VISIBLE-INFRARED SPECTROSCOPY OF UNGROUPED AND RARE METEORITES BRINGS FURTHER CONSTRAINTS ON METEORITE-ASTEROID CONNECTIONS.

L. Krämer Ruggiu[1], P. Beck[2], J. Gattacceca[1], J. Eschrig[2]
[1]Aix Marseille Univ, CNRS, IRD, INRAE, CEREGE, Aix-en-Provence, France (kramer@cerege.fr)
[2]Univ. Grenoble Alpes, CNRS, IPAG, Grenoble, France

Introduction: The composition of asteroids gives crucial insights into the formation and evolution of the Solar System. The composition of small bodies is mainly known from the analysis of the sunlight reflected from their surfaces. Spectral surveys have measured the reflectance of asteroids in the visible range of wavelengths (~0.4–1.1 µm) [1-4] and spectra up to 2.5 µm are available for several hundreds of objects. Using those spectra, asteroids have been grouped into different asteroids classes [5]. Although spectral surveys and spacecraft missions provide information on small bodies, many important analyses can only be performed in terrestrial laboratories. Meteorites represent our main source of samples of extraterrestrial material. Determining the source asteroids of these meteorites is crucial to interpret their analyses in the broader context of the inner Solar System. For now, the total number of parent bodies represented in our meteorites collection is estimated to about 150 parent bodies [6], of which 50 parent bodies are represented by the poorly studied ungrouped chondrites [7]. Linking ungrouped meteorites to their parent bodies is thus crucial to significantly increase our knowledge of asteroids.

Methodology: To this end, the petrography of 25 ungrouped chondrites and rare meteorite groups was studied. We then acquired visible-near-infrared (VIS-NIR) reflectance spectroscopy data of those 25 meteorites, using SHADOWS instrument [8], in a range from 0.3 µm to 2.6 µm, with a step of 20 nm order to compare them to ground-based telescopic observations of asteroids. The reflectance spectra of meteorites were obtained on powdered samples, as usually done for such studies, but also on raw samples and polished sections. With asteroids surfaces being more complex than fine-grained regolith (e.g., asteroid (101955) Bennu), in particular near-Earth asteroids, the use of raw samples is a necessary addition for investigating parent bodies.

Petrography: In order to introduce some logic in the population of studied meteorites, we grouped them into six meaningful petrographic groups, labelled A to F. The petrographic group A comprises ungrouped carbonaceous chondrites with CM-like petrography, type 3.00, without aqueous alteration nor metamorphism traces. The petrographic group B is composed of CM-like meteorites, with the addition of significant traces of aqueous alteration. The petrographic group C comprises ungrouped chondrites that show traces of aqueous alteration, with the addition of small thermal metamorphism traces. The petrographic group D is formed by the relatively rare Rumuruti chondrites group. The petrographic group E gathers significantly metamorphosed ungrouped chondrites. Finally, petrographic group F gathers highly metamorphosed meteorites. Spectral groups were made based on spectral similarities, in order to simplify the comparison to asteroid spectra and interpretations.

Spectroscopy: The main part of the petrographic group mirrors the spectral grouping, except for four meteorites, showing that spectra features reflect mineral abundances and compositions. In order to better match real asteroid surfaces that can be dusty and/or rocky, we measured raw samples in addition to powdered samples. The two types of samples have different spectral characteristics. Raw samples show bluer VIS-NIR slopes than powders, especially for carbonaceous chondrites. We also compare the powders' spectra to polished section spectra, as polished sections are widely available for study. We show that polished section spectra can be good equivalent to raw sample spectra, with similar spectral parameters and similar matches to asteroids.

The meteorite spectra were then compared with reference end-member spectra of asteroids taxonomy. We matched the 25 studied meteorites to asteroid types, using a qualitative match of the shape of the spectra, as well as a quantitative comparison of spectral parameters (bands positions, bands depths and slopes at 1 and 2 µm). We define links between some of the studied ungrouped chondrites and asteroid types that had no meteorite connection proposed before, such as some very primitive type 3.00 ungrouped chondrites to B-type or Cg-type asteroids. We also matched metamorphosed ungrouped carbonaceous chondrites to S-complex asteroids, suggesting that this complex is not only composed of ordinary chondrites or primitive achondrites, as previously established, but may also host carbonaceous chondrites. Conversely, some ungrouped chondrites could not be matched to any known asteroid type, showing that those are potential samples from yet unidentified asteroid types.

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