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Linear spectral unmixing: a tool to quantitatively map different lithologies on Vesta

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Abstract

Spectra provided by the Visible and InfraRed spectrometer (VIR) on board the Dawn spacecraft allow for mapping the principal lithologies of Vesta. We applied linear spectral unmixing on VIR spectra to determine the abundances of the different lithologies present on the surface of the protoplanet.

1. Introduction

VIR mapped most of Vesta's surface at varying spatial resolution [1]. Data were acquired in two channels covering the visible (0.25 μm to 1.07 μm) to the near-infrared (1.02 μm to 5.10 μm) [2]. Vesta's spectra are characterized by two crystal field absorption bands at $\sim$0.9 and 1.9 μm, consistent with those found in the laboratory spectra of the howardite, eucrite and diogenite (HED) clan of meteorites [3, 4]. Often Vesta's spectra have a reduction of the bands and/or a variation of the band shape, indicating the presence of other mineralogical phases mixed with pyroxenes [5, 6]. The application of linear spectral unmixing on VIR data reveals that different components can be mapped (eucrite, diogenite, olivine, chondrite) with variable abundances across the surface.

2. Dataset analysis

We apply linear spectral unmixing on VIR spectra of localized regions. We selected pixels of some characteristic areas and we calculated the mean spectrum. For mineralogical mapping, we focus on the spectral interval between 0.6 and 2.5 μm, where the most prominent pyroxene bands are present. We consider three different type of regions: Aelia crater ejecta (lon 145.5°, lat -14.4°) which contain bright and dark material [7], Arruntia crater (lon 72.4°, lat 39°), an olivine-bearing area [6], and Licinia crater (lon 17.7°, lat 23.2°), which is diogenitic [8]. The locations of the regions considered are given in the Dawn team's preferred coordinate system for Vesta, known as the "Dawn-Claudia" system [9, 10, 11].

3. Description of the method

[12] carried out linear unmixing on telescopic spectra of Vesta. Here we apply this method to the VIR spectra of the regions described above. We consider that the measured spectrum is a linear combination of three endmembers. From the Reflectance Experiment Laboratory (RELAB) database (http://www.planetary.brown.edu/relab/), we chose a set of spectra of 9 possible analogues that are representative of Vesta composition: four eucrites (E), two diogenites (D), two olivines (Ol) and one carbonaceous chondrite (C). We performed unmixing of all the possible combinations of three endmembers chosen among the selected sample, allowing a precision of 1%. We retain the combination providing the minimum χ^2 value. Since we are interested in the mineralogy, in order to make the laboratory spectra comparable with those acquired by VIR, we remove the spectral slope before applying spectral unmixing [13].

4. Summary and feature works

Linear spectral unmixing applied on VIR data reveals the mineralogical variety present on Vesta. We studied three example of regions that represent the principal mineralogical types on Vesta. Both dark and bright materials are present in Aelia ejecta. This appears to be a eucritic region with a 17% carbonaceous chondrite component that reduces the strength of the two pyroxene bands (Fig. 1A). Linear unmixing applied to the Licinia region, classified as diogenitic [8], reveals a diogenite abundance of about 70% (Fig. 1B), while the Arruntia region is composed by howardite with $\sim$ 49% olivine (Fig. 1C). Our findings are in agreement with the qualitative interpretation made by

[14, 15] considering band shape, band depth and band area ratio, and they give more information related to understand the relative spectroscopic contribution of other components. In the future, the method can be applied to larger regions to extrapolate the contribution of different lithologies present on several areas of Vesta.

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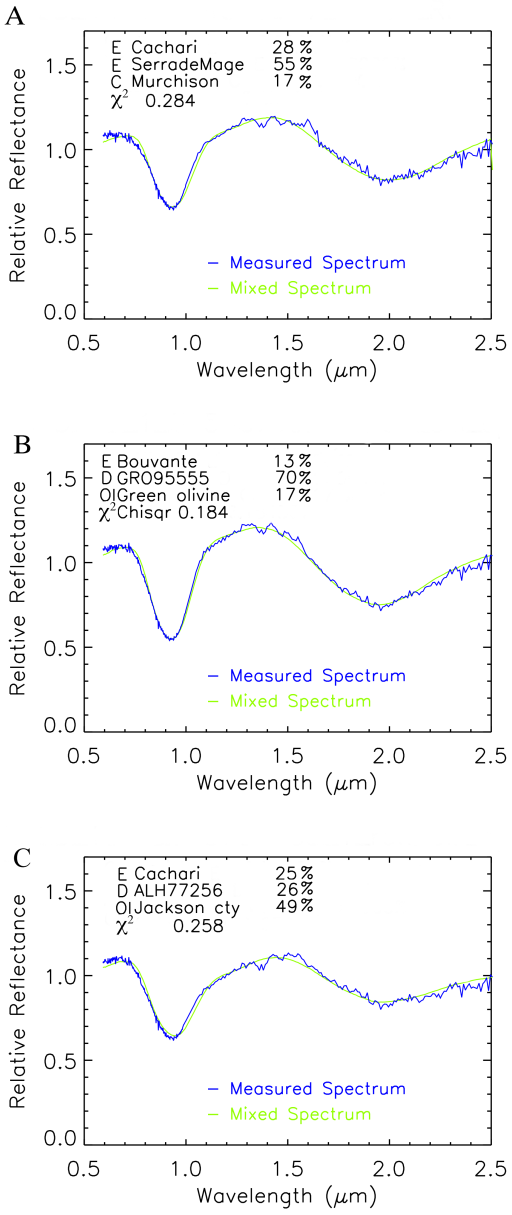

Figure 1: **A.** The plot shows the mean VIR spectrum of Aelia ejecta and the spectrum obtained by linear unmixing (here called 'Mixed'). Linear unmixing reveals the presence of 18% of chondrite, indicating a relative high amount of dark material. **B.** Linear unmixing applied to the Licinia region indicates an abundance of diogenite of 70% in agreement with the interpretation of the composition from [8]. **C.** Arruntia is supposed to be characterized by olivine [6]. Linear unmixing best fit for this region reveal an amount of olivine of 49%.