VIS-NIR REFLECTANCE MICRO-SPECTROSCOPY OF INTERPLANETARY DUST PARTICLES.

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Introduction: Meteorites have long been considered as the best analogues of asteroidal surfaces. However some classes of asteroid (B, C, G, P and D-types) have no analogues clearly identified in the meteorite collections [1]. These asteroids represent not less than 66% of the mass of the main belt. But meteorites are not the only cosmomaterials found on Earth since no less than 30 000 tons of interplanetary dust particles (IDPs) enter the Earth‘s atmosphere each year [2]. Chondritic porous (CP-) IDPs are among the most primitive objects that can be found on Earth [3]. It has been shown, by comparing mid to far infrared spectra (8- 45 µm) that some IDPs originate from icy objects such as comets [4]. Reflectance measurements in the visible range (0.4 - 0.8 µm) performed on CP-IDPs in 1996 showed that these objects could also be good analogs of a large number of primitive asteroids and thus provide a sampling of these bodies complementary to meteorites [5]. But since then, no reflectance measurements have been reported on CP-IDPs in the visible near infrared (Vis-NIR) range for comparison with asteroid surface whose reflectance spectra cover a wider range (0.4-2.5 µm). In 2015, Vernazza et al., simulated Vis-NIR spectra of IDPs according to their composition and showed that these objects could be representative of asteroids not currently sampled by meteorites [1]. The comparison was also supported by MIR spectra of IDPs obtained by our team at the French synchrotron SOLEIL [6]. We report here the recent developments and preliminary results of an experimental device for measuring diffuse reflectance of IDPs in the Vis-NIR (0.45-1.0 µm).

Experiments: Our setup is installed in a clean room and consists of a Vis-NIR spectrometer (Maya2000 Pro from Ocean Optics) coupled to a new macroscope (Leica Z16 APO) which replaces the old microscope that we used for the previous analyses performed on three IDPs [7]. A Vis-NIR optical fiber (100 or 50 µm in diameter) is used to collect the light diffused by the sample which is unilaterally illuminated by a 1000 µm diameter fiber coupled to a halogen source. The used phase angle in our experiments is about 45°. A similar setup was used to analyze Itokawa particles [8]. By changing the magnification and/or the diameter of the collection fiber it is possible to adapt the collection spot to the grain size down to 7 µm size.

Results: Before analyzing the IDPs, we performed measurements on different standards (olivine, pyroxene and four meteorites Dar al Gani 684 (Eucrite, DAG 684 in the followings), Gilgoin (H5), Allende (CV3) and Frontier Mountain 95002 (CO3)) to establish a protocol and obtain the reflectance spectrum of an isolated µm-sized grain with one-sided illumination, which is a common configuration for macroscopic measurements (spot size ~ mm) [9]. We first performed macroscopic measurements on these different materials prepared in the form of not compacted powder that we compare to the microscopic measurements made on the same samples. In Fig. 1 an average microscopic spectrum of the powder is compared to the macroscopic measurement on the same surface in the case of the meteorite DAG 684 and we find similar spectral features in terms of the 0.95 µm band position and shape.

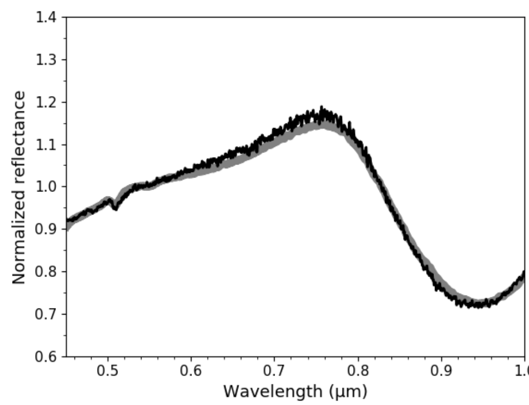

Figure 1 : Comparison between the average of the microscopic spectra (black), spot size 16 µm and the macroscopic measurement (gray), spot size 4 mm on the powder of DAG 684. Both spectra were normalized to their albedo value (0.55 µm) for a better comparison of the spectral shape.

To obtain the reflectance spectrum of an isolated grain it is necessary to take into account its different orientations with respect to the incident light. To investigate the effect of the orientation of the grain (versus the illuminating light), we performed measurements on a ~ 30 µm sized grain of DAG 684 with 4, 8, 20 and 40 different rotations. The obtained spectra are shown in Fig. 2. The reflectance spectra converge between 20 and 40 rotations (which corresponds to the number of rotations necessary for the grain to be illuminated at 360 °). Thus we obtain the spectrum of the isolated grain by rotating it in the observation plane over 360° and averaging the spectra obtained at 20 different rotation angles.

