PHOTOMETRIC CHARACTERIZATION OF PLANETARY SURFACES: WHEN THE EARTH MEETS THE MOON.

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Introduction: The knowledge of the physical properties of terrestrial and planetary surfaces is essential to understand the mechanisms of formation and evolution of landscapes, but also to prepare the landing and mobility of future planetary rovers. Of all the experimental and theoretical approaches to access these properties, photometry that exploits reflected or emitted light radiation at different wavelengths and angles of emergence is often the only one that can be used [1]. In the solar domain, the light scattered from the surface is recorded as a bidirectional reflectance distribution function (BRDF), which is a multiscale and multispectral quantity characteristic of the observed target [2]. With appropriate processing, the BRDF can reveal surface properties such as surface roughness, porosity, grain size and shape, granulometry, micro-texture, mineralogy, etc. [3].

To this end, we have focused our research on two sites, the Asal-Ghoubbet rift (Republic of Djibouti) and the Moon, particularly the Apollo 17 landing site (Taurus-Littrow Valley). The first site was selected because of the wide variety of terrain in terms of albedo and surface roughness, preserved by the desert climate, as well as its accessibility [4]. The second one was also selected for the diversity of the terrain and the large amount of field data acquired by the American astronauts. To carry out such research, data from various instruments have been gathered: laboratory and field goniometers, UAVs as well as satellites (Pleiades, Lunar Reconnaissance Orbiter). All these data will be analyzed using physical models to extract soil properties. In particular, we focus on surface roughness which can be quantified from elevation data and estimated by remote sensing [4, 5].

Method: BRDF extraction requires multi-angular data and therefore optical sensors with pointing capability. In the laboratory or in the field, spectro- goniophotometers are available to measure the BRDF of small samples; from space, satellites like the Pleiades constellation operated by CNES allow the BRDF to be obtained on a larger scale [6]. On January 26, 2013, during the in-flight commissioning of the Pleiades 1B satellite, about 20 images were acquired in video mode over the Asal-Ghoubbet rift in a single four-minute flyby, at viewing angles ranging from -56.7° to +52.6°. These images were recently corrected for atmospheric effects using a variant of MACCS ATCOR Joint Algorithm (MAJA), which uses ancillary data to determine water vapor content and aerosol optical thickness [7]. Because of its pointing agility, Pleiades can target the Moon for sensor calibration (Fig.1). The data base of images covers a wide range of phase angles [8], from about 0° to 110°. The processing chain is similar to that used for terrestrial data. The Hapke model [1] will then be inverted on the BRDFs of these two sites.

Figure 1: Pleiades 1B image of the Moon in stereographic projection.

Special attention was paid to surface roughness, which can be quantified in several ways from a digital terrain model (DTM). We generated multiscale DTMs of the Asal-Ghoubbet rift and the Apollo 17 landing site by photogrammetry. In particular, we applied MicMac, a free and open-source software developed by the Institut national de l'information géographique et forestière (IGN) and the Ecole Nationale des Sciences Géographiques (ENSG) [9], to multi-view images acquired by hand, drone or satellite. Surface roughness can be defined as mean slope angle, the root-mean-square (RMS) height or autocorrelation length [5, 10].

Results and discussion: Some preliminary results are presented. The BRDFs extracted from Pleiades images over the Asal-Ghoubbet rift are in agreement with previous knowledge of the photometric behavior of this site [4, 5]. In the visible and near-infrared, the angular signatures of the different surfaces are distinct from each other. We observe a preferential backscattering and an increase of the BRDF value near the lowest phase angle direction, more or less marked around the fixed sun viewing angle (38°), depending on the surface roughness (Fig.2). The BRDF of site A, which corresponds to smoother terrain at the same scale, gradually decreases as the viewing zenith angle increases.

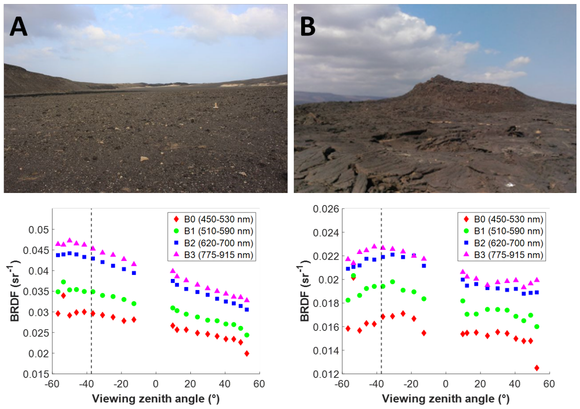

Figure 2: Photos and Pleiades BRDFs of two sites of the Asal-Ghoubbet rift. The dashed line indicates the sun zenith angle. Site A corresponds to lapilli deposits and site B to ropy pahoehoe lava [4].

On the Moon, the surface roughness of the Apollo 17 landing site was determined from two LRO instruments operating at different scales: 1.5 m for the Lunar Reconnaissance Orbiter Camera (LROC) and 57 m for the Lunar Orbiter Laser Altimeter (LOLA) (Fig.3). The calculation was first performed on four types of surfaces corresponding to geological units identified in the Apollo 17 pre-mission map [11]: Massif (exposed breccia layers), Dark Mantle (exposed volcanic material), Bright Mantle (avalanche from massif), and Hilly Terra (interlayered breccias in ejecta blanket). The rougher a surface is, the higher its mean slope angle, RMS height and the lower its autocorrelation length. At the 1.5 m scale of the LROC DTM, the two mantle units appear rougher than the other units, with the dark mantle being the roughest. This is consistent because the mantle is cratered as opposed to the hills and mountains. LOLA elevation data at the 57 m scale are in broad agreement, despite an uneven distribution in term of acquisition orbits.

This study will be extended to other Apollo landing sites where sufficient field data have been collected. The next step will be the extraction of BRDFs on the surface of the Moon surface from Pleiades images. Then, an efficient model inversion technique based on a fast Bayesian inversion [12] will be applied to retrieve surface characteristics, including surface roughness and single scattering albedo. Other roughness parameters than the ones mentioned above will also be investigated [5, 10].

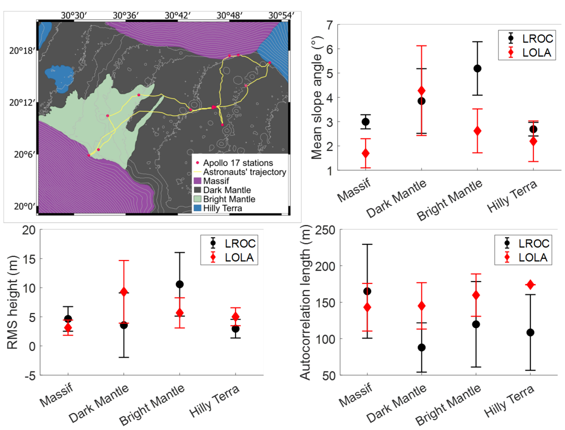

Figure 3: Map of four terrain units and comparison of roughness parameters between these units in the Taurus-Littrow valley (Apollo 17 landing site).

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