CHARACTERIZATION OF THE OPTICAL PROPERTIES OF J. HERSCHEL PYROCLASTIC DEPOSIT USING SMART-1/AMIE PHOTOMETRIC DATA. A. L. Souchon[1], S. D. Chevrel[1], P. C. Pinet[1], Y. H. Daydou[1], V. V. Shevchenko[2], B. Grieger[3], J. L. Josset[4], S. Beauvivre[5], Y. Shkuratov[6], V. G. Kaydash[6] and the AMIE team, [1]UMR5562/CNRS/Observatoire Midi-Pyrénées (Toulouse, France, souchon@dtp.obs-mip.fr), [2]Sternberg Astronomical Institute (Moscow, 119899, Russia), [3]ESA/ESAC (Madrid, Spain), [4]Space Exploration Institute (Case postale, CH-2002 Neuchâtel, Switzerland), [5]Micro-cameras & Space Exploration (Jaquet-Droz 1, CH-2000 Neuchâtel, Switzerland), [6]Astronomical Institute of Kharkov, National University (Kharkov, Ukraine).

Introduction: Lunar pyroclastic deposits are considered to be the results of ancient explosive volcanic eruptions and may provide some insight about the Moon's early phases of volcanism [1]. Improving our knowledge about their composition and surface state could lead to a better understanding of the Moon's interior as well as the still poorly known lunar volcanic history (e.g., [2]). Earlier works on the small dark deposit located at Herschel crater (61.4°N, 36.9°W), e.g., [1, 3], focused on a mapping based on its spectral characteristics (Fig.1). We implement here a photometric approach aimed at determining the surface physical properties of this geological unit, to ascertain their consistency with an explosive volcanic origin.

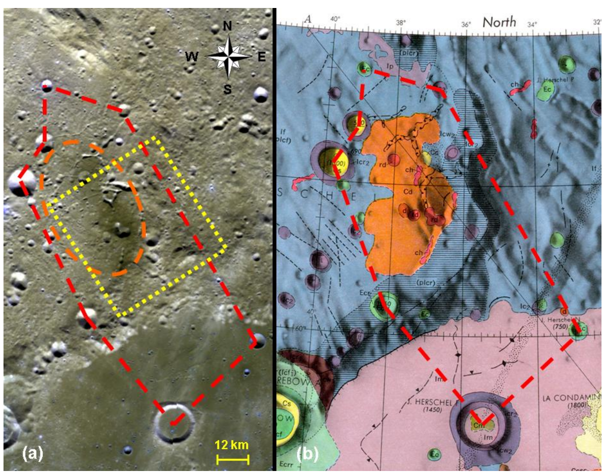

Figure 1. (a) composite IR Clementine image of Herschel crater, the dark deposit is circled in orange; (b) USGS geologic map (Ulrich, 1969) showing the same deposit in orange. Yellow dots delimit the area studied with AMIE observations (see Fig.2).

Data processing: A set of 71 images taken in the visible range by the AMIE camera of the SMART-1 spacecraft [4], with phase angles ranging from 35.3° to 103.4°, has been processed and coregistered to make them radiometrically consistent with the Clementine basemap. Physical surface properties are derived through bidirectional reflectance data acquired with multi-angular observations by applying an inverse method which relies on Hapke's semi-empirical photometric model [5]. A genetic algorithm dedicated to this problem has been implemented and successfully tested both on laboratory measurements and orbital data [6, 7, 8]. It permits to determine the four Hapke parameters b, c, θ and w, which respectively describe the phase function form, the forward or backward scattering of particles, the surface roughness and the single scattering albedo, associated with a surface element. The derivation of these photometric quantities is most sensitive both to the phase function coverage and influence of the local topography. To alleviate these effects, the spatial resolution of the images has been lowered, and only pixels present on every multi-angular image have been retained in order to work on a region presenting a large range of geometrical configurations (yellow dots in Fig.2). In order to account for the effects of shadow, which are enhanced by the high latitude of the area and surrounding topographic features such as the Herschel crater rim, a telescopic image has been used to create a mask that discards the pixels for which the photometry may be disturbed by shadowing effects. Fortunately, the remaining part of the image encompasses the location of the dark deposit to be analyzed (Fig.2).

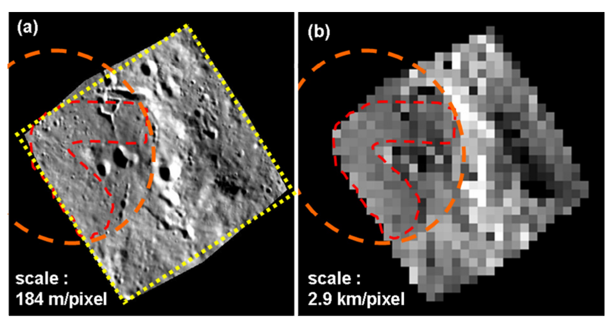

Figure 2. (a) full-scale AMIE image, with the dark deposit circled in orange; area of study within the red contour; (b) same as (a), but with the actual resolution at which the inversion was run.

