extract the scientific results from the Planck mission. These two components should be developed with different standards and reviewed differently. The Board considered that SGS1 should comply with industrial development standards, whereas SGS2 should be developed along less strict, more experimental - *research and development* - lines. Although SGS2 is less critical than SGS1 for the conduct of satellite operations, it nonetheless is an essential element for the scientific success and legacy of Planck.

The Board also recommended that the pipeline should be thoroughly tested, in an incremental and phased manner, using simulated skies generated from perfectly defined input parameters. The pipeline should run a number of iterations of the end- to-end processing with different goals to find out if the results of the data processing match the input values. The Board requested that a specific plan be put in place for the end-to-end testing and the scientific validation of the DPCs data processing functions.

At this moment the detailed definition of SGS1 and SGS2 is well underway, and will be presented by a dedicated working group by the end of April. The plan for the end-to-end tests is being discussed in parallel and should be issued by the first of June. All these activities should give full confidence that the Planck Science Ground Segment will be ready at launch and will contribute to the scientific success of the mission.



Graphical overview of the science ground segment and the main interfaces between them.

HFI/LFI Consortium Meeting 2005, Garching

René Laureijs and Jan Tauber

This year's HFI and LFI Joint Consortium Meeting was hosted by the Max Planck Institut für Astrophysik in Garching between 26 and 28 January.

More than 170 people attended the meeting, a record number for a joint consortium meeting. The attendees were eager to learn about the present status of the project and the latest results of the instrument level testing campaigns for HFI and LFI. In addition, the Planck Science Team announced the release of the near final version of the "Bluebook" (pre-publication version available in Livelink). The afternoon of the 26th of January was dedicated to the separate HFI and LFI Consortium meetings. The programmes of these meetings included reports of the instrument performance based on the measurements of individual instrument components and the cryogenic qualification model (CQM) for HFI. The HFI calibration discussion included the planning of the future activities in particular the activities envisaged for the flight model tests to be carried out in the second half of this year.

The second day was completely dedicated to working group meetings. A summary of the WG5 meeting is given elsewhere in this Newsletter. With the completion of payload components, more concrete information is requested (and can be applied) from the working groups to guide the testing and assessment of instrument and spacecraft components. The systematic effects working group (SEWG) realized that a lot of their work on optics, polarisation, and thermal modeling, have reached a level of maturity where level S simulations can be set up. The output of the simulations has to be analyzed by the CTP group to close the testing loop. Initiatives were taken for joint SEWG-CTP actions.

The CTP working group also discussed in detail the question of what accuracies are required for the cold measurements of the reflectors. Preparations are underway for the testing or the Planck reflectors at cold temperatures, and clear testing requirements need to be provided. These requirements should be based on scientific considerations and our present knowledge of the instruments. The CTP working group is now busy simulating the effects of the measured reflector deformations on the power spectra. Also a "younger" working group, the scanning strategy working group (WG9) now faces tasks for operational development support. There is a request for a consolidated baseline scanning strategy on which the operational procedures will be based.

The third and last day was dedicated to plenary presentations from project, instrument teams and DPC representatives. The reports from the project and instrument teams gave an impressive summary of how much hardware has already been created at this stage of the development. No artist impressions or CAD generated images but pictures of real hardware were shown! The DPC managers introduced the "SGS1/2" concept and the impact on their activities.

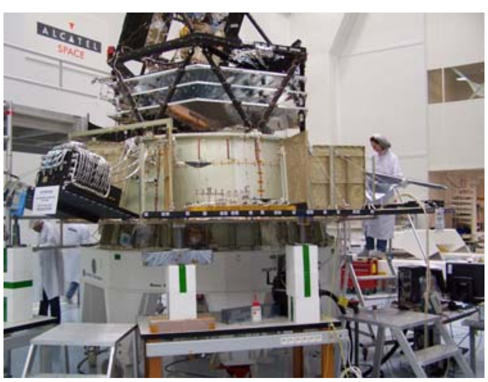
With only two and a half years to go before launch, the joint consortium meeting provided the opportunity to obtain first hand information on the rapidly evolving status of the Planck project as well as latest developments on CMB science related to the Planck mission. The prospect attracted a lot of participants and it was a major achievement of the organizing committee that each of us could attend as many presentations as possible. It will be a challenge for the organizers of the next consortium meeting to come up to the near perfect organization by MPA.

