STUDIES ON THE OPTICAL CHARACTERISTICS OF THE PLANCK TELESCOPE

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The next generation of satellite missions, like Planck and MAP, require large telescopes coupled to detector arrays to measure CMB anisotropies at small angular scales. The careful prediction of the optical performances of such telescopes plays a crucial role for the optimization of the optical configuration and for the evaluation of associated systematic effects. A brief review of the optical calculations for the Planck telescope is presented. Results are used to evaluate the optical distortions and to optimize the location of the Planck/LFI (Low Frequency Instrument) feedhorns.

1 Optical Calculations

The properties of the radiation pattern have been calculated for three optical configurations of the Planck telescope. The first one is the STANDARD configuration assumed during the "Phase A" study[1]. The second and third, called ENLARGED.1550 and ENLARGED.1750, are proposed to improve the optical quality of the Planck telescope, by increasing the aperture diameter (from 1.3m to 1.55m and 1.75m respectively), maintaining the same secondary reflector and the same equivalent focal ratio. All the configurations are "Gregorian off-axis telescopes": the incident wave is scattered by the primary parabolic mirror to the secondary ellipsoidal mirror and then to the focal region where the detectors are located[4]. The secondary reflector axis is tilted at 14 degrees with respect to the parabola axis in order to minimize the beam distortions at the center of the focal region. For each configuration, we calculated the position and the shape of the focal surface (i.e. the surface of maximum directivity)[6]. Geometrical optics approximation has been used: circular bundles of rays from the rim of the primary mirror are propagated through the telescope optics. The points at which the bundles converge to the minimum size (in least-square sense) trace the focal surface and also give the correspondence between angles from the optical axis and the linear displacements in the focal surface, often referred as the plate scale (that depends on the effective focal length of the telescope).

These results are used as input to calculate the response of the telescopes on the sky[7] (the beam pattern). A FORTRAN code, based on the Physical Optics (PO) and Geometrical Optics (GO) techniques, has been implemented to calculate the response as a function of the view direction on the sky[5]. Given the position of the detector (a corrugated feedhorn) in the focal region and the corresponding view direction with respect to the chief ray, the integration of the currents on the aperture surface of the main reflector is calculated in order to obtain the Far Field radiation pattern. For each configuration, the response of the telescope in a regular elevation-azimuth grid on the sky that covers the field of view has been obtained. The evaluation of the distortion as a function of the detector position on the focal surface has been used to optimize the location (in the focal region) and the pointing direction of each feed. We have also taken into account the physical size of the feedhorns and of the receivers, as well as the HFI focal box located in the central region.

2 Conclusion

Optical calculations have been used to optimize the LFI FPU assembling and to predict the sistematic effects of the optics. We notice that the STANDARD optical design of Planck suffers from beam distortion effects which lead to a large degradation of the effective angular resolution of the beams [3]. The new arrangement of the Focal Plane Unit (FPU), with HFI in the center and LFI around it, is not ideal from the LFI point of view [2].

In order to recover the nominal LFI (and presumably HFI) Planck angular resolution introduced by beam distortions at an acceptable level, a larger primary mirror is demanded.

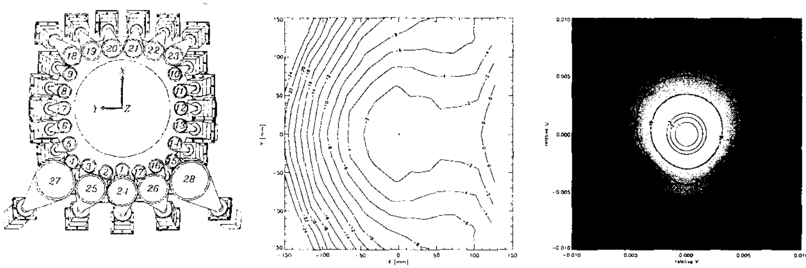

Figure 1: Left panel: new Focal Plane Assembling Unit. The feeds from 1 to 17 are at 100 GHz. The other feeds are working at 70 GHz (18-23) , at 44 GHz (24-26) and at 30 GHz (28-29). Middle panel: contour plot of the focal surface of the STANDARD telescope design. It is worth noticing that the focal surface is not a plane. Right panel: example of the beam simulation calculated at 100 GHz for the LFI feedhorn # 1 and the STANDARD configuration.

References

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