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Irradiation experiments on HED meteorites: simulating the space weathering of Vesta and V-types

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Abstract

Several tens of main belt asteroids (V-types) have been found to exhibit basaltic surface composition, similar to the one of Vesta and basaltic Howardite, Eucrite, and Diogenite achondrite meteorites (HEDs). Several questions on the relationship between Vesta, V-types, and HEDs are still unresolved. In particular, Vesta is spectroscopically bluer than most V-types. To date, it has not yet been understood whether these spectral differences are due to space weathering. To test this hypothesis, ion irradiation experiments were performed on different samples of eucrites.

1. Introduction

Many V-type asteroids belong to Vesta's dynamical family ("Vestoids") and are believed to derive from the collisional event responsible for the large crater (460 km wide) near the south pole of this asteroid [1]. The reflectance spectra of Vesta also show spectral features (and brightness) common to those of the HED meteorites. This unique agreement is considered to be the main proof of the relationship between Vesta and these meteorites. The similarity between Vesta and the HEDs' reflectance spectra also suggests that Vesta's surface is free of heavy space weathering, see for instance [2] and references therein. Here we describe new laboratory data on Ar^+ and C^+ ion irradiation on HEDs as a simulation of space weathering of Vesta and V-type asteroids and demonstrate that the slope spread shown by V-type asteroids can be explained by space weathering.

2. Experimental apparatus

Experiments were performed at the Laboratorio di Astrofisica sperimentale (LASP) of INAF - Osservatorio Astrofisico di Catania (Italy). The experimental setup was composed of a stainless steel high-vacuum chamber operating at a base pressure $P < 10^{-7}$ mbar interfaced to an ion implanter. The experiments were performed at room temperature. In this work we collected "ex-situ" hemispherical reflectance spectra in the spectral range 0.4–2.5 μm (resolution 2 nm) of unirradiated and irradiated samples using a VIS-NIR spectrometer equipped with an integrating sphere in $BaSO_4$. Further details of the experimental apparatus can be found in [3].

Pellets of the eucrite meteorites Bereba and Dar Al Gani 684 (hereafter referred to as DaG) were obtained, simulating asteroidal regolith, by pressing the original meteorite powder. From the VIS-NIR spectra normalized at 0.55 μm, we measured the spectral slope (μm^{-1}) of the linear continuum across the 1 μm absorption band (from 0.8 μm to 1.5 μm). This band is, as usual, hereafter referred to as BI.

3. Results

Fig. 1 shows the reflectance spectra of one pellet of Bereba as prepared and after two irradiation steps with different ions.

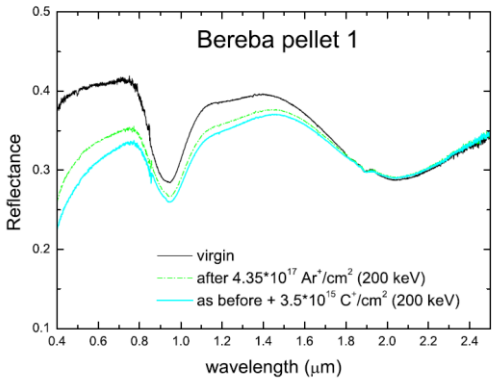

Figure 1: VIS-NIR reflectance spectra of Bereba pellet 1, before and after multiple irradiations.

Fig. 2 shows the reflectance spectra of one pellet of DaG, normalized at 0.55 μm, before and after multiple ion irradiation steps. The typical effects of ion irradiation on iron-bearing silicates are seen for all of the considered samples: spectral darkening, reddening, and subdued absorption bands with progressive irradiation [2-5]. The effects of different ions on DaG and Bereba are made clear in Fig. 3, where BI slopes scaled to the corresponding initial value (i.e., slope of the irradiated spectrum – slope of the virgin spectrum) are shown for all of the pellets irradiated [6]. We can see that the spectral alterations induced by C^+ ions are faster and more effective than in the case of Ar^+.

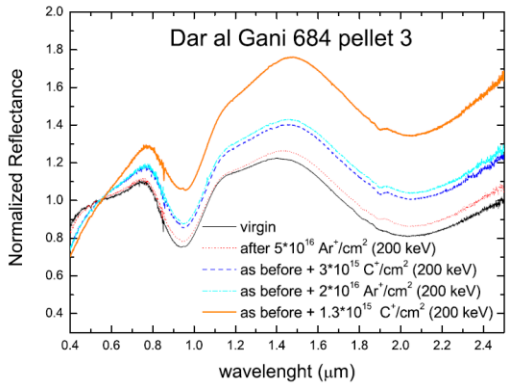

Figure 2: VIS-NIR reflectance spectra Dar Al Gani 684 pellet 3 (normalized reflectance), before and after multiple irradiations.

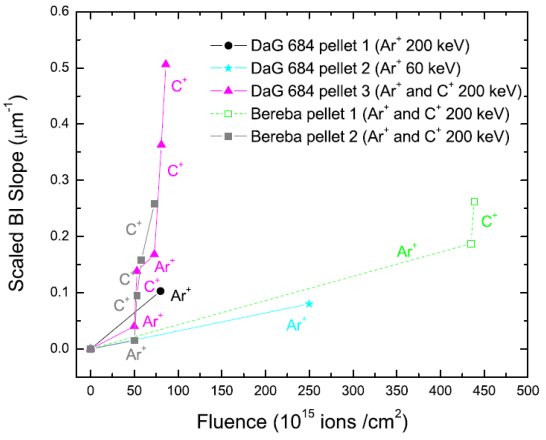

Figure 3: BI slope as a function of irradiation fluences and ions for different Bereba and DaG pellets.

4. Discussion

We estimate that, at Vesta's heliocentric distance, laboratory fluence of 10^{15} 200 keV Ar ions cm^{-2} corresponds to an astrophysical timescale of about 7×10^3 yrs for the solar wind ions to induce the same spectral effects observed in laboratory. Similarly, laboratory fluence of 10^{15} C ions cm^{-2} corresponds to about 1.4×10^4 yrs. To better understand the connection between Vesta, V-types, and HEDs, we will compare DaG and Bereba spectra, before and after Ar^+ and C^+ irradiation, with those of Vesta and V-type asteroids and show that the slope spread observed for V-type asteroids can be explained by space weathering [6].

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