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Observations of Transient Luminescent Phenomena on the Moon From a Deep Space Platform

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Abstract

We propose monitoring of the lunar surface for impact flashes and other transient events from the Deep Space Gateway. Such observations from space, which overcome the terrestrial day-and night cycles, cloudy skies, and atmospheric stray-light effects, may shed light on the relationships between lunar crater statistics, seismic detections of impacts and the terrestrial meteor rates – as well as on impact hazards.

1. Introduction

Several thousand tons of extraterrestrial material enter the Earth's atmosphere every year. Most of our knowledge on this "meteoroid flux" is based on the observations of the terrestrial "meteors". However, the Moon is an efficient meteoroid detector likewise, as is attested by the large inventory of craters and the substantial number of impacts recorded by the Apollo seismic station network [1]. From the temporal/spatial distribution of impact events, constraints can be obtained on the meteoroid approach trajectories, velocities, and shower memberships. Only as late as 1999, it was successfully demonstrated that meteoroids produce "flashes" upon impact. During the peak of the Leonid meteor shower, at least 6 impact flashes were recorded on a single night [2]. Today, observatories worldwide are engaged in the observation of impact flashes. A unique very large impact flash (m=2.9) was detected on September 11, 2013 [3], and a crater presumably related to the event was later identified in LRO images [4].

We propose monitoring of the lunar surface for impact flashes from the Deep Space Gateway. Detections from the Gateway may be complemented by the inspection of craters resulting from the events by high-resolution cameras (if available in lunar orbit). Precise impact locations and impact times are also useful for lunar seismic experiments (if available on the lunar surface), as the impacts represent useful energy sources for sounding of the lunar interior. The impact monitoring will also provide a direct assessment of the danger to human assets or humans on and near the Moon.

2. Science Goals

We foresee the following science goals:

- Determine the rate of crater formation on the Moon on the different hemispheres
- Determine the temporal/spatial distribution of the impactor flux
- Study characteristics of impact events to improve our understanding of impact dynamics
- Determine impact locations for follow-up crater inspections by cameras
- Locate impact events for use as seismic energy sources in seismic experiments
- Identify specific event characteristics, which might allow us to distinguish between asteroidal or cometary impactors
- Search and characterize other lunar transient luminous events, e.g., outgassing
- Estimate the threat from a meteoroid impact and associated ejecta to a future lunar habitat

We foresee capturing effectively > 2000 hours of observations of the night hemisphere in one experiment run, during which we would expect to detect several hundreds of flash events.

3. Camera Systems

We have previously carried out camera studies (two parallel studies with industry partners Jena Optronics, Germany, and Officine Galileo, now Leonardo, Italy, contract through ESA) dedicated to imaging faint transient noctilucent phenomena, such as aurorae, electric discharges, meteors or impact flashes, on dark planetary hemispheres [5]. The German-led SPOSH (Smart Panoramic Optical Sensor Head) is equipped with a back-illuminated 1024 x 1024 CCD chip and a custom-made optical system of high light-gathering power and wide field of view, 120º x 120º. The Italian solution is based on a so-called EM-CCD (electron-multiplied CCD), which features 512 x 512 pixels and a 70º field of view. Images can be obtained over extended periods at high rate (up to 3 images per second) to enable monitoring for transient events. To reduce data volumes, only those images (or portions) are returned that contain events. Tests demonstrate that the cameras have excellent radiometric performance at low light levels over their large field of view. We estimate that a SPOSH-like camera would see about one impact per 2 hrs from 40000 km distance to the Moon.

Upgraded camera systems (e.g., equipped with CMOS sensors) may produce detailed impact flash lightcurves and/or flash spectra. We propose to use multiple camera systems operating jointly, each of them optimized for high temporal-, high spatial- or high spectral resolution. At least dual systems are also required eliminate false detections by cosmic-ray hits. Owing to the varying distance from the Moon of the platform, we may consider the deployment of complimentary wide-angle and narrow-angle optical systems. We propose the impact detection system to be complemented by a dust detector to allow for a full characterization of the near-Lunar meteoroid environment over a wide range of meteoroid sizes.

4. Operation

The sensor systems of moderate mass (< 20 kg) and size is to be mounted on the outer surface of the Gateway. A mechanism is required to ensure camera pointing to the Lunar surface (i.e., the dark portion). For special observing runs, we require Earth pointing or star observations. Once the system is set-up, the operation is autonomous and does not require any actions by the crew. The operation of the system in space will be supported by ground-based observations worldwide

5. Proposing Team

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