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BIRDY : an interplanetary CubeSat to collect radiation data on the way to Mars and back

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Abstract

The studies of the space radiations are facing a lack of observational data. Simultaneous measurements from multiple locations in the solar system are necessary to properly assess the knowledge about the solar wind and the cosmic rays. A specialized CubeSat is a smart and cheap solution to take part in the global effort: a new concept for autonomous space probes will be demonstrated by BIRDY. Moreover the "CubeSat" standard allows numerous students to get involved in the BIRDY team, managed by two major institutions for space science and technology, in France at the Paris Observatory and in Taiwan at the National Cheng Kung University. A prototype shall be ready to fly in Geostationary Transfer Orbit from 2018, before a flight model being sent on a free-return Earth-Mars-Earth trajectory.

1. Interplanetary Data for Space Weather Understanding

Our science case is to take advantage of an Earth-Mars journey to participate to the space weather understanding. BIRDY's scientific payload will gather data that are useful to improve the current models of radiations due to the solar wind, the galactic cosmic rays (GCR) and their mutual interactions. In 2011 the MSL-Curiosity mission with the RAD (Radiation Assessment Detector) was the only mission that successfully measured radiations between Earth and Mars. But RAD was optimized for measures on the Martian surface, not from the interplanetary space. In BIRDY, the RAD is considered as a technical baseline for a new, small and specialized instrument.

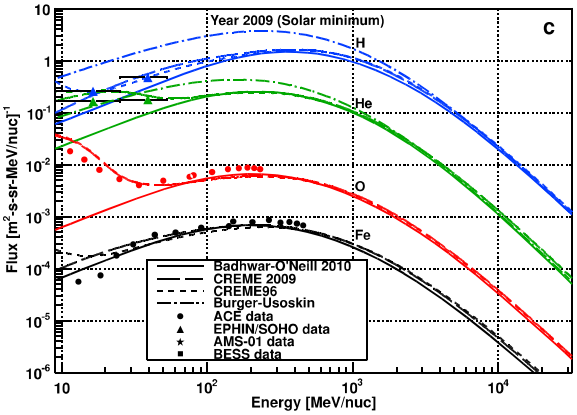

Figure 1: Different GCR models (Mrigakshi, et al., 2012). Density of ions wrt energy per nucleon. The colors code the different ions, each symbol is associated to a given model

BIRDY will characterize the energetic particle spectrum in interplanetary space on an Earth-Mars-Earth free-return trajectory. It will focus on the energy range 10 MeV/nucleon – 1 GeV/nucleon with a priority on the assessment of the radiations hazards for an eventual manned mission to Mars. The primary particles, from GCR and SPE (Solar Particle Events) will be measured with an indication in the direction and velocity of arrival. Indeed, the energy range of interest for GCR is from 10 MeV/nucleon to a few GeV/nucleon and the various models for GCR abundances disagree at energy lower than 200 MeV/nucleon (fig.1). SPE may be produced by impulsive flares or by Coronal Mass Ejections (CMEs). Those particles get through interplanetary medium along the IMF (Interplanetary Magnetic Field) with a spiral shape within the solar system, the “Parker spirals” (fig.2). The typical angle between the IMF lines and the direction of the Sun is the scientific factor driving the observation attitude requirement for the payload. We then expect to verify

the “Hohmann-Parker” effect that links the SPE flux detected by a probe between Earth and Mars with the one detected nearby Earth or nearby Mars by another space probe. Such a confirmation would contribute to space weather awareness for future deep-space missions.

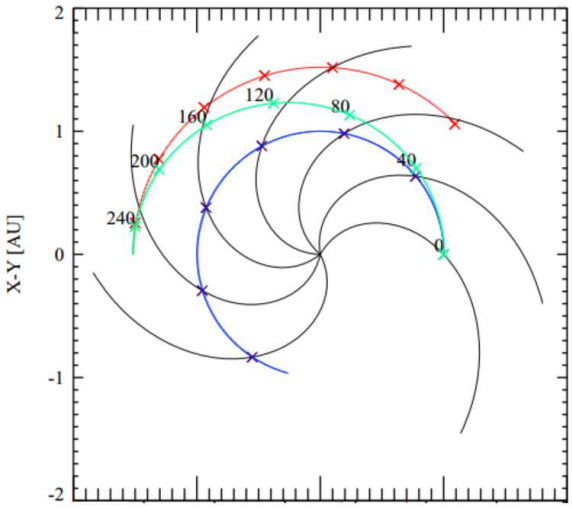

Figure 2: IMF lines (black spirals). Tick marks are successive positions of Earth (blue), of a probe on a Hohmann trajectory (green), of Mars (red). Positions are magnetically connected if the marks are on a same IMF line (Posner, 2013)

2. Engineering

BIRDY is launched as piggy-back of a host mission to Mars. It is jettisoned at the beginning of the journey: it is independent from the host mission and thus fully compatible with any mission to Mars. A navigation system based on a “planet tracker” and on electric propulsion allows small trajectory corrections to achieve the exact flyby of Mars that permits a free return to the Earth. The collected science data are kept on-board and only downloaded while in Mars' vicinity and later while approaching Earth on the way back. A beacon signal allows tracking the trajectory and the status by the VLBI network on Earth. Preliminary feasibility studies have shown that the technical challenges can be solved. The design is now on-going.

3. Design Management

The newly established space campus of the Paris Observatory, CERES, hosts the project, for design & test facilities and for support in the dialog with partners. Indeed BIRDY is an educational project by students coming from several universities and countries, mainly in France and Taiwan. The AGILE principles, coming from the software industry will be applied to BIRDY. The development anticipates a structural and thermal model (STM, in 2015), a protoflight model (PFM, in 2018) to be sent on a geostationary transfer orbit to test the propulsion and the navigation, before an actual flyby of Mars.

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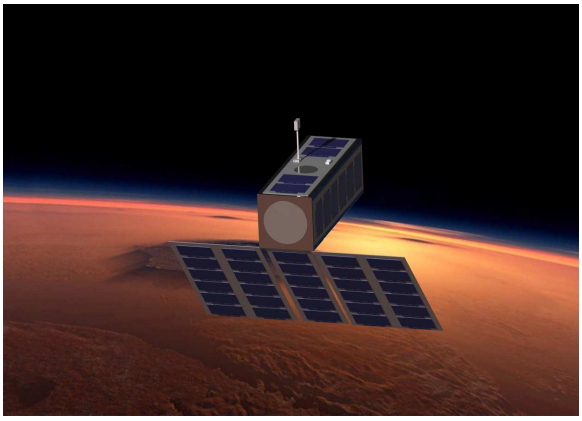

Figure 3: Artistic view of the deployed 3-Unit BIRDY CubeSat over Mars (size of 10x10x30 cm3 before deploying)