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Space weathering and the spectral slopes of CM chondrites

Z. Kaňuchová (1), C. Lantz (2), M. A. Barucci (2), R. Brunetto (3), and G. Strazzulla (4)
(1) Astronomical Institute of Slovak Academy of Sciences, SK-059 60 Tatranská Lomnica, Slovakia, (zkanuch@ta3.sk)
(2) LESIA - Observatoire de Paris, CNRS, UPMC Univ. Paris 6, Univ. Paris-Diderot, Meudon, France
(3) Institut d'Astrophysique Spatiale, CNRS, UMR-8617, Université Paris-Sud, bâtiment 121, F-91405, Orsay Cedex, France
(4) INAF-Osservatorio Astrofisico di Catania, Via S. Sofia 78, I-95123 Catania

Abstract

The findings of irradiation experiments of different organic materials obtained in recent years are applied in a model of expected spectral slopes of weathered carbonaceous chondrites – CM class. Results are compared with the spectral slopes of CM (altered and unaltered) and carbonaceous asteroids.

1. Introduction

Association of carbonaceous chondrites (CC) with the different classes of dark asteroids is not completely proven. If CC mostly originate from sub superficial (unweathered) layers of asteroids, as it is supposed [5], differences between spectral characteristic and albedo of meteorites and asteroids are expected due to the effects of space weathering. This work is based on the recent work of Lantz et al., 2013 [5], with the use of the same meteorite samples and asteroidal spectra. We apply the finding of the experiments obtained in recent years and try to give a contribution to answer the following question: are the spectral characteristics of carbonaceous asteroids compatible with the (cosmic ion induced) space weathering of CM carbonaceous chondrites?

2. Observational and experimental data

The spectra of different CM2 carbonaceous chondrites were taken from RELAB database. There are 70 spectra of unaltered meteorites and 36 of thermally heated or laser irradiated samples. The spectra of carbonaceous (low-albedo) asteroids come from SMASS. The spectral slopes in two spectral regions 0.44-0.7 μm (S1) and 1.10-1.45 μm (S2) were calculated in units μm^{-1} (Fig. 1) [5].

We have measured the spectral slopes S1 and S2 of several samples irradiated with different ions in recent years at the Experimental Astrophysics Laboratory in Catania (asphaltite A3, olivine pellets with deposited layer of polystyrene OP1, OP2; for details on experiments see Table 1 and [6] and [3]).

3. Model

Carbonaceous chondrites are generally characterized by the presence of finely-dispersed carbonaceous materials that impart an overall dark appearance [6], [8]. Organic material in CMs is intimately associated with the phyllosilicate-rich matrix [9], [1]. In our model, we are considering different organic materials as templates of the C-bearing matter present in CMs.

We consider the meteorite spectrum as composed of two components: a silicate material which is organic poor (sil.) and an organic component (org.). We assume that the small amount of carbonaceous material in the silicate component (e.g. 5% as is typical for the CC) might be in a form which cannot be further altered by space weathering. On the other hand the organic component is “weatherable”. It is well known, that ion irradiation induces spectral reddening in VIS-NIR of silicates (blueing is observed in NUV, [2]). Spectral changes of silicates induced by ion irradiation are smaller comparing the changes of organic material [4]. That's why we suppose that changes in S1 and S2 (especially blueing in VIS-NIR spectral range) of CM chondrites could be caused mainly by the presence of "wheaterable" organic material, which becomes "blue" when irradiated. The contribution of pure irradiated silicates is neglected in our model.

We suggest that measured/observed spectrum is a linear combination of the two components. The resulting reflectance R is simply

$$\boldsymbol{R = X.R_s + Y.R_o} \qquad (1)$$

where R_s is reflectance spectra of silicate and R_o reflectance spectra of organic component. X is the fraction of silicate material, Y the fraction of organic material (X+Y=1).

As organic component we use spectra of different virgin and ion irradiated samples (Table 1); as silicate component the spectrum of a meteorite sample (S1=0.167, S2=-0.042, R_s (0.55 μm) =4.1%). The spectral slopes of the linear combination of two components using X=0.9 and Y=0.1 in Eq. 1 are in Fig. 1. Zero indicates the S1, S2 values of the silicate component; numbers 2 to 6 indicate the organic sample used in the model (see Table 1).

Table 1: The list of organic samples.

Sample	Ion fluence	No.
OP1	0	1
OP1	$6.9x10^{15}$ 200 keV H^+	2
OP2	$4.3x10^{15}$ 400 keV Ar^{++}	3
A3	0	4
A3	$0.5x10^{15}$ 60 keV Ar^{++}	5
A3	$1.5x10^{15}$ 60 keV Ar^{++}	6

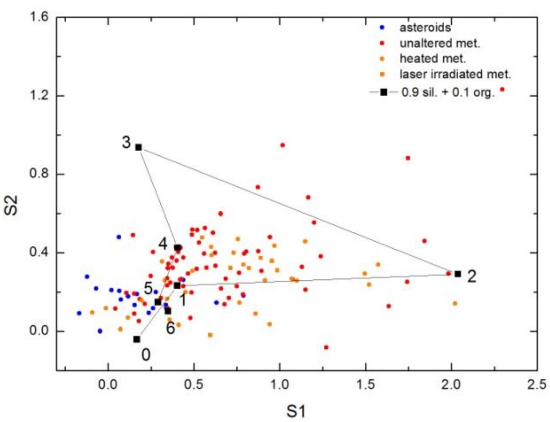

Figure 1: Comparison of the spectral slopes of asteroids, CM meteorites, and laboratory altered CM meteorites with the results of the model.

4. Discussion

According to systematic study of several spectral characteristics of Ch/Cgh asteroids, unaltered and altered CM chondrites by Lantz et al. (2013) the values of spectral slope in the range 0.44-0.7μm for the asteroids are significantly smaller compared with those of meteorites, but there are not significant differences between pristine and altered meteorites. Using different fractions of organic material with respect to silicate material in our model it is possible to cover the whole range of CM spectral slopes both unaltered and altered.

The results indicate that a fully weathered sample occupies the place, in the S1-S2 graphs, that is in fact occupied by C-asteroids that are, in fact, fully weathered. We assume that a meteoritic sample could be altered by ion irradiation only if it contains a not too low fraction of (soluble) organic material. Ion irradiation experiments of meteorite samples are necessary to check this hypothesis.

Acknowledgements

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