Results and analysis: From the photometric inversion, the values of the parameters, averaged on the selected area of study within the red outline (Fig.2) are: $b = 0.15 \pm 0.06$, $c = 0.62 \pm 0.08$, $\theta = 25.9° \pm 1.7°$ and $w = 0.69 \pm 0.02$. Their apparent homogeneity suggests that the area may be considered as homogeneous from a geologic point of view. Values comprised between 0.5 and 1 for the parameter c indicates a predominantly backward scattering, which is indeed a general property of lunar regolith [9]. According to the experimental values of the photometric parameters derived from synthetic materials by [10], our results for the area under study (orange star in Fig.3) call for the presence of glass spheres with a moderate density of internal scatterers. This corresponds to a glass with a crystalline structure in some parts which induces a certain scattering anisotropy. Our estimates of the Hapke parameters for Herschel are also very close to those experimentally derived from Hawaiian basaltic sand (Kualua Sand, noted KS in Fig.3) by [11]. This sand is made of a mixture of dark basaltic spherical grains. The fact that our parameters fall into this region of the diagram is a key result that supports the basaltic nature for the Herschel deposit. In order to determine the particle size of the deposit, we plot the radiance factor versus the single scattering albedo for Herschel (Fig.4) and compare with results previously established by our team on basaltic and tephra samples divided into four granulometric classes from G1 to G4 [6]. The closest optical similarity observed on this diagram corresponds to the G1 tephra particles, which suggests that a characteristic size for the grains constitutive of the Herschel dark deposit (orange triangle in Fig.4) would be about 70 µm or less. The observed closeness with tephra, which is from explosive volcanic origin, would further agree with a pyroclastic deposit. Interestingly, the size estimate of particles of primitive pyroclastic material is about 40 µm [12], and agrees with our estimate, especially if one takes into consideration the role of maturation effect, which tends to increase the size of particles by aggregation since the formation of the deposit.

Conclusion: Hapke's parameters derived in this study showed that the dark deposit present at Herschel crater displays a strong photometric homogeneity. The confrontation of the photometric behavior of the particles with those of dark spherical basaltic grains from Hawaii and of a fine grain-sized sample of terrestrial basaltic tephra shows strong similarities. The grain size of the deposit is estimated to be 70 µm or less. These results, based on a detailed analysis of optical properties related to the surface state of the lunar regolith, strengthen the case for the presence of pyroclastic materials, initially proposed on the basis of geomorphological and spectral data. Future work, in particular experimental studies on terrestrial analogs of the lunar regolith, will be helpful to further analyze and interpret orbital data such as LSPIM/Kaguya-Selene observations on other pyroclastic deposits, e.g., [13].

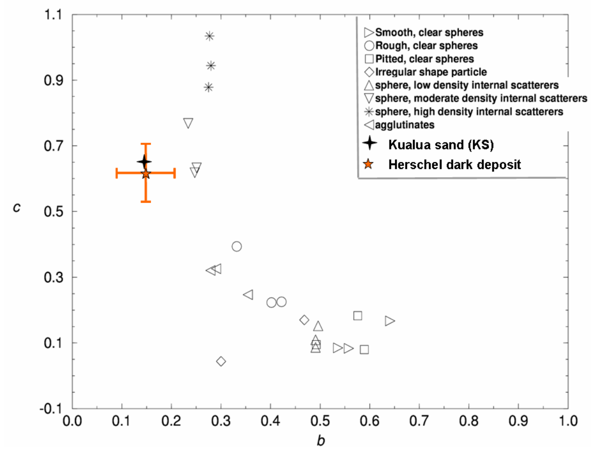

Figure 3. c parameter vs. b for synthetic materials (white symbols, from [10]), Hawaiian sand (black cross, from [11]) and the studied Herschel area (orange star and associated uncertainties).

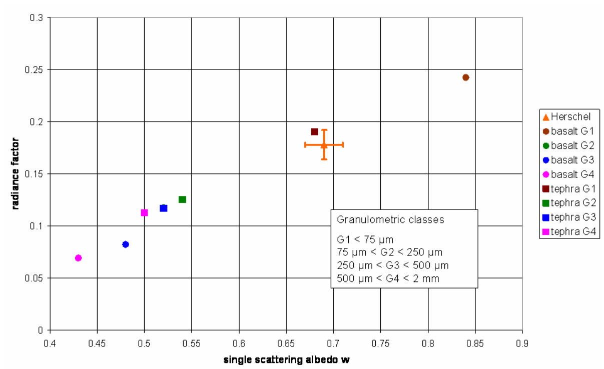

Figure 4. radiance factor vs. w plot of experimental values on basalt and tephra samples. Herschel deposit results shown in orange with associated uncertainties.

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