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Deriving global Olivine distribution on Hayabusa's target (25143) Itokawa using Near-Infrared Spectrometer data

L. Nardi (1-2), E. Palomba (1), A. Longobardo (1), A. Galiano (1-3), F. Dirri (1)

(1) INAF-IAPS, Rome, Italy, (2) Università degli Studi di Roma La Sapienza, Rome, Italy, (3) Università degli Studi di Roma Tor Vergata, Rome, Italy

Abstract

In 2005 Hayabusa spacecraft visited asteroid Itokawa, bringing back surface samples to Earth in 2010. Near-Infrared spectra acquired by NIRS and samples analysis confirmed hypothesis made through ground-based observations, in particular the one that sees Itokawa as an LL-chondrite like asteroid processed by space weathering. In this work, we apply spectral indices for olivine detection on NIRS data. In particular, we define the BAR* and relate it to the olivine abundance, by means of calibration on laboratory data.

1. Introduction

Hayabusa was a JAXA spacecraft mission aimed at exploring the near-Earth asteroid (25143) Itokawa and bringing back surface samples. The spacecraft was equipped with four main scientific instruments:

1. Light Detection And Ranging instrument (LIDAR)
2. Asteroid Multi-band Imaging Camera (AMICA)
3. X-ray Fluorescence Spectrometer (XRS)
4. Near Infra-Red Spectrometer (NIRS)

Here we consider data from NIRS, which mapped the surface in the effective spectral range 850-2100 nm, where main olivine and pyroxene absorption features are partially visible. Between September and November 2005, NIRS took thousands of near-infrared spectra with a footprint within 6 and 90 m^2 and solar phase angle within 0° and 38°. Ground-based observations [3][5] have found out that Itokawa has an LL chondrite-like average composition with a sensible reddening due to space weathering effects. Subsequent samples analysis [9][11] confirmed these hypothesis, narrowing the classification range of analogs to LL4-LL6 ordinary chondrites [12].

First results from NIRS data [1] found a similarity between NIRS spectrum and Alta'ameem LL5 [8] spectrum measured by RELAB with a grain size of 125 μm. The 2 μm band centre, which is related to pyroxenes, is slightly different from Alta'ameem, suggesting some difference in mineralogical composition.

[4] used chondrites spectral data from [6] to evaluate Fa and Fs abundances on Itokawa's surface. They analyzed nearly 1600 spectra, obtaining Fa values between 25 and 30, and Fs values between 21 and 25, consistently with LL-like composition.

2. Methods

Since the NIRS spectral range does not cover entirely the two olivine and pyroxene bands, centered at ~1 μm and ~2 μm, we have to define suitable spectral parameters for retrieval of olivine. Band Area Ratio (BAR), which is defined as the ratio between the two band areas, is a good diagnostic for olivine detection [10], but is not really suitable here, since the two bands are not entirely covered by the NIRS spectral range. This issue could be avoided if the two bands were symmetric, but this is not the case, since olivine band at 1 μm is strongly asymmetric. The same problem exists at defining a band center at 1 μm, because it has to be calculated after continuum removal.

The BAR* parameter could be fundamental in this analysis because it regards just half band, from band shoulder to band minimum. The data used are the ones calibrated from [2]. These data are not photometrically corrected, but since BAR* is independent from illumination condition [7] we could avoid this passage. We have defined the band shoulder as the wavelength related to the maximum reflectance value between the two bands; then, half-band area is calculated as the area between a straight horizontal line with maximum value and the spectral curve, considered between its shoulder and its band minimum. We can use RELAB data of binary (olivine + low calcium pyroxenes) and ternary (olivine + low calcium pyroxenes + high calcium pyroxenes) mixtures to evaluate a relation between BAR* and olvine distribution; the next step is to apply this relation to NIRS data of Itokawa, in order to map the olivine distribution.

3. Preliminary results

In Figure 1 we show the distribution of BAR* calculated for nearly 38.000 spectra acquired from an altitude of ~3.5-7 km, defined as Home Position, which was the longest mission observation phase. In Figure 2 a plot of olivine normalized content versus BAR* for RELAB compounds is given. Olivine normalized content is defined as

$$\widetilde{Ol} = \frac{Ol}{(Ol + Px)}$$

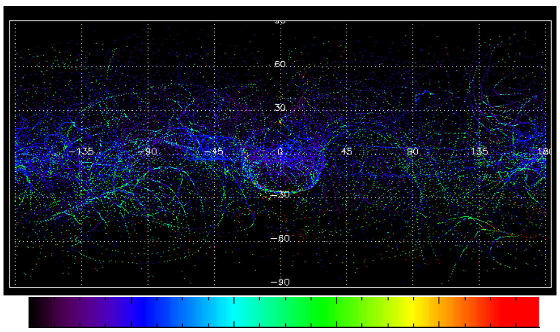

Figure 1: distribution of BAR from Home Position NIRS spectra. Blue is the lowest value, near 0.4, while red is the highest value, near 1.*

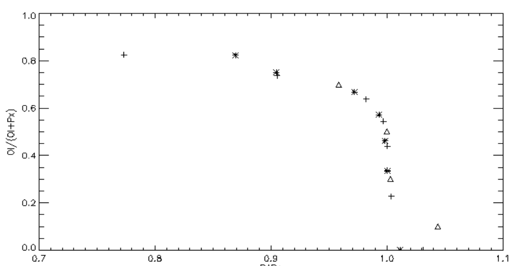

Figure 2: Olivine normalized content versus BAR as calculated in this work. Triangles indicates binary RELAB compounds, which are composed by olivine and low calcium pyroxenes. Crosses and stars indicates the two ternary mixtures, which are composed by olivine, low-calcium pyroxenes (LCP) and high-calcium pyroxenes (HCP). The difference is in the LCP/HCP ratio, which is 6 for LCP ternary mixtures (stars) and 1 for HCP ternary mixtures (crosses).*

4. References

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