PhD Thesis Proposal

Subject: Optimization of the ESA EUCLID satellite mission from the systematic effect studies of ESA Planck satellite mission, in particular cosmic ray interaction with detectors.

A. General Information

Thesis Advisors: Dr. Yannick Giraud-Héraud and Ass.Prof. Guillaume Patanchon – AstroParticle and Cosmology (APC) laboratory – Paris Diderot University – France.

B. Area of Research

The cosmic microwave background (CMB) is a relic emission from the epoch in the Universe when the matter decoupled from radiation, 380 000 years after the Big-Bang. The small fluctuations of the CMB of the order of 10^{-5} times the average temperature result from initial perturbations in the Universe generated during the inflation phase, which is an early phase of exponential expansion happening 10^{-35} second after the Big-Bang. The CMB anisotropies as well as the polarization are a wonderful tool of exploration of the primordial Universe since their statistics, and in particular their power spectrum, depend on the fundamental cosmological parameters describing the Universe as a whole. The main cosmological parameters are energy density of the different components (baryonic matter, dark matter, dark energy), the Hubble parameters, as well as primordial spectra parameters. The measurement of the tensorial modes of the CMB polarization, the so called B-mode patterns by analogy with the magnetic field symmetry, is one of the main objectives of modern cosmology since those modes can only be generated by primordial gravitational waves and hence are a direct and unique probe of the inflation phase of the Universe.

C. Scientific context of the thesis

The Planck satellite of European Space Agency (ESA), the 3^{rd} $generation$ space CMB mission, was launched 2009 from Kourou France Guyana to Lagrange point 2 of the Sun, Earth and Moon system, located at 1.5 million km far from the Earth. It measures temperature and polarization anisotropies of the CMB. Planck observes the CMB with two instruments Low Frequency Instrument (LFI) and High Frequency Instrument (HFI). The HFI instrument operates with 50 signal bolometers including 12 polarization sensitive bolometers (PSB) and unpolarization spider-web bolometers (SWB), also 16 thermometers, two dark bolometers, a resister and capacitor. Each PSB module has two bolometers back together measuring linear polarization in the range of frequencies between 100 GHz and 1 THz.

A first set of results including constraints on cosmological parameters from the measured CMB anisotropy maps has already been published in March 2013 and final results on temperature anisotropies in January 2015. Planck scientists are still analyzing the polarization data and robust results will be published in 2016. Numerous other scientific studies based on the Planck maps will be published after this date since the Planck maps will be the reference at large angular scales for the next two decades.

The processing of Planck data, and in particular of Planck-HFI data which is the most sensitive instrument, is very challenging and requires intensive work of the whole Planck collaboration many years after the launch due to numerous systematic effects affecting the data. One of the most important effect results from the interaction of cosmic rays with the different components of the

Planck HFI bolometers. At the Earth-Sun Lagrange point L2, high energy particles from the Sun and Galactic sources primarily protons, electrons and helium nuclei are incident on the spacecraft. This particle flux causes a significant rate of glitches in the bolometer signal.

Cosmic rays (CRs) which are high energy particles interact on the 100 mK HFI bolometer, deposit energy produce glitches (Planck collaboration result I) on data. Generally, CRs can interact with each module of bolometer. The high energy particle hitting to the silicon die of polarization sensitive bolometers (PSB) and spider wed bolometers (SWB) deposit energy and produce the *glitches (2 per second)* on the scientific data as figure 1. The *glitches* effect to lose 50 % of the Planck data.