The Planck Consortia once again thank MPA and the Planck group for their warm hospitality and excellent organization !

The Planck Scientist list up to January 1, 2005.

Below is the list of those members of the Planck Collaboration who, according to the rules established by the Planck Science Team, have exceeded two years of equivalent contribution to the Planck project, and are therefore considered as Planck Scientists with corresponding data and publication rights. The list has been endorsed by the Science Team, and includes all contributions up to January 1, 2005, as evaluated by PIs, CoIs, Instrument and DPC team leaders, and Working Group coordinators. The Science Team will shortly make available to each member of the Collaboration her/his current integrated level of contribution to Planck.

Ade	HFI	De Zotti	LFI	Lawrence, C.	LFI	Rebolo	LFI
Ashdown	HFI	Delabrouille	HFI	Levin	LFI	Ristorcelli	HFI
Baccigalupi	LFI	Desert	HFI	Lilje	LFI	Sandri	LFI
Balbi	LFI	Efstathiou	HFI	Lubin	LFI	Seiffert	LFI
Banday	LFI, HFI	Finelli	LFI	Maffei	HFI	Sjöman	LFI
Bartelmann	LFI, HFI	Fosalba	HFI	Maino	LFI	Smareglia	LFI
Bennett	LFI, HFI	Gaier	LFI	Mandolesi	LFI	Smoot	LFI
Benoit	HFI	Ganga	LFI, HFI	Mann	HFI	Stolyarov	HFI
Bernard	HFI	Giard	HFI	Maris	LFI	Stompor	LFI
Bersanelli	LFI	Giraud-Heraud	HFI	Martínez-González	LFI	Sudiwala	HFI
Bhatia	HFI	Gispert	HFI	Masi	HFI	Sygnet	HFI
Bock	HFI	Gorski	LFI, HFI	Meinhold	LFI	Tauber	PSO
Borrill	LFI	Haissinski	HFI	Mendes	HFI	Terenzi	LFI
Bouchet	HFI	Harrison	HFI	Mennella	LFI	Torre	HFI
Bradshaw	HFI	Hell	LFI, HFI	Moneti	HFI	Tuovinen	LFI
Brossard	HFI	Henrot-Versille	HFI	Morgante	LFI, HFI	Valenziano	LFI
Burigana	LFI	Hivon	LFI, HFI	Mortlock	HFI	van Leeuwen	HFI
Butler	LFI	Hobson	HFI	Munshi	HFI	Varis	LFI
Cayon	LFI	Holmes	HFI	Murphy	HFI	Vibert	HFI
Chiang	DK-Planck	Hovest	LFI, HFI	Naselsky	DK-Planck	Villa	LFI
Christensen	DK-Planck	Hughes	LFI	Natoli	LFI	Vittorio	LFI
Church	HFI	Jukkala	LFI	Norgaard-Nielsen	DK-Planck, LFI, HFI	Vuerli	LFI
Couchot	HFI	Kaplan	HFI	Novikov I.	DK-Planck	Wade	LFI, HFI
Cuttaia	LFI	Keihanen (Sihvola)	LFI	Pajot	HFI	White M	LFI
D'Arcangelo	LFI	Lahteenmaki	LFI	Pasian	LFI	White S	LFI, HFI
Davies, R.	LFI	Lamarre	HFI	Piat	HFI	Wilkinson	LFI
Davis	LFI	Lange	HFI	Popa	LFI	Williams	HFI
De Bernardis	HFI	Lasenby	HFI	Poutanen	LFI	Yurchenko	HFI
de Gasperis	LFI	Laureijs	PSO	Puget	HFI	Yvon	HFI



Two views of the integration of the Planck Cryo-Qualification Model spacecraft.At left, Alcatel technicians install part of the units in the Service Module (in particular, the HFI DPU can be seen with its massive harness). At right, the focal plane is being put in place. A cap placed over the HFI horns stands out in bright red.

