

UV-VIS-NIR Reflectance Spectroscopy of Vesta Analogs: the case of Millbillillie. E. Ammannito^{1,2}, A. Coradini¹, M.C. De Sanctis³, D. Garoli^{4,5}, G. Naletto^{5,4}, M.G. Pelizzo^{4,5} and C.T. Russell⁶. ¹INAF-IFSI Via Fosso del Cavaliere, 100, 00133, Roma, Italy, eleonora.ammannito@iasf-roma.inaf.it, ²CISAS, University of Padova, Via Venezia, 15, 53131, Padova, Italy. ³INAF-IASF Via Fosso del Cavaliere, 100, 00133, Roma, Italy, ⁴CNR-INFM LUXOR, Via Gradenigo 6B, 35131 Padova, Italy, ⁵DEI, University of Padova, Gradenigo 6B, 35131 Padova, Italy, ⁶Institute of Geophysics and Planetary Physics, University of California, 603 Charles Young Drive East, 3845 Slichter Hall, Los Angeles, CA 90095-1567, USA.

Introduction: We discuss here the main experimental results obtained with VIS-NIR reflectance spectroscopy techniques applied to a slice extracted from the Millbillillie meteorite. This activity was done to support the scientific interpretation of the hyperspectral data produced by VIR-MS, the imaging spectrometer aboard the Dawn mission to minor planets 1 Ceres and 4 Vesta. Using suitable laboratory equipments, we can study terrestrial rocks and meteorites, considered analogs of the Vesta surface, in order to extract information from reflectance spectra that will be acquired during the mission.

Millbillillie is a meteorite which fell in Australia in October 1960. It was classified as an ordinary basaltic eucrite [1] even if it is texturally quite variable [2], [3]. This meteorite was observed by several authors, describing the physical properties such as the magnetic properties and the dating [4], [3], [5]. Despite the observed textures variation, it is considered one of the most equilibrated eucrites from a mineralogical point of view [3]. In the past spectra of this meteorite were acquired both in the visual and near infrared range ([6], [7]) in order to find a clear correlation between this eucrite and the supposed parent body Vesta. Moreover in the relab spectral library there are spectra of several grain size powders and a slice of Millbillillie [8].

Here we intend to extend the measured spectral range in the UV wavelengths of this meteorite and to confirm previous analysis.

Measurements. Measurements have been performed at the LUXOR laboratory in Padova using a Varian Cary 5000 UV/VIS/NIR Spectrophotometer. The spectra have been acquired in the 190-2500 nm range with a spectral sampling of 1 nm. Both specular at 30° and diffuse reflectance, by the use of an integrating sphere, have been measured. The sample was at ambient temperature and the ambient atmosphere was dry air. In figures 1 and 2 the specular reflectance spectra are plotted. Reflectance data have been normalized to an acquired Al+MGF₂ mirror reflectivity. In the figures different colours are representative of different portions of the meteorite slice.

Analysis: Looking at the spectra in figure 1, we can state that the spectra from the three selected areas show

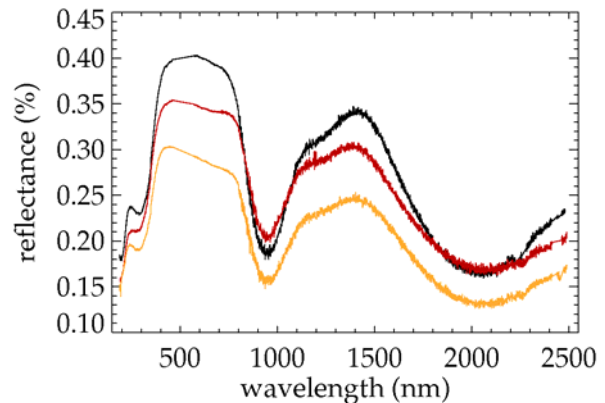


Figure 1. Spectra of a slice of the Millbillillie meteorite (full range). Different colors represent respectively: blue, matrix; red, fine grained area; orange: coarse grained area.

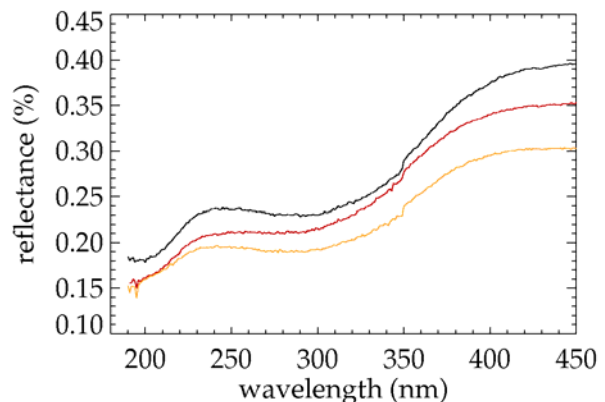


Figure 2. Spectra of a slice of the Millbillillie meteorite (zoom 190-500nm). Colors represent respectively: blue, matrix; red, fine grained area; orange: coarse grained area.

several differences both in the continuum level and in the band strengths while the band positions seem to experience only minor changes.