Therefore deep understanding and careful data processing of the glitches are necessary. Moreover the result can impact the measurement of the polarization of the CMB. The effect of CRs have been characterized in the Planck data, but analytic and modeling of the interaction is very important to improve further the CMB analysis, but particularly for the preparation of future missions, such as the Euclid satellite of ESA for which the launch is expected in 2020. The Euclid instrument is composed of 2 cameras, one CCD camera in visible and the other in near-infrared. Euclid will also operate at Lagrange point L2 and cosmic rays will be an important issue that scientists will have to address. The mission will investigate the distance-redshift relationship and the evolution of cosmic structures by measuring shapes and redshifts of galaxies and clusters of galaxies out to redshifts 2, or equivalently to a look-back time of 10 billion years. In this way, Euclid will cover the entire period over which dark energy, which is the dominant form of energy in the Universe today and is totally unknown, played a significant role in accelerating the expansion. Euclid will also constrain the distribution of dark matter in the Universe by measuring the weak gravitational lensing effect induced to the photons by mass in the line of sight.

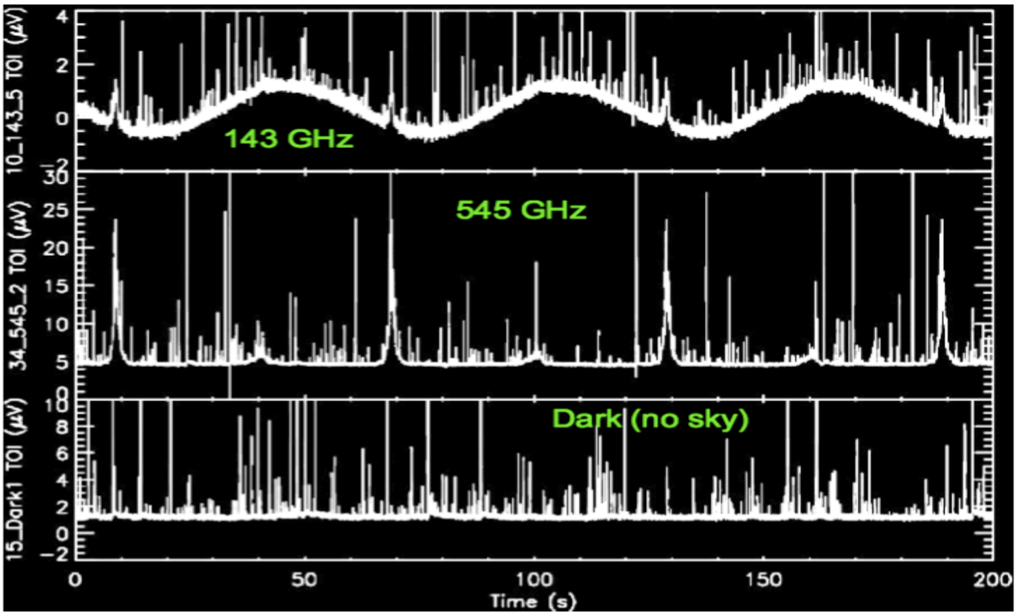

Figure 1: The Planck raw data (unprocessed) of two frequency band and a dark bolometer show in time(>3 cycle). The time order information (TOI) is dominated by the CMB dipole, the Galactic dust emission and glitches. The rate of glitches are quite conspicuous (Planck early results IV).

Another important aspect of the thesis will be the preparation of the future CMB satellite mission. The objective of will be the measurement of CMB B-mode polarization signal and to provide the ultimate measurement of the polarization on the whole sky (as Planck for the temperature). This will be one of the main objectives of cosmology in the next ten years. The CORE+ is one of the projects which is proposed to the ESA agency. The prediction of the impact of cosmic ray will obviously be an important task to choice the detectors, observation frequencies, telescope configuration, etc...

D. Scope and Objective of The Thesis

The accurate modeling of the interaction of particles with the different components of the Planck detectors and of the instrument is very important for the optimization of future missions operating at the Lagrange L2 point. A first simple model, that I have been developed during my training period in the frame of the USTH master 2 program “Space and Applications” in AstroParticle and Cosmology laboratory – Paris Diderot University, already gave numerous useful new informations about the interactions of cosmic rays with the Planck detectors, however the results obtained showed that very accurate modeling including interactions with secondary particles and particle showers produced by the interaction of primary particles with other components of the satellite is necessary. This accurate modeling will be my first objective during the PhD. I will then use this model to predict the effect of cosmic rays on the future CORE+ CMB mission, and also on the Euclid mission. I will then have to adapt my method to interaction with CCD camera composing the Euclid instrument. I will participate to the experiment testing the impact of cosmic rays with Euclid detectors using radioactive sources.