Recent Planck-related Publications

Aja, B., J.P. Pascual, L. de la Fuente, J. Gallegos, E. Artal, " A new method to obtain total power receiver equivalent noise temperature", 33rd European Microwave Conference, Munich , October 2003, Conference Proceedings, Vol. I, pp 355-358.

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Artal, E., B. Aja, M.L. de la Fuente, N. Roddis, D. Kettle, F. Winder, L. Pradell, P. De Paco, "Radiometers at 30 and 44 GHz for the Planck mission", Microwave Technology and Techniques Workshop, 8-9 October 2002, ESA-ESTEC, Noordwijk, The Netherlands. Proceedings WPP-203, pp 41-48.

Barreiro,R.B., E. Martinez-Gonzalez, P. Vielva, M.P. Hobson astro-ph/0503039 "Effect of component separation on the temperature distribution of the CMB"

Burigana, C., L.A. Popa, F. Finelli, R. Salvaterra, G. De Zotti, N.Mandolesi , astro-ph/0411415 "Cosmological reionization after WMAP: perspectives from PLANCK and future CMB missions"

de Gasperis, G., Amedeo Balbi, Paolo Cabella, Paolo Natoli, Nicola Vittorio astro-ph/0502142 "ROMA: a map-making algorithm for polarised CMB data sets"

De Zotti, G. et al. astro-ph/0411182 "Surveys of extragalactic sources with Planck"

Dupac, X., Tauber, J. astro-ph/0409405 "Scanning strategy for mapping the CMB anisotropies with Planck"

Eriksen, H.K., Lilje, P.B., Banday, A.J., Górski, K.M., 2004 ApJ Supp. 151, 1, "Estimating N-Point Correlation Functions from Pixelized Sky Maps"

Geisbuesch, J., Kneissl, R., Hobson , M. astro-ph/0406190 "Sunyaev-Zel'dovich Cluster Survey Simulations for Planck"

Hansen, S. astro-ph/0410004 "SZ cluster science with the Planck HFI experiment"

Keihänen, E., Kurki-Suonio, H., Poutanen, T., Maino, D., Burigana, C., 2004 A&A 428, 287, "A maximum likelihood approach to the destriping technique"

Keihänen, E., Kurki-Suonio, H., Poutanen, T., astro-ph/0412517, "Madam - a map-making method for CMB experiments"

Mandolesi, N. et al. astro-ph/0411412 "The Planck Low Frequency Instrument"

Pascual, J.P., B. Aja, M.L. de la Fuente, E. Artal, "Radiometer simulation using RF platforms: Application to Planck Mission", 2004 International Workshop on Electronics and System Analysis, IWESA'04, Bilbao (Spain), 21-22 October 2004.

Poutanen, T., Maino, D., Kurki-Suonio, H., Keihänen, E., Hivon, E., 2004 MNRAS 353, 43, "Cosmic microwave background power spectrum estimation with the destriping technique"

Poutanen, T., G. de Gasperis, E. Hivon, et al. astro-ph/0501504 "Comparison of map-making algorithms for CMB experiments"

Roddis, N., D. Kettle, F. Winder, B.Aja, E. Artal, L. de la Fuente, J.P. Pascual, A. Mediavilla, L. Pradell, P. de Paco, "Differential radiometer at 30 GHz for the Planck mission", 3dr ESA Workshop on Millimetre Wave Technology and Applications", 21-23 May 2003, Millilab, Espoo, Finland.

Rosset, C. astro-ph/050218 "Systematic Effects in CMB Polarization Measurements"

Schafer, B., Pfrommer, C. et al. astro-ph/0407089& astro-ph/0407090 "Detecting Sunyaev-Zel'dovich clusters with PLANCK: I. Construction of all-sky thermal and kinetic SZ-maps & II. Foreground components and optimised filtering schemes"

M. Tucci, E. Martinez-Gonzalez, P. Vielva, J. Delabrouille astro-ph/0411567 "Limits on the detectability of the CMB B-mode polarization imposed by foregrounds"

Yurchenko, V.B., Murphy, J.A., Lamarre,J.M. astro-ph/0411642, "Ultrafast multireflector physical-optics beam simulations for the HFI instrument on the ESA PLANCK Surveyor"

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