A laboratory study of the eucritic meteorite Acfer 353 and the regolith of Vesta

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1. Introduction

Pyroxenes are important components of the regolith of terrestrial planets as well as of the minor bodies of the solar system. In a recent work [1] we analyzed the spectral characteristics in the Vis/NIR of two pyroxenes, enstatite - the prototype of the Low Calcium Pyroxenes (LCPs) - and diopside - a typical High Calcium Pyroxenes (HCPs) - and their spectral behaviour varying the grain sizes of the samples. In particular we focused our attention on the minor absorption band (reflectance minimum) near 670 nm, whose exact position varies from sample to samples (depending on size, composition, etc.) and which is generally characterized by its emission wings (reflectance maxima) approximately at 560 nm and 700 nm. We found a good correlation between the grain size of our samples and the relative intensities of the two reflectance maxima. Such correlation, very similar to that already found for olivine [2] can potentially be used to derive the average size of the regolith on the surface of various bodies of the solar system.

As an application of the above results to a case study of planetological interest, we have analyzed powdered samples of an Howardite-Eucrite-Diogenite (HED) meteorite (Acfer 353, [3]) of putative Vestian origin and containing a high percentage of pyroxenes. Also in this case we have found a clear dependence of the Vis spectral trend on the grain size. A comparison between the laboratory spectra of Acfer 353 and those obtained by the Dawn spacecraft for the Vestian surface, shows that the observed spectral trend is quite close to that exhibited by the finest (size less than 50 μm) laboratory grains sample, giving information on the mean size of the Vestian regolith.

Even if a variety of effects (e.g. space weathering, mineral mixtures, surface roughness) can influence the reflectance spectra of asteroidal and planetary surfaces, we think that our results, although preliminary and qualitative, demonstrate that both laboratory and observational study of the minor features, frequently ignored in the literature, can give complementary and useful information for the interpretation of the spectra acquired in remote sensing conditions.

2. The case of Acfer 353 meteorite and application to Vesta

The study of the spectral behaviour of pyroxenes with a different composition can be useful for the understanding and the interpretation of the reflectance spectra of HED meteorites and, as a consequence, of Vesta which is the most probable HEDs parent body [4,5].

Here, as a representative example, we consider the case of an eucritic meteorite containing a large fraction of pyroxenes. Our sample is composed by fragments of the meteorite called Acfer 353, classified as a cumulate eucrite [3] and found in Algerian Sahara in 2001. The delta values of the two oxygen isotopes δ^{17}O and δ^{18}O (1.52 and 3.34 respectively, see Table 6 of Russel *et al.* [3]) and the relative Δ^{17}O (-0.252) [6] allow to ascribe this meteorite to the same subgroup of HED meteorites with similar Δ^{17}O values already studied by McSween *et al.* [4]. These meteorites probably have a common parent body which has experienced large scale or complete melting and differentiation, like Vesta. The mineralogy of Acfer 353 is characterized by the presence of a plagiocase component together with two different pyroxene components with ferrosilite indices of Fs_{60-62} (ortopyroxene) and Fs_{27-30} (clinopyroxene), respectively [3].

The largest fragment of our meteoritic sample (approximately 100 g) has been processed with the same procedure used for the enstatite and diopside minerals and the powdered samples have been divided into the same six granulometric classes [1]. SEM investigations have shown that the grains morphologies are virtually the same as in the cases of enstatite and diopside suggesting similar granulometric distributions. At the same time, an inspection of the grain fraction with a size greater than 425 μm, has shown the presence of three different kind of grains: some whitish (grain A in the inset of Figure 1), a few reddish (grain B), and others light grey (grain C).

