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Identification of best particle radiation shielded region through Energetic Neutral Atoms mapping

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Abstract

The lunar surface is directly exposed either to direct solar wind, or to Earth's magnetospheric plasma due to the Moon's lack of a magnetosphere or a dense atmosphere. This exposure could create inhospitable conditions for a possible human presence on the Moon, so it is crucial to investigate the close-to-surface environment for establishing the best reliable locations for future human bases. Although it lacks a global magnetic field, the Moon possesses magnetic anomalies that create mini-magnetospheres, where the solar wind is partly deflected. The local protection of the surface from the solar wind radiation inside the mini-magnetospheres could make these sites preferred for future lunar colonization. In this paper, an investigation based on the detection of Energetic Neutral Atoms (ENA) from the surface for identifying the best particle radiation shielded region is proposed.

1. Introduction

Plasma precipitation results in intense space weathering of the regolith-covered surface. Whenever any precipitating particle population hits the surface, a fraction of it is back-scattered as charged particles [1] or as neutral atoms [2][3]. The impacting ions also produce surface release via ion-sputtering. The back-scattered neutral population (mostly hydrogen) has a typical spectrum peaking at hundreds of eVs, while the ion sputtered population spectrum peaks at few eVs, its energetic tail includes remarkable fluxes up to hundreds of eVs [4]. Since the particles are neither deflected by magnetic field nor by gravity (negligible at these energies), the detection with high angular resolution of the Energetic Neutral Atoms (ENA) emitted from the surface could produce a real image of the bombarded regions, similar to the albedo imaging obtained by photons [5]. The observations obtained by Chandrayaan-1 Indian mission demonstrated the feasibility of such measurement [6], even if the low angular resolution of the CENA sensor was only able to produce a low resolution ENA image of the surface (pixel projected instantaneous field-of-view bigger than ~ 80 x 10 km^2 [7]. The regions of local magnetization, referred as magnetic anomalies, with magnetic field strengths of up to 100 nT at the surface [8], create a sort of mini-magnetospheres, where the precipitating plasma is significantly deflected. In fact, the observed ENA intensity reduces by a factor 2 (respect to the directly exposed regions) within the mini-magnetosphere while it increases at the border of the region [9]. Simulations indicate that even a much higher shielding of solar wind is possible [10].

2. ALENA

A Cubesat mission for Lunar Exploration, like the LUCIANUS (LUnar Cubesat Initiative Aimed to Novel and Unique Science) mission would allow an optimal opportunity to host ALENA (Analyser for Lunar Energetic Neutral Atoms), a reduced version of the ELENA sensor for ENA mapping on board of the BepiColombo mission to Mercury [11]. ALENA should be flown on board a low-altitude orbit (between 75-120 km) cubesat, so that it would be able to resolve intensity and direction of the neutral flux coming from the lunar surface [12]. Thanks to the very high angular resolution of ALENA (< 5°) in the low-altitude orbit a detailed mapping of the lunar surface at spatial resolution lower than 8 x 8 km^2 will be possible. The instantaneous FoV will provide a mono-dimensional array, the satellite cross track will provide the second dimension of the image.

The scientific objectives of ALENA will be:

- investigation of the interaction of the solar wind with the mini-magnetospheres at the magnetic anomalies;

- evaluation of the effectiveness of the 'space weathering' on the Lunar surface;
- interactions between the Moon and its environment (Earth's magnetospheric plasma and solar wind);
- paradigm for Mercury and other airless bodies and feasibility test for the SERENA-ELENA instrument. In fact, even if the Moon and Mercury differ in important aspects, their lack of atmosphere and similar regolitic surface make these bodies frequently compared [13]. Given the long cruise of BepiColombo, this cubesat mission could also be the opportunity for testing ELENA before the science operation at Mercury (2025).

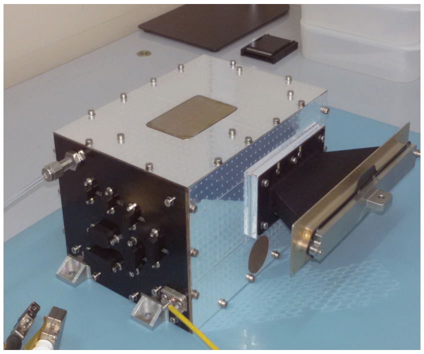

Figure 1: BepiColombo/SERENA-ELENA sensor.

Table 1: ALENA proposed performances and expected resources

Parameter	Value
Energy range	>0.01 – 5 keV
Viewing angle	$4.5^o \times 60^o$
Angular resolution	$4.5^o \times 4.5^o$ (actual) 4.5° × 1.9° (nominal pixel)
Optimal temporal resolution	>=5 s
Pixel Geometric factor G	$3\ 10^{-5}$ cm^2 sr
Integral Geometric factor	$8\ 10^{-4}$ cm^2 sr
Mass	1.5 kg
Power	10 W
Telemetry	100 bit/s

3. Summary and Conclusions

The local protection of the surface from the solar wind radiation inside the mini-magnetospheres could make these sites preferred for future lunar colonization. It is crucial a detailed characterization of these sites. A high spatial resolution mapping via ENA is a feasible and it is powerful way for reaching this goal.

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