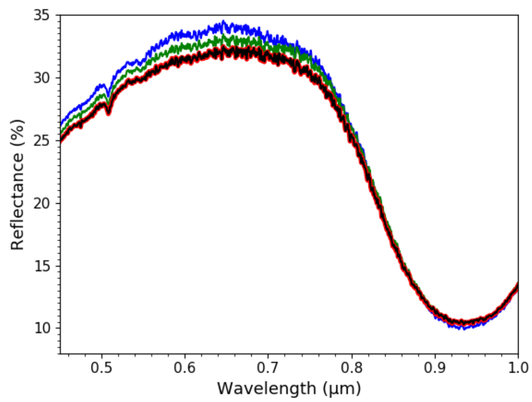

Figure 2 : Reflectance spectra obtained on an isolated grain (~ 30 µm) from DAG 684 with 4 (blue), 8 (green), 20 (red) and 40 (black) rotations.

Finally, we applied our analytical protocol to measure the reflectance spectra of three IDPs that we had analyzed with the old microscope which allowed only four rotations [7]: L2079 C18 (35×27µm), W7068 C40 (25×23µm) and L2071 E34 (22×20µm). The first IDP is transferred onto a diamond window, the two others are kept on their original glass slides substrate as provided by NASA curator. The obtained reflectance spectra are represented in figure 3 below.

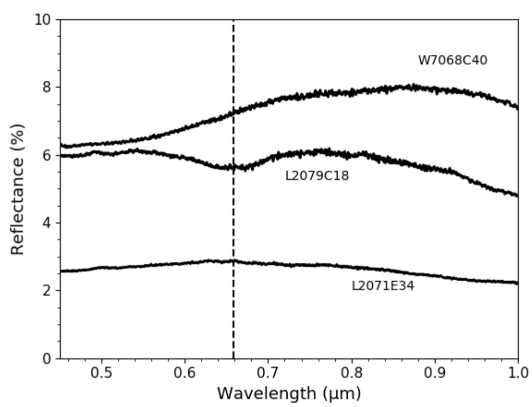

Figure 3 : Reflectance spectra obtained on three IDPs (L2079 C18, W7068 C40 and L2071 E34). The dotted line points out the feature around 0.66 µm for L2079 C18.

The reflectance levels of the analyzed IDPs are in good agreement with i/ those reported by Bradley et al. [5] and ii/ those reported by DeMeo et al. [9] for asteroids classes that have no meteoritic analogues. Note that with our previous set-up we observed a drastic fall of the reflectance beyond 0.8 µm which was due to the objective of the microscope (chromatic aberration) [7]. Fig. 3 shows that we have no longer this problem with our new setup. The IDP L2079 C18 spectrum exhibits an absorption band around 0.66 µm which could be attributed to phyllosilicate such as serpentine (which is commonly found in CS-IDPs) that have a feature between 0.6 and 0.7 µm. The IDP L2071 E34 has a reflectance level ~3% that could reveal a richness in carbonaceous material and/or the presence of magnetite induced by the atmospheric entry. The presence of magnetite produces a reflectance decrease and a drop-off of the slope [5]. The IDP W7068 C40 spectrum has a red slope and a reflectance level ~ 6% that could indicate a pristine IDP with no magnetite on its surface. The absence of the band between 0,6 and 0,7 µm in the two other IDPs could indicate that they are anhydrous and therefore belong to the class of CP-IDPs. These preliminary conclusions will be verified thanks to mid-IR and Raman measurements and comparisons with small bodies spectra will also be conducted.

Conclusion/future work: We show that it is possible to obtain reflectance spectra of micrometric isolated grains using one-sided illumination. We will in a forthcoming work apply this analytical technique to 17 other IDPs (available in our laboratory). We aim to complete our study with mid-IR and Raman measurements. The combination of the obtained results would help us to propose a classification and identification of the IDPs according to their Vis-NIR spectra (reflectance levels, shape of spectra, features). This could be performed with the IDPs still in their holders as sent by NASA. In a long term, our device will allow us to analyze grains returned by the Hayabusa2 and OSIRIS-REx missions for a direct comparison between the macroscopic reflectance spectra of the asteroids obtained by remote sensing measurements to laboratory spectra of micrometric grains collected from their surfaces.

Acknowledgments: We are grateful to the CAPTEM NASA for providing the IDPs. This work has been supported by the French spatial agency CNES, the PNP and the P2IO LabEx (ANR-10-LABX-0038) in the framework Investissements d'Avenir (ANR-11-IDEX-0003-01). We thank O. Mivumbi for help and support, A. Aléon-Toppani, D. Baklouti, C. Lantz, R. Urso and P. Vernazza for useful discussions.

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