The EDX spectra, shown in Figure 1, indicate that the three kinds of grains are representative of three distinct components of the studied meteorite. The presence of Na and the relative low intensity of the Fe signals in the EDX spectrum

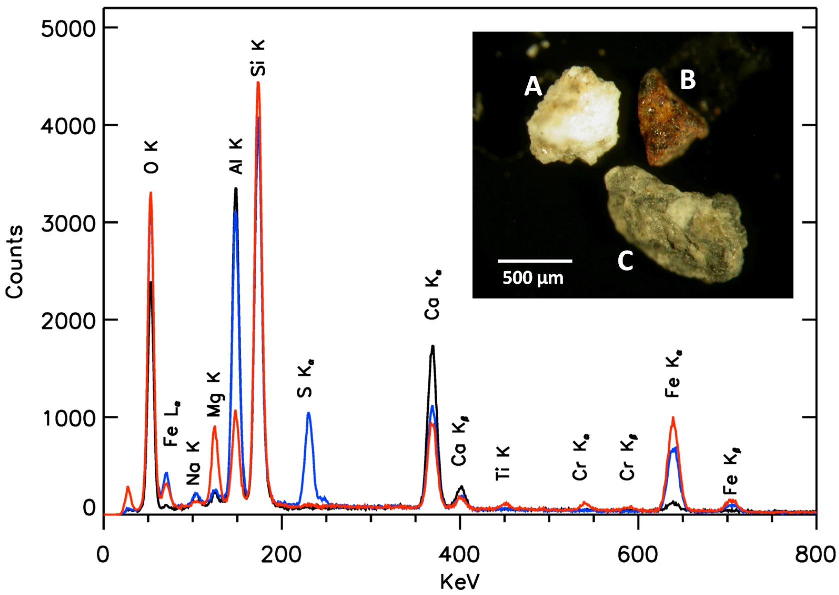

Figure 1. EDX spectra of the three distinct types of grains (from Acfer 353) shown in the inset image. The black curve refers to particle A; the blue and red ones refer to particle B and C, respectively. The inset image is a photo, at 10X of magnification, taken with a Nikon Coolpix 4500 camera assembled on a microscope Nikon SMZ 1500.

of grain A (black curve in Figure 1) allows to associate this type of grains with the plagioclase component, whereas the low intensity of Na and the relative intensities of Fe, Ca and Mg signals in grain C is consistent with a LCP component (red curve). For the reddish grain B, the EDX spectrum (blue curve) shows the presence of S suggesting the existence of some inclusions of Troilite (FeS).

The reflectance spectra of the six granulometric meteoritic samples are shown in the top panel of Figure 2 for the whole spectral range and, in an expanded view (350 ÷ 850 nm), in the bottom panel.

The presence of plagioclase is indicated only by the shoulder around 1300 nm, while the spectra are dominated by two absorption bands located at about 950 nm (Band I) and 1970 nm (Band II) due to the LCP component. The bands are similar to those shown by our enstatite sample [1], although they are located at slightly longer wavelengths, probably due to the higher level of ferrosilite in the pyroxene component of the meteorite. Different slopes of the continuum can also be noticed.

A comparison between the band positions of the two main absorptions (Band I and Band II) of Acfer 353 and those of other HEDs, extracted from the RELAB database (see Pieters [7] and RELAB User's manual, http://www.planetary.brown.edu/relab/), seems to suggest a basaltic eucrite composition in disagreement with the current classification among cumulate eucrites [3]. Some minor features lo-

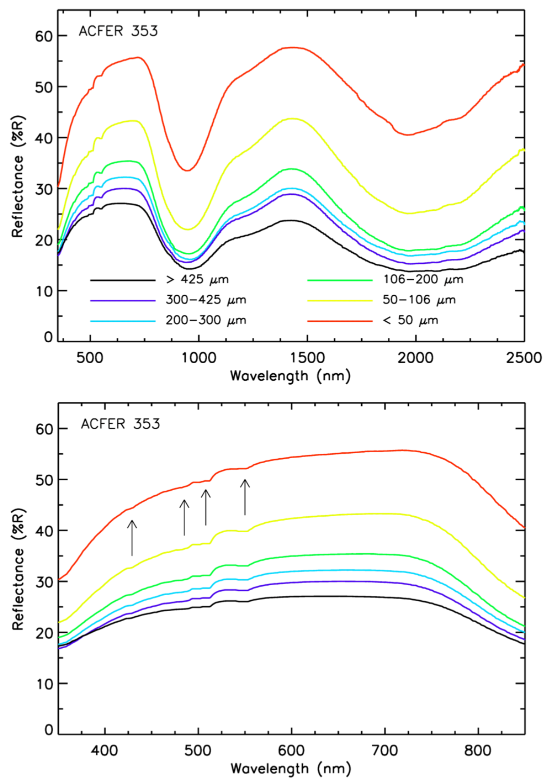

Figure 2. Reflectance spectra of the six granulometric samples of Acfer 353 in the range 350 ÷ 2500 nm (upper panel) and 350 ÷ 850 nm (lower panel). Arrows indicate the position of some minor bands.