A second objective of the thesis will be the preparation of the future CMB mission. I will quantify potential systematic effects affecting the results of the mission. This analysis will be used to optimize the mission configuration such as the choice of detectors, the scanning strategy, or the choice of frequencies.
Another aspect of the thesis will be the analysis of Planck polarization maps in order to measure the large scale polarization.

The PhD thesis objective are summarized in the following:

1. Simulate the interaction of Cosmic Rays with satellite detectors at Lagrange point 2.
2. Accurate model of interaction with Planck detectors, prediction for Euclid and COrE+ Project , analyze the effect on Planck polarization spectrum.
3. Estimate low multipoles polarization from Planck maps. Measure and quantify the anomalies in CMB large scale polarization.
4. Dedicate the coding method for CMB large scale polarization of Planck data.
5. Apply the method in Planck data.
6. Work on quantifying the potential systematics for the COrE++ project.

I will work within a large international collaboration and the APC laboratory play a central role in this collaboration with many researchers involved in the Planck and Euclid experiments.

E. Expected result

I will attend to large international collaboration meeting and present my work to those meetings and to international conferences. I expect the following publications during my thesis:

1. A publication of the model of the full interaction of particle with Planck environment.
2. A publication for the expected contribution of glitches from comic rays in Euclid data.
3. A significant contribution to the next CMB mission CORE+ proposal.
4. A publication on the methodology and results from the analysis of low multipole polarization in Planck maps.

Depending of the results obtained, other publications on analysis methods for future CMB

experiments can be envisaged.
Preliminary work:

This figure shows preliminary results I obtained during my training period on the prediction of number of interaction from proton and Helium on Planck detectors:

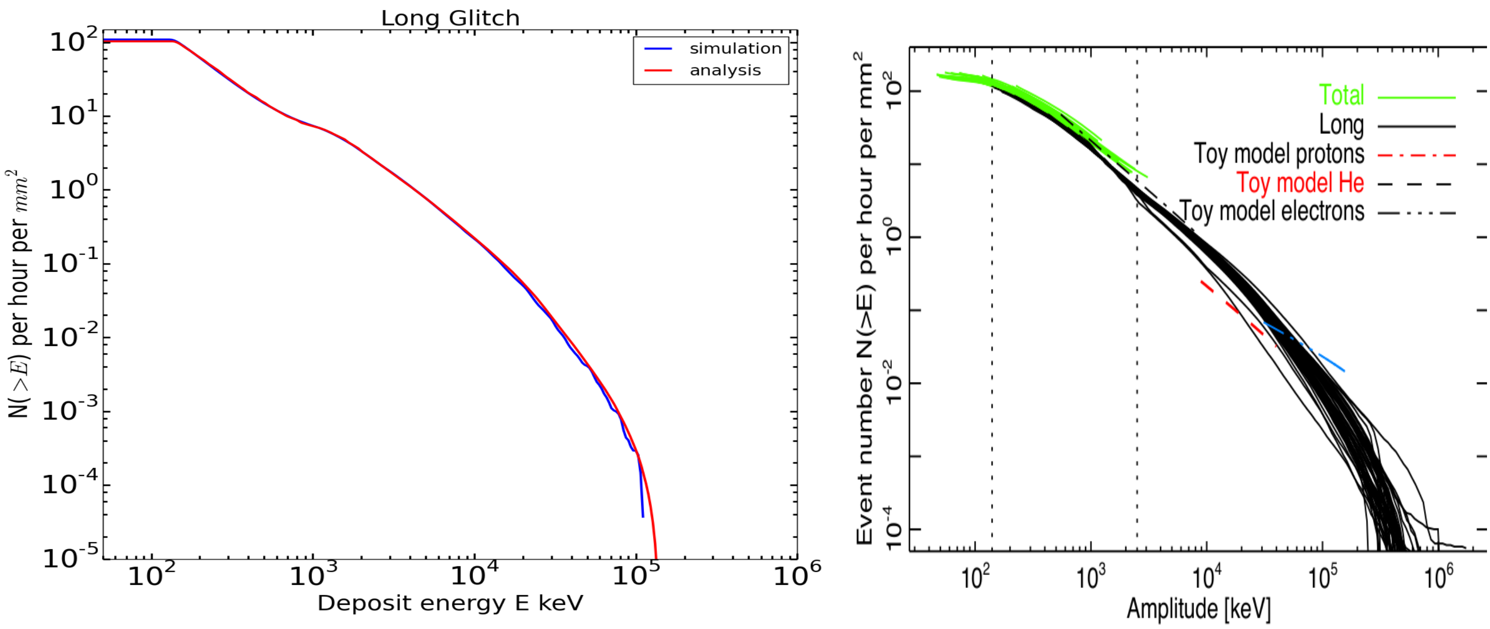

Figure 2: The 6 months internship result show the number of particles (Cosmic rays) per hour permm^2respect to deposit energy of coming energy particle interact with detectors of Planck satellite between observation data (right) and simulation, analysis (left).

F. <u>Schedule</u>

It is important that the various stages of the work must be done in a logical sequence and these various stages require different amounts of time. Fortunately, I have been started 6 months the first task of the thesis before then it is a boost to improve the thesis successful.

Thesis missions	**Completion Target Time(Stage = 6 months)**					
	Stage1	Stage2	Stage3	Stage4	Stage5	Stage6
1. Literature review and accurate model of interaction with Planck detectors	X					
2. Prediction for Euclid and COrE+ Project , analyze the effect on Planck polarization spectrum.		X	X			
3. Participate to particle interaction testing for Euclid			X			

4. Estimate low multipoles polarization from Planck maps. Measure and quantify the anomalies in CMB large scale polarization.				X	X	
5 Work on quantifying the potential systematics for the COrE++ project and develop methods					X	X
6. Write the PhD thesis						X

G. Preliminary Bibliography

[1] Planck Collab. Planck 2013 results. *I. Overview of products and scientific results*, accepted by A&A, 2014, astro-ph/1303.5062.

[2] Planck Collab. Planck 2013 results. *VI. High Frequency Instrument data processing,* accepted by A&A, 2014, astro-ph/1303.5067.

[3] Planck Collab. Planck 2013 results *X. Energetic particle effects: characterization, removal, and simulation,* accepted by A&A, 2014, astro-ph/1303.5071.

[4] Planck early results.iv. *first assessment of the high frequency instrument inflight performance.* Astronomy & Astrophysics special feature, 11.Jan.2011. URL http://arxiv.org/abs/1101.2039.

[5] *Record-setting cosmic rays intensities in 2009 and 2010.* The Astrophysics journal letter, 1.November.2010. URL http://iopscience.iop.org/2041-8205/723/1/L1/.

[6] *Energetic particles in the universe; how does nature beat cern? Plasmaphysics and controlled fusion,* 20 July 2009. URL http://iopscience.iop.org/0741-3335/51/12/124005.

[7] Planck. *vi. high frequency instrument data processing.* Astronomy & Astrophysics manuscript no. HFIDPC, 26 March 2013. URL http://arxiv.org/abs/1303.5067.

[8] P. Cabella and M. Kamionkowski. *Theory of Cosmic Microwave Background Polarization.* rXiv Astrophysics e-prints, March 2004. URL http://adsabs.harvard.edu/abs/2004astro.ph..3392C.