Spectra analysis. The spectrum is dominated by two deep absorption bands at 1 and 2 μm that are typical of pyroxenes (crystal field transitions of Fe^{2+} in M2 sites) and the weaker absorption around 1.2 μm typical of plagioclase (crystal field transitions of Fe^{2+}) or pyroxene (crystal field transitions of Fe^{2+} in M1 sites [9]). In the visible part of the spectrum, there are several absorptions possibly due to spin-forbidden crystal field transitions of Fe^{2+} in both M1 (480,550)

and M2 (430, 508) sites; alternatively, such minima could be attributed to Fe^{3+} that, in any case, is responsible for the 300nm absorption. To notice the presence of an absorption feature at 195nm, attributed to bonding-antibonding transitions, present in the spectra of the two spots but completely missing in the matrix spectrum. The position of the absorption at 508nm is not the same for the three spectra: in fact it is shifted at 509nm for the spectra acquired in correspondence of the two spots, as well known ([10], [11]), meaning that the spots have more iron content than the matrix. Another indication of the increasing of iron content in the selected spots is the absence of the 195nm minima in the matrix (see figure 2); in fact the bonding-antibonding transitions are known to occur at longer wavelength as the Fe^{2+} content increases [12]. This means that for the matrix it occurs at wavelengths out of the spectral range of the spectrometer we are using (too short), while we are able to detect the absorption in the grained areas.

MGM analysis. To get further investigation and to better compare the spectra, we applied a custom version of the MGM ([13], [14]) in order to get the band parameters. In the spectra used as input for the MGM we have excluded the wavelengths from 450 up to 570 nm because further investigations are needed to get a reasonable model for this part of the spectrum; on the contrary, in the present work, we are mostly interested in studying the behavior of the two major bands of the pyroxene 1 and 2 μm . We tried several mixtures in order to see if there are changes in the composition of the portions of the surface that we have analyzed. The mixtures we tried are: A. opx+cpx+plagio, B. opx+plagio and C. cpx+plagio. Analyzing the results of the fit we found that the mineral composition that better represents the measured spectra requires in every case both ortho and clino pyroxenes (case A); thus, we can conclude that the sample has an homogeneous composition. In figure 3 is plotted the result obtained applying the MGM to the spectra of a coarse grained spot.

With respect to the iron content estimated from the MGM parameters, applying previous calibrations ([10], [11],[15]), we can state that the matrix has roughly 50% of total iron content while the grained areas have 80%-90%.

We used the parameters calculated with the MGM to get the percentage of clinopyroxenes in the sample. Waiting for further investigations, we used a simple relationship [13] in order to have at least an idea if the differences in the spectra are due to a different mixture ratio of the pyroxenes in the sample. For the matrix we found a percentage of clinopyroxenes from 50% up to 90% depending on the band we use to calculate the

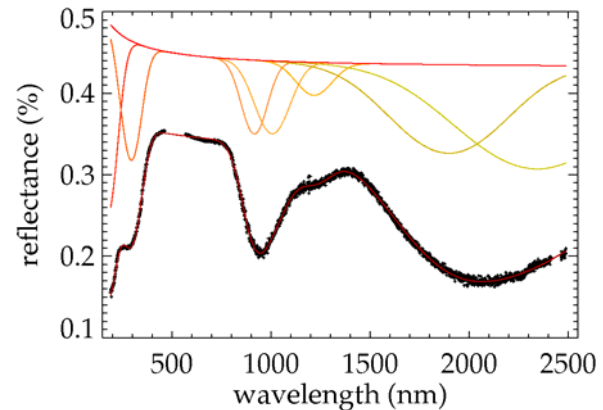


Figure 3. MGM fit applied to the spectra of a coarse grained spot. In black are plotted the experimental data, while the superimposed red line is the result of the fit. Stacked for clarity of 0.1 are plotted the continuum and the components of the modeled spectrum representing the absorption bands of the end-members.

value, so this parameter is not well constrained by our analysis. On the contrary for the fine grained spot and the coarse one we found values respectively of 70%-80% and 70%-75%. From this values we found that the mixture ratios are compatible for the two grained area we have up to now analyzed, while more precise calculations are needed to find a value for the matrix.

Conclusions: The result from MGM are compatible with the one of the visual inspection of the spectrum: in both cases we have concluded that the spots, both fine grained and coarse grained, have a high level of iron content (80-90%) while the matrix has only 50% of total iron content. Even if this work is just started, it confirms how powerful is the spectroscopic analysis for the identification of mineralogical evolution of airless bodies.

References: [1] Basaltic Volcanism Study Project (1981) Pergamon Press, New York, 1286. [2] Bobe et al. (1989) LPICo 712, 17. [3] Yamaguchi, A. et al. (1994) *Meteoritics*, 29, 237-245. [4] Collinson, D. W. and Morden, S. J. (1993) *LPS* 319-320. [5] Tanimizu, M. and Tanaka, T. (1999) *LPS*, Abstracts # 1181. [6] Schade, U. and Wasch, R. (1999), *Ad. Sp. R.*, 23, 1253-1256. [7] Miyamoto, M. Mikouchi, T. (2002) *LPS*, Abstracts # 1468. [8] www.planetary.brown.edu. [9] Sunshine J. M. et al. (1993) *Icarus*, 105, 79-91. [10] Cloutis, E.A. and Gaffey M.J. (1991) *JGR*, 96(E5): 22809-22826. [11] Adams, J.B. (1974) *JGR* 79(32): 4829-4836. [12] Wagner J.K. (1987) *Icarus*, 69, 14-28. [13] Sunshine J. M. (1990) *JGR*, 95, 6955-6966. [14] Sunshine J. M. and Pieters C. M. (1993) *JGR*, 98, 9075-9087. [15] Klima R. L. et al. (2006) *LPS XXXVII*, Abstract #1637.