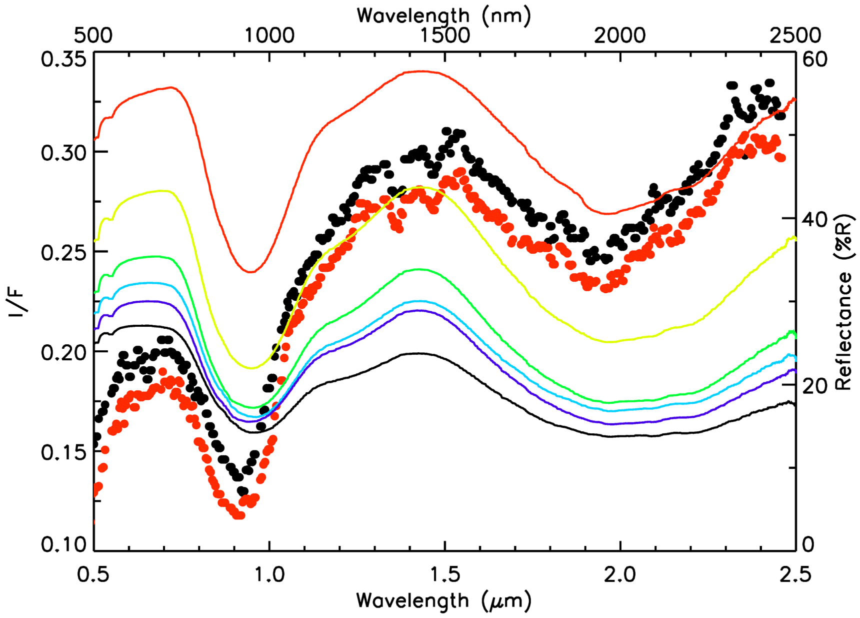

Figure 3. VIR/Dawn spectra of the southern region A (black dots) and of the equatorial region B (red dots) of the asteroid Vesta [2], superimposed to our laboratory reflectance spectra of Acfer 353 samples (the color code is the same as in Figure 2).

cated at 425 nm, 480 nm, 508 nm and 550 nm, probably due to crystal field electronic transitions of Fe^{2+}, can also be seen in the spectra (bottom panel of Figure 2).

As in the case of enstatite, the spectral contrast increases as the grain size becomes smaller while, considering the whole wavelength range, the spectra become generally bluer as the grain size increases. On the other hand, as in the case of enstatite and diopside, it is evident a clear dependence on the grain size of the spectral slope in the 600 ÷ 700 nm range.

The above mentioned result can be applied to the case of the asteroid Vesta. This body has been recently reached by the Dawn spacecraft which mapped a large part of the asteroidal surface by means of the VIR spectrometer [8]. In Figure 3, we compare the spectra of two Vestian regions (A, southern, and B, equatorial, as described by DeSanctis *et al.* [9]) with those measured for the Acfer 353 samples. It is worthwhile to stress that such comparison, quite general and qualitative, is made merely with the purpose of pointing out the potential of studying the minor bands (the 670 nm feature, in this case) in order to obtain more useful information on the planetary and asteroidal regolith.

The general shape of the spectra of the two Vestian regions is similar to that shown by our Acfer 353 samples, as expected on the basis of previous results [5,8,9]. Focusing our attention to the 600 ÷ 700 nm range, we note that the spectral trend of the Dawn data is close to that shown by the finest (mean size less than 50 μm) grains sample; this could suggest that the surface of the studied regions of Vesta should be fine grained, as already suggested by Hiroi *et al.* [10,11]. However, it is necessary to note that space weathering can affect the whole Vis/NIR wavelength range (350 ÷ 2500 nm), by reddening the spectra, increasing the band spectral contrast and changing the underlying continuum [12,13]. This means that our conclusions, as already mentioned, should be considered only tentative and very qualitative.

Work is now in progress both in analyzing other HED meteorites, which could be more appropriate to mimic the reflectance of Vesta surface, and to investigate weathering effects by means of laser pulses on meteoritic